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**ACCURACY ASSESSMENT OF A MOBILE VIDEO PLATFORM USED FOR  
KINEMATIC ANALYSIS OF ROWING**

**By**

**Matthew Joseph Weise**

**A THESIS**

**Submitted to  
Michigan State University  
in partial fulfillment of the requirements  
for the degree of**

**MASTER OF SCIENCE**

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## **ABSTRACT**

# **ACCURACY ASSESSMENT OF A MOBILE VIDEO PLATFORM USED FOR KINEMATIC ANALYSIS OF ROWING**

**By**

**Matthew Joseph Weise**

**A Mobile Video Platform(MVP) was developed to study three dimensional kinematics of rowing. The MVP holds two cameras and is towed by the rowing shell. Systematic errors occur in digitized data obtained from video images of the MVP due to movement of the cameras relative to the field of view. The effect of camera movements on calculated spacial coordinates were examined by testing the change in known spacial coordinates when systematic changes occurred along the x, y and z axes and in the xz, yz and xy planes.**

**It was concluded that the MVP's present design is not a valid technique for studying the kinematics of rowing. However, by mounting the cameras to the shell the uncertainty decreases substantially, especially in x-coordinate data. Mounting the cameras as well as increasing the angle between cameras and the field of view will yield a valuable tool in studying the kinematics of rowing.**

**To my wife, Lisa. Thank you for your patience, support and motivation  
through this endeavor.**

## **ACKNOWLEDGEMENTS**

**I would like to thank Karl Pearson for constructing of the Mobile Video Platform and aid in data collection. Also, thank you to Dr. Eugene Brown, Dr. Simon Billinge and Dr. James Pivarnik for their advice and guidance in this experiment.**

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## LIST OF ABBREVIATIONS AND SYMBOLS

| Symbol        | Definition                                                                                              |
|---------------|---------------------------------------------------------------------------------------------------------|
| $dX'$         | maximum change in the position of the cameras along the x-axis                                          |
| $dY'$         | maximum change in the position of the cameras along the y-axis                                          |
| $dZ'$         | maximum change in the position of the cameras the cameras along the z-axis                              |
| $d\theta'$    | maximum change in the position of the cameras the cameras along the xz plane<br>when towed by the shell |
| $d\phi'$      | maximum change in the position of the cameras along the yz plane                                        |
| $d\Psi'$      | maximum change in the position of cameras along the xy plane                                            |
| $\partial$    | partial derivative                                                                                      |
| $i$           | digitized point A, B, C, D, E, F, G, or H                                                               |
| $n$           | x, y, or z                                                                                              |
| $n_i$ control | control x, y, or z coordinate of the ith point                                                          |
| $Q$           | X, Y, Z, $\theta$ , $\phi$ , or $\Psi$                                                                  |
| $dQ$          | camera movement in X, Y, Z, $\theta$ , $\phi$ , or $\Psi$                                               |
| $U_x$         | uncertainty in the digitized x coordinate                                                               |
| $U_y$         | uncertainty in the digitized y coordinate                                                               |
| $U_z$         | uncertainty in the digitized z coordinate                                                               |
| $x$           | digitized x coordinate                                                                                  |
| $y$           | digitized y coordinate                                                                                  |
| $z$           | digitized z coordinate                                                                                  |
| $X$           | change in position of the cameras along the x-axis                                                      |
| $Y$           | change in position of the cameras along the y-axis                                                      |
| $Z$           | change in position of the cameras along the z-axis                                                      |

| Abbreviation | Definition                        |
|--------------|-----------------------------------|
| APAS         | Ariel Performance Analysis System |
| CMB          | Camera Mounting Board             |
| FMB          | Floor Mounting Board              |
| MVP          | Mobile Video Platform             |

### List of Appendix Symbols

|           |                                                                                       |
|-----------|---------------------------------------------------------------------------------------|
| ltfrtcam: | left camera's front marker                                                            |
| lfbkcam:  | left camera's back marker                                                             |
| rtfrtcam: | right camera's front marker                                                           |
| rtbkcam:  | right camera's back marker                                                            |
| shell:    | shell marker                                                                          |
| len:      | calculated length of the distance between the right camera's front and<br>back marker |
| i:        | frame number                                                                          |

## CHAPTER 1

### Introduction

The sport of rowing consists of a repetitive motion that uses sequential muscular contractions to exert force on an oar to propel a shell through the water. A typical race covers a distance of 2000 meters, takes anywhere from five to eight minutes and requires each rower to take 250-300 strokes. These strokes are performed at a frequency of approximately 30-40 per minute.

Forces applied to the oar during each stroke range from 450-600N in elite male pair rowers (Schneider, Angst & Brandt, 1978). Hosea and Boland (1989) measured compressive loads on the fourth lumbar vertebrae of subjects who rowed Concept II rowing ergometers. These loads averaged 4.5 times body weight throughout the rowing stroke. During a rower's career, these forces produce a protracted strain on anatomical structures. The amount of force exerted and the repetition involved may cause a number of overuse injuries. Low back and knee injuries have been reported to account for 50% of injuries in rowers (Boland & Hosea, 1991). Howell's (1984) musculoskeletal profiles of 17 elite lightweight women rowers documented five knee, two hip, two wrist-hand, two back, one hamstring, and one ankle injury among the subjects. Biomechanical analysis of the rowing stroke to study injury mechanisms are few in number due to the difficult nature of recording the movement on the water. Land based studies of subjects

on rowing ergometers can provide some insight into injury mechanisms but rowing ergometers use a flywheel that is accelerated by the rower starting at the catch position. This is not the same as the actual rowing movement. A rower cannot accelerate the shell at the catch because the athlete must first accelerate the oar to equal the speed of the shell system (Celentano, Cortili, Prampero & Cerretelli, 1971; Munroe, 1979; Pannell, 1979). The shell also pitches and rolls during the rowing cycle unlike the stable rowing ergometer. Therefore, study of the actual rowing motion of an athlete in a shell is important in establishing injury mechanisms in rowers.

Few kinematic analyses of the rowing stroke have been attempted due to the difficult nature of recording this activity. Kinematic studies of rowing have been limited to two dimensional analysis on rowing equipment, filming from shore, or filming from a motorized launch (Nelson & Widule, 1983; Lamb, 1989; Marindale & Robertson, 1984; Martin & Bernfield, 1980). A two dimensional approach is very limited, especially in sweep rowing, where rotation and three dimensional movements are important components of performance. The development of a videotape technique to study the three dimensional kinematics of rowing, without adding to errors in the Direct Linear Transformation Method employed by the Ariel Performance Analysis System (APAS) will greatly enhance the study of rowing (Ariel, 1993). Once an accurate technique is established, three dimensional analysis can be synchronized with on-board kinetic recording devices to provide a comprehensive understanding of the mechanics of performance and mechanisms of injury.



### **Purpose**

The purpose of this study was to develop and test the accuracy of a Mobile Video Platform (MVP) that could be towed by a rowing shell. This was done by establishing the movements of the cameras on the MVP with respect to a calibration frame while the MVP was towed by a rowing shell. These camera movements were then mimicked in the laboratory to determine their effect on digitized coordinate data.

### **Hypothesis**

Movement of the MVP, relative to the shell, will negatively affect the accuracy of the Direct Linear Transformation Method used by the Ariel Performance Analysis System.

### **Definition of Terms**

**Ariel Performance Analysis System(APAS):** computer program used for kinematic analysis in this study.

**Blade of the oar:** portion of the oar that is in the water and acts as the resistance of a first class lever system at the catch and then as the fulcrum in a second class lever system during the remainder of the drive (Rowing as a lever system is described in Chapter 2).

**Collar of the oar:** portion of the oar that keeps it from sliding laterally in the oarlock.

**Feathering:** occurs as the oar exits the water. The wrist and fingers flex to turn the oar so that the blade of the oar is parallel to the water.

**Handle of the oar:** portion of the oar where force is exerted by the hand.

**Inboard:** the distance from the medial edge of the handle of the oar to the lateral edge of the collar of the oar.

**Outboard:** the distance from the lateral edge of the collar to the lateral end of the blade.

**Pin and oarlock:** swivels on the rigger to allow the oar to travel through an arc.

It is the fulcrum of the first class lever system used to bring the oar up to the speed of the shell at the catch. It later acts as the resistance of the lever arm which allows shell propagation in a class two lever system in rowing (Rowing as a lever system is described in Chapter 2.)

**Planing:** to skim across the surface of the water.

**Rigger:** support on the boat that holds the pin and the oarlock.

**Sculling:** type of rowing in which the rower holds one oar in each hand.

**Shell:** a boat used in rowing.

**Sweep:** type of rowing in which each rower holds one oar with two hands.

**X-axis:** axis running in the anterior-posterior direction relative to the rower.

**Y-axis:** axis running in the vertical direction relative to the rower.

**Z-axis:** axis running in the medial-lateral direction relative to the rower.

*The following definitions have been modified from Martin and Bernfield (1980) to explain the stages of the rowing stroke.*

**Catch:** the instant at which the hands begin to move vertically to place the oar in the water (see Figure 1.1a).

**Drive phase:** begins with the catch and ends with the finish. This phase is used for propulsion of the shell and consists of the leg drive and the upper body drive.

**Leg drive:** begins with the catch and ends when the rower's knees are fully extended.

**Upper body drive:** continuation of the drive phase in which the boat is propelled by trunk extension in combination with adduction of the shoulder girdle and flexion of the elbow. This phase ends when all oars begin to rotate (feather) after being lifted out of the water.

**Finish:** period when the wrist begins flexion in order to feather the oar (see Figure 1.1b).

**Hand and upper body away:** begins with extension of the elbow, abduction of the shoulder girdle and flexion of the trunk. This phase ends when flexion of the knee begins (see Figure 1.1c).

**Seat movement:** begins when the rower starts the movement of the seat by flexing the knees and ends when the shank is parallel to the y-axis.

Assumption

- The resistance of the Mobile Video Platform system minimally effects kinematic characteristics of the rowing cycle.



Figure 1.1a. Catch.



Figure 1.1b. Finish.

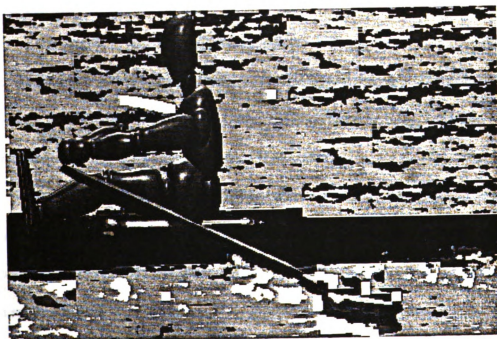


Figure 1.1c. Hands and upper body away.

## CHAPTER 2

### Literature Review

Literature, pertinent to this study, is presented in three categories: two dimensional cinematography, three dimensional methods of analysis, and rowing mechanics. Two dimensional cinematography involves the use of a single motion picture camera to record and subsequently analyze the kinematics of rowing. Three dimensional methods of analysis involves the use and validation of a specific technique for obtaining three-dimensional coordinates of body and object landmarks from two or more cameras simultaneously recording. Rowing mechanics involves a description of rowing technique and mechanics of propulsion of the shell.

#### Two Dimensional Cinematography

Four studies have used two dimensional cinematography to study the kinematics of rowing (Lamb, 1989; Martin & Bernfield, 1980; Martindale & Robertson, 1984; Nelson & Widule, 1983). Three of the four studies focused on body mechanics, while the fourth focused on the kinematics of the rowing shell.

Martindale and Robertson (1984) studied two dimensional segmental energies in rowing a shell and compared them to segmental energies in rowing on an ergometer. Two male and two female scullers were used in their study. Markers were placed on each subject's ankle, knee, hip, shoulder, elbow, wrist, and neck. One 16 mm camera filmed the events at 25 frames per second. Martindale and Robertson (1984) concluded that significant differences exist between sculling and ergometry due to differences in

energy exchanges between the rower and the equipment. Technical limitations involving the size of the subjects in the field of view were noted by the researchers. Their recommended changes included using a moving camera system when recording rowing to provide a greater number of images as well as a larger subject image in the field of view. The field of view in this study was 20 m and was large enough to film only one complete rowing stroke.

Martin and Bernfield (1980) measured shell velocity of the 1976 U.S. Olympic Men's Eight by placing markers on the shell and filming with one 16 mm camera at 70 frames per second. The authors found that the velocity of the shell decreased after the catch and reached a minimum at approximately 27% into the leg drive phase. Martin and Bernfield concluded that this decrease in velocity occurred due to the time it takes for the blade's velocity to equal the velocity of the water moving past the boat.

A two-dimensional kinematic analysis of rowing and ergometry was performed by Lamb (1989) using 30 members of the 1982 Heavyweight Men's Rowing Team Selection Camp. One 16 mm camera was used at a frame rate of 50 frames per second. The camera was mounted on a motorized launch which followed the crew at a comparable speed. Film images of the toe, ankle, knee, hip, shoulder, elbow, wrist, fingers (oar handle), and head were digitized. The digitized points were used to determine and compare the body segments' effects on linear oar velocity for rowing and rowing ergometry. Lamb concluded that the trunk is the segment with the greatest effect on linear oar velocity. The filming method used by Lamb (1989) is not possible with three dimensional analysis because cameras need to be fixed relative to one another

and to the field of view. This is not possible if cameras are mounted on a motorized launch because the hull speed of a shell cannot be synchronized with a motorized launch.

Nelson and Widule (1983) conducted a kinematic analysis on 18 intercollegiate female rowers. The subjects' rowing experience ranged from four to 40 months. Subjects were filmed at 50 frames per second from one 16 mm camera on a Stanford rowing ergometer. Film images of the toe, ankle, knee, hip, shoulder, elbow, wrist, fingers (oar handle), head and seat were digitized. Nelson and Widule concluded that when the oar is perpendicular to the shell, experienced rowers have greater knee angular velocity and a greater sum of trunk and knee angular velocity. These researchers also found that the time between maximum angular velocity of the trunk and maximum angular velocity of the knee was significantly less in skilled rowers. It was concluded that the legs are the primary force producing segment and the trunk has little effect on horizontal oar velocity. This contradicts conclusions made by Lamb (1989). Therefore, further studies of rowing are necessary to determine the effect of body segments on horizontal oar velocity.

### Three Dimensional Methods of Analysis

Three-Dimensional analysis requires the use of two or more cameras to simultaneously film or videotape an object. The Direct Linear Transformation Method (DLT) is used to take two-dimensional information from two or more cameras and calculate three-dimensional coordinates. The DLT equations are:

$$x_i + L_1X_i + L_2Y_i + L_3Z_i + L_4 + L_9x_iY_i + L_{11}x_iZ_i = 0 \text{ and}$$

$$y_i + L_5X_i + L_6Y_i + L_7Z_i + L_8 + L_9y_iX_i + L_{10}y_iY_i + L_{11}y_iZ_i = 0$$



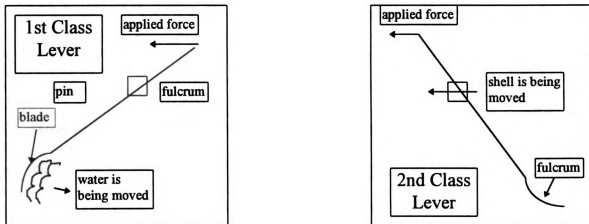
where  $x_i$ ,  $y_i$  are the film coordinates of the  $i$ th point;  $X_i$ ,  $Y_i$ ,  $Z_i$  are the object spatial coordinates of the  $i$ th point; and  $L_1 \dots L_{11}$  contain information on camera orientations and lens and film distortions (Shapiro, 1978).  $L_1 \dots L_{11}$  need not be known but are solved for by using a calibration frame with at least six known object spatial coordinates (Challis, 1995). The linear least squares technique is applied to solve the DLT equations using the known object spatial coordinates.

Shapiro (1978) tested the accuracy of the DLT method for cinematography by using three tests. A control frame with 48 stationary points was filmed. Twenty points were used for calibration in all trials. The first test treated the remaining 28 markers as unknowns. DLT calculations of the positions of the unknown points yielded an accuracy of 0.51 cm. The second method used the DLT to calculate the length of a meter stick at various locations in the field of view. This method yielded a calculated length within 2 to 4% of the known length. Finally, a free flight golf ball was filmed and the DLT method was used to calculate the acceleration of the ball. The DLT yielded an error of 1 to 4%.

Challis and Kerwin (1992) tested the DLT method to determine the accuracy of different shaped calibration frames. After filming the calibration frame, it was rotated 180 degrees and the points were calculated using the DLT method. Challis and Kerwin (1992) concluded the calibration frame need only have points on the edge of the field of view rather than throughout the field of view.

### Rowing Mechanics

In rowing, muscular force is applied to a lever resulting in movement of the rowing shell. Rowing has been described as a first and second class lever system (Celentano, Cortili, Prampero & Cerretelli, 1971; Munroe, 1979; Pannell, 1979). At the catch, the boat is a first class lever system with the pin and oarlock acting as the fulcrum and the water acting as the resistance (see Figure 2.1). As the blade speed matches the shell speed, the lever switches to a second class lever system in which the fulcrum is the center of pressure of the blade and the shell is the resistance (see Figure 2.1). Pannell (1979) stated that if the catch is executed perfectly, the blade will achieve shell speed in the first ten degrees or 0.05 s of the drive. Martin & Bernfield (1980) found that in the 1976 Olympic Men's Eight it took approximately 0.12 s for the blade speed to match the shell speed.



**Figure 2.1.** The rowing motion as a first and second class lever.

## CHAPTER 3

### Methods

#### The Mobile Video Platform

A Mobile Video Platform (MVP) was designed to be towed by a shell (see Figure 3.4). The pontoons for the MVP were designed so that their planing on the water could occur throughout the rowing cycle. The pontoons were made of Styrofoam and covered for protection with epoxy. The platform was designed to allow the boat to pitch and roll through the use of a specialized hitch that was attached to the gunnels of the boat (see Figure 3.1a & b). Wooden supports were attached to the pontoons which then connected to two pieces of 1.27 cm aluminum box tubing (see G & H in Figure 3.2 a & b). This tubing provided a stiff connection between the pontoons. 1.63cm right angle aluminum shafts connected the platform to the hitch (see F in Figure 3.2 a & b). The length of separation of the pontoons (227.5 cm) was set at a distance that did not interfere with the oar or shell.

Movement in the MVP relative to the cartesian coordinate system fixed to the shell occurred along the x, y, and z axes and in the xz, yz, and xy plane.

Movement along the x-axis occurred from lack of stiffness in the materials when the system accelerated. This was minimized by using materials and connections that yielded little under the stresses encountered.

Movement along the z-axis occurred from looseness in the connections of the hitch to the pontoons and from the hitch to the shell. This was minimized by tightening connections before testing.

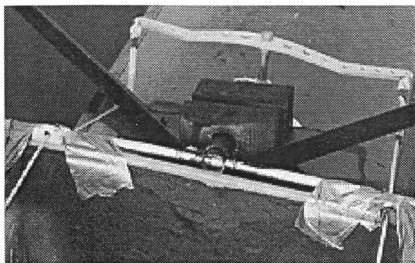
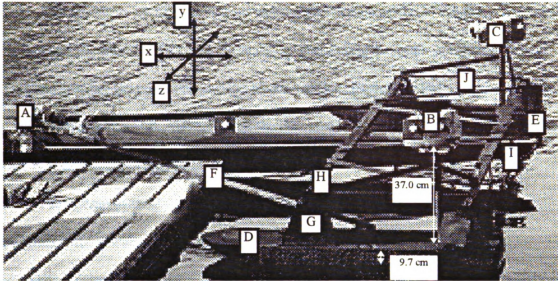


Figure 3.1. Specialized hitch to allow the shell to pitch and roll.

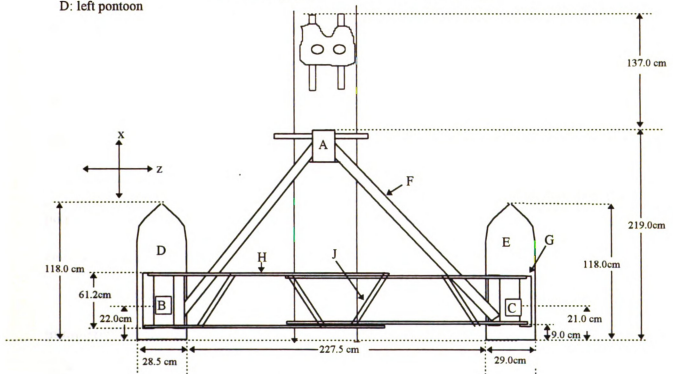


**Figure 3.2a.** Three dimensional view of the MVP.

A: hitch  
B: left camera  
C: right camera  
D: left pontoon

E: right pontoon  
F: 1.27 cm right angle aluminum  
G: wooden supports

H: 1.27 aluminum box tubing  
I: line attached to the shell  
J: wooden slats



**Figure 3.2b.** Top view sketch of the MVP.

Movement in the xz plane occurred through rotation of the MVP about a vertical axis through the hitch. This was minimized by connecting the hitch to the shell at two locations, keeping the pontoons parallel to one another, using stiff building materials and by using a line which was attached from the rear piece of the 1.27 cm box tubing on the MVP to the shell (see Figure 3.2a).

Movement in the xy plane and along the y-axis occurred as a result of accelerations of the shell and water resistance on the pontoon. As the MVP was positively accelerated, the bows of the pontoons lifted up and out of the water causing a rotation about a z-axis through the calibration frame in the xy plane. Likewise, the bows moved downward towards the water when the shell was decelerating. This was minimized by designing the platform to plane on the water through the entire stroke cycle. Movements in the xy plane were further minimized by designing the connection from the hitch to the MVP to be as linear as possible (see F in Figure 3.2a). This kept forces applied from the shell to the MVP from adding to angular accelerations of the MVP.

Movement in the yz plane occurred as a result of wave activity. Waves effect the pontoons unequally and cause the MVP to rotate. This was minimized by testing during calm water conditions.

Movements in the xz plane, yz plane and along the x, y and z axes were minimized but caused systematic error in the data. These errors were examined in order to determine their effect on the accuracy of three dimensional cartesian coordinates derived from two dimensional images by two cameras mounted on the MVP.

### Pilot Study

A pilot study was conducted to determine the effects of MVP movement on the quality of the video images taken from the MVP. A single scull was the shell of choice for this study because success of planing at the lower hull speeds of a single would allow the MVP to be used on any shell.

The pilot study was performed on a male single sculler who had ten years of competitive rowing experience. The sculler was 172.7 cm in height and weighed 69.5 kg. Cameras were placed on the MVP and video was taken of the sculler. The videotape of the sculler was digitized but problems arose in this process. Movements in the MVP, especially during the leg drive, made the results suspect to error. This was due to the MVP falling from its plane on the water. This coincides with Martin's (1980) finding that the lowest shell velocity is achieved during the leg drive. An eight oared shell rather than a single scull was used in the actual testing so that the MVP would remain planing through the entire rowing cycle. Also, the resistance of the MVP was distributed among the eight rowers. This minimized the effects of resistance of the MVP on the rowers.

Other problems that arose during the pilot study included:

1. a lack of an adequate synchronizing event for the cameras causing difficulty when digitizing the two camera views,
2. errors in measuring points on the calibration frame causing errors in the digitized information, and
3. a lack of markers on the shell and on anatomical landmarks of the rower causing inaccuracies in the digitization of the video images.

Changes were made from the methods used in the pilot study to limit these problems.

These changes included:

1. adding markers to locations that were digitized to allow easier tracking of these video images,]
2. increasing precision in measurements of calibration points through repeated measures ,
3. adding a synchronization event involving the coxswain popping a balloon over her head when in the field of view and
4. making the connection from the shell to the pontoons more linear so that movements in the shell had less effect on movement in the MVP.

### Videotaping MVP Movement When In Tow

#### Calibration Frame

A calibration frame was constructed from 3.81 cm diameter PVC pipe and floated on the water. The calibration frame was square (6.14 m by 6.14 m). A 1 m piece of 1.27 cm diameter PVC pipe was vertically attached at each corner of the square. Markers were created on these vertical pieces by spray painting the pipe black then adding five 1.5 cm white stripes to the pipe. Stakes were placed on the inside corners of the calibration frame and driven into the river bed to hold the frame in place when videotaping and to act as guides for the coxswain to steer the shell between when the calibration frame was removed (see Figure 3.3). The size of the calibration frame was chosen because it allowed the markers on the calibration frame and the MVP to be easily tracked during digitization. However, it took less than one rowing stroke to cover this distance. In order to reconstruct the movements of the MVP through an entire rowing cycle, multiple trials were conducted.



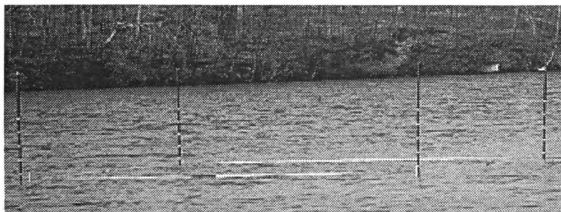


Figure 3.3. Calibration frames with stakes.

### Markers

Five markers on the MVP were digitized: two markers on each camera (right camera front and back and left camera front and back) and one marker on the shell (see Figure 3.4). The markers were white Styrofoam balls with a diameter of 2.54 cm. The MVP was painted black to enhance the contrast with the white markers. The marker on the shell was mounted to a piece of black painted plywood.

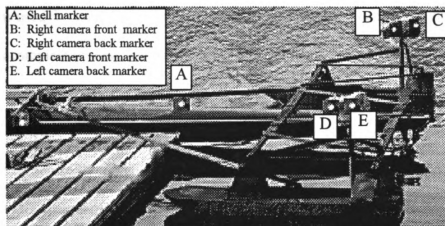
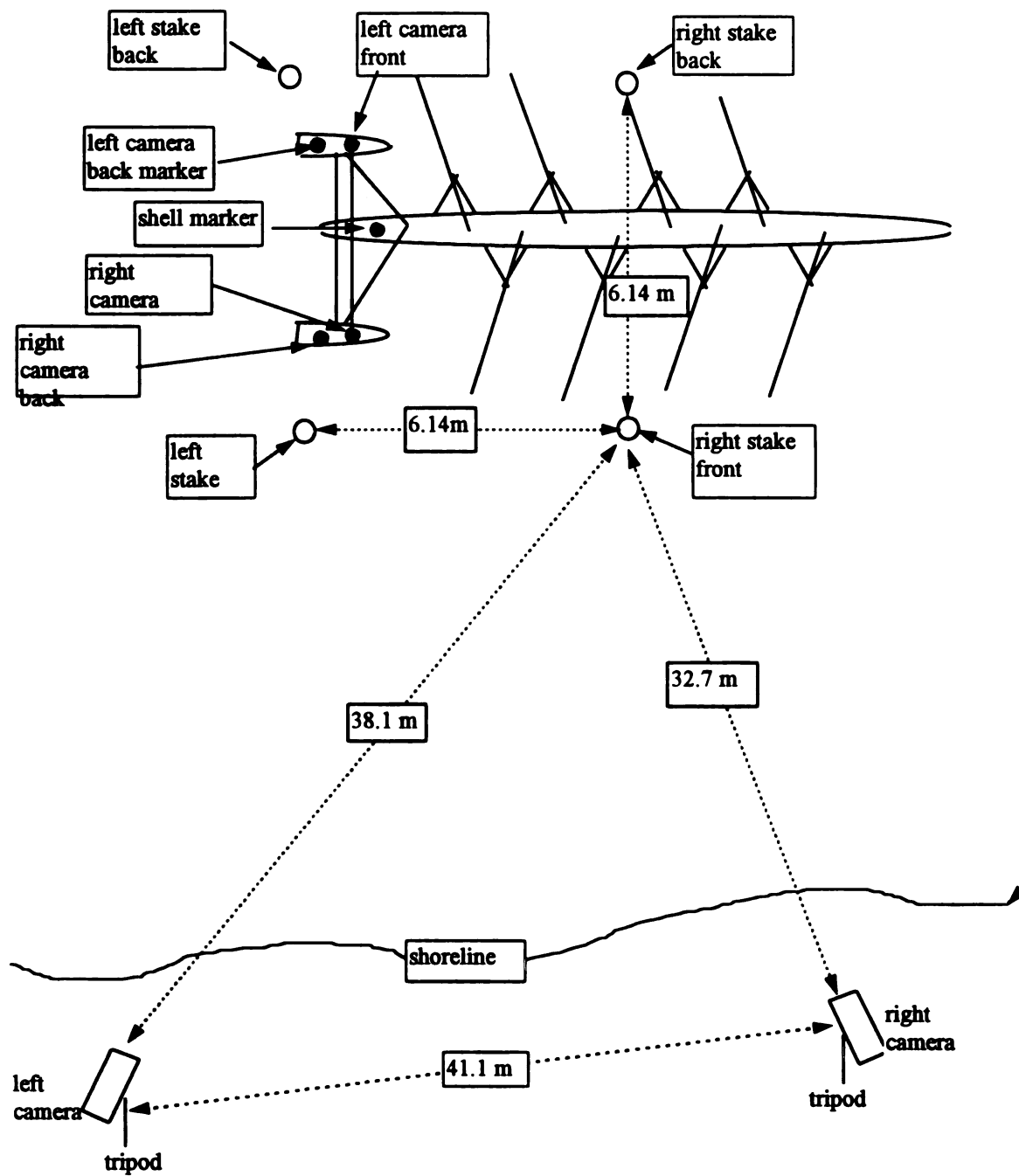


Figure 3.4. Five markers used to study the movement of the MVP.

### Videotaping and Digitizing

First, the calibration frame was videotaped then removed. Then the rowers were instructed to row the shell at 34 strokes per minute starting 100 m before the stakes and ending ten strokes beyond the stakes. The stroke rate was held constant through the use of a Nielson Kellerman Cox Box. This rate was chosen because it is a typical stroke rate used in collegiate racing. Two Panasonic AG455P video cameras, which operated at sixty fields per second with a shutter speed of 1/2000 s, were mounted on tripods and located on shore to record the calibration frame, shell, and MVP. The cameras were separated by a distance of 41.1 m. The right camera was 32.7 m from the right front stake of the calibration frame and the left camera was 38.1 m from this same stake. Next the shell and MVP were videotaped as they passed through the space previously occupied by the calibration frame (see Figure 3.5). The coxswain of the shell popped a balloon over her head while in the cameras' fields of view. The first field in which the balloon popped was used for synchronization of the two video records. The field of view was too small for a complete rowing cycle to be videotaped within it. Therefore, multiple trials were used to capture the movements of the MVP throughout two rowing cycles. Seven trials were recorded but only trials 1 and 5 captured a complete drive phase and only trials 2 and 6 captured a complete recovery phase. These four trials were used to reconstruct movements of the MVP over two rowing cycles. Events of the rowing cycle: the catch, leg drive, upper body drive, finish, hands and body away and seat movement, were observed from the videotape and recorded for each trial. These events provided reference points when tracking the movements of the MVP during the rowing cycle.



**Figure 3.5.** Top view sketch of the videotaping area.

The video of the right and left, front and back camera markers and the shell marker were digitized for each of the four trials using APAS. The catch was used as the beginning event of the drive phase and the ending event of the recovery phase. The finish was used as the beginning event of the recovery phase and the ending event of the drive phase.

Nine frames were taken before and after the beginning and ending event for each trial. Trials 1 and 5, the drive phase, consisted of 64 and 70 frames, respectively. Trials 2 and 6, the recovery phase, consisted of 75 and 76 frames, respectively. The raw data was then used to calculate movements of the MVP.

#### Calculation of MVP Movements

The digitizing error was estimated by calculating the distance between the right camera's front and back markers and the distance between the left camera's front and back markers for each frame. Maximum and minimum values of the distance between markers were taken from these calculations. The greatest difference of the minimum and maximum x, y and z value was used as the maximum value of digitization error.

Movements along the x-axis were calculated by subtracting the x-coordinate of the front camera markers for each camera and the x-coordinate of the shell marker for each frame. The maximum and minimum values of the distance between the front camera markers and the shell marker were taken for each trial. The greatest difference of the maximum and minimum values of the distance between the cameras and the shell was used as the movement of the MVP with respect to the shell along the x-axis.

Y-axis movements were defined as the greatest difference in maximum and minimum y-coordinates for each camera's front markers for each trial.

Z-axis movements were difficult to account for because the shell was allowed to roll in the yz plane. Movement of the MVP along the z-axis relative to the shell was established in the following way:

1. The change in the z-coordinate from one frame to the next was calculated for the shell marker.
2. The change in length along the z-axis between the right camera's front marker and the shell was calculated from one frame to the next.
3. The change in length along the z-axis between the left camera's front marker and the shell was calculated from one frame to the next.
4. The sum of 2. and 3. was calculated.
5. The greatest difference in maximum and minimum values from 4. was used as the movement of the MVP with respect to the shell along the z-axis.

Movement of the MVP in the xz plane was estimated by calculating the

$$\arctangent \text{ of } \frac{\text{the (x-axis movement)}}{[(\text{length of the MVP from the midpoint to the camera}) - (\text{z axis movement})]}$$

(see Figure 3.6a & b). The greatest difference in maximum and minimum values of the arctangent was used as the movement of the MVP in the xz plane.

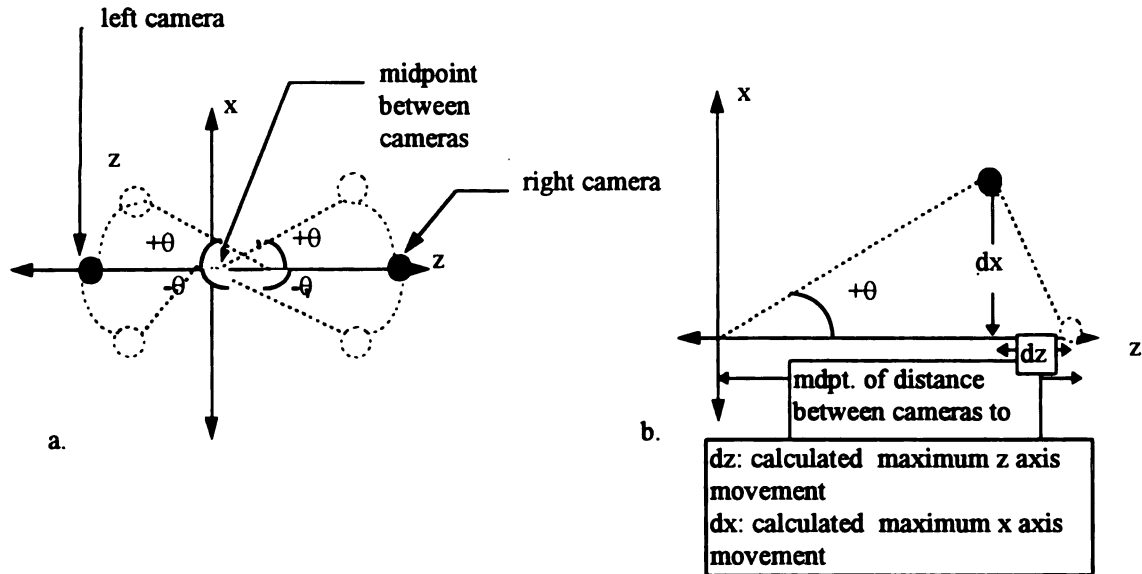
Movement of the MVP in the yz plane was estimated by:

1. Calculating the difference in the y coordinates and the z coordinates of the right camera's front marker and the left camera's front marker, and the right camera's back marker and the left camera's back marker for each frame.
2. From 1., calculating the arctangent of the (difference in the y coordinate)/ (the difference in the z coordinate) for each frame.
3. The greatest difference between the maximum and minimum of 2. was used as the estimate of movement of the MVP in the yz plane.

Movement of the MVP in the xy plane was estimated by:

1. Calculating the difference in the y and x coordinates of the right camera's front marker and the right camera's back marker, and the left camera's front marker and the left camera's back marker for each frame.

2. From 1, calculating the arctangent of the (difference in the y coordinate)/ (the difference in the x coordinate) for each frame.
3. The greatest difference between the maximum and minimum of 2. was used as the estimate of movement of the MVP in the xy plane.



**Figure 3.6.** a. Positive and negative MVP movements in the xz plane. b. Diagram of variables used to solve for movements in the xz plane.

### Treatment of the Movements of the MVP

Maximum and minimum displacements of the MVP along the x, y and z axes and in the xz, yz and xy planes were taken from the digitized data. These data were used to establish the range for laboratory tests on the uncertainty in digitized data when movement occurs in the cameras.

Movements of the MVP were linked with events of the rowing cycle to establish how the MVP responds during different portions of the cycle. This was important because the pilot study showed jostling of the cameras during the initiation of the leg

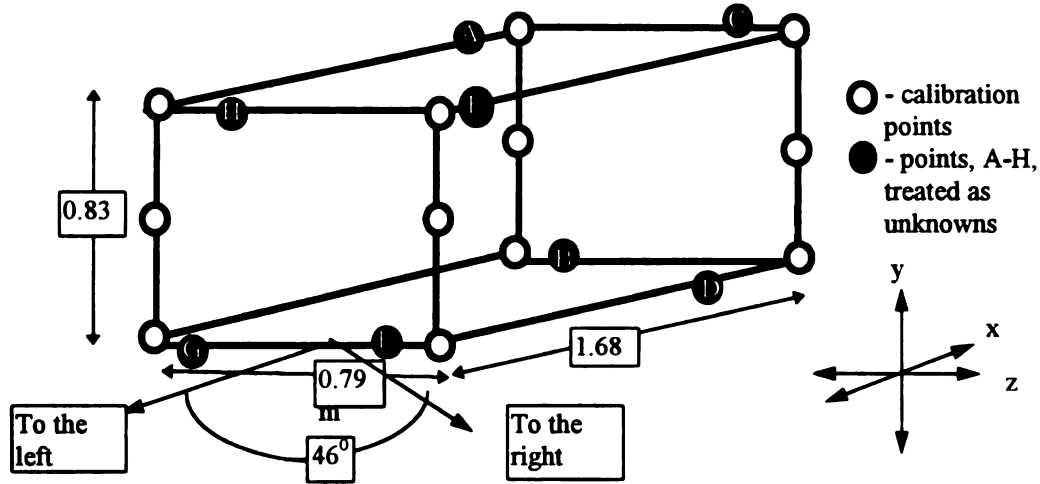
drive phase but little problems elsewhere in the stroke. During the first half of the leg drive phase, the shell's velocity was minimum which caused the pontoons to stop planing. An eight oared shell was used to maximize the minimum speed thereby minimizing movement in the MVP during this phase.

### Establishing Control Coordinates

#### Calibration Frame

A PVC calibration frame, 1.68 m by 0.79m by 0.83 m , included 12 points on the edges of the field of view of each camera. Eight extra markers were attached to the calibration frame (see figure 3.7). The coordinates of these extra markers were measured then treated as unknowns in the digitization. The calibration frame was placed so that it was a comparable distance (2.90 m from the cameras to the front edge of the frame) from the cameras as a rower was from the MVP cameras in the shell.

The calibration frame was videotaped by the two cameras. The cameras used for videotaping were Panasonic AG455P. The cameras ran at 60 fields per second with a shutter speed of 1/200 s. A 46 degree angle existed between the cameras and the midpoint of the front lower edge of the calibration frame(see figure 3.7).



**Figure 3.7.** Calibration frame and points treated as unknowns.

The points treated as unknowns were digitized and the locations of these points were calculated using APAS. The locations of these positions were treated as the control coordinates to establish the amount of uncertainty in digitized coordinates when movements occur in the cameras.

### Establishing Uncertainty of the MVP

Systematic testing of the changes in known spatial coordinates due to changes in camera positions were examined in the laboratory. Tests on movement of cameras along the x, y and z axes and the xz, yz and xy planes were examined by using incremental changes along these parameters and by comparing digitized values with the control coordinate values. The uncertainty in the system was calculated as follows:

$$\begin{aligned}
 U_{xi} &= 2x_i/2X \, dX' + 2x_i/2Y \, dY' + 2x_i/2Z' \, dZ + 2x_i/2\theta \, d\theta' + 2x_i/2\phi \, d\phi' + 2x_i/2\Psi \, d\Psi' \\
 U_{yi} &= 2y_i/2X \, dX' + 2y_i/2Y \, dY' + 2y_i/2Z \, dZ' + 2y_i/2\theta \, d\theta' + 2y_i/2\phi \, d\phi' + 2y_i/2\Psi \, d\Psi' \\
 U_{zi} &= 2z_i/2X \, dX' + 2z_i/2Y \, dY' + 2z_i/2Z \, dZ' + 2z_i/2\theta \, d\theta' + 2z_i/2\phi \, d\phi' + 2z_i/2\Psi \, d\Psi'
 \end{aligned}$$

where



$U_x$  is the uncertainty in the digitized x coordinate,

$U_y$  is the uncertainty in the digitized y coordinate,

$U_z$  is the uncertainty in the digitized z coordinate,

i is the digitized point A, B, C, D, E, F, G or H

x is the digitized x coordinate,

y is the digitized y coordinate,

z is the digitized z coordinate,

X is the change in position of the cameras along the x-axis,

Y is the change in position of the cameras along the y-axis,

Z is the change in position of the cameras along the z-axis,

$\theta$  is the change in position of the cameras along the xz plane,

$\phi$  is the change in position of the cameras along the yz plane,

$\Psi$  is the change in position of the cameras along the xy plane

$dX'$  is the maximum change in the cameras along the x-axis when towed by the shell,

$dY'$  is the maximum change in the cameras along the y-axis when towed by the shell,

$dZ'$  is the maximum change in the cameras along the z-axis when towed by the shell,

$d\theta'$  is the maximum change in the cameras along the xz plane when towed by the shell,

$d\phi'$  is the maximum change in the cameras along the yz plane when towed by the shell,

and  $d\Psi'$  is the maximum change in cameras along the xy plane when towed by the shell.

The partial derivatives listed in the uncertainty equations were solved

empirically and therefore, could only be estimated because measurable increments were used rather than infinitesimally small increments. The partial derivatives were estimated by:

$$\frac{\partial n_i}{\partial Q} = \frac{dn_i}{dQ}$$

where n is x, y, or z,

i is the digitized point A, B, C, D, E, F, G, or H and

Q is X, Y, Z,  $\theta$ ,  $\phi$ , or  $\Psi$ .

$$dn_i = n_i - n_{i \text{ control}}$$

where  $n_{i \text{ control}}$  is the control x, y or z coordinate of the ith point and

dQ is the camera movement in X, Y, Z,  $\theta$ ,  $\phi$ , or  $\Psi$

By estimating the partial derivatives  $\frac{\partial n_i}{\partial Q}$  with  $dn_i / dQ$ , the affect of each camera movements on the total uncertainty was estimated. These pinpoint areas of concern in movements of the MVP.

### Measuring X, Y, Z, $\theta$ , $\phi$ , and $\Psi$

A Floor Mounting Board (FMB) was constructed to allow a change in one of X, Y, Z,  $\theta$ ,  $\phi$  or  $\Psi$  while holding the other parameters constant (see Figure 3.10a). The FMB was made of two 60.96 cm by 10.16 cm by 10.16 cm boards. Hinges were mounted to these boards to allow rotation in the xy and yz planes (see Figure 3.10b). Holes with a diameter of 2.54 cm were drilled into the FMB in two directions: along the x-axis and in an arc centered at the midpoint of the FMB (see Figure 3.10c). Two cameras were then mounted to a 5.08 cm by 10.16 cm by 304.80 cm board known as the Camera Mounting Board (CMB). Four holes with a diameter 2.54 cm were drilled into the CMB (see Figure 3.10c). A 2.54 cm dowel was placed through two of the holes and into the FMB (see Figure 3.10a). An adjustable aluminum bracket kept the CMB from sliding on the dowel and allowed the CMB to be moved along the y-axis (see Figure 3.10a).

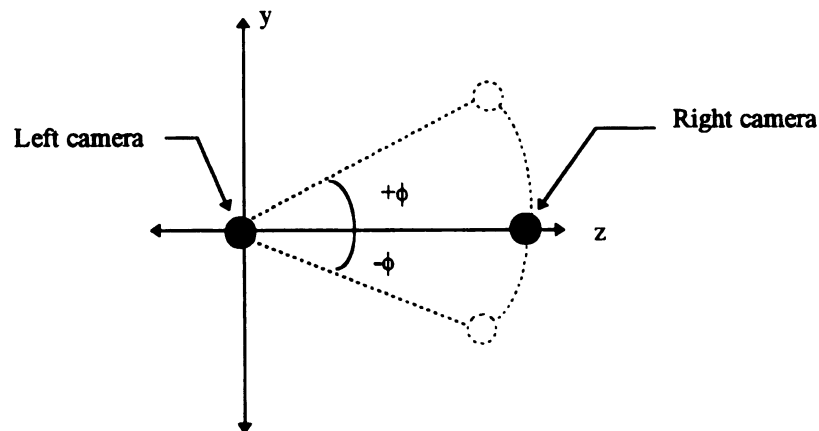
The CMB was moved through the dQ values listed in Table 3.1 for each Q:

**Table 3.1.** dQ values for each Q.

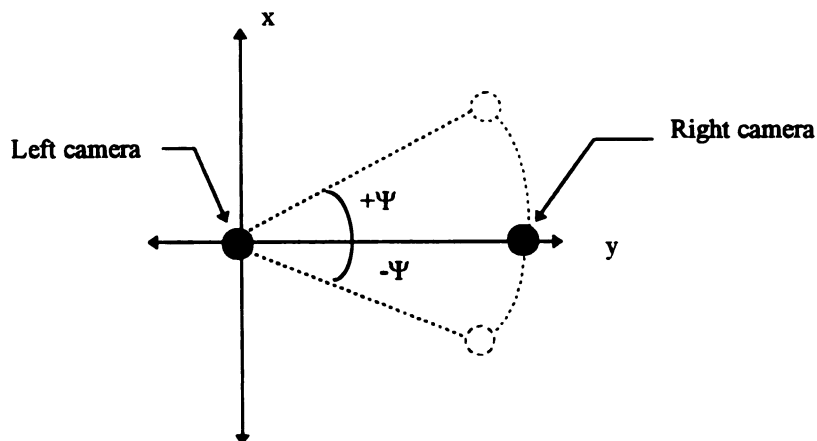
| Q              | dQ values                                                        |
|----------------|------------------------------------------------------------------|
| X (cm)         | -18.0, -14.4, -10.8, -7.2, -3.6, 0.0, 3.6, 7.2, 10.8, 14.4, 18.0 |
| Y (cm)         | -10.0, -8.0, -6.0, -4.0, -2.0, 0.0, 2.0, 4.0, 6.0, 8.0, 10.0     |
| Z (cm)         | -18.0, -14.4, -10.8, -7.2, -3.6, 0.0, 3.6, 7.2, 10.8, 14.4, 18.0 |
| $\theta$ (deg) | -10.0, -8.0, -6.0, -4.0, -2.0, 0.0, 2.0, 4.0, 6.0, 8.0, 10.0     |
| $\phi$ (deg)   | -9.3, -5.9, -3.9, -1.9, 0, 1.9, 3.9, 5.9, 9.3                    |
| $\Psi$ (deg)   | -10.3, -5.9, -3.2, -3.0, 0, 3.0, 3.2, 5.9, 10.3                  |

Definitions of positive and negative angles of  $\theta$ ,  $\phi$ , and  $\Psi$  are shown in Figures 3.6a, 3.8 and 3.9, respectively.

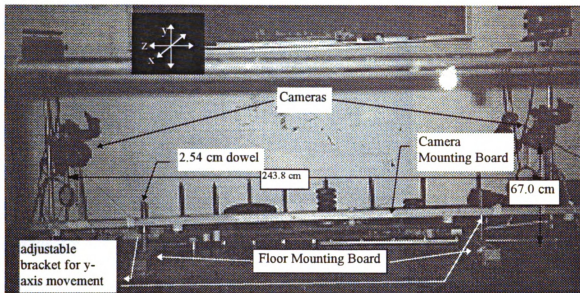
Measurements were taken at each increment,  $dQ$ , for each plane or axis movement,  $Q$ . Ten fields of video were then digitized using APAS. The digitized information was used to establish the effect of camera position and orientation on the digitization of known spatial coordinates.



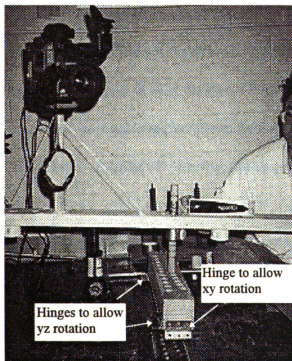
**Figure 3.8.** Positive and negative MVP movements in the yz plane.



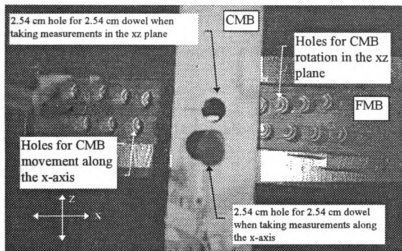
**Figure 3.9.** Positive and negative MVP movements in the xy plane.



**Figure 3.10a.** The Floor Mounting Boards and the Camera Mounting Board as seen from the calibration frame.



**Figure 3.10b.** Right half view of Camera Mounting Board and Floor Mounting Board as the system is rotated in the yz plane.



**Figure 3.10c.** Top view of right Camera Mounting Board and right Floor Mounting Board.

### Treatment of the Laboratory Data

The ten fields of video for each  $Q$  at each  $dQ$  value were digitized. The partial derivatives  $\partial n_i / \partial Q$  were estimated from the calculations of  $dn_i / dQ$ . The uncertainty equations were analyzed to determine the weight of each  $Q$  on the uncertainty of the movements of the MVP. Finally, the uncertainty of the MVP was calculated.

## CHAPTER 4

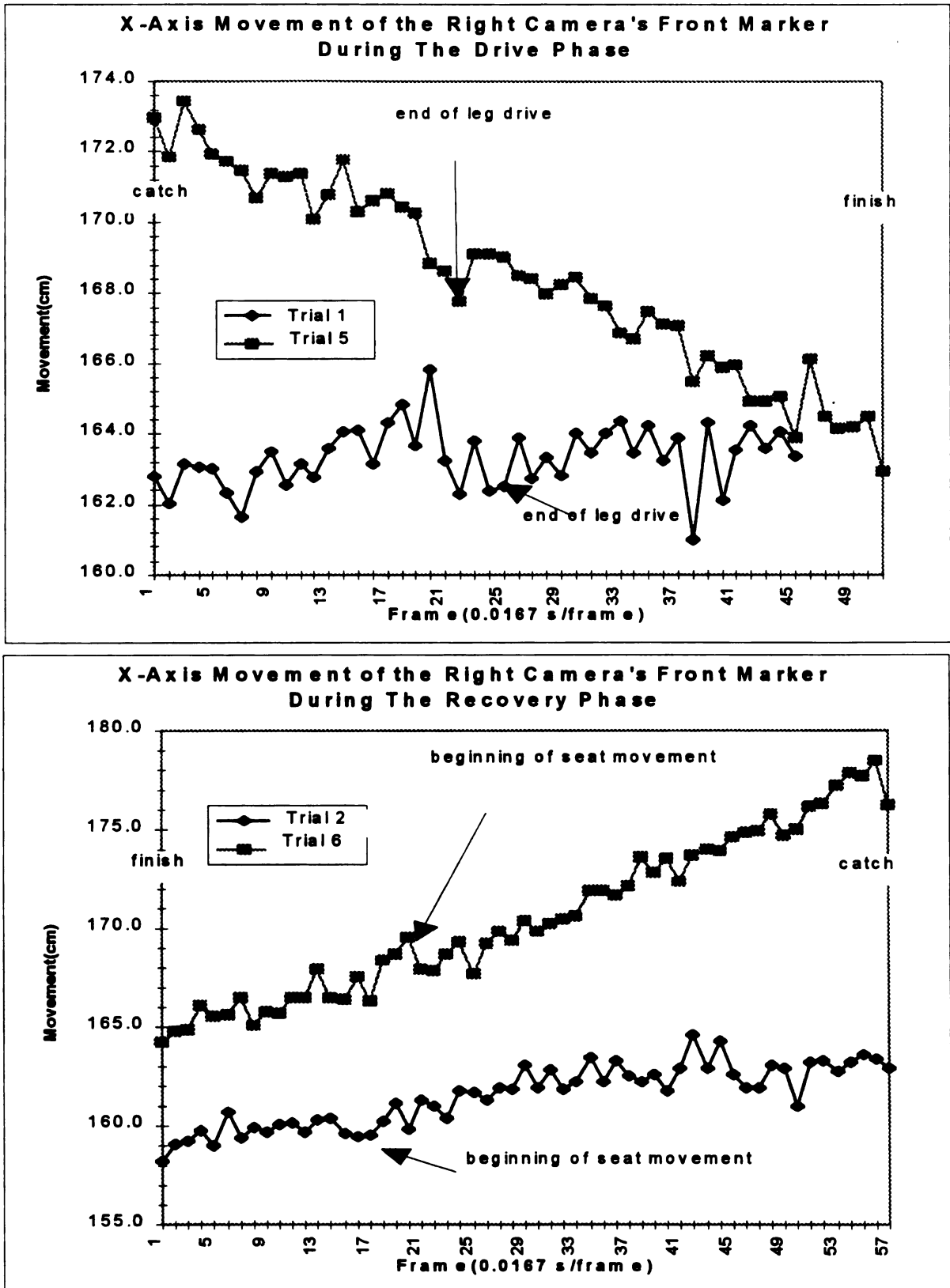
### Results

Five points on the MVP were digitized using APAS. The coordinates for these markers are listed in Appendix A. Trials 1 and 5 represent recorded events during the drive phase of the rowing cycle. Trials 2 and 6 represent recorded events during the recovery phase of the rowing cycle.

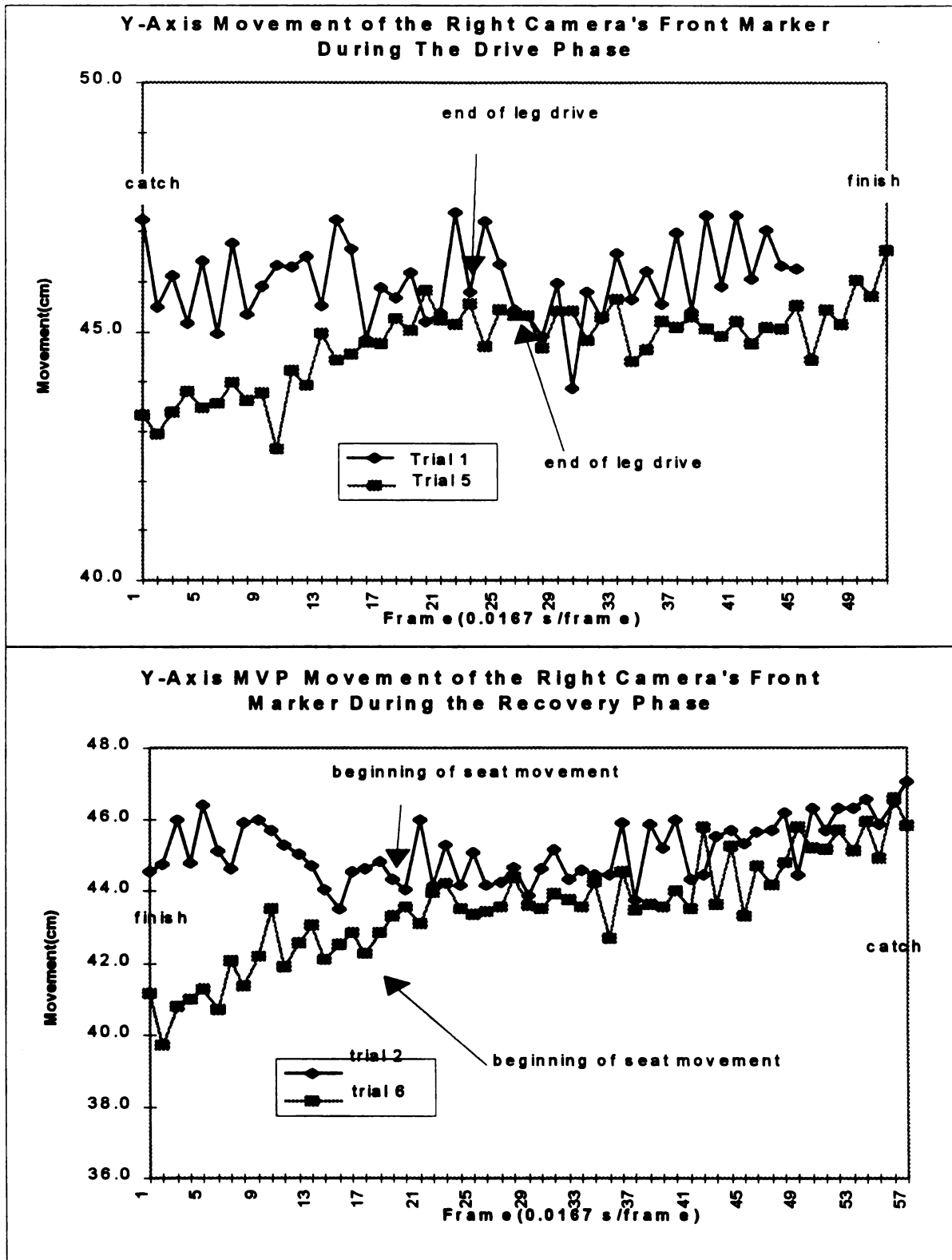
#### Effects of the Rowing Cycle Events on MVP Movements

The movements of the MVP were plotted for each frame to determine the effect of rowing events (catch, leg drive, upper body drive, hands and body away and seat movement) on the movements of the MVP. Figure 4.1 a,b and c shows the movement of the MVP along the x, y, and z axes. Figure 4.2 a,b and c shows the movement of the MVP along the xy, yz and xz planes.

No distinguishable patterns linking rowing events to erratic MVP movements were found. Instead, erratic movements were found throughout the rowing cycle. This may be due to the large field of view used to track the MVP. A smaller field of view would increase the accuracy of the digitization. This would provide greater insight into the effects of the shell movement on the movement of the MVP.

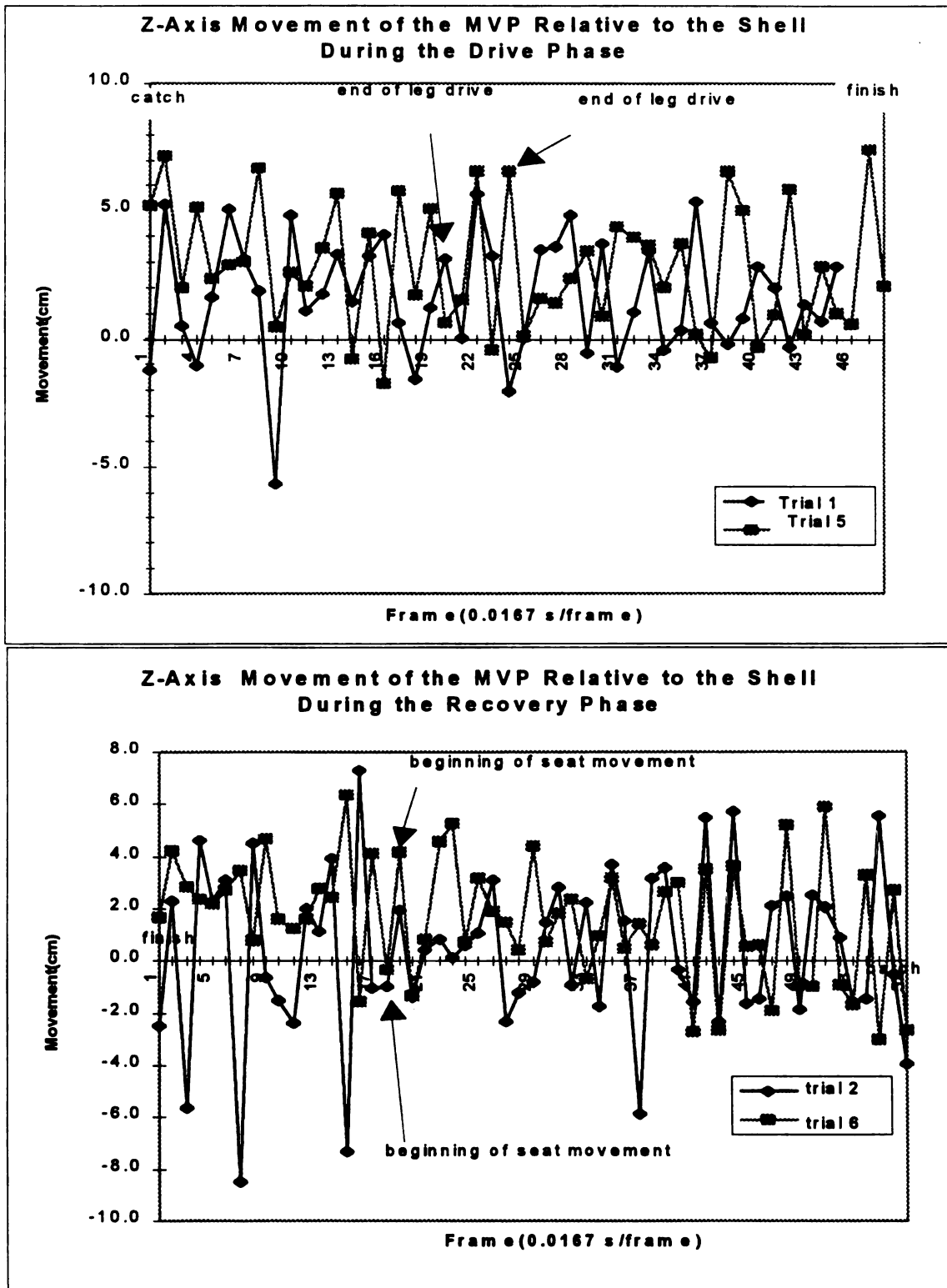


**Figure 4.1a.** Movement of the MVP relative to the shell along the x-axis.

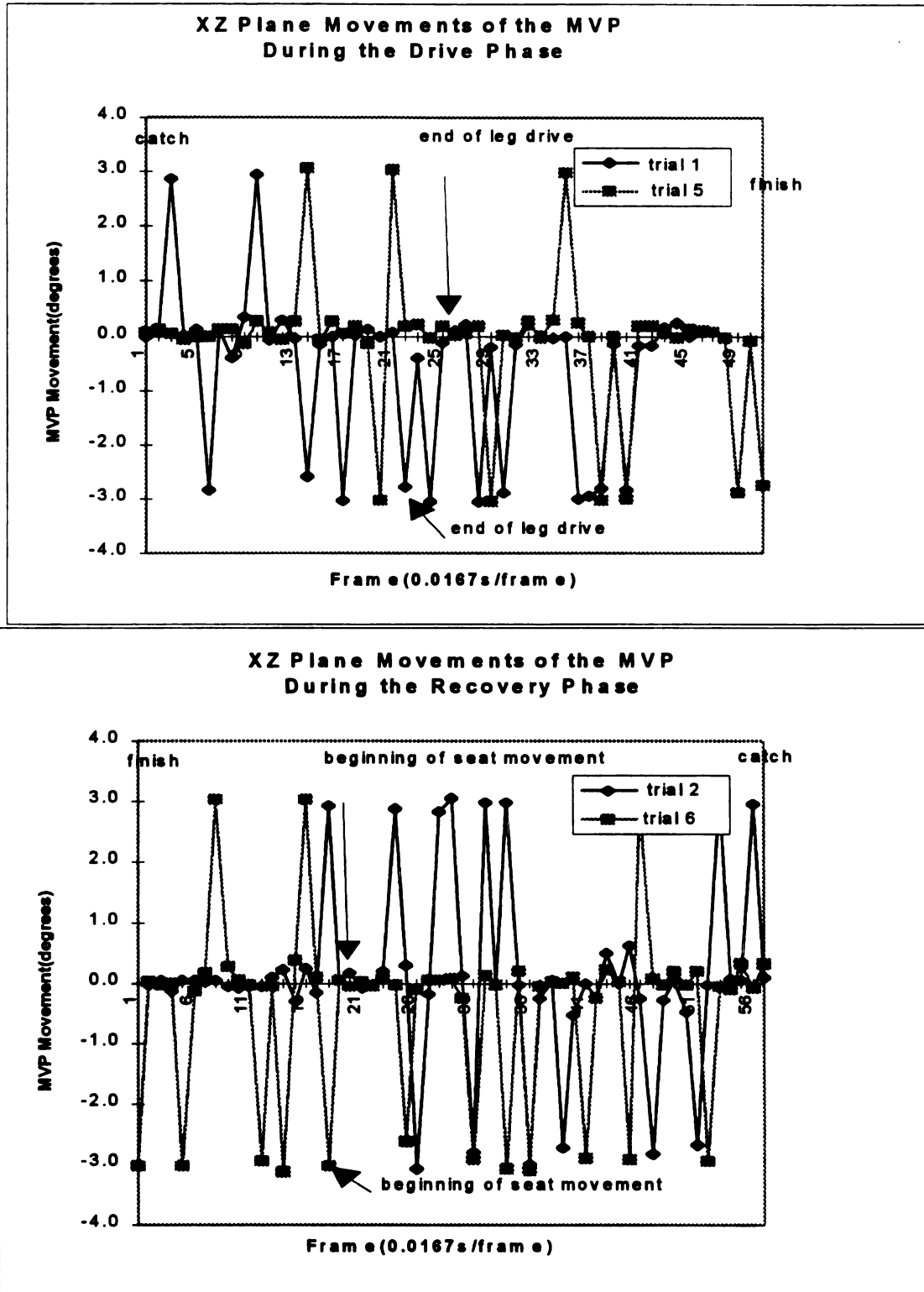


**Figure 4.1b.** Movement of the MVP along the y-axis.

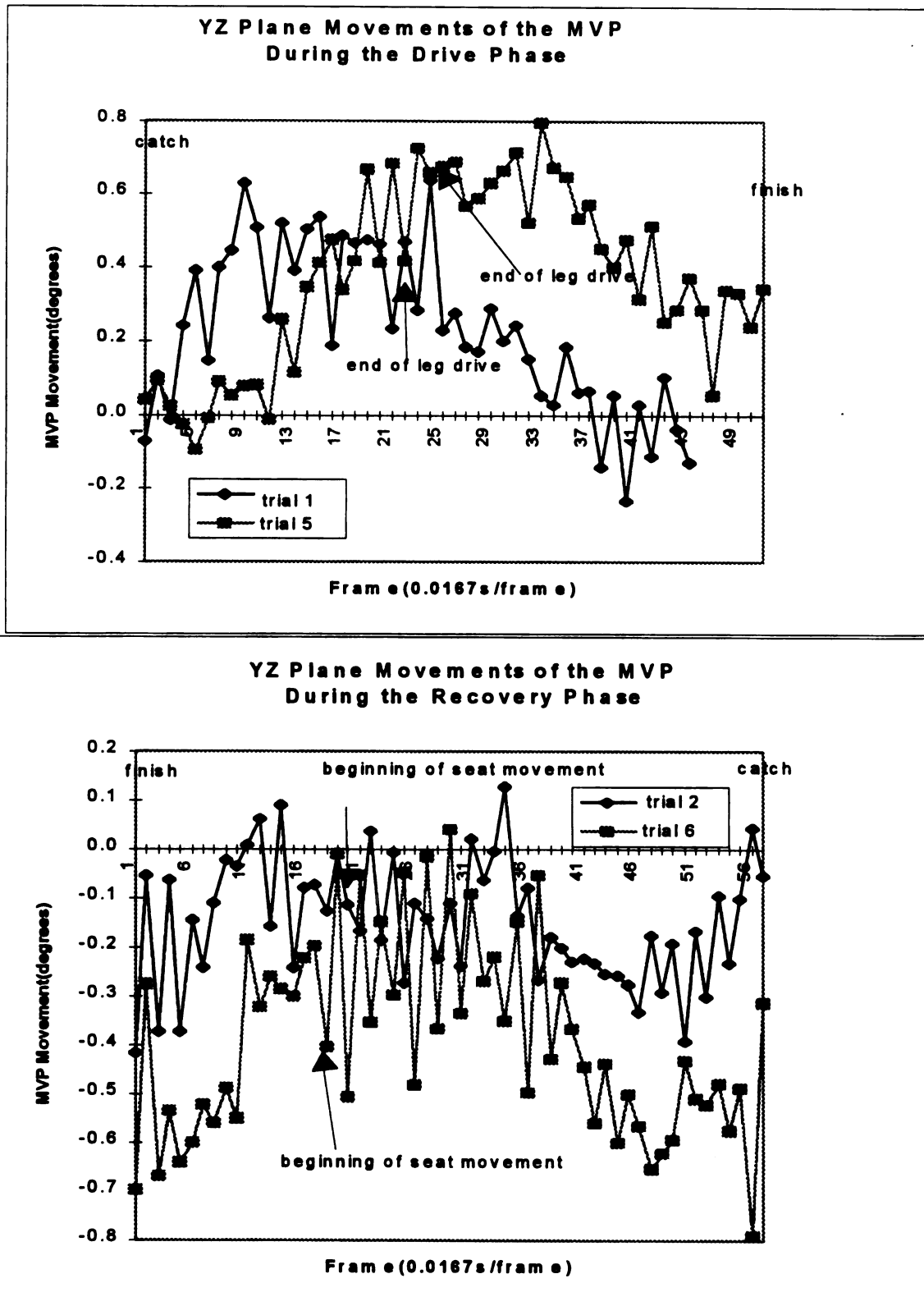




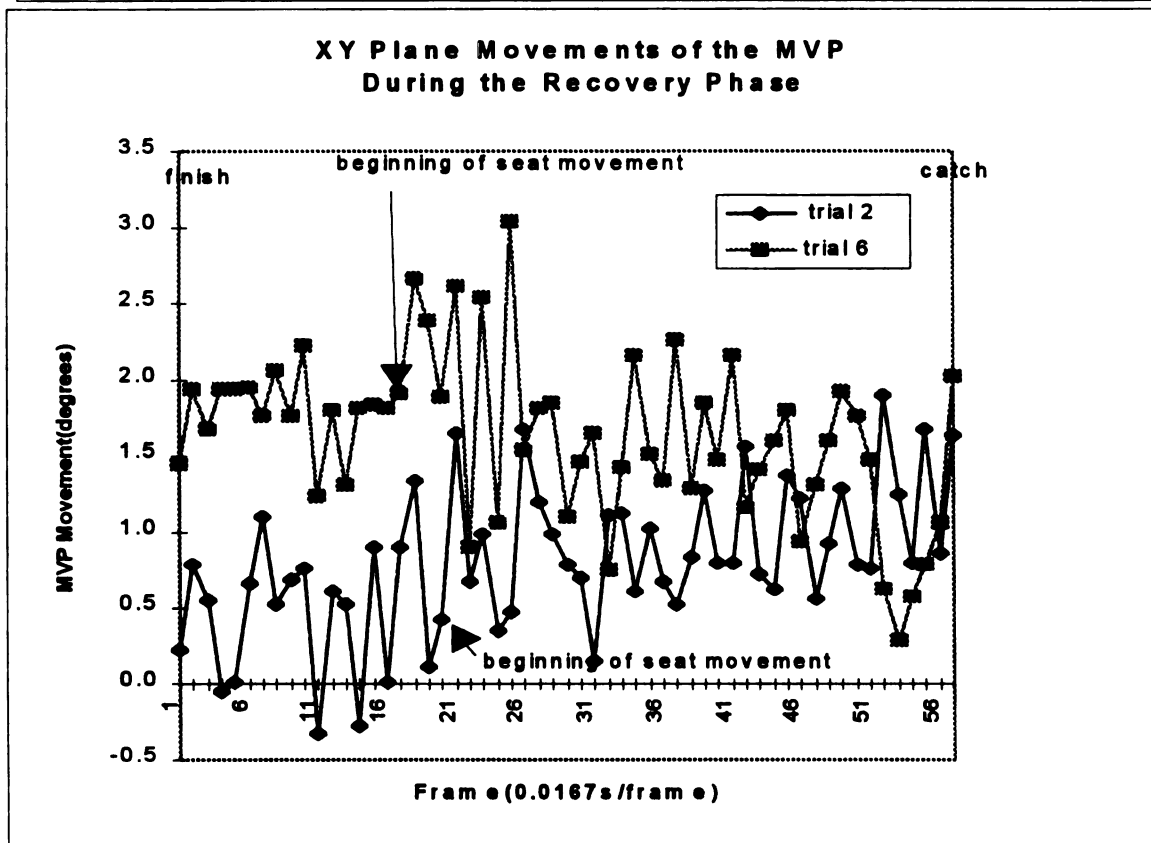
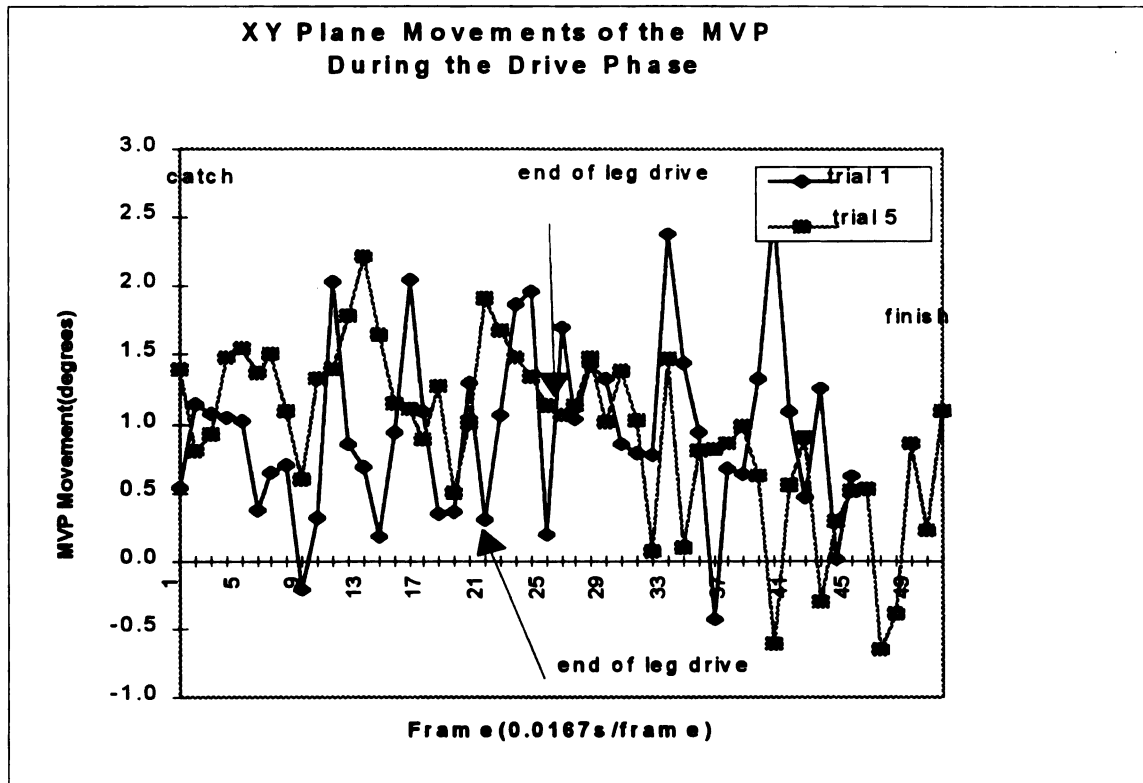
**Figure 4.1c.** Movement of the MVP relative to the shell along the z-axis.



**Figure 4.2a.** Movement of the MVP relative to the shell in the xz plane.



**Figure 4.2b.** Movement of the MVP in the yz plane.



**Figure 4.2c.** Movement of the MVP in the xy plane.

### Maximum Movements of the MVP

Table 4.1 lists the maximum movements of the MVP and the average digitizing error for the four trials used in the MVP analysis.

Table 4.1. Movements of the MVP from the digitized data.

| Digitizing(cm)       | X(cm) | Y(cm) | Z(cm) | $\theta$ (deg) | $\phi$ (deg) | $\Psi$ (deg) |
|----------------------|-------|-------|-------|----------------|--------------|--------------|
| x:5.6, y:0.9, z: 7.8 | 17.4  | 10.0  | 16.6  | 8.9            | 2.9          | 6.6          |

The large digitizing error along the x and z axis can be attributed to the large field of view. This large error corresponded with large MVP movements along the x and z axes and in the three planes. The y-axis was approximately 1/20 the length of the x and z axes. This resulted in a smaller digitization error for the y coordinates. The calculations for the movements of the MVP are in Appendixes B through H. A table of movements of the MVP for all trials is listed in Appendix I.

The values from Table 4.1 set the maximum values for testing in the laboratory. However, the calculation of the MVP movements did not distinguish between positive and negative values but gave only a range of values. Therefore, the values used in the laboratory were moved through the positive and negative range of values. The range of values used for the camera movements(Q) with respect to the control frame are listed in Table 4.2.

**Table 4.2.** Range of values used in laboratory testing.

| X(cm)  | Y(cm)  | Z(cm)  | $\theta$ (deg) | $\phi$<br>(deg) | $\Psi$ (deg) |
|--------|--------|--------|----------------|-----------------|--------------|
| +/- 18 | +/- 10 | +/- 18 | +/- 10         | +/- 9.3         | +/- 10.3     |

**Uncertainty Measurements**

Ten fields of video were taken of the eight unknown points: A, B, C, D, E, F, G and H for each Q at each dQ value (see Appendices J-Q). The average x, y and z coordinates were taken from the digitized fields for each Q at each dQ value (see Appendices J-Q).] These average coordinates were used as  $n_i$  in the equation  $dn_i = n_i - n_{i \text{ control}}$ . The values  $dn_i / dQ$  were then calculated. Analysis of the  $dn_i / dQ$  values showed constant traits. Therefore, the average of the  $dn_i / dQ$  values were taken for each point at each Q (see Table 4.3). Analysis of the average  $dn_i / dQ$  for each point showed similarities across points A, B, C and D and E, F, G and H. Therefore, the average  $dn_i / dQ$  values for points A through D and E through H were calculated and were used to approximate the partial derivative  $\partial n_i / \partial Q$  (see Table 4.3). Two sets of uncertainty equations, one for points A, B, C and D and one for points E, F, G and H, were written. These equations are:

$$U_{xA-D} = 1.12 dX' - 0.28 dY' + 0.63 dZ' - 1.21 d\theta' - 0.12 d\phi' + 2.15 d\Psi'$$

$$U_{xE-H} = 0.04 dX' + 0.01 dY' + 0.22 dZ' - 0.46 d\theta' + 0.01 d\phi' + 0.39 d\Psi'$$

$$U_{yA-D} = -0.17 dX' + 0.48 dY' - 0.04 dZ' + 0.01 d\theta' + 0.55 d\phi' + 0.02 d\Psi'$$

$$U_{yE-H} = -0.12 dX' + 0.03 dY' - 0.02 dZ' + 0.04 d\theta' + 0.31 d\phi' - 0.15 d\Psi'$$

$$U_{zA-D} = -0.12 dX' + 0.02 dY' + 0.42 dZ' + 0.36 d\theta' - 0.78 d\phi' - 0.13 d\Psi'$$

$$U_{zE-H} = -0.09 dX' + 0.02 dY' + 0.03 dZ' - 0.09 d\theta' - 0.49 d\phi' - 0.13 d\Psi'$$

**Table 4.3.** Average  $dn_i/dQ$ .

| I              | A     |       |       | B     |       |       | C     |       |       | D     |       |       | Average: points A - D |       |       |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----------------------|-------|-------|
| n              | x     | y     | z     | x     | y     | z     | x     | y     | z     | x     | y     | z     | x                     | y     | z     |
| $dn_i/dX$      | 1.00  | 0.00  | -0.28 | 1.17  | -0.33 | -0.22 | 1.25  | -0.02 | -0.01 | 1.05  | -0.33 | 0.03  | 1.12                  | -0.17 | -0.12 |
| $dn_i/dY$      | -0.10 | 0.42  | 0.01  | -0.10 | 0.51  | 0.00  | -0.84 | 0.56  | 0.09  | -0.07 | 0.44  | -0.02 | -0.28                 | 0.48  | 0.02  |
| $dn_i/dZ$      | 0.81  | 0.02  | 0.39  | 0.69  | -0.11 | 0.45  | 0.81  | -0.05 | 0.41  | 0.21  | -0.04 | 0.43  | 0.63                  | -0.04 | 0.42  |
| $dn_i/d\theta$ | -2.01 | -0.10 | 0.45  | -1.77 | 0.26  | 0.36  | -0.72 | -0.05 | 0.37  | -0.35 | -0.06 | 0.28  | -1.21                 | 0.01  | 0.36  |
| $dn_i/d\phi$   | -0.19 | 0.95  | -0.48 | 0.08  | 0.81  | -1.19 | 0.02  | 0.34  | -0.37 | 0.58  | 0.09  | -1.05 | 0.12                  | 0.55  | -0.78 |
| $dn_i/d\Psi$   | 1.34  | 0.29  | -0.46 | 2.88  | -0.23 | -0.27 | 2.21  | 0.24  | -0.02 | 2.18  | -0.23 | 0.24  | 2.15                  | 0.02  | -0.13 |
| I              | E     |       |       | F     |       |       | G     |       |       | H     |       |       | Average: points E - H |       |       |
| n              | x     | y     | z     | x     | y     | z     | x     | y     | z     | x     | y     | z     | x                     | y     | z     |
| $dn_i/dX$      | 0.06  | -0.01 | 0.00  | 0.04  | -0.24 | -0.02 | -0.06 | -0.01 | -0.14 | 0.09  | -0.23 | -0.20 | 0.04                  | -0.12 | -0.09 |
| $dn_i/dY$      | -0.02 | 0.04  | -0.04 | 0.03  | 0.02  | -0.03 | 0.02  | -0.01 | 0.00  | 0.02  | 0.07  | -0.01 | 0.01                  | 0.03  | -0.02 |
| $dn_i/dZ$      | 0.03  | -0.01 | 0.04  | 0.04  | -0.01 | 0.02  | 0.34  | 0.01  | 0.03  | 0.48  | -0.09 | 0.05  | 0.22                  | -0.02 | 0.03  |
| $dn_i/d\theta$ | -0.02 | -0.02 | 0.00  | -0.11 | -0.04 | -0.16 | -0.69 | -0.06 | -0.16 | -1.04 | 0.28  | -0.06 | -0.46                 | 0.04  | -0.09 |
| $dn_i/d\phi$   | 0.00  | 0.01  | -0.10 | 0.30  | -0.01 | -0.82 | -0.22 | 0.51  | -0.16 | -0.04 | 0.73  | -0.90 | 0.01                  | 0.31  | -0.49 |
| $dn_i/d\Psi$   | 0.19  | 0.06  | -0.01 | 0.02  | -0.29 | -0.03 | 0.04  | 0.02  | -0.30 | 1.33  | -0.37 | -0.18 | 0.39                  | -0.15 | -0.13 |

The contribution of each  $dn_i/dQ$  to the sum of the  $dn_i/dQ$  values for each coordinate was examined to determine the weight of each camera movement on the uncertainty equation (see Table 4.4). The Q's with the greatest affect on the uncertainty for points A through D were:

1.  $\Psi$ , 39% of the total  $dx/dQ$ ,
2.  $\phi$  and  $Y$ , 81% of the total  $dy/dQ$  and
3.  $\phi$ , 42% of the total  $dz/dQ$ .

The Q's with the greatest affect on uncertainty for points E through H were:

1.  $\Psi$  and  $\theta$ , 75% of total  $dx/dQ$ ,
2.  $\phi$ , 46% of the total  $dy/dQ$  and
3.  $\phi$ , 57% of the total  $dz/dQ$ .

$U_{x\ A-D}$  was the only equation with  $dx/dQ$  values greater than one. This means that small camera movements cause large errors in the digitized data. These large  $dx/dQ$

values were not present in  $U_{x\ E-H}$ . This is due to the increase in angle between the cameras and the field of view.

**Table 4.4.** Percent of total  $dn_i/dQ$ .

| <b>Points A-D</b>                         |          |          |          | <b>Points E-H</b>                         |          |          |          |
|-------------------------------------------|----------|----------|----------|-------------------------------------------|----------|----------|----------|
| <b>Percent Total <math>dn_i/dQ</math></b> |          |          |          | <b>Percent Total <math>dn_i/dQ</math></b> |          |          |          |
| <b>n</b>                                  | <b>x</b> | <b>y</b> | <b>z</b> | <b>n</b>                                  | <b>x</b> | <b>y</b> | <b>z</b> |
| $dn_i / dX$                               | 20       | 13       | 7        | $dn_i / dX$                               | 3        | 18       | 10       |
| $dn_i / dY$                               | 5        | 38       | 1        | $dn_i / dY$                               | 1        | 5        | 2        |
| $dn_i / dZ$                               | 11       | 3        | 23       | $dn_i / dZ$                               | 20       | 4        | 4        |
| $dn_i / d\theta$                          | 22       | 1        | 20       | $dn_i / d\theta$                          | 41       | 6        | 11       |
| $dn_i / d\phi$                            | 1        | 43       | 42       | $dn_i / d\phi$                            | <1%      | 46       | 57       |
| $dn_i / d\psi$                            | 39       | 1        | 7        | $dn_i / d\psi$                            | 34       | 22       | 16       |

### Uncertainty of the MVP

Using the maximum values from the MVP movement and assuming that these movements have the same sign as the average  $dn_i/dQ$ . The maximum uncertainty values obtained for the MVP were:

$$\begin{array}{lll}
 U_{xA-D} = 58.1 \text{ cm} & U_{yA-D} = 10.3 \text{ cm} & U_{zA-D} = 15.6 \text{ cm} \\
 U_{xB-H} = 11.1 \text{ cm} & U_{yA-D} = 5.0 \text{ cm} & U_{zB-H} = 13.5 \text{ cm}
 \end{array}$$

Points at the finish position of the rowing cycle will have greater uncertainty than points at the catch. However, the uncertainty at either position is too great for any biomechanical model since these errors would be amplified with velocity measurements.

Structural changes to the MVP are necessary to limit movement of the MVP along the x-axis and reduce rotations in the xy and yz planes. Errors can be substantially decreased by either moving the MVP closer to the rower or increasing the distance



between the cameras. Either option would increase the angle between the cameras and the rower in the field of view.

## CHAPTER 5

### Discussion

The analysis of the MVP while under tow by the shell yielded large movements and large digitizing error, especially along the x and z axes. These large errors corresponded to a large field of view in the xz plane. Digitized data of the MVP showed erratic movements throughout the rowing cycle.

The laboratory tests on affects of camera movement on digitized data showed that proper triangulation between the cameras and the field of view greatly minimized the uncertainty. For points that had approximately 46 degrees between cameras, movements along the xz and xy planes were the major contributors to the uncertainty in the digitized x coordintates. Movements along the yz plane were the main contibutor spelling to uncertainty in y and z coordinates.

### Reducing Uncertainty by Mounting Cameras to the Shell

The derived uncertainty equations:

$$\begin{aligned} U_{xA-D} &= 1.12 dX' - 0.28 dY' + 0.63 dZ' - 1.21 d\theta' - 0.12 d\phi' + 2.15 d\Psi', \\ U_{xE-H} &= 0.04 dX' + 0.01 dY' + 0.22 dZ' - 0.46 d\theta' + 0.01 d\phi' + 0.39 d\Psi', \end{aligned}$$

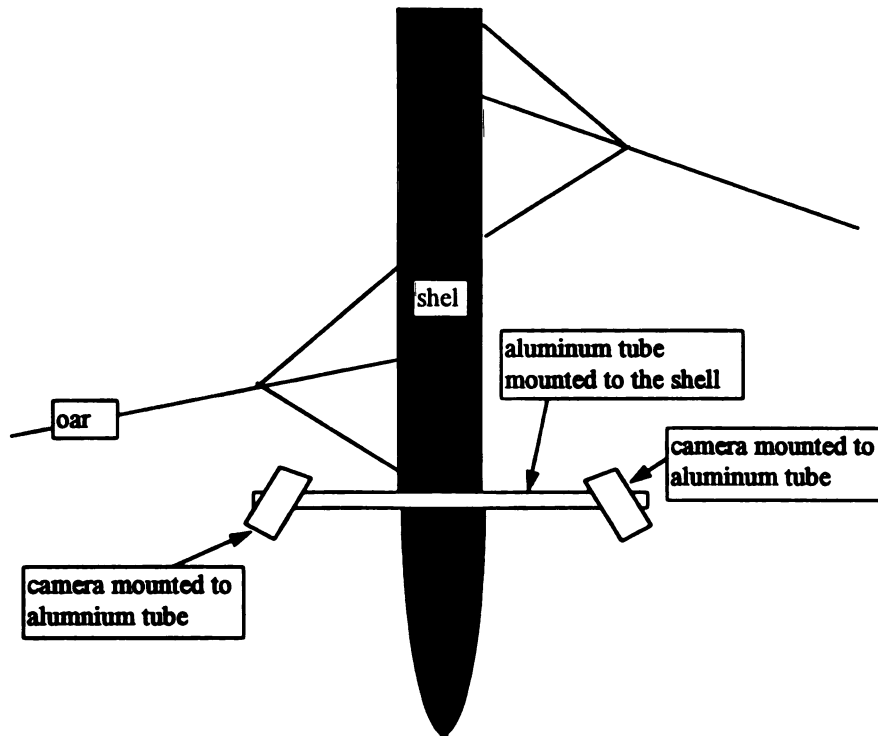
$$\begin{aligned} U_{yA-D} &= -0.17 dX' + 0.48 dY' - 0.04 dZ' + 0.01 d\theta' + 0.55 d\phi' + 0.02 d\Psi', \\ U_{yE-H} &= -0.12 dX' + 0.03 dY' - 0.02 dZ' + 0.04 d\theta' + 0.31 d\phi' - 0.15 d\Psi', \end{aligned}$$

$$\begin{aligned} U_{zA-D} &= -0.12 dX' + 0.02 dY' + 0.42 dZ' + 0.36 d\theta' - 0.78 d\phi' - 0.13 d\Psi', \text{ and} \\ U_{zE-H} &= -0.09 dX' + 0.02 dY' + 0.03 dZ' - 0.09 d\theta' - 0.49 d\phi' - 0.13 d\Psi' \end{aligned}$$

show that the MVP's three degrees of freedom caused great inaccuracies in the digitized data. The uncertainty of digitized data could be greatly reduced if the cameras were attached directly to the shell, rather than towed by it (see Figure 5.1). Attaching the cameras would limit rotations of the cameras to the yz plane. By establishing proper triangulation between the cameras and the field of view the uncertainty equations could be reduced

to the following:

$$\begin{aligned} U_x &= 0.01 \, d\phi', \\ U_y &= 0.31 \, d\phi' \text{ and} \\ U_z &= 0.49 \, d\phi'. \end{aligned}$$



**Figure 5.1.** Top view sketch of cameras attached directly to a shell.

#### Disadvantages of a Camera System Attached Directly to a Shell

The main disadvantage of attaching the cameras to the shell is the inability to calculate the rolling of the shell from digitized data. However, a goniometer could be used to measure the rolling of a shell that corresponds to each field of video. This would allow the uncertainty of each field to be calculated.

Another disadvantage is the possibility of balance problems caused by suspending cameras from the shell. This is especially true for small boats such as singles and doubles because the weight of the shell is much smaller than an eight or four person shell. Lightweight cameras could be used to limit this problem.

#### **Advantages of a Camera System Attached Directly to a Shell**

The greatest advantage of attaching a camera system to a shell is the increase in accuracy, especially along the x-axis. The rowing motion takes place mainly in the xy plane. The MVP had large movements in this plane causing large errors in the digitized data. The error in digitized x-coordinate data that was caused by camera rotations in the yz plane was minimal.

A second advantage is that a shell mounted system would be much lighter than the MVP and would not drag in the water. This means that testing can be done in less than ideal rowing conditions (i.e., smooth water).

#### **Estimated Error in Kinematic Calculations when Cameras Rotate in the YZ Plane**

The calculations that are most uncertain when calculating kinematic variables from digitized information are linear and angular accelerations. Table 5.1 leads through the calculation of the uncertainty in linear and angular accelerations given a rotation in the yz plane of five degrees. Five degrees was chosen as a better estimate of yz rotations. The calculated 10.3 degrees would make the riggers submerge in the water, which did not occur.

**Table 5.1.** Calculation of the uncertainty in linear and angular acceleration given a rotation in the cameras of five degrees in the yz plane.

|                                               | Linear                                                                                                                                                                                                                                                                                                                                            | Angular                                                                                                                                                                                                          |                                                                                                                                      |                                                                                                                                      |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>definitions</b>                            | a: linear acceleration<br>$\Delta t$ : time between frames<br>x: x coordinate(y or z could also be used)<br>i: frame number                                                                                                                                                                                                                       | $\alpha$ : angular acceleration<br>$\theta$ : segment angle<br>$\Delta t$ : time between frames<br>x: x coordinate(y or z could also be used)<br>y: y coordinate(x or z could also be used)<br>i: frame number   |                                                                                                                                      |                                                                                                                                      |
| <b>equations</b>                              | $a_{xi} = x_{i+1} - 2x_i + x_{i-1} / \Delta t^2$<br>from Winter(1990)                                                                                                                                                                                                                                                                             | $\theta_i = \tan^{-1} (y_i - y_{i-1}) / (x_i - x_{i-1})$<br>$\alpha\theta_i = \theta_{i+1} - 2\theta_i + \theta_{i-1} / \Delta t^2$<br>from Blatt(1986) and Winter(1990)                                         |                                                                                                                                      |                                                                                                                                      |
| <b>uncertainty equation</b>                   | $\delta (a_{xi}) = [\delta(x_{i+1})^2 + 2\delta(x_i)^2 + \delta(x_{i-1})^2]^{1/2}$                                                                                                                                                                                                                                                                | $\delta (\theta_i) = [\delta(y_i)^2 + \delta(y_{i-1})^2 + \delta(x_i)^2 + \delta(x_{i-1})^2]^{1/2}$<br>$\delta (\alpha\theta_i) = [\delta(\theta_{i+1})^2 + 2\delta(\theta_i)^2 + \delta(\theta_{i-1})^2]^{1/2}$ |                                                                                                                                      |                                                                                                                                      |
| <b>assumptions</b>                            | proper triangulation and small movements yield:<br>$\delta(x_{i+1}) = \delta(x_i) = \delta(x_{i-1})$                                                                                                                                                                                                                                              | proper triangulation and small movements yield:<br>$\delta(y_i) = \delta(y_{i-1})$ and $\delta(x_i) = \delta(x_{i-1})$ and<br>$\delta(\theta_{i+1}) = \delta(\theta_i) = \delta(\theta_{i-1})$                   |                                                                                                                                      |                                                                                                                                      |
| <b>uncertainty equation after assumptions</b> | $\delta (a_{xi}) = 2 \delta(x_i)$                                                                                                                                                                                                                                                                                                                 | $\delta (\theta_i) = [2 \delta(y_i)^2 + 2 \delta(x_i)^2]^{1/2}$<br>$\delta (\alpha\theta_i) = 2 \delta(\theta_i)$                                                                                                |                                                                                                                                      |                                                                                                                                      |
| <b>Given yz rotation of 5 degrees</b>         | $\delta(x_i) = 0.01 \text{ cm/deg (5 deg)} = \pm 0.05 \text{ cm}$<br>$\delta(y_i) = 0.31 \text{ cm/deg(5deg)} = \pm 1.55 \text{ cm}$<br>$\delta(z_i) = 0.49 \text{ cm/deg(5deg)} = \pm 2.45 \text{ cm}$<br>$\delta (a_{xi}) = \pm 0.1 \text{ cm/s}^2$<br>$\delta (a_{yi}) = \pm 3.1 \text{ cm/s}^2$<br>$\delta (a_{zi}) = \pm 4.9 \text{ cm/s}^2$ | <u><math>\theta</math> in xy</u><br>$\delta(\theta_i) = \pm 2.1 \text{ deg,}$<br>$\delta (\alpha\theta_i) = \pm 4.2 \text{ deg/s}^2$                                                                             | <u><math>\theta</math> in xz</u><br>$\delta(\theta_i) = \pm 3.4 \text{ deg,}$<br>$\delta (\alpha\theta_i) = \pm 6.8 \text{ deg/s}^2$ | <u><math>\theta</math> in yz</u><br>$\delta(\theta_i) = \pm 4.1 \text{ deg,}$<br>$\delta (\alpha\theta_i) = \pm 8.2 \text{ deg/s}^2$ |

### Estimated Percent Error

The following example estimates the linear x and angular xy accelerations of a rower's right shank. Martin and Bernfield (1980) found that the leg drive for elite male rowers took 0.67 seconds. The shank rotates approximately 90 degrees in the xy plane during the leg drive phase and will travel a distance of approximately 50 cm along the x axis. If constant acceleration is assumed, the linear and angular acceleration of a rower's right shank can be estimated by the following calculations:

$$\theta_f = \theta_o + \omega_o t + 1/2 \alpha_{xy} t^2 \text{ and}$$

$$x_f = x_i + v_o t + 1/2 a_x t^2$$

where  $\theta_o$ ,  $\omega_o$ ,  $x_i$  and  $v_o = 0$ .

$$\alpha_{xy} = 2(90 \text{ deg}) / (0.67 \text{ s})^2 = 400.98 \text{ deg/s}^2 \text{ +/- } 4.2 \text{ deg/s}^2 \text{ and}$$

$$a_x = 2(50 \text{ cm}) / (0.67 \text{ s})^2 = 222.77 \text{ cm/s}^2 \text{ +/- } 0.1 \text{ cm/s}^2.$$

Therefore, the percent error in calculating

$$\alpha_{xy} = 100\% * 8.4 \text{ deg/s}^2 / 400.98 \text{ deg/s}^2 = 2.1\% \text{ and in calculating}$$

$$a_x = 100\% * 0.2 \text{ cm/s}^2 / 222.77 \text{ cm/s}^2 = 0.09\%$$

### Further Testing on the Uncertainty Coefficient

The present study showed that the uncertainty depends largely on the angle between the cameras and the field of view. Proper triangulation (>60 degrees) between the cameras and the field of view may change the uncertainty coefficient. A follow-up study on the affects of yz camera rotation on digitized data needs to be completed before any kinematic testing of rowers takes place.

### Conclusions

The MVP in its present state is not accurate enough for use in an acceptable kinematic analysis of the rowing cycle. However, this study provided the basis for establishing a better tool in studying the kinematics of rowing. The equations established

in the laboratory allows for an approximation of the uncertainty in calculated  $x, y$  and  $z$  coordinates when rotation and movement in the cameras occurs. By attaching the cameras to the shell rather than towing them, the effect on the uncertainty of digitized data is greatly reduced. However, further testing of the uncertainty coefficient is necessary because of the change in angle between the cameras and the field of view.

A goniometer will need to be attached to the cameras to measure the  $yz$  movements of the cameras and the shell. A shell mounted system yields estimates of less than 5% error on linear accelerations along the  $x$ -axis and in angular accelerations in the  $xy$  plane.

## APPENDIX A

### Coordinates of Mobile Video Platform Markers





|    |                     |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |
|----|---------------------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|
| 32 | END<br>Log<br>Drive | 0.527 | 147.5 | 44.0 | 244.6 | 132.0 | 43.7 | 242.7 | 114.5 | 46.8 | 549.1 | 96.6  | 45.2 | 547.0 | 278.3 | 16.3 | 404.6 |
| 33 |                     | 0.544 | 163.6 | 44.0 | 244.2 | 138.1 | 43.7 | 243.5 | 121.6 | 47.2 | 549.4 | 102.8 | 47.2 | 549.5 | 284.0 | 17.0 | 404.4 |
| 34 |                     | 0.561 | 180.4 | 44.8 | 246.2 | 144.3 | 44.6 | 245.7 | 128.2 | 46.4 | 550.9 | 110.6 | 45.8 | 549.8 | 290.7 | 15.7 | 408.8 |
| 35 |                     | 0.578 | 167.9 | 44.0 | 248.0 | 132.2 | 43.7 | 246.6 | 134.4 | 45.4 | 552.7 | 118.0 | 45.1 | 551.0 | 296.3 | 16.0 | 408.1 |
| 36 |                     | 0.595 | 178.5 | 44.1 | 250.5 | 159.7 | 43.9 | 249.2 | 141.6 | 45.3 | 555.0 | 124.7 | 44.9 | 552.8 | 304.3 | 15.1 | 408.7 |
| 37 |                     | 0.612 | 181.0 | 43.9 | 249.8 | 165.3 | 43.6 | 248.0 | 147.6 | 44.9 | 555.1 | 129.7 | 44.5 | 552.4 | 310.9 | 15.6 | 408.1 |
| 38 |                     | 0.629 | 187.8 | 44.6 | 252.9 | 171.4 | 44.2 | 250.1 | 154.4 | 46.0 | 555.7 | 137.3 | 45.7 | 555.0 | 317.2 | 16.4 | 410.0 |
| 39 |                     | 0.646 | 194.4 | 42.8 | 251.1 | 179.6 | 42.6 | 249.2 | 161.9 | 43.9 | 556.5 | 145.3 | 43.6 | 553.3 | 325.9 | 14.6 | 408.6 |
| 40 |                     | 0.663 | 201.0 | 44.4 | 251.7 | 185.1 | 44.2 | 251.3 | 168.0 | 45.8 | 556.9 | 150.2 | 45.5 | 556.5 | 331.4 | 17.8 | 409.8 |
| 41 |                     | 0.68  | 208.1 | 44.0 | 253.1 | 192.6 | 43.7 | 252.5 | 175.7 | 45.3 | 558.9 | 158.0 | 44.5 | 556.2 | 339.7 | 15.3 | 410.1 |
| 42 |                     | 0.697 | 213.8 | 46.3 | 254.0 | 197.8 | 45.8 | 252.0 | 181.7 | 46.6 | 557.6 | 164.1 | 46.1 | 555.8 | 346.0 | 18.7 | 408.6 |
| 43 |                     | 0.714 | 221.6 | 44.9 | 253.0 | 206.8 | 45.2 | 253.5 | 189.7 | 45.6 | 558.9 | 171.0 | 45.3 | 557.5 | 353.2 | 15.7 | 410.0 |
| 44 |                     | 0.731 | 230.2 | 45.7 | 254.3 | 212.7 | 45.3 | 253.4 | 196.8 | 46.2 | 561.0 | 178.8 | 46.3 | 560.9 | 361.0 | 17.2 | 412.3 |
| 45 |                     | 0.748 | 236.2 | 45.3 | 256.1 | 219.6 | 45.0 | 254.8 | 203.2 | 45.5 | 561.8 | 184.6 | 45.3 | 561.3 | 366.4 | 16.4 | 412.3 |
| 46 |                     | 0.765 | 245.0 | 46.5 | 256.5 | 227.4 | 46.4 | 253.6 | 211.9 | 47.0 | 562.2 | 193.5 | 46.8 | 561.2 | 375.7 | 20.4 | 411.0 |
| 47 |                     | 0.782 | 252.5 | 46.0 | 255.6 | 235.0 | 45.7 | 256.5 | 219.6 | 45.4 | 562.9 | 200.7 | 45.0 | 560.7 | 380.6 | 15.3 | 409.8 |
| 48 |                     | 0.799 | 259.2 | 46.3 | 258.0 | 241.3 | 46.3 | 257.7 | 225.4 | 47.3 | 563.3 | 207.2 | 46.5 | 562.3 | 389.7 | 17.3 | 411.8 |
| 49 |                     | 0.816 | 266.2 | 46.8 | 256.6 | 249.2 | 46.8 | 256.2 | 232.8 | 45.9 | 564.7 | 213.8 | 45.6 | 564.4 | 394.9 | 14.1 | 411.2 |
| 50 |                     | 0.833 | 273.3 | 47.2 | 258.1 | 256.3 | 47.0 | 258.0 | 240.6 | 47.3 | 564.9 | 222.3 | 47.2 | 565.5 | 404.2 | 17.3 | 413.3 |
| 51 |                     | 0.85  | 280.9 | 46.4 | 259.3 | 264.1 | 46.3 | 260.1 | 248.2 | 46.1 | 565.0 | 230.8 | 45.7 | 564.9 | 412.4 | 15.8 | 414.8 |
| 52 |                     | 0.867 | 288.3 | 46.7 | 260.5 | 273.3 | 46.5 | 258.8 | 255.6 | 47.0 | 564.5 | 237.4 | 47.0 | 565.0 | 419.2 | 16.8 | 413.4 |
| 53 |                     | 0.884 | 295.4 | 46.4 | 261.4 | 279.1 | 46.4 | 261.3 | 263.2 | 46.3 | 566.4 | 245.3 | 46.1 | 566.9 | 427.2 | 15.8 | 413.5 |
| 54 | Finish              | 0.901 | 302.7 | 46.7 | 260.8 | 286.4 | 46.7 | 260.0 | 270.7 | 46.2 | 566.6 | 252.5 | 46.0 | 567.8 | 434.1 | 15.6 | 413.9 |
| 55 |                     | 0.918 | 309.8 | 46.5 | 261.2 | 293.9 | 46.3 | 260.3 | 278.9 | 47.4 | 567.3 | 260.3 | 47.3 | 569.3 | 443.0 | 16.3 | 413.6 |
| 56 |                     | 0.935 | 319.0 | 46.9 | 262.1 | 302.7 | 46.8 | 261.4 | 287.0 | 46.5 | 567.9 | 267.7 | 46.7 | 570.0 | 450.3 | 15.5 | 414.0 |
| 57 |                     | 0.952 | 326.5 | 45.6 | 260.7 | 310.8 | 45.2 | 259.7 | 294.0 | 46.6 | 568.7 | 275.9 | 46.5 | 567.3 | 457.2 | 14.0 | 412.2 |
| 58 |                     | 0.969 | 333.2 | 47.2 | 261.8 | 316.8 | 46.7 | 261.7 | 300.6 | 46.9 | 567.7 | 283.2 | 46.4 | 567.1 | 464.8 | 15.6 | 413.5 |
| 59 |                     | 0.986 | 339.9 | 45.8 | 261.0 | 324.9 | 45.5 | 261.3 | 308.3 | 46.7 | 568.0 | 290.2 | 46.8 | 566.7 | 472.9 | 14.0 | 413.3 |
| 60 |                     | 1.003 | 347.7 | 46.2 | 262.5 | 332.1 | 46.0 | 260.9 | 315.6 | 47.5 | 569.6 | 297.8 | 47.2 | 568.7 | 480.0 | 15.4 | 413.4 |
| 61 |                     | 1.02  | 355.2 | 46.4 | 263.8 | 339.3 | 46.1 | 263.1 | 322.5 | 47.3 | 569.1 | 305.6 | 47.2 | 569.7 | 488.0 | 15.0 | 413.9 |
| 62 |                     | 1.037 | 364.0 | 46.1 | 264.2 | 347.9 | 46.0 | 263.4 | 331.1 | 47.8 | 571.4 | 313.1 | 47.4 | 569.8 | 496.3 | 15.0 | 413.9 |
| 63 |                     | 1.054 | 371.5 | 45.2 | 262.5 | 355.3 | 44.9 | 262.8 | 339.4 | 47.0 | 570.2 | 321.3 | 46.9 | 571.0 | 504.0 | 14.2 | 413.1 |

|                                                  |        |         |           |           |           |           |           |           |           |           |           |           |           |           |         |         |         |
|--------------------------------------------------|--------|---------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|---------|---------|---------|
| 64                                               |        | 1.971   | 379.4     | 47.3      | 265.0     | 363.7     | 47.0      | 264.8     | 346.8     | 46.0      | 572.2     | 327.8     | 48.8      | 572.7     | 510.2   | 15.1    | 415.6   |
| Coordinates of Mobile Video Platform Markers(cm) |        |         |           |           |           |           |           |           |           |           |           |           |           |           |         |         |         |
| Trial 2                                          |        |         |           |           |           |           |           |           |           |           |           |           |           |           |         |         |         |
| From                                             | Event  | Time(s) | X(rfbcam) | Y(rfbcam) | Z(rfbcam) | X(rfbcam) | Y(rfbcam) | Z(rfbcam) | X(rfbcam) | Y(rfbcam) | Z(rfbcam) | X(rfbcam) | Y(rfbcam) | Z(rfbcam) | X(boat) | Y(boat) | Z(boat) |
| 1                                                | 0      | 0       | 67.8      | 43.8      | -92.8     | 82.8      | 44.0      | -89.6     | 47.7      | 42.7      | 215.6     | 30.8      | 42.6      | 215.9     | 205.3   | 17.1    | 61.6    |
| 2                                                |        | 0.017   | 76.8      | 46.1      | -98.3     | 61.1      | 46.1      | -90.7     | 55.7      | 44.1      | 212.3     | 37.1      | 44.2      | 215.7     | 213.6   | 16.3    | 59.2    |
| 3                                                |        | 0.034   | 83.2      | 45.2      | -92.1     | 65.4      | 44.9      | -89.4     | 62.6      | 43.9      | 216.1     | 43.4      | 43.6      | 216.6     | 220.1   | 16.8    | 61.8    |
| 4                                                |        | 0.091   | 89.7      | 45.9      | -93.6     | 73.2      | 45.9      | -89.7     | 69.8      | 44.7      | 214.0     | 51.2      | 44.4      | 215.8     | 227.5   | 16.0    | 61.2    |
| 5                                                |        | 0.068   | 96.0      | 45.6      | -91.9     | 81.3      | 45.7      | -88.1     | 77.4      | 43.5      | 215.6     | 59.6      | 43.4      | 217.4     | 235.4   | 16.1    | 61.6    |
| 6                                                |        | 0.095   | 103.1     | 44.8      | -94.6     | 86.6      | 44.6      | -93.0     | 83.5      | 44.0      | 213.3     | 64.4      | 43.5      | 214.6     | 240.8   | 14.4    | 59.0    |
| 7                                                |        | 0.102   | 112.2     | 46.5      | -92.2     | 95.3      | 46.2      | -91.5     | 90.3      | 44.4      | 213.7     | 72.6      | 44.3      | 216.7     | 249.7   | 16.5    | 62.6    |
| 8                                                |        | 0.119   | 119.4     | 46.2      | -90.6     | 103.1     | 46.0      | -90.5     | 97.8      | 44.7      | 214.2     | 79.2      | 44.4      | 217.4     | 256.7   | 15.8    | 61.2    |
| 9                                                |        | 0.136   | 127.0     | 46.8      | -91.4     | 110.4     | 46.4      | -90.7     | 105.0     | 44.2      | 215.8     | 86.4      | 44.2      | 219.2     | 264.7   | 16.5    | 61.6    |
| 10                                               | Finish |         |           |           |           |           |           |           |           |           |           |           |           |           |         |         |         |
| 11                                               |        | 0.17    | 141.0     | 46.7      | -91.2     | 125.3     | 46.6      | -89.9     | 119.0     | 44.7      | 215.3     | 100.5     | 44.6      | 216.6     | 278.1   | 15.9    | 60.6    |
| 12                                               |        | 0.187   | 147.9     | 46.4      | -94.7     | 136.8     | 46.3      | -91.3     | 125.5     | 46.0      | 215.2     | 107.0     | 46.0      | 215.8     | 284.7   | 15.9    | 58.1    |
| 13                                               |        | 0.204   | 155.3     | 46.8      | -91.7     | 139.2     | 46.8      | -91.8     | 132.6     | 44.8      | 214.8     | 114.4     | 44.8      | 216.9     | 292.4   | 15.9    | 61.0    |
| 14                                               |        | 0.221   | 162.6     | 47.3      | -90.3     | 146.9     | 47.0      | -92.4     | 140.9     | 46.4      | 216.2     | 121.5     | 46.2      | 216.9     | 299.9   | 16.5    | 61.9    |
| 15                                               |        | 0.238   | 171.2     | 46.3      | -88.8     | 154.0     | 46.1      | -87.4     | 147.8     | 45.1      | 217.3     | 129.7     | 44.8      | 217.7     | 308.4   | 15.6    | 62.8    |
| 16                                               |        | 0.255   | 178.1     | 45.3      | -93.2     | 159.5     | 45.0      | -92.0     | 154.9     | 44.6      | 215.3     | 136.4     | 44.4      | 214.8     | 314.4   | 14.0    | 59.3    |
| 17                                               |        | 0.272   | 185.0     | 46.0      | -91.7     | 167.2     | 45.8      | -91.1     | 162.2     | 45.9      | 216.2     | 144.0     | 46.7      | 216.6     | 322.1   | 15.9    | 61.9    |
| 18                                               |        | 0.289   | 191.6     | 46.1      | -91.1     | 175.3     | 45.9      | -91.6     | 169.2     | 46.0      | 216.0     | 151.6     | 46.8      | 214.9     | 328.9   | 15.4    | 61.2    |
| 19                                               |        | 0.306   | 199.1     | 45.9      | -92.6     | 181.8     | 45.8      | -92.5     | 176.5     | 45.7      | 215.1     | 158.3     | 45.8      | 217.2     | 336.6   | 15.6    | 61.8    |
| 20                                               |        | 0.323   | 206.1     | 44.7      | -92.8     | 189.7     | 44.7      | -90.5     | 183.0     | 45.3      | 215.9     | 165.3     | 45.1      | 213.7     | 343.1   | 14.4    | 59.9    |
| 21                                               |        | 0.34    | 213.3     | 46.0      | -92.0     | 196.1     | 45.7      | -91.4     | 190.8     | 45.0      | 214.1     | 173.1     | 44.9      | 215.6     | 350.5   | 15.5    | 61.4    |
| 22                                               |        | 0.357   | 220.5     | 44.5      | -91.9     | 203.4     | 44.3      | -90.5     | 197.4     | 44.7      | 215.1     | 179.5     | 44.8      | 216.5     | 357.7   | 13.8    | 61.8    |
| 23                                               |        | 0.374   | 229.7     | 45.3      | -90.2     | 212.0     | 45.1      | -91.4     | 207.1     | 44.0      | 217.3     | 189.4     | 43.8      | 218.2     | 367.4   | 15.1    | 61.8    |
| 24                                               |        | 0.391   | 238.9     | 44.1      | -92.9     | 221.0     | 43.9      | -94.6     | 214.5     | 43.5      | 215.7     | 195.5     | 43.5      | 213.6     | 374.1   | 13.8    | 60.1    |
| 25                                               |        | 0.408   | 245.1     | 44.9      | -91.7     | 229.3     | 44.6      | -89.6     | 222.6     | 44.5      | 216.7     | 204.0     | 44.2      | 216.8     | 382.0   | 15.0    | 63.3    |
| 26                                               |        | 0.425   | 253.1     | 45.5      | -90.6     | 236.3     | 44.8      | -91.7     | 231.0     | 44.6      | 216.6     | 211.4     | 44.1      | 219.6     | 390.5   | 14.1    | 62.5    |
| 27                                               |        | 0.442   | 261.1     | 45.0      | -90.8     | 244.1     | 44.9      | -90.2     | 238.0     | 44.8      | 216.9     | 220.0     | 44.8      | 219.1     | 398.2   | 15.7    | 63.4    |
| 28                                               |        | 0.459   | 268.9     | 44.9      | -89.7     | 250.9     | 44.8      | -91.4     | 245.5     | 44.3      | 216.7     | 226.9     | 44.2      | 217.2     | 406.6   | 14.0    | 64.0    |
| 29                                               |        | 0.476   | 276.7     | 44.8      | -90.5     | 258.1     | 44.4      | -91.3     | 253.5     | 44.0      | 216.2     | 234.4     | 43.5      | 215.0     | 413.3   | 15.4    | 62.4    |

|    |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |      |
|----|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|------|
| 30 | 0.493 | 284.2 | 45.9 | -90.3 | 267.7 | 45.6 | -91.6 | 260.9 | 46.0 | 216.4 | 243.5 | 45.8 | 216.1 | 422.3 | 15.2 | 63.3 |
| 31 | 0.51  | 293.0 | 46.0 | -90.3 | 276.7 | 44.8 | -89.8 | 269.3 | 44.2 | 217.2 | 260.7 | 43.9 | 216.7 | 430.3 | 15.8 | 64.3 |
| 32 | 0.527 | 300.7 | 45.4 | -90.0 | 283.8 | 45.2 | -89.7 | 277.5 | 45.3 | 217.1 | 259.2 | 45.2 | 218.1 | 437.9 | 15.7 | 62.7 |
| 33 | 0.544 | 308.2 | 45.8 | -89.3 | 292.0 | 45.6 | -90.4 | 286.0 | 44.2 | 216.0 | 266.1 | 44.0 | 216.5 | 446.8 | 15.7 | 63.8 |
| 34 | 0.561 | 316.8 | 45.5 | -90.6 | 299.4 | 45.1 | -90.6 | 293.1 | 46.1 | 219.4 | 274.5 | 44.5 | 217.8 | 454.8 | 16.8 | 64.5 |
| 35 | 0.578 | 326.7 | 44.9 | -87.7 | 309.5 | 44.5 | -89.1 | 303.2 | 44.2 | 219.6 | 283.5 | 43.7 | 216.6 | 464.5 | 14.8 | 63.9 |
| 36 | 0.595 | 333.2 | 45.3 | -86.5 | 316.6 | 45.1 | -90.6 | 308.7 | 44.2 | 218.1 | 291.0 | 43.9 | 217.6 | 471.6 | 16.1 | 63.5 |
| 37 | 0.612 | 341.6 | 45.1 | -86.8 | 324.5 | 45.0 | -89.5 | 317.8 | 44.7 | 217.2 | 298.5 | 44.4 | 218.6 | 479.6 | 15.2 | 65.2 |
| 38 | 0.629 | 350.8 | 46.0 | -86.9 | 333.5 | 45.0 | -89.0 | 326.3 | 43.9 | 216.5 | 309.4 | 43.7 | 217.3 | 489.4 | 15.4 | 65.3 |
| 39 | 0.646 | 358.6 | 44.9 | -89.0 | 340.4 | 44.5 | -89.7 | 333.9 | 44.6 | 218.1 | 316.6 | 44.6 | 218.1 | 495.9 | 15.4 | 65.9 |
| 40 | 0.663 | 366.7 | 45.4 | -87.9 | 349.2 | 45.1 | -89.9 | 342.1 | 45.2 | 219.8 | 323.6 | 44.8 | 218.7 | 504.9 | 15.8 | 64.6 |
| 41 | 0.68  | 375.7 | 44.5 | -86.7 | 358.4 | 44.0 | -90.6 | 352.0 | 44.3 | 219.6 | 333.1 | 44.0 | 218.1 | 513.8 | 15.0 | 65.8 |
| 42 | 0.697 | 383.4 | 44.1 | -86.9 | 366.2 | 43.7 | -87.8 | 359.2 | 44.6 | 220.1 | 339.9 | 44.4 | 219.8 | 521.4 | 15.7 | 66.5 |
| 43 | 0.714 | 393.1 | 45.1 | -86.3 | 376.7 | 44.8 | -87.3 | 367.9 | 44.4 | 219.7 | 349.2 | 44.1 | 220.7 | 531.3 | 14.6 | 67.8 |
| 44 | 0.731 | 400.4 | 45.1 | -85.1 | 383.1 | 44.7 | -86.3 | 375.8 | 44.5 | 220.2 | 357.7 | 44.2 | 221.0 | 538.1 | 15.9 | 68.5 |
| 45 | 0.748 | 408.9 | 47.2 | -84.5 | 391.5 | 47.1 | -85.2 | 384.1 | 45.9 | 221.1 | 365.0 | 45.7 | 221.0 | 547.4 | 15.5 | 68.0 |
| 46 | 0.765 | 416.9 | 44.6 | -87.9 | 399.7 | 44.4 | -88.5 | 392.2 | 43.7 | 218.7 | 373.3 | 43.5 | 219.3 | 554.7 | 15.5 | 67.7 |
| 47 | 0.782 | 425.1 | 46.8 | -86.4 | 409.0 | 46.5 | -88.6 | 401.8 | 45.9 | 220.3 | 382.6 | 45.4 | 219.8 | 564.0 | 16.1 | 69.8 |
| 48 | 0.799 | 432.7 | 46.4 | -84.1 | 416.8 | 46.2 | -87.7 | 409.4 | 45.2 | 221.6 | 390.9 | 44.9 | 221.4 | 572.0 | 15.9 | 66.8 |
| 49 | 0.816 | 442.9 | 47.2 | -84.7 | 426.6 | 46.9 | -86.8 | 417.5 | 46.0 | 221.8 | 396.8 | 45.7 | 223.6 | 579.3 | 16.2 | 71.3 |
| 50 | 0.833 | 449.8 | 46.5 | -84.2 | 432.8 | 45.0 | -85.5 | 424.6 | 44.3 | 219.8 | 405.9 | 43.8 | 219.2 | 587.5 | 15.4 | 69.0 |
| 51 | 0.85  | 457.8 | 46.0 | -82.5 | 441.6 | 45.6 | -85.7 | 433.3 | 44.5 | 223.5 | 414.7 | 44.2 | 223.1 | 598.0 | 17.0 | 76.6 |
| 52 | 0.867 | 466.4 | 47.1 | -82.8 | 449.1 | 46.7 | -87.7 | 440.1 | 45.5 | 221.5 | 423.0 | 45.3 | 222.5 | 603.1 | 16.0 | 71.4 |
| 53 | 0.884 | 473.8 | 46.9 | -80.8 | 449.1 | 46.7 | -87.7 | 449.2 | 45.7 | 225.2 | 429.1 | 45.2 | 223.2 | 613.6 | 14.8 | 75.8 |
| 54 | 0.901 | 481.1 | 47.0 | -81.3 | 449.1 | 46.7 | -87.7 | 454.9 | 46.3 | 224.1 | 435.7 | 44.9 | 222.1 | 617.5 | 15.7 | 71.5 |
| 55 | 0.918 | 487.9 | 46.7 | -82.9 | 471.4 | 46.4 | -83.0 | 463.6 | 45.7 | 224.3 | 444.6 | 45.5 | 222.7 | 625.5 | 17.0 | 73.9 |
| 56 | 0.935 | 496.7 | 47.3 | -81.3 | 478.9 | 46.9 | -81.5 | 471.1 | 45.7 | 224.8 | 451.0 | 45.4 | 223.9 | 633.0 | 15.8 | 71.8 |
| 57 | 0.952 | 503.0 | 47.0 | -80.7 | 485.3 | 46.7 | -81.0 | 478.0 | 46.2 | 226.7 | 458.0 | 45.7 | 224.3 | 641.0 | 15.8 | 76.7 |
| 58 | 0.969 | 509.8 | 46.5 | -81.0 | 491.7 | 46.3 | -81.4 | 483.9 | 44.4 | 225.1 | 465.6 | 44.2 | 224.8 | 646.9 | 14.8 | 74.8 |
| 59 | 0.986 | 515.7 | 47.1 | -80.2 | 496.4 | 46.9 | -79.3 | 491.1 | 46.3 | 226.9 | 471.8 | 46.1 | 225.8 | 652.0 | 15.4 | 79.3 |
| 60 | 1.003 | 523.1 | 47.1 | -78.4 | 505.6 | 46.7 | -81.7 | 498.0 | 45.7 | 227.2 | 478.9 | 46.1 | 224.8 | 661.2 | 15.3 | 75.1 |
| 61 | 1.02  | 530.2 | 47.0 | -76.3 | 512.6 | 46.4 | -80.9 | 504.5 | 46.3 | 227.9 | 486.0 | 45.9 | 227.7 | 667.8 | 16.1 | 76.1 |

| Coordinates of Mobile Video Platform Markers(cm) |       | Trial 5  |          |          |          |          |          |          |          |          |          |          |          |          |          |          |      |  |
|--------------------------------------------------|-------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|------|--|
|                                                  |       | X(100cm) | Y(100cm) | Z(100cm) | X(100cm) | Y(100cm) | Z(100cm) | X(100cm) | Y(100cm) | Z(100cm) | X(100cm) | Y(100cm) | Z(100cm) | X(100cm) | Y(100cm) | Z(100cm) |      |  |
| 62                                               |       | 1.037    | 536.2    | 47.6     | -79.6    | 518.1    | 47.3     | -82.2    | 511.2    | 46.3     | 227.7    | 491.9    | 46.0     | 227.0    | 674.0    | 16.2     | 76.2 |  |
| 63                                               |       | 1.054    | 542.0    | 47.0     | -80.7    | 523.7    | 46.6     | -80.1    | 517.0    | 46.6     | 227.4    | 498.3    | 46.0     | 225.5    | 680.2    | 16.1     | 75.5 |  |
| 64                                               |       | 1.071    | 549.3    | 45.8     | -76.7    | 531.0    | 45.3     | -79.0    | 523.9    | 45.9     | 229.0    | 504.8    | 45.6     | 228.5    | 687.5    | 15.0     | 76.8 |  |
| 65                                               |       | 1.088    | 555.1    | 46.5     | -76.8    | 537.7    | 46.2     | -78.7    | 529.9    | 46.5     | 228.5    | 510.9    | 45.9     | 227.5    | 693.3    | 16.0     | 77.5 |  |
| 66                                               | Catch | 1.105    | 559.8    | 46.8     | -79.1    | 542.1    | 46.5     | -82.7    | 535.5    | 47.1     | 226.9    | 516.4    | 46.3     | 226.5    | 698.3    | 15.3     | 75.5 |  |
| 67                                               |       | 1.122    | 567.2    | 46.4     | -76.4    | 550.2    | 45.8     | -78.6    | 542.2    | 46.9     | 231.0    | 523.3    | 46.5     | 228.5    | 704.9    | 15.0     | 79.1 |  |
| 68                                               |       | 1.139    | 571.7    | 46.7     | -77.4    | 555.5    | 46.5     | -78.2    | 547.1    | 47.4     | 231.0    | 528.4    | 47.0     | 229.5    | 710.5    | 16.6     | 79.3 |  |
| 69                                               |       | 1.156    | 577.1    | 46.6     | -76.2    | 559.9    | 46.4     | -79.7    | 551.1    | 46.3     | 229.9    | 532.9    | 46.0     | 229.2    | 716.3    | 15.6     | 81.0 |  |
| 70                                               |       | 1.173    | 584.4    | 46.0     | -75.5    | 566.2    | 45.9     | -80.2    | 556.6    | 47.3     | 231.4    | 538.7    | 46.9     | 227.4    | 721.6    | 16.6     | 78.3 |  |
| 71                                               |       | 1.19     | 588.3    | 46.7     | -74.9    | 570.2    | 46.5     | -78.6    | 562.9    | 45.9     | 229.8    | 544.0    | 45.5     | 229.7    | 726.3    | 16.6     | 80.3 |  |
| 72                                               |       | 1.207    | 592.8    | 44.8     | -76.4    | 575.8    | 44.4     | -78.3    | 568.3    | 45.9     | 233.2    | 549.5    | 46.5     | 231.5    | 730.9    | 15.1     | 80.2 |  |
| 73                                               |       | 1.224    | 599.0    | 46.9     | -74.1    | 581.3    | 46.5     | -78.1    | 573.5    | 45.9     | 232.0    | 555.0    | 45.6     | 231.6    | 738.4    | 16.2     | 80.7 |  |
| 74                                               |       | 1.241    | 604.9    | 45.6     | -73.6    | 586.4    | 45.2     | -77.5    | 578.6    | 45.4     | 232.0    | 560.2    | 45.0     | 230.4    | 743.1    | 15.9     | 80.0 |  |
| 75                                               |       | 1.258    | 609.2    | 45.9     | -75.8    | 591.3    | 45.5     | -77.5    | 584.7    | 45.2     | 231.8    | 564.5    | 45.1     | 229.3    | 749.2    | 15.7     | 79.5 |  |

|                  |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |  |
|------------------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|--|
| 18               | 0.289 | 100.5 | 43.3 | 241.0 | 83.6  | 43.1 | 239.1 | 61.4  | 43.8 | 548.8 | 43.1  | 43.6 | 546.5 | 232.8 | 11.8 | 417.2 |  |
| 19               | 0.306 | 105.5 | 42.6 | 240.0 | 89.1  | 42.3 | 238.1 | 66.9  | 42.6 | 548.1 | 48.5  | 42.2 | 545.3 | 238.2 | 11.2 | 414.9 |  |
| 20               | 0.323 | 112.4 | 42.5 | 243.5 | 95.0  | 42.4 | 242.0 | 73.6  | 44.2 | 550.4 | 54.6  | 43.8 | 549.1 | 245.0 | 11.5 | 416.7 |  |
| 21               | 0.34  | 119.1 | 42.9 | 243.6 | 100.2 | 42.7 | 241.9 | 79.2  | 43.9 | 551.9 | 59.2  | 43.3 | 548.2 | 249.3 | 12.2 | 418.2 |  |
| 22               | 0.357 | 124.3 | 42.6 | 245.7 | 107.1 | 42.3 | 243.4 | 86.5  | 44.9 | 555.0 | 66.7  | 44.2 | 552.3 | 257.3 | 11.3 | 419.2 |  |
| 23               | 0.374 | 130.5 | 42.0 | 246.7 | 113.1 | 41.7 | 244.4 | 91.9  | 44.4 | 554.6 | 73.8  | 43.9 | 550.2 | 263.6 | 11.2 | 419.3 |  |
| 24               | 0.391 | 134.7 | 41.8 | 247.2 | 118.6 | 41.6 | 246.2 | 97.8  | 44.5 | 555.6 | 78.7  | 44.1 | 552.4 | 268.1 | 11.5 | 420.4 |  |
| 25               | 0.408 | 141.3 | 42.8 | 251.3 | 124.8 | 42.6 | 247.6 | 103.6 | 44.8 | 558.2 | 84.5  | 44.4 | 555.7 | 274.2 | 11.3 | 421.3 |  |
| 26               | 0.425 | 150.6 | 42.6 | 250.4 | 133.7 | 42.2 | 247.9 | 112.0 | 44.7 | 558.6 | 93.1  | 44.4 | 553.9 | 282.8 | 12.0 | 421.4 |  |
| 27               | 0.442 | 156.3 | 41.6 | 253.1 | 140.2 | 41.2 | 251.2 | 118.0 | 45.2 | 562.4 | 98.9  | 44.8 | 559.1 | 288.4 | 11.3 | 423.8 |  |
| 28               | 0.459 | 163.8 | 42.8 | 253.2 | 146.8 | 42.6 | 251.0 | 124.9 | 45.0 | 562.5 | 106.0 | 44.9 | 559.4 | 295.2 | 12.4 | 424.9 |  |
| 29               | 0.476 | 171.5 | 42.2 | 253.8 | 155.0 | 41.8 | 252.1 | 133.4 | 45.8 | 563.4 | 114.2 | 45.5 | 559.5 | 302.3 | 11.8 | 424.9 |  |
| 30               | 0.493 | 177.5 | 42.6 | 256.3 | 161.0 | 42.3 | 253.3 | 140.3 | 45.2 | 563.3 | 120.4 | 44.6 | 559.6 | 308.9 | 11.8 | 425.6 |  |
| 31               | 0.51  | 182.6 | 40.8 | 255.2 | 166.6 | 40.7 | 254.1 | 146.4 | 45.1 | 563.8 | 127.1 | 44.6 | 561.5 | 314.1 | 11.4 | 426.7 |  |
| 32               | 0.527 | 191.2 | 41.8 | 256.9 | 175.2 | 41.6 | 256.6 | 153.4 | 45.5 | 567.4 | 135.9 | 45.1 | 564.2 | 322.5 | 11.3 | 427.0 |  |
| 33               | 0.544 | 196.4 | 40.9 | 257.2 | 180.3 | 40.6 | 256.4 | 159.2 | 44.7 | 568.0 | 141.3 | 44.3 | 564.8 | 328.3 | 11.6 | 427.8 |  |
| 34               | 0.561 | 204.4 | 41.8 | 259.3 | 186.3 | 41.4 | 258.3 | 167.4 | 45.4 | 570.3 | 149.7 | 45.1 | 567.4 | 336.4 | 12.3 | 428.4 |  |
| 35               | 0.578 | 210.8 | 42.0 | 261.2 | 194.9 | 41.9 | 260.2 | 173.9 | 45.3 | 572.3 | 155.3 | 45.0 | 568.9 | 342.4 | 12.4 | 430.3 |  |
| End of Leg Drive |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |  |
| 36               | 0.595 | 216.2 | 41.8 | 263.6 | 203.0 | 41.8 | 262.3 | 181.4 | 45.3 | 573.6 | 163.0 | 45.0 | 571.1 | 349.8 | 13.1 | 431.3 |  |
| 37               | 0.612 | 224.6 | 40.8 | 264.0 | 209.0 | 40.8 | 263.0 | 189.1 | 44.7 | 575.1 | 170.1 | 44.2 | 572.1 | 357.0 | 11.8 | 431.5 |  |
| 38               | 0.629 | 233.9 | 41.9 | 267.1 | 216.9 | 41.5 | 264.6 | 196.7 | 45.4 | 575.7 | 179.7 | 45.1 | 573.4 | 364.9 | 12.6 | 431.4 |  |
| 39               | 0.646 | 239.8 | 41.1 | 265.9 | 224.0 | 41.1 | 265.7 | 202.8 | 45.4 | 577.0 | 184.3 | 45.0 | 575.3 | 371.2 | 12.7 | 432.8 |  |
| 40               | 0.663 | 247.0 | 41.9 | 265.9 | 232.5 | 41.7 | 265.3 | 210.8 | 44.8 | 578.3 | 192.8 | 44.5 | 575.1 | 378.7 | 12.9 | 432.5 |  |
| 41               | 0.68  | 253.4 | 41.0 | 268.9 | 239.0 | 41.0 | 268.1 | 218.5 | 45.3 | 579.8 | 200.7 | 45.3 | 578.2 | 386.1 | 13.4 | 433.7 |  |
| 42               | 0.697 | 263.5 | 41.5 | 271.0 | 247.6 | 41.6 | 269.8 | 227.7 | 45.6 | 582.7 | 209.7 | 45.2 | 579.4 | 394.6 | 13.7 | 436.8 |  |
| 43               | 0.714 | 269.1 | 40.9 | 271.2 | 253.4 | 40.9 | 269.7 | 232.9 | 44.4 | 582.2 | 214.6 | 44.4 | 581.9 | 399.5 | 13.3 | 434.8 |  |
| 44               | 0.731 | 277.4 | 41.4 | 272.4 | 261.6 | 41.5 | 272.0 | 242.2 | 44.6 | 582.0 | 223.1 | 44.4 | 581.9 | 409.6 | 12.6 | 436.2 |  |
| 45               | 0.748 | 284.6 | 41.9 | 274.5 | 268.3 | 41.8 | 272.7 | 248.6 | 45.2 | 585.7 | 230.3 | 44.9 | 583.7 | 415.7 | 13.5 | 437.9 |  |
| 46               | 0.765 | 292.3 | 42.4 | 274.2 | 276.6 | 42.3 | 273.3 | 256.7 | 45.1 | 586.2 | 238.9 | 44.8 | 584.0 | 423.8 | 13.5 | 438.6 |  |
| 47               | 0.782 | 300.4 | 42.7 | 276.3 | 283.8 | 42.8 | 275.2 | 263.9 | 45.3 | 586.9 | 247.9 | 45.0 | 585.4 | 431.4 | 13.6 | 438.3 |  |
| 48               | 0.799 | 307.6 | 42.4 | 277.1 | 291.3 | 42.3 | 275.6 | 273.3 | 45.0 | 587.1 | 255.0 | 44.8 | 585.9 | 439.5 | 14.3 | 438.5 |  |
| 49               | 0.816 | 315.0 | 43.4 | 276.8 | 299.4 | 43.4 | 277.4 | 280.2 | 44.9 | 587.9 | 262.4 | 45.1 | 587.4 | 446.0 | 14.0 | 438.3 |  |
| 50               | 0.833 | 324.8 | 42.5 | 280.7 | 306.5 | 42.2 | 279.0 | 289.7 | 45.2 | 591.5 | 271.5 | 45.0 | 590.2 | 455.6 | 14.1 | 440.0 |  |
| 51               | 0.85  | 330.9 | 43.5 | 281.0 | 314.9 | 43.1 | 280.4 | 296.0 | 44.7 | 593.1 | 277.3 | 44.4 | 592.0 | 460.9 | 13.6 | 440.4 |  |



|    |       |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |  |
|----|-------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|--|
| 15 |       | 0.238 | 149.9 | 43.4 | 78.1  | 135.3 | 42.8 | 76.7  | 116.4 | 40.7 | 377.3 | 96.0  | 40.1 | 374.0 | 281.1 | 12.9 | 243.2 |  |
| 16 |       | 0.255 | 158.9 | 44.7 | 79.4  | 143.4 | 44.5 | 76.9  | 123.6 | 42.1 | 379.5 | 106.3 | 41.5 | 375.8 | 290.0 | 14.1 | 243.9 |  |
| 17 |       | 0.272 | 167.5 | 43.8 | 80.2  | 151.3 | 43.3 | 76.5  | 132.7 | 41.4 | 379.5 | 114.9 | 40.7 | 378.0 | 297.8 | 12.9 | 244.8 |  |
| 18 |       | 0.289 | 174.9 | 45.0 | 82.6  | 159.4 | 44.5 | 78.8  | 139.6 | 42.2 | 381.8 | 122.3 | 41.7 | 378.9 | 305.3 | 13.9 | 245.2 |  |
| 19 |       | 0.306 | 182.8 | 44.0 | 82.2  | 168.5 | 43.7 | 82.1  | 147.6 | 43.5 | 383.7 | 129.1 | 42.8 | 380.2 | 313.3 | 13.3 | 246.8 |  |
| 20 |       | 0.323 | 191.3 | 43.6 | 83.0  | 177.2 | 43.2 | 82.6  | 155.8 | 41.9 | 384.1 | 138.2 | 41.5 | 382.0 | 322.3 | 13.3 | 247.5 |  |
| 21 |       | 0.34  | 199.4 | 43.5 | 84.2  | 183.6 | 43.3 | 83.9  | 163.1 | 42.5 | 384.5 | 145.0 | 42.0 | 383.0 | 329.5 | 12.9 | 246.5 |  |
| 22 |       | 0.357 | 205.8 | 44.2 | 85.0  | 191.2 | 44.1 | 84.8  | 170.8 | 43.1 | 386.5 | 153.6 | 42.7 | 383.0 | 338.7 | 13.7 | 249.4 |  |
| 23 |       | 0.374 | 215.9 | 43.6 | 87.3  | 200.2 | 43.1 | 84.9  | 180.2 | 42.1 | 386.5 | 163.1 | 41.6 | 383.4 | 346.6 | 13.0 | 249.4 |  |
| 24 |       | 0.391 | 223.9 | 43.5 | 89.7  | 208.2 | 43.1 | 85.8  | 188.7 | 42.5 | 390.6 | 170.3 | 41.9 | 387.7 | 355.1 | 12.0 | 249.9 |  |
| 25 |       | 0.408 | 230.5 | 43.7 | 88.5  | 214.6 | 43.3 | 87.9  | 195.7 | 42.8 | 390.2 | 177.9 | 42.3 | 386.8 | 363.3 | 14.0 | 250.4 |  |
| 26 |       | 0.425 | 239.5 | 44.1 | 90.6  | 224.8 | 43.7 | 89.7  | 206.0 | 42.3 | 392.2 | 187.0 | 41.6 | 387.1 | 372.3 | 13.3 | 251.2 |  |
| 27 |       | 0.442 | 246.7 | 42.5 | 89.7  | 231.7 | 42.1 | 89.5  | 211.7 | 42.9 | 392.8 | 194.3 | 42.0 | 388.3 | 380.1 | 13.3 | 251.0 |  |
| 28 | Seat  | 0.459 | 255.5 | 45.6 | 91.0  | 240.0 | 45.2 | 91.5  | 220.5 | 43.3 | 395.6 | 203.0 | 42.6 | 391.3 | 389.2 | 14.4 | 253.6 |  |
| 29 | Movt. | 0.476 | 265.4 | 43.4 | 92.3  | 249.2 | 43.2 | 91.5  | 229.4 | 43.5 | 393.1 | 211.3 | 42.9 | 391.8 | 399.0 | 14.0 | 251.2 |  |
| 30 |       | 0.493 | 273.0 | 44.3 | 92.0  | 256.5 | 44.1 | 93.1  | 238.0 | 43.1 | 394.1 | 219.8 | 42.3 | 390.4 | 405.9 | 14.2 | 251.9 |  |
| 31 |       | 0.51  | 280.5 | 44.6 | 93.6  | 265.2 | 44.4 | 92.7  | 246.9 | 43.9 | 397.1 | 228.5 | 43.7 | 394.6 | 414.8 | 15.1 | 255.4 |  |
| 32 |       | 0.527 | 291.3 | 45.2 | 96.7  | 275.7 | 45.0 | 95.3  | 256.5 | 44.2 | 399.3 | 238.1 | 43.4 | 396.1 | 425.2 | 15.1 | 256.8 |  |
| 33 |       | 0.544 | 300.5 | 44.1 | 96.5  | 285.4 | 43.4 | 95.3  | 264.1 | 43.5 | 396.2 | 247.2 | 43.2 | 397.1 | 433.4 | 14.1 | 255.9 |  |
| 34 |       | 0.561 | 307.7 | 45.3 | 96.4  | 292.9 | 44.9 | 95.8  | 273.1 | 43.3 | 401.5 | 254.5 | 42.3 | 396.7 | 440.8 | 15.0 | 254.8 |  |
| 35 |       | 0.578 | 317.3 | 43.7 | 100.2 | 301.4 | 43.0 | 97.3  | 281.3 | 43.4 | 401.6 | 263.6 | 43.0 | 400.2 | 450.6 | 14.8 | 255.9 |  |
| 36 |       | 0.595 | 328.1 | 45.3 | 99.5  | 311.0 | 44.9 | 98.7  | 290.6 | 43.5 | 403.7 | 272.8 | 43.0 | 399.5 | 460.5 | 15.4 | 257.7 |  |
| 37 |       | 0.612 | 335.8 | 44.1 | 100.3 | 320.3 | 43.6 | 98.5  | 299.9 | 44.4 | 403.3 | 281.5 | 43.8 | 399.6 | 469.3 | 14.8 | 256.9 |  |
| 38 |       | 0.629 | 346.2 | 45.4 | 102.8 | 329.7 | 45.0 | 101.5 | 309.5 | 43.6 | 405.2 | 292.0 | 43.3 | 403.1 | 479.9 | 16.0 | 258.1 |  |
| 39 |       | 0.646 | 353.9 | 44.1 | 103.5 | 337.5 | 43.5 | 102.6 | 317.6 | 43.5 | 405.3 | 299.7 | 43.0 | 405.1 | 487.4 | 14.1 | 260.2 |  |
| 40 |       | 0.663 | 363.2 | 45.3 | 104.3 | 347.3 | 44.8 | 102.5 | 326.5 | 43.9 | 406.3 | 308.2 | 43.4 | 403.8 | 496.7 | 16.2 | 259.3 |  |
| 41 |       | 0.68  | 373.1 | 45.1 | 104.5 | 357.2 | 44.7 | 104.4 | 335.6 | 43.8 | 406.3 | 318.1 | 43.5 | 405.8 | 506.1 | 15.1 | 260.3 |  |
| 42 |       | 0.697 | 380.9 | 46.4 | 104.3 | 365.2 | 44.9 | 103.0 | 344.9 | 43.5 | 407.9 | 326.9 | 43.1 | 405.4 | 515.5 | 15.5 | 260.2 |  |
| 43 |       | 0.714 | 390.8 | 44.5 | 104.9 | 376.4 | 44.4 | 105.8 | 353.4 | 44.2 | 408.2 | 335.8 | 43.6 | 407.0 | 525.4 | 15.0 | 260.0 |  |
| 44 |       | 0.731 | 400.0 | 45.0 | 106.3 | 384.9 | 44.8 | 105.9 | 362.4 | 42.7 | 410.0 | 344.8 | 42.2 | 408.6 | 534.3 | 15.0 | 260.0 |  |
| 45 |       | 0.748 | 407.2 | 44.8 | 106.6 | 393.1 | 44.4 | 104.5 | 370.7 | 44.5 | 410.2 | 352.3 | 44.1 | 408.2 | 542.4 | 14.6 | 259.8 |  |
| 46 |       | 0.765 | 418.3 | 45.1 | 105.8 | 402.5 | 45.0 | 106.5 | 381.1 | 43.9 | 412.4 | 362.6 | 42.7 | 409.3 | 553.2 | 15.3 | 262.6 |  |



|    |       |       |      |       |       |      |       |       |      |       |       |      |       |       |      |       |  |
|----|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|-------|------|-------|--|
| 47 | 0.782 | 427.0 | 46.0 | 107.2 | 412.3 | 44.7 | 106.6 | 390.3 | 43.6 | 411.5 | 372.0 | 43.2 | 409.8 | 563.9 | 14.2 | 261.3 |  |
| 48 | 0.799 | 435.9 | 45.4 | 108.6 | 419.8 | 44.9 | 107.2 | 398.7 | 43.6 | 412.8 | 379.5 | 42.9 | 409.8 | 571.5 | 13.8 | 262.6 |  |
| 49 | 0.816 | 444.7 | 46.4 | 110.5 | 428.4 | 45.9 | 109.0 | 407.3 | 44.0 | 413.9 | 389.5 | 43.5 | 412.8 | 580.8 | 15.0 | 262.8 |  |
| 50 | 0.833 | 452.1 | 46.0 | 107.3 | 436.5 | 45.8 | 108.2 | 416.3 | 43.5 | 414.4 | 397.8 | 42.8 | 412.9 | 586.7 | 14.7 | 261.3 |  |
| 51 | 0.85  | 463.0 | 48.0 | 110.1 | 446.7 | 47.8 | 108.8 | 424.2 | 45.8 | 415.0 | 406.8 | 45.4 | 414.1 | 597.9 | 15.4 | 264.4 |  |
| 52 | 0.867 | 470.8 | 46.7 | 108.2 | 456.2 | 46.4 | 108.0 | 432.8 | 43.6 | 414.3 | 415.1 | 43.2 | 412.7 | 606.8 | 15.6 | 261.5 |  |
| 53 | 0.884 | 480.3 | 47.8 | 110.0 | 465.4 | 47.3 | 109.9 | 442.6 | 45.2 | 416.1 | 423.2 | 44.7 | 413.9 | 616.5 | 14.1 | 263.1 |  |
| 54 | 0.901 | 489.7 | 46.0 | 110.2 | 473.1 | 45.8 | 109.3 | 449.6 | 43.3 | 416.5 | 431.2 | 42.7 | 414.9 | 624.2 | 14.3 | 261.8 |  |
| 55 | 0.918 | 498.4 | 48.0 | 111.1 | 482.3 | 47.9 | 110.9 | 458.0 | 44.7 | 416.2 | 440.3 | 44.4 | 415.0 | 632.9 | 14.1 | 262.8 |  |
| 56 | 0.936 | 506.0 | 47.4 | 109.4 | 489.9 | 47.1 | 110.0 | 465.8 | 44.2 | 416.0 | 448.0 | 43.8 | 415.0 | 640.8 | 14.9 | 261.9 |  |
| 57 | 0.952 | 514.2 | 47.9 | 113.2 | 499.3 | 47.4 | 113.3 | 474.0 | 44.8 | 417.3 | 457.0 | 44.3 | 417.2 | 649.8 | 13.5 | 263.6 |  |
| 58 | 0.969 | 521.9 | 48.0 | 112.5 | 505.6 | 47.5 | 110.3 | 482.4 | 45.8 | 417.1 | 464.7 | 45.2 | 416.6 | 657.1 | 14.6 | 262.0 |  |
| 59 | 0.986 | 529.4 | 47.6 | 110.4 | 512.4 | 47.3 | 111.6 | 491.3 | 45.2 | 418.3 | 471.9 | 44.6 | 417.7 | 666.3 | 14.1 | 263.4 |  |
| 60 | 1.003 | 536.1 | 47.9 | 114.5 | 519.2 | 47.4 | 112.9 | 497.1 | 45.1 | 420.0 | 477.4 | 44.6 | 418.7 | 673.2 | 14.3 | 264.0 |  |
| 61 | 1.02  | 543.2 | 48.5 | 112.9 | 528.2 | 48.0 | 112.6 | 506.2 | 45.7 | 420.8 | 486.8 | 45.5 | 419.4 | 682.5 | 13.9 | 263.0 |  |
| 62 | 1.037 | 550.0 | 48.6 | 111.9 | 536.0 | 48.1 | 113.3 | 512.0 | 45.1 | 420.1 | 494.1 | 45.0 | 420.6 | 689.2 | 14.0 | 262.4 |  |
| 63 | 1.054 | 557.7 | 48.7 | 113.7 | 542.4 | 48.4 | 114.6 | 519.4 | 45.9 | 421.6 | 501.8 | 45.7 | 420.9 | 697.3 | 15.0 | 264.7 |  |
| 64 | 1.071 | 564.8 | 49.4 | 112.2 | 548.3 | 48.9 | 112.2 | 525.5 | 44.9 | 420.1 | 507.1 | 44.6 | 419.1 | 703.2 | 14.1 | 261.0 |  |
| 65 | 1.088 | 572.4 | 48.2 | 112.9 | 556.5 | 47.9 | 113.4 | 533.4 | 46.6 | 422.1 | 515.1 | 46.3 | 420.2 | 711.8 | 15.5 | 263.8 |  |
| 66 | 1.105 | 577.4 | 48.1 | 111.7 | 561.1 | 48.0 | 114.6 | 539.8 | 45.8 | 420.6 | 521.6 | 45.2 | 418.5 | 716.0 | 13.7 | 261.2 |  |
| 67 | 1.122 | 586.4 | 48.9 | 114.2 | 570.1 | 48.4 | 113.5 | 546.5 | 47.4 | 421.4 | 528.4 | 47.0 | 420.7 | 725.0 | 14.6 | 264.5 |  |
| 68 | 1.139 | 592.1 | 47.8 | 114.0 | 576.0 | 47.4 | 113.0 | 553.6 | 44.8 | 421.0 | 534.9 | 44.3 | 420.2 | 731.3 | 13.3 | 260.3 |  |
| 69 | 1.156 | 597.9 | 49.4 | 115.3 | 582.9 | 49.2 | 116.0 | 559.9 | 47.4 | 423.0 | 541.4 | 46.9 | 422.3 | 738.0 | 15.0 | 264.0 |  |
| 70 | 1.173 | 603.5 | 48.6 | 113.4 | 588.3 | 48.4 | 114.4 | 565.1 | 45.9 | 422.8 | 546.5 | 46.6 | 421.5 | 743.4 | 13.6 | 261.4 |  |
| 71 | 1.19  | 611.4 | 48.0 | 113.4 | 594.5 | 47.7 | 113.3 | 571.8 | 46.2 | 423.4 | 553.0 | 45.7 | 422.4 | 750.5 | 13.8 | 262.1 |  |
| 72 | 1.207 | 617.1 | 49.1 | 112.4 | 599.7 | 48.9 | 112.4 | 578.4 | 47.0 | 420.2 | 556.1 | 46.6 | 423.1 | 754.9 | 14.2 | 260.5 |  |
| 73 | 1.224 | 624.3 | 48.2 | 112.8 | 606.6 | 47.7 | 114.6 | 582.7 | 46.4 | 421.1 | 563.3 | 45.9 | 422.5 | 763.1 | 14.3 | 261.2 |  |
| 74 | 1.241 | 628.4 | 47.9 | 112.9 | 609.7 | 47.4 | 112.8 | 588.6 | 46.5 | 421.6 | 569.0 | 46.2 | 422.5 | 768.7 | 13.6 | 259.4 |  |
| 75 | 1.258 | 633.4 | 48.7 | 114.1 | 616.3 | 48.4 | 115.1 | 594.7 | 46.7 | 423.6 | 575.1 | 45.9 | 423.3 | 774.7 | 15.5 | 260.8 |  |
| 76 | 1.275 | 640.8 | 47.1 | 113.2 | 624.5 | 47.0 | 114.0 | 601.3 | 45.3 | 421.1 | 582.8 | 45.0 | 421.9 | 783.0 | 13.5 | 260.2 |  |

## APPENDIX B

### Digitizing Error on Movements of the MVP

| Digitizing Error(cm) |      |      |      |      |      | Trial 1 |      |      |
|----------------------|------|------|------|------|------|---------|------|------|
| Frame(0.017s)        | dx   | dy   | dz   | len  | dx   | dy      | dz   | len  |
| 1                    | 16.5 | 0.4  | 3.0  | 17.3 | 19.4 | 0.1     | 0.9  | 19.5 |
| 2                    | 15.8 | 0.5  | 2.2  | 15.9 | 19.0 | 0.3     | 2.8  | 19.2 |
| 3                    | 16.1 | 0.4  | 5.1  | 16.9 | 17.8 | 0.5     | 4.1  | 18.3 |
| 4                    | 15.6 | 0.4  | 2.1  | 15.7 | 18.7 | 0.6     | 3.7  | 19.0 |
| 5                    | 14.6 | 0.0  | 1.8  | 14.7 | 17.6 | 0.4     | 3.4  | 18.0 |
| 6                    | 16.2 | 0.3  | 2.2  | 16.3 | 18.8 | 0.6     | 5.2  | 19.5 |
| 7                    | 16.7 | 0.5  | 3.0  | 17.0 | 18.1 | 0.2     | 3.4  | 18.4 |
| 8                    | 15.6 | 0.3  | 4.7  | 16.3 | 18.5 | 0.4     | 4.3  | 19.0 |
| 9                    | 15.3 | 0.4  | 3.2  | 15.6 | 17.5 | 0.2     | 1.3  | 17.6 |
| 10                   | 16.9 | 0.2  | 3.2  | 17.2 | 17.4 | 0.3     | 4.5  | 18.0 |
| 11                   | 16.8 | 0.0  | 1.7  | 16.9 | 18.5 | 0.3     | 2.9  | 18.8 |
| 12                   | 16.9 | 0.2  | 2.8  | 17.1 | 17.8 | 0.3     | 1.2  | 17.8 |
| 13                   | 16.2 | 0.4  | 2.7  | 16.4 | 17.2 | 0.3     | 1.7  | 17.3 |
| 14                   | 16.6 | 0.5  | 0.5  | 16.6 | 17.1 | 0.1     | 3.2  | 17.4 |
| 15                   | 15.8 | 0.2  | 2.6  | 16.0 | 18.5 | 0.2     | 4.0  | 19.0 |
| 16                   | 15.2 | 0.3  | 2.0  | 15.3 | 18.6 | 0.2     | 3.6  | 19.0 |
| 17                   | 16.9 | 0.0  | -0.9 | 16.9 | 19.2 | -0.1    | -1.8 | 19.3 |
| 18                   | 16.6 | 0.3  | 0.8  | 16.6 | 17.2 | 0.1     | 1.5  | 17.3 |
| 19                   | 16.6 | 0.3  | 0.7  | 16.6 | 18.0 | 0.6     | 1.8  | 18.1 |
| 20                   | 16.0 | 0.1  | 0.1  | 16.0 | 18.4 | 0.3     | 0.9  | 18.4 |
| 21                   | 16.1 | 0.1  | -0.4 | 16.1 | 18.3 | 0.2     | 2.1  | 18.5 |
| 22                   | 16.3 | 0.1  | -0.9 | 16.3 | 18.0 | 0.1     | 1.4  | 18.1 |
| 23                   | 16.8 | 0.1  | 0.1  | 16.8 | 18.4 | 0.3     | 2.1  | 18.5 |
| 24                   | 16.1 | 0.2  | -1.0 | 16.1 | 18.7 | 0.7     | 3.6  | 19.1 |
| 25                   | 15.5 | 0.2  | 0.7  | 15.5 | 18.7 | 0.4     | 2.3  | 18.9 |
| 26                   | 15.4 | 0.2  | 2.0  | 15.5 | 18.1 | 0.1     | 2.3  | 18.2 |
| 27                   | 16.7 | 0.6  | 0.0  | 16.7 | 16.8 | 0.1     | 1.7  | 16.9 |
| 28                   | 16.7 | 0.4  | 2.4  | 16.9 | 18.9 | 0.4     | 3.6  | 19.2 |
| 29                   | 16.3 | 0.1  | 0.2  | 16.3 | 17.1 | 0.1     | 1.4  | 17.2 |
| 30                   | 16.2 | 0.1  | 1.5  | 16.3 | 18.4 | 0.3     | 2.8  | 18.6 |
| 31                   | 16.7 | -0.1 | -0.6 | 16.7 | 19.0 | 0.6     | 4.8  | 19.6 |
| 32                   | 15.5 | 0.4  | 1.9  | 15.6 | 18.0 | 0.6     | 2.0  | 18.1 |
| 33                   | 15.5 | 0.2  | 0.8  | 15.5 | 18.8 | 0.1     | -0.1 | 18.8 |
| 34                   | 16.1 | 0.2  | 0.4  | 16.1 | 17.5 | 0.5     | 1.2  | 17.6 |
| 35                   | 15.6 | 0.4  | 1.4  | 15.7 | 16.4 | 0.3     | 1.6  | 16.5 |
| 36                   | 16.8 | 0.2  | 1.3  | 16.8 | 16.9 | 0.4     | 2.3  | 17.1 |
| 37                   | 15.7 | 0.4  | 1.8  | 15.8 | 17.9 | 0.4     | 2.7  | 18.1 |
| 38                   | 16.4 | 0.5  | 2.8  | 16.6 | 17.1 | 0.3     | 0.7  | 17.1 |
| 39                   | 14.8 | 0.3  | 1.8  | 14.9 | 16.7 | 0.2     | 3.2  | 17.0 |
| 40                   | 15.9 | 0.2  | 0.3  | 15.9 | 17.8 | 0.2     | 0.4  | 17.8 |
| 41                   | 15.6 | 0.3  | 0.6  | 15.6 | 17.6 | 0.7     | 2.8  | 17.9 |
| 42                   | 16.0 | 0.4  | 2.0  | 16.1 | 17.6 | 0.4     | 1.8  | 17.7 |
| 43                   | 16.0 | -0.3 | -0.6 | 16.0 | 18.7 | 0.3     | 1.4  | 18.8 |
| 44                   | 17.5 | 0.4  | 2.9  | 17.7 | 18.0 | -0.1    | 0.0  | 18.0 |
| 45                   | 16.6 | 0.3  | 1.3  | 16.6 | 18.6 | 0.2     | 0.6  | 18.6 |
| 46                   | 17.7 | 0.1  | 1.9  | 17.8 | 18.4 | 0.2     | 1.0  | 18.4 |
| 47                   | 17.5 | 0.2  | -0.9 | 17.5 | 18.9 | 0.4     | 2.2  | 19.0 |

|                      |      |      |      |         |      |      |      |      |
|----------------------|------|------|------|---------|------|------|------|------|
| 48                   | 17.8 | 0.0  | 0.3  | 17.8    | 18.2 | 0.8  | 1.1  | 18.3 |
| 49                   | 17.0 | 0.0  | 0.4  | 17.0    | 19.0 | 0.4  | 0.3  | 19.0 |
| 50                   | 15.0 | 0.1  | 0.1  | 15.0    | 18.3 | 0.1  | -0.6 | 18.3 |
| 51                   | 16.8 | 0.1  | -0.7 | 16.8    | 17.4 | 0.4  | 0.1  | 17.4 |
| 52                   | 15.0 | 0.3  | 1.7  | 15.1    | 18.2 | 0.0  | -0.4 | 18.2 |
| 53                   | 16.3 | 0.0  | 0.1  | 16.3    | 17.9 | 0.2  | -0.5 | 17.9 |
| 54                   | 16.3 | 0.0  | 0.8  | 16.3    | 18.3 | 0.3  | -1.2 | 18.3 |
| 55                   | 15.9 | 0.2  | 0.9  | 15.9    | 18.6 | 0.1  | -2.0 | 18.7 |
| 56                   | 16.3 | 0.0  | 0.7  | 16.3    | 19.3 | -0.1 | -2.1 | 19.4 |
| 57                   | 15.8 | 0.4  | 1.0  | 15.8    | 18.0 | 0.1  | -0.6 | 18.1 |
| 58                   | 16.4 | 0.4  | 0.1  | 16.4    | 17.4 | 0.5  | 0.6  | 17.4 |
| 59                   | 15.0 | 0.3  | -0.3 | 15.0    | 18.1 | 0.0  | 1.3  | 18.2 |
| 60                   | 15.6 | 0.2  | 1.7  | 15.7    | 17.7 | 0.3  | 1.0  | 17.8 |
| 61                   | 16.0 | 0.2  | 0.7  | 16.0    | 17.0 | 0.1  | -0.6 | 17.0 |
| 62                   | 16.1 | 0.1  | 0.7  | 16.1    | 18.0 | 0.4  | 1.7  | 18.1 |
| 63                   | 16.2 | 0.2  | -0.3 | 16.2    | 18.0 | 0.1  | -0.8 | 18.0 |
| 64                   | 15.8 | 0.3  | 0.2  | 15.8    | 19.0 | 0.2  | -0.5 | 19.0 |
| Maximum              | 17.8 | 0.6  | 5.1  | 17.8    | 19.4 | 0.8  | 5.2  | 19.6 |
| Minimum              | 14.6 | -0.3 | -1.0 | 14.7    | 16.4 | -0.1 | -2.1 | 16.5 |
| Difference           | 3.2  | 0.9  | 6.1  | 3.1     | 3.0  | 0.9  | 7.3  | 3.1  |
| Digitizing Error(cm) |      |      |      | Trial 2 |      |      |      |      |
| Frame(0.017s)        | dx   | dy   | dz   | len     | dx   | dy   | dz   | len  |
| 1                    | 15.0 | -0.2 | -3.2 | 15.4    | 16.9 | 0.1  | -3.3 | 17.3 |
| 2                    | 15.7 | 0.0  | -5.7 | 16.7    | 18.6 | 0.0  | -3.4 | 18.9 |
| 3                    | 17.8 | 0.3  | -2.7 | 18.0    | 19.2 | 0.2  | -0.4 | 19.2 |
| 4                    | 16.5 | 0.0  | -3.8 | 16.9    | 18.6 | 0.3  | -1.8 | 18.7 |
| 5                    | 16.7 | -0.1 | -3.8 | 17.2    | 17.8 | 0.1  | -1.8 | 17.9 |
| 6                    | 14.4 | 0.1  | -1.6 | 14.5    | 19.1 | 0.4  | -1.4 | 19.2 |
| 7                    | 16.9 | 0.3  | -0.6 | 16.9    | 17.8 | 0.1  | -1.0 | 17.8 |
| 8                    | 16.3 | 0.2  | -0.1 | 16.3    | 18.7 | 0.2  | -3.2 | 19.0 |
| 9                    | 16.6 | 0.3  | -0.7 | 16.6    | 18.6 | 0.1  | -3.4 | 18.9 |
| 10                   | 17.6 | 0.0  | -3.2 | 17.8    | 18.9 | 0.3  | 0.3  | 18.9 |
| 11                   | 15.7 | 0.1  | -1.3 | 15.8    | 18.6 | 0.2  | -1.3 | 18.6 |
| 12                   | 17.1 | 0.1  | -3.4 | 17.4    | 18.5 | 0.0  | -2.7 | 18.7 |
| 13                   | 16.0 | 0.1  | 0.1  | 16.0    | 18.1 | 0.0  | -2.1 | 18.2 |
| 14                   | 15.8 | 0.3  | 1.6  | 15.8    | 19.4 | 0.2  | -0.6 | 19.4 |
| 15                   | 17.3 | 0.2  | -1.5 | 17.3    | 18.1 | 0.3  | -0.4 | 18.1 |
| 16                   | 18.6 | 0.3  | -1.2 | 18.6    | 18.6 | 0.2  | -1.6 | 18.7 |
| 17                   | 17.8 | 0.2  | -0.6 | 17.8    | 18.1 | 0.2  | -0.3 | 18.1 |
| 18                   | 16.3 | 0.2  | 0.5  | 16.3    | 17.6 | 0.2  | 0.1  | 17.6 |
| 19                   | 17.3 | 0.1  | -0.1 | 17.3    | 18.2 | -0.1 | -2.2 | 18.3 |
| 20                   | 16.4 | 0.0  | -2.3 | 16.6    | 17.7 | 0.2  | -0.8 | 17.7 |
| 21                   | 17.2 | 0.3  | -0.6 | 17.2    | 17.7 | 0.2  | -1.5 | 17.8 |
| 22                   | 17.1 | 0.2  | -1.4 | 17.2    | 17.9 | -0.1 | -1.5 | 17.9 |
| 23                   | 17.7 | 0.3  | 1.2  | 17.8    | 17.7 | 0.3  | -0.8 | 17.7 |
| 24                   | 17.8 | 0.2  | 1.7  | 17.9    | 18.9 | 0.0  | -0.9 | 18.9 |
| 25                   | 16.8 | 0.2  | -2.1 | 16.9    | 18.6 | 0.3  | 1.9  | 18.7 |
| 26                   | 16.8 | 0.7  | 1.1  | 16.9    | 19.6 | 0.5  | -3.0 | 19.8 |
| 27                   | 17.0 | 0.1  | -0.6 | 17.0    | 17.9 | 0.0  | -3.2 | 18.2 |

|         |      |     |      |      |      |     |      |      |
|---------|------|-----|------|------|------|-----|------|------|
| 28      | 18.0 | 0.1 | 1.8  | 18.1 | 18.5 | 0.1 | -0.6 | 18.5 |
| 29      | 18.6 | 0.4 | 0.8  | 18.6 | 19.1 | 0.6 | 1.2  | 19.2 |
| 30      | 16.5 | 0.3 | 1.3  | 16.6 | 17.4 | 0.2 | 0.3  | 17.4 |
| 31      | 16.4 | 0.2 | -0.4 | 16.4 | 18.6 | 0.3 | 0.5  | 18.6 |
| 32      | 16.9 | 0.2 | -0.3 | 16.9 | 18.2 | 0.1 | -1.0 | 18.2 |
| 33      | 16.2 | 0.3 | 2.0  | 16.4 | 18.9 | 0.2 | -0.4 | 18.9 |
| 34      | 17.4 | 0.3 | 0.0  | 17.4 | 18.7 | 0.5 | 1.8  | 18.8 |
| 35      | 17.2 | 0.4 | 1.4  | 17.3 | 19.7 | 0.4 | 3.0  | 20.0 |
| 36      | 16.6 | 0.2 | 2.1  | 16.7 | 18.6 | 0.3 | 0.5  | 18.6 |
| 37      | 17.1 | 0.1 | 0.7  | 17.1 | 19.2 | 0.3 | -1.4 | 19.3 |
| 38      | 17.3 | 0.1 | 0.1  | 17.3 | 16.9 | 0.2 | -0.8 | 16.9 |
| 39      | 18.2 | 0.4 | 0.7  | 18.2 | 17.4 | 0.0 | 0.0  | 17.4 |
| 40      | 17.5 | 0.3 | 2.0  | 17.6 | 18.5 | 0.4 | 1.1  | 18.5 |
| 41      | 17.3 | 0.5 | 2.0  | 17.4 | 18.8 | 0.4 | 1.5  | 18.9 |
| 42      | 17.3 | 0.4 | 0.8  | 17.3 | 19.3 | 0.2 | 0.3  | 19.3 |
| 43      | 16.4 | 0.3 | -1.0 | 16.4 | 18.7 | 0.3 | -1.0 | 18.7 |
| 44      | 17.3 | 0.4 | 3.2  | 17.6 | 18.1 | 0.2 | -0.8 | 18.1 |
| 45      | 17.3 | 0.1 | 0.7  | 17.4 | 19.0 | 0.2 | 0.1  | 19.0 |
| 46      | 17.2 | 0.2 | 0.5  | 17.2 | 18.9 | 0.3 | -0.7 | 18.9 |
| 47      | 16.1 | 0.3 | 2.2  | 16.2 | 19.2 | 0.4 | 0.5  | 19.2 |
| 48      | 15.9 | 0.3 | 3.6  | 16.3 | 18.5 | 0.3 | 0.2  | 18.5 |
| 49      | 17.3 | 0.3 | 2.1  | 17.4 | 20.7 | 0.3 | -1.8 | 20.8 |
| 50      | 17.1 | 0.5 | 1.3  | 17.1 | 18.6 | 0.5 | 0.6  | 18.6 |
| 51      | 16.2 | 0.4 | 3.2  | 16.5 | 18.7 | 0.2 | 0.4  | 18.7 |
| 52      | 16.2 | 0.4 | 4.9  | 17.0 | 17.1 | 0.2 | -0.9 | 17.1 |
| 53      | 24.6 | 0.2 | 7.0  | 25.6 | 20.2 | 0.5 | 2.0  | 20.3 |
| 54      | 31.9 | 0.3 | 6.4  | 32.6 | 19.2 | 0.4 | 2.0  | 19.3 |
| 55      | 16.4 | 0.3 | 0.0  | 16.4 | 19.0 | 0.2 | 1.6  | 19.1 |
| 56      | 16.8 | 0.4 | 0.2  | 16.8 | 20.1 | 0.3 | 0.9  | 20.1 |
| 57      | 17.7 | 0.3 | 0.3  | 17.7 | 20.0 | 0.4 | 2.4  | 20.1 |
| 58      | 18.0 | 0.2 | 0.4  | 18.0 | 18.3 | 0.3 | 0.3  | 18.4 |
| 59      | 17.3 | 0.2 | -0.9 | 17.3 | 19.2 | 0.3 | 1.1  | 19.3 |
| 60      | 17.6 | 0.4 | 3.3  | 17.9 | 19.0 | 0.6 | 2.3  | 19.2 |
| 61      | 17.6 | 0.6 | 2.7  | 17.8 | 18.5 | 0.4 | 0.2  | 18.5 |
| 62      | 17.0 | 0.3 | 2.6  | 17.2 | 19.3 | 0.3 | 0.6  | 19.3 |
| 63      | 18.2 | 0.4 | -0.6 | 18.3 | 18.6 | 0.5 | 1.9  | 18.7 |
| 64      | 18.3 | 0.5 | 2.3  | 18.5 | 19.1 | 0.3 | 0.4  | 19.1 |
| 65      | 17.4 | 0.3 | 1.9  | 17.5 | 18.0 | 0.5 | 1.0  | 18.0 |
| 66      | 17.7 | 0.3 | 3.7  | 18.1 | 19.0 | 0.7 | 0.4  | 19.0 |
| 67      | 17.0 | 0.6 | 2.2  | 17.1 | 18.9 | 0.3 | 2.6  | 19.1 |
| 68      | 16.3 | 0.2 | 0.7  | 16.3 | 18.7 | 0.4 | 1.5  | 18.7 |
| 69      | 17.1 | 0.3 | 3.5  | 17.5 | 18.2 | 0.3 | 0.5  | 18.2 |
| 70      | 18.2 | 0.1 | 4.7  | 18.8 | 20.8 | 0.4 | 4.0  | 21.2 |
| 71      | 18.1 | 0.2 | 3.7  | 18.5 | 18.9 | 0.4 | 0.2  | 18.9 |
| 72      | 17.0 | 0.4 | 2.9  | 17.2 | 18.8 | 0.3 | 1.6  | 18.9 |
| 73      | 17.7 | 0.3 | 4.0  | 18.1 | 18.5 | 0.3 | 0.4  | 18.5 |
| 74      | 18.5 | 0.5 | 3.9  | 18.9 | 18.3 | 0.3 | 1.6  | 18.4 |
| 75      | 17.9 | 0.4 | 1.7  | 18.0 | 20.2 | 0.1 | 2.5  | 20.3 |
| Maximum | 31.9 | 0.7 | 7.0  | 32.6 | 20.8 | 0.7 | 4.0  | 21.2 |

|                      |      |      |      |      |      |         |      |      |
|----------------------|------|------|------|------|------|---------|------|------|
| Minimum              | 14.4 | -0.2 | -5.7 | 14.5 | 16.9 | -0.1    | -3.4 | 16.9 |
| Difference           | 17.5 | 0.9  | 12.6 | 18.1 | 3.9  | 0.8     | 7.5  | 4.3  |
| Digitizing Error(cm) |      |      |      |      |      | Trial 5 |      |      |
| Frame(0.017s)        | dx   | dy   | dz   | len  | dx   | dy      | dz   | len  |
| 1                    | 18.6 | 0.2  | 1.6  | 22.5 | 20.8 | 0.0     | 2.4  | 21.0 |
| 2                    | 16.3 | 0.1  | 1.6  | 21.3 | 21.7 | 0.4     | 4.4  | 22.2 |
| 3                    | 16.6 | 0.1  | 3.8  | 22.6 | 20.3 | 0.5     | 5.9  | 21.1 |
| 4                    | 17.4 | 0.6  | 4.1  | 21.8 | 20.3 | 0.5     | 6.3  | 21.2 |
| 5                    | 16.7 | 0.1  | 3.1  | 22.5 | 18.6 | 0.7     | 4.6  | 19.2 |
| 6                    | 17.0 | 0.4  | 3.4  | 21.9 | 19.3 | 0.5     | 4.3  | 19.8 |
| 7                    | 17.2 | 0.3  | 3.5  | 23.3 | 18.2 | 0.5     | 3.5  | 18.5 |
| 8                    | 16.8 | 0.3  | 3.9  | 24.2 | 19.3 | 0.2     | 4.0  | 19.7 |
| 9                    | 16.7 | 0.5  | 4.4  | 24.3 | 18.0 | 0.3     | 2.7  | 18.2 |
| 10                   | 16.1 | 0.2  | 2.4  | 23.3 | 19.0 | 0.5     | 3.3  | 19.3 |
| 11                   | 15.4 | 0.0  | 2.1  | 23.2 | 18.9 | 0.3     | 2.7  | 19.1 |
| 12                   | 15.8 | 0.1  | 2.1  | 23.1 | 18.6 | 0.3     | 4.0  | 19.0 |
| 13                   | 15.4 | 0.1  | 1.7  | 22.4 | 19.8 | 0.5     | 4.0  | 20.2 |
| 14                   | 15.8 | 0.4  | 4.8  | 22.1 | 19.5 | 0.5     | 3.6  | 19.8 |
| 15                   | 15.8 | 0.4  | 5.0  | 22.9 | 18.6 | 0.4     | 3.5  | 18.9 |
| 16                   | 16.6 | 0.3  | 1.7  | 21.3 | 18.9 | 0.5     | 4.5  | 19.4 |
| 17                   | 17.2 | 0.4  | 2.7  | 21.1 | 19.2 | 0.4     | 4.4  | 19.7 |
| 18                   | 16.9 | 0.2  | 2.0  | 22.2 | 18.3 | 0.2     | 2.3  | 18.5 |
| 19                   | 16.3 | 0.3  | 1.9  | 22.2 | 18.4 | 0.4     | 2.8  | 18.7 |
| 20                   | 17.5 | 0.1  | 1.4  | 21.3 | 19.0 | 0.5     | 1.3  | 19.1 |
| 21                   | 18.0 | 0.2  | 1.7  | 20.8 | 20.0 | 0.6     | 3.8  | 20.4 |
| 22                   | 17.2 | 0.3  | 2.3  | 20.5 | 19.8 | 0.8     | 2.7  | 20.0 |
| 23                   | 17.4 | 0.3  | 2.4  | 21.3 | 18.1 | 0.5     | 4.3  | 18.6 |
| 24                   | 16.1 | 0.2  | 1.0  | 20.8 | 19.1 | 0.4     | 3.2  | 19.4 |
| 25                   | 16.5 | 0.2  | 3.7  | 21.1 | 19.1 | 0.4     | 2.5  | 19.3 |
| 26                   | 16.9 | 0.3  | 2.5  | 21.7 | 18.9 | 0.3     | 2.7  | 19.1 |
| 27                   | 16.2 | 0.3  | 1.9  | 22.1 | 19.1 | 0.4     | 3.3  | 19.4 |
| 28                   | 16.9 | 0.2  | 2.2  | 21.9 | 17.0 | 0.1     | 3.0  | 17.2 |
| 29                   | 16.5 | 0.4  | 1.8  | 21.5 | 18.2 | 0.3     | 3.8  | 19.6 |
| 30                   | 16.5 | 0.2  | 2.0  | 20.8 | 19.9 | 0.7     | 3.7  | 20.3 |
| 31                   | 15.9 | 0.1  | 1.1  | 20.3 | 19.2 | 0.6     | 4.3  | 19.7 |
| 32                   | 15.9 | 0.2  | 0.4  | 21.8 | 17.5 | 0.5     | 3.3  | 17.8 |
| 33                   | 16.1 | 0.3  | 0.7  | 21.1 | 17.9 | 0.4     | 3.3  | 18.2 |
| 34                   | 16.1 | 0.4  | 1.0  | 20.9 | 17.7 | 0.4     | 2.9  | 17.9 |
| 35                   | 15.9 | 0.1  | 1.1  | 21.0 | 18.6 | 0.3     | 3.4  | 18.9 |
| 36                   | 16.2 | 0.0  | 1.3  | 21.6 | 18.4 | 0.4     | 2.5  | 18.6 |
| 37                   | 15.6 | 0.1  | 1.0  | 19.9 | 18.9 | 0.5     | 3.0  | 19.2 |
| 38                   | 17.0 | 0.4  | 2.6  | 20.1 | 17.0 | 0.3     | 2.3  | 17.1 |
| 39                   | 14.8 | 0.0  | 0.2  | 21.2 | 18.5 | 0.4     | 1.8  | 18.6 |
| 40                   | 14.5 | 0.3  | 0.6  | 21.7 | 18.0 | 0.3     | 1.2  | 18.0 |
| 41                   | 14.4 | 0.1  | 0.8  | 20.5 | 17.8 | 0.0     | 1.7  | 17.9 |
| 42                   | 16.0 | 0.0  | 1.2  | 19.9 | 18.0 | 0.5     | 3.3  | 18.3 |
| 43                   | 15.7 | 0.0  | 1.6  | 20.5 | 18.3 | 0.0     | 0.3  | 18.3 |
| 44                   | 15.8 | 0.0  | 0.4  | 19.5 | 19.1 | 0.3     | 0.1  | 19.1 |
| 45                   | 16.3 | 0.1  | 1.8  | 19.7 | 18.3 | 0.3     | 2.1  | 18.4 |

|                      |      |      |      |         |      |      |      |      |
|----------------------|------|------|------|---------|------|------|------|------|
| 46                   | 15.7 | 0.0  | 0.9  | 19.9    | 17.9 | 0.3  | 2.2  | 18.0 |
| 47                   | 16.6 | 0.0  | 1.0  | 17.9    | 18.0 | 0.3  | 1.5  | 18.1 |
| 48                   | 16.3 | 0.1  | 1.5  | 18.0    | 18.3 | 0.2  | 1.1  | 18.4 |
| 49                   | 15.6 | 0.0  | -0.6 | 19.2    | 17.8 | -0.2 | 0.6  | 17.8 |
| 50                   | 16.3 | 0.3  | 1.6  | 18.9    | 18.2 | 0.2  | 1.3  | 18.2 |
| 51                   | 16.0 | 0.4  | 0.6  | 18.8    | 18.7 | 0.3  | 1.2  | 18.8 |
| 52                   | 14.7 | 0.2  | 1.5  | 18.2    | 18.6 | -0.1 | 0.7  | 18.6 |
| 53                   | 16.4 | -0.1 | 1.4  | 17.5    | 16.9 | 0.1  | 1.3  | 16.9 |
| 54                   | 15.2 | 0.1  | -0.4 | 18.3    | 18.5 | 0.2  | 1.8  | 18.6 |
| 55                   | 15.9 | 0.2  | 0.9  | 18.5    | 17.1 | 0.2  | 0.9  | 17.1 |
| 56                   | 15.8 | 0.2  | 0.8  | 18.2    | 17.6 | -0.2 | -0.2 | 17.6 |
| 57                   | 16.1 | 0.1  | -0.1 | 17.7    | 17.5 | -0.1 | -0.9 | 17.5 |
| 58                   | 15.4 | 0.0  | 1.6  | 17.9    | 17.6 | 0.3  | 2.2  | 17.7 |
| 59                   | 15.1 | 0.2  | 0.1  | 17.9    | 17.2 | 0.1  | 0.2  | 17.2 |
| 60                   | 15.4 | -0.1 | -0.4 | 17.4    | 17.8 | 0.3  | 0.6  | 17.8 |
| 61                   | 15.9 | -0.3 | -1.2 | 17.3    | 17.7 | 0.3  | 1.3  | 17.8 |
| 62                   | 15.8 | -0.1 | -1.0 | 16.6    | 19.2 | 0.1  | 3.2  | 19.5 |
| 63                   | 15.6 | 0.0  | 1.1  | 17.7    | 17.6 | 0.3  | 1.9  | 17.7 |
| 64                   | 16.1 | 0.2  | 1.0  | 16.7    | 17.8 | 0.2  | 0.6  | 17.8 |
| 65                   | 14.9 | -0.1 | 0.0  | 17.8    | 18.2 | -0.1 | 0.6  | 18.2 |
| 66                   | 16.0 | 0.0  | 0.2  | 17.7    | 17.3 | 0.3  | 1.1  | 17.4 |
| 67                   | 16.0 | 0.2  | -0.1 | 16.4    | 16.8 | 0.3  | 0.4  | 16.8 |
| 68                   | 15.1 | 0.0  | -0.2 | 16.6    | 18.3 | 0.1  | 0.8  | 18.3 |
| 69                   | 15.3 | 0.0  | 0.0  | 16.9    | 18.5 | 0.2  | 0.5  | 18.5 |
| 70                   | 15.7 | 0.1  | -0.5 | 17.2    | 17.2 | 0.1  | -0.4 | 17.2 |
| Maximum              | 18.6 | 0.6  | 5.0  | 24.3    | 21.7 | 0.8  | 6.3  | 22.2 |
| Minimum              | 14.4 | -0.3 | -1.2 | 16.4    | 16.8 | -0.2 | -0.9 | 16.8 |
| Difference           | 4.2  | 0.9  | 6.2  | 7.9     | 4.9  | 1.0  | 7.1  | 5.4  |
| Digitizing Error(cm) |      |      |      | Trial 6 |      |      |      |      |
| Frame(0.017s)        | dx   | dy   | dz   | len     | dx   | dy   | dz   | len  |
| 1                    | 16.3 | 0.5  | 2.8  | 20.7    | 18.5 | 0.4  | 2.7  | 18.7 |
| 2                    | 14.0 | 0.4  | 0.9  | 21.1    | 18.1 | 0.7  | 5.9  | 19.0 |
| 3                    | 16.1 | 0.4  | 2.5  | 20.3    | 17.1 | 0.7  | 2.2  | 17.2 |
| 4                    | 15.8 | 0.5  | 3.7  | 21.2    | 16.8 | 0.8  | 4.3  | 17.4 |
| 5                    | 15.1 | 0.4  | 1.5  | 20.8    | 17.6 | 0.6  | 3.3  | 17.9 |
| 6                    | 14.1 | 0.3  | 2.4  | 20.4    | 17.5 | 0.4  | 2.1  | 17.6 |
| 7                    | 14.9 | 0.5  | 2.2  | 19.6    | 18.2 | 0.5  | 1.8  | 18.3 |
| 8                    | 15.4 | 0.5  | 2.0  | 20.0    | 17.2 | 0.5  | 3.1  | 17.4 |
| 9                    | 15.3 | 0.3  | 2.2  | 19.1    | 17.6 | 0.6  | 3.6  | 18.0 |
| 10                   | 15.4 | 0.7  | 2.4  | 17.9    | 18.2 | 0.5  | 3.5  | 18.5 |
| 11                   | 15.8 | 0.6  | 1.7  | 19.0    | 17.8 | 0.6  | 4.1  | 18.2 |
| 12                   | 16.0 | 0.3  | 1.6  | 18.7    | 18.5 | 0.5  | 4.3  | 19.0 |
| 13                   | 15.5 | 0.4  | 1.0  | 18.8    | 17.7 | 0.6  | 3.3  | 18.1 |
| 14                   | 15.3 | 0.3  | 1.1  | 18.8    | 17.9 | 0.6  | 1.7  | 18.0 |
| 15                   | 14.5 | 0.6  | 2.4  | 19.9    | 17.4 | 0.6  | 3.3  | 17.8 |
| 16                   | 15.6 | 0.2  | 2.4  | 19.8    | 17.2 | 0.5  | 3.7  | 17.6 |
| 17                   | 16.1 | 0.5  | 3.6  | 18.6    | 17.8 | 0.6  | 1.4  | 17.9 |
| 18                   | 15.5 | 0.5  | 3.8  | 19.8    | 17.3 | 0.5  | 2.9  | 17.5 |
| 19                   | 14.3 | 0.2  | 0.1  | 20.9    | 18.4 | 0.7  | 3.5  | 18.8 |

|    |      |     |      |      |      |     |      |      |
|----|------|-----|------|------|------|-----|------|------|
| 20 | 14.1 | 0.4 | 0.4  | 21.3 | 17.6 | 0.4 | 2.1  | 17.8 |
| 21 | 15.8 | 0.1 | 0.2  | 20.5 | 18.1 | 0.6 | 1.6  | 18.2 |
| 22 | 14.6 | 0.1 | 0.2  | 20.4 | 17.3 | 0.4 | 3.5  | 17.6 |
| 23 | 15.7 | 0.5 | 2.5  | 20.0 | 17.1 | 0.5 | 3.1  | 17.4 |
| 24 | 15.7 | 0.4 | 4.0  | 19.5 | 18.4 | 0.6 | 2.8  | 18.6 |
| 25 | 16.0 | 0.4 | 0.6  | 18.8 | 17.9 | 0.6 | 3.4  | 18.2 |
| 26 | 14.7 | 0.4 | 0.9  | 18.8 | 19.0 | 0.6 | 5.1  | 19.7 |
| 27 | 15.0 | 0.5 | 0.2  | 19.9 | 17.4 | 0.8 | 4.5  | 18.0 |
| 28 | 15.5 | 0.4 | -0.5 | 19.5 | 17.5 | 0.7 | 4.3  | 18.1 |
| 29 | 16.3 | 0.2 | 0.7  | 19.8 | 18.1 | 0.6 | 1.3  | 18.1 |
| 30 | 16.5 | 0.2 | -1.1 | 18.5 | 18.2 | 0.8 | 3.7  | 18.6 |
| 31 | 15.3 | 0.2 | 0.9  | 18.3 | 18.4 | 0.3 | 2.5  | 18.6 |
| 32 | 15.6 | 0.3 | 1.4  | 19.2 | 18.5 | 0.8 | 3.1  | 18.7 |
| 33 | 15.1 | 0.7 | 3.2  | 21.3 | 16.9 | 0.3 | 1.1  | 17.0 |
| 34 | 14.8 | 0.5 | 2.6  | 19.7 | 18.6 | 1.0 | 4.8  | 19.3 |
| 35 | 15.9 | 0.6 | 2.8  | 20.1 | 17.8 | 0.5 | 1.4  | 17.8 |
| 36 | 15.1 | 0.4 | 0.8  | 20.4 | 17.8 | 0.6 | 4.2  | 18.3 |
| 37 | 15.5 | 0.5 | 1.8  | 20.4 | 18.4 | 0.6 | 3.7  | 18.7 |
| 38 | 16.5 | 0.4 | 1.3  | 20.2 | 17.5 | 0.3 | 2.1  | 17.6 |
| 39 | 16.4 | 0.6 | 0.9  | 19.9 | 17.9 | 0.5 | 0.2  | 17.9 |
| 40 | 15.9 | 0.5 | 1.8  | 20.8 | 18.3 | 0.5 | 2.4  | 18.5 |
| 41 | 15.9 | 0.4 | 0.1  | 21.6 | 17.5 | 0.2 | 2.5  | 17.7 |
| 42 | 15.7 | 0.4 | 1.3  | 20.3 | 18.0 | 0.4 | 2.5  | 18.1 |
| 43 | 15.4 | 0.2 | -0.9 | 21.9 | 17.6 | 0.7 | 1.3  | 17.7 |
| 44 | 15.1 | 0.2 | 0.3  | 22.5 | 17.5 | 0.5 | 1.5  | 17.6 |
| 45 | 14.1 | 0.4 | 2.1  | 22.4 | 18.4 | 0.4 | 2.0  | 18.5 |
| 46 | 15.8 | 0.1 | -0.7 | 21.5 | 18.5 | 0.7 | 3.1  | 18.8 |
| 47 | 14.7 | 0.3 | 0.7  | 22.0 | 18.3 | 0.4 | 1.8  | 18.4 |
| 48 | 16.1 | 0.5 | 1.4  | 21.1 | 19.2 | 0.6 | 3.1  | 19.5 |
| 49 | 16.3 | 0.5 | 1.5  | 21.1 | 17.8 | 0.5 | 1.1  | 17.8 |
| 50 | 15.5 | 0.2 | -0.9 | 20.2 | 18.5 | 0.7 | 1.5  | 18.5 |
| 51 | 16.3 | 0.3 | 1.4  | 22.5 | 17.4 | 0.4 | 0.9  | 17.5 |
| 52 | 14.7 | 0.4 | 0.1  | 23.4 | 17.7 | 0.4 | 1.6  | 17.7 |
| 53 | 14.8 | 0.4 | 0.1  | 22.8 | 19.4 | 0.5 | 2.2  | 19.5 |
| 54 | 16.6 | 0.3 | 0.9  | 23.5 | 18.4 | 0.6 | 1.6  | 18.5 |
| 55 | 16.1 | 0.1 | 0.2  | 24.3 | 17.7 | 0.3 | 1.2  | 17.7 |
| 56 | 15.1 | 0.4 | -0.6 | 24.1 | 17.8 | 0.4 | 1.0  | 17.8 |
| 57 | 14.9 | 0.5 | -0.1 | 25.3 | 17.1 | 0.5 | 0.1  | 17.1 |
| 58 | 16.4 | 0.4 | 2.2  | 23.2 | 17.6 | 0.6 | 0.5  | 17.7 |
| 59 | 17.0 | 0.3 | -1.2 | 21.1 | 19.4 | 0.6 | 0.6  | 19.5 |
| 60 | 16.9 | 0.5 | 1.6  | 22.1 | 19.7 | 0.5 | 1.3  | 19.7 |
| 61 | 15.0 | 0.5 | 0.3  | 21.9 | 19.5 | 0.2 | 1.4  | 19.5 |
| 62 | 15.0 | 0.5 | -1.4 | 23.0 | 17.9 | 0.1 | -0.5 | 17.9 |
| 63 | 15.3 | 0.3 | -0.9 | 23.0 | 17.7 | 0.2 | 0.7  | 17.7 |
| 64 | 16.5 | 0.5 | 0.0  | 22.8 | 18.4 | 0.3 | 1.0  | 18.4 |
| 65 | 15.9 | 0.2 | -0.5 | 23.1 | 18.4 | 0.3 | 1.9  | 18.5 |
| 66 | 16.3 | 0.1 | -2.9 | 21.3 | 18.2 | 0.6 | 2.1  | 18.4 |
| 67 | 16.3 | 0.6 | 0.7  | 23.5 | 18.1 | 0.4 | 0.7  | 18.1 |
| 68 | 16.1 | 0.4 | 1.0  | 22.4 | 18.7 | 0.5 | 0.7  | 18.7 |



|            |      |     |      |      |      |     |      |      |
|------------|------|-----|------|------|------|-----|------|------|
| 69         | 15.0 | 0.2 | -0.7 | 23.0 | 18.5 | 0.5 | 0.7  | 18.5 |
| 70         | 15.2 | 0.2 | -1.0 | 23.2 | 18.6 | 0.3 | 1.3  | 18.6 |
| 71         | 16.9 | 0.2 | 0.0  | 22.7 | 18.8 | 0.5 | 1.1  | 18.8 |
| 72         | 17.4 | 0.2 | 0.0  | 23.3 | 20.3 | 0.3 | -2.9 | 20.5 |
| 73         | 17.7 | 0.4 | -1.8 | 23.9 | 19.4 | 0.5 | -1.3 | 19.5 |
| 74         | 18.6 | 0.5 | 0.1  | 21.2 | 19.6 | 0.4 | -1.0 | 19.6 |
| 75         | 15.1 | 0.3 | -0.9 | 23.5 | 19.6 | 0.8 | 0.4  | 19.6 |
| 76         | 16.3 | 0.1 | -0.8 | 23.2 | 18.5 | 0.4 | -0.8 | 18.5 |
| Maximum    | 18.6 | 0.7 | 4.0  | 25.3 | 20.3 | 1.0 | 5.9  | 20.5 |
| Minimum    | 14.0 | 0.1 | -2.9 | 17.9 | 16.8 | 0.1 | -2.9 | 17.0 |
| Difference | 4.7  | 0.6 | 6.9  | 7.4  | 3.5  | 0.9 | 8.8  | 3.5  |

## APPENDIX C

### Calculations of x axis movements of the Mobile Video Platform

| Calculation of X-axis movements(cm) |               |             |            | Trial 1  | x(shell)-   | x(shell)-  |
|-------------------------------------|---------------|-------------|------------|----------|-------------|------------|
| Frame(0.017s)                       | Event         | X(lftrtcam) | X(rtrtcam) | X(shell) | x(lftrtcam) | x(rtrtcam) |
| 1                                   |               | -37.2       | -71.0      | 90.2     | 127.4       | 161.2      |
| 2                                   |               | -31.1       | -63.7      | 97.8     | 128.9       | 161.5      |
| 3                                   |               | -25.8       | -59.4      | 103.3    | 129.1       | 162.7      |
| 4                                   |               | -17.3       | -51.0      | 111.1    | 128.5       | 162.1      |
| 5                                   |               | -10.1       | -43.5      | 119.2    | 129.3       | 162.7      |
| 6                                   |               | -3.7        | -37.4      | 124.8    | 128.5       | 162.3      |
| 7                                   |               | 2.3         | -32.0      | 129.5    | 127.2       | 161.5      |
| 8                                   |               | 7.8         | -25.7      | 136.7    | 128.9       | 162.4      |
| 9                                   |               | 14.2        | -21.0      | 141.9    | 127.7       | 162.9      |
| 10                                  | Catch         | 19.2        | -14.2      | 148.6    | 129.5       | 162.8      |
| 11                                  |               | 27.8        | -6.9       | 155.1    | 127.4       | 162.0      |
| 12                                  |               | 31.8        | -2.7       | 160.5    | 128.6       | 163.2      |
| 13                                  |               | 38.2        | 3.2        | 166.2    | 128.0       | 163.1      |
| 14                                  |               | 42.0        | 7.4        | 170.4    | 128.3       | 163.0      |
| 15                                  |               | 47.2        | 14.0       | 176.3    | 129.0       | 162.3      |
| 16                                  |               | 52.3        | 19.2       | 180.9    | 128.6       | 161.6      |
| 17                                  |               | 59.4        | 25.4       | 188.3    | 128.9       | 162.9      |
| 18                                  |               | 64.6        | 29.3       | 192.8    | 128.2       | 163.5      |
| 19                                  |               | 69.3        | 35.5       | 198.0    | 128.7       | 162.5      |
| 20                                  |               | 75.1        | 41.1       | 204.3    | 129.2       | 163.2      |
| 21                                  |               | 81.5        | 47.7       | 210.5    | 129.0       | 162.7      |
| 22                                  |               | 87.4        | 54.0       | 217.6    | 130.2       | 163.6      |
| 23                                  |               | 92.3        | 58.7       | 222.7    | 130.4       | 164.0      |
| 24                                  |               | 98.2        | 64.7       | 228.8    | 130.6       | 164.1      |
| 25                                  |               | 103.7       | 71.4       | 234.5    | 130.8       | 163.1      |
| 26                                  |               | 110.3       | 78.6       | 240.9    | 130.5       | 164.3      |
| 27                                  |               | 117.3       | 81.9       | 246.7    | 129.4       | 164.8      |
| 28                                  |               | 123.9       | 90.3       | 253.9    | 130.0       | 163.7      |
| 29                                  |               | 129.1       | 95.0       | 260.8    | 131.7       | 165.8      |
| 30                                  |               | 135.0       | 101.7      | 264.9    | 129.9       | 163.2      |
| 31                                  |               | 141.8       | 109.1      | 271.4    | 129.6       | 162.3      |
| 32                                  | End Leg Drive | 147.5       | 114.5      | 278.3    | 130.8       | 163.8      |
| 33                                  |               | 153.6       | 121.6      | 284.0    | 130.3       | 162.4      |
| 34                                  |               | 160.4       | 128.2      | 290.7    | 130.3       | 162.5      |
| 35                                  |               | 167.8       | 134.4      | 298.3    | 130.5       | 163.9      |
| 36                                  |               | 176.5       | 141.6      | 304.3    | 127.8       | 162.7      |
| 37                                  |               | 181.0       | 147.6      | 310.9    | 129.9       | 163.3      |
| 38                                  |               | 187.8       | 154.4      | 317.2    | 129.5       | 162.8      |
| 39                                  |               | 194.4       | 161.9      | 325.9    | 131.5       | 164.0      |
| 40                                  |               | 201.0       | 168.0      | 331.4    | 130.4       | 163.4      |
| 41                                  |               | 208.1       | 175.7      | 339.7    | 131.6       | 164.0      |
| 42                                  |               | 213.8       | 181.7      | 346.0    | 132.2       | 164.4      |
| 43                                  |               | 221.8       | 189.7      | 353.2    | 131.4       | 163.4      |
| 44                                  |               | 230.2       | 196.8      | 361.0    | 130.8       | 164.2      |
| 45                                  |               | 236.2       | 203.2      | 366.4    | 130.3       | 163.3      |
| 46                                  |               | 246.0       | 211.9      | 375.7    | 130.7       | 163.9      |
| 47                                  |               | 252.5       | 219.6      | 380.6    | 128.1       | 161.0      |

|                                     |        |            |            |          |            |            |
|-------------------------------------|--------|------------|------------|----------|------------|------------|
| 48                                  |        | 259.2      | 225.4      | 389.7    | 130.6      | 164.3      |
| 49                                  |        | 266.2      | 232.8      | 394.9    | 128.7      | 162.1      |
| 50                                  |        | 273.3      | 240.6      | 404.2    | 130.9      | 163.5      |
| 51                                  |        | 280.9      | 248.2      | 412.4    | 131.5      | 164.2      |
| 52                                  |        | 288.3      | 255.6      | 419.2    | 130.9      | 163.6      |
| 53                                  |        | 295.4      | 263.2      | 427.2    | 131.8      | 164.0      |
| 54                                  | Finish | 302.7      | 270.7      | 434.1    | 131.4      | 163.4      |
| 55                                  |        | 309.8      | 278.9      | 443.0    | 133.3      | 164.1      |
| 56                                  |        | 319.0      | 287.0      | 450.3    | 131.3      | 163.3      |
| 57                                  |        | 326.5      | 294.0      | 457.2    | 130.7      | 163.3      |
| 58                                  |        | 333.2      | 300.6      | 464.8    | 131.6      | 164.2      |
| 59                                  |        | 339.9      | 308.3      | 472.9    | 133.0      | 164.6      |
| 60                                  |        | 347.7      | 315.6      | 480.0    | 132.3      | 164.4      |
| 61                                  |        | 355.2      | 322.5      | 488.0    | 132.8      | 165.5      |
| 62                                  |        | 364.0      | 331.1      | 496.3    | 132.3      | 165.2      |
| 63                                  |        | 371.5      | 339.4      | 504.0    | 132.5      | 164.6      |
| 64                                  |        | 379.4      | 346.8      | 510.2    | 130.8      | 163.4      |
|                                     |        |            |            | Max      | 133.3      | 165.8      |
|                                     |        |            |            | Min      | 127.2      | 161.0      |
|                                     |        |            |            | Diff     | -6.1       | -4.8       |
|                                     |        |            |            |          |            |            |
| Calculation of X-axis movements(cm) |        |            |            | Trial 2  | x(shell)-  | x(shell)-  |
| Frame(0.017s)                       | Event  | X(lftrcam) | X(rftrcam) | X(shell) | x(lftrcam) | x(rftrcam) |
| 1                                   |        | 67.8       | 47.7       | 206.3    | 138.5      | 158.6      |
| 2                                   |        | 76.8       | 55.7       | 213.6    | 136.8      | 157.9      |
| 3                                   |        | 83.2       | 62.6       | 220.1    | 136.9      | 157.5      |
| 4                                   |        | 89.7       | 69.8       | 227.5    | 137.8      | 157.6      |
| 5                                   |        | 98.0       | 77.4       | 235.4    | 137.4      | 158.0      |
| 6                                   |        | 103.1      | 83.5       | 240.8    | 137.7      | 157.3      |
| 7                                   |        | 112.2      | 90.3       | 249.7    | 137.5      | 159.4      |
| 8                                   |        | 119.4      | 97.8       | 256.7    | 137.3      | 158.8      |
| 9                                   |        | 127.0      | 105.0      | 264.7    | 137.7      | 159.7      |
| 10                                  | Finish | 132.9      | 111.6      | 269.9    | 137.0      | 158.3      |
| 11                                  |        | 141.0      | 119.0      | 278.1    | 137.1      | 159.1      |
| 12                                  |        | 147.9      | 125.5      | 284.7    | 136.8      | 159.2      |
| 13                                  |        | 155.3      | 132.6      | 292.4    | 137.1      | 159.8      |
| 14                                  |        | 162.6      | 140.9      | 299.9    | 137.3      | 159.0      |
| 15                                  |        | 171.2      | 147.8      | 308.4    | 137.2      | 160.7      |
| 16                                  |        | 178.1      | 154.9      | 314.4    | 136.2      | 159.4      |
| 17                                  |        | 185.0      | 162.2      | 322.1    | 137.1      | 159.9      |
| 18                                  |        | 191.6      | 169.2      | 328.9    | 137.4      | 159.7      |
| 19                                  |        | 199.1      | 176.5      | 336.6    | 137.5      | 160.1      |
| 20                                  |        | 206.1      | 183.0      | 343.1    | 137.0      | 160.1      |
| 21                                  |        | 213.3      | 190.8      | 350.5    | 137.2      | 159.7      |
| 22                                  |        | 220.6      | 197.4      | 357.7    | 137.2      | 160.3      |
| 23                                  |        | 229.7      | 207.1      | 367.4    | 137.7      | 160.4      |
| 24                                  |        | 238.9      | 214.5      | 374.1    | 135.2      | 159.6      |
| 25                                  |        | 245.1      | 222.6      | 382.0    | 136.9      | 159.4      |
| 26                                  |        | 253.1      | 231.0      | 390.5    | 137.4      | 159.6      |

|    |               |       |       |       |       |       |
|----|---------------|-------|-------|-------|-------|-------|
| 27 |               | 261.1 | 238.0 | 398.2 | 137.1 | 160.2 |
| 28 |               | 268.9 | 245.5 | 406.6 | 137.7 | 161.1 |
| 29 |               | 276.7 | 253.5 | 413.3 | 136.6 | 159.8 |
| 30 | Beg Seat Movt | 284.2 | 260.9 | 422.3 | 138.1 | 161.3 |
| 31 |               | 293.0 | 269.3 | 430.3 | 137.2 | 161.0 |
| 32 |               | 300.7 | 277.5 | 437.9 | 137.1 | 160.4 |
| 33 |               | 308.2 | 285.0 | 446.8 | 138.5 | 161.8 |
| 34 |               | 316.8 | 293.1 | 454.8 | 138.1 | 161.7 |
| 35 |               | 326.7 | 303.2 | 464.5 | 137.8 | 161.3 |
| 36 |               | 333.2 | 309.7 | 471.6 | 138.4 | 162.0 |
| 37 |               | 341.6 | 317.8 | 479.6 | 138.0 | 161.8 |
| 38 |               | 350.8 | 326.3 | 489.4 | 138.5 | 163.1 |
| 39 |               | 358.6 | 333.9 | 495.9 | 137.3 | 162.0 |
| 40 |               | 366.7 | 342.1 | 504.9 | 138.2 | 162.8 |
| 41 |               | 375.7 | 352.0 | 513.8 | 138.1 | 161.8 |
| 42 |               | 383.4 | 359.2 | 521.4 | 138.0 | 162.2 |
| 43 |               | 393.1 | 367.9 | 531.3 | 138.2 | 163.5 |
| 44 |               | 400.4 | 375.8 | 538.1 | 137.6 | 162.3 |
| 45 |               | 408.9 | 384.1 | 547.4 | 138.5 | 163.3 |
| 46 |               | 416.9 | 392.2 | 554.7 | 137.8 | 162.5 |
| 47 |               | 425.1 | 401.8 | 564.0 | 138.9 | 162.2 |
| 48 |               | 432.7 | 409.4 | 572.0 | 139.4 | 162.6 |
| 49 |               | 442.9 | 417.5 | 579.3 | 136.4 | 161.8 |
| 50 |               | 449.8 | 424.6 | 587.5 | 137.6 | 162.9 |
| 51 |               | 457.8 | 433.3 | 598.0 | 140.2 | 164.6 |
| 52 |               | 465.4 | 440.1 | 603.1 | 137.7 | 162.9 |
| 53 |               | 473.8 | 449.2 | 613.6 | 139.8 | 164.3 |
| 54 |               | 481.1 | 454.9 | 617.5 | 136.4 | 162.7 |
| 55 |               | 487.9 | 463.6 | 625.5 | 137.6 | 161.9 |
| 56 |               | 495.7 | 471.1 | 633.0 | 137.4 | 161.9 |
| 57 |               | 503.0 | 478.0 | 641.0 | 138.1 | 163.1 |
| 58 |               | 509.8 | 483.9 | 646.9 | 137.1 | 163.0 |
| 59 |               | 515.7 | 491.1 | 652.0 | 136.4 | 161.0 |
| 60 |               | 523.1 | 498.0 | 661.2 | 138.1 | 163.2 |
| 61 |               | 530.2 | 504.5 | 667.8 | 137.6 | 163.3 |
| 62 |               | 536.2 | 511.2 | 674.0 | 137.8 | 162.8 |
| 63 |               | 542.0 | 517.0 | 680.2 | 138.2 | 163.2 |
| 64 |               | 549.3 | 523.9 | 687.5 | 138.2 | 163.6 |
| 65 |               | 555.1 | 529.9 | 693.3 | 138.3 | 163.4 |
| 66 | Catch         | 560.8 | 535.5 | 698.3 | 138.5 | 162.9 |
| 67 |               | 567.2 | 542.2 | 704.9 | 137.8 | 162.7 |
| 68 |               | 571.7 | 547.1 | 710.5 | 138.7 | 163.4 |
| 69 |               | 577.1 | 551.1 | 716.3 | 139.2 | 165.2 |
| 70 |               | 584.4 | 559.6 | 721.6 | 137.2 | 162.0 |
| 71 |               | 588.3 | 562.9 | 726.3 | 138.0 | 163.4 |
| 72 |               | 592.8 | 568.3 | 730.9 | 138.1 | 162.6 |
| 73 |               | 599.0 | 573.5 | 738.4 | 139.5 | 165.0 |
| 74 |               | 604.9 | 578.6 | 743.1 | 138.2 | 164.5 |
| 75 |               | 609.2 | 584.7 | 749.2 | 140.0 | 164.5 |

|                                            |                  |             |             | Max            | 140.2       | 165.2       |
|--------------------------------------------|------------------|-------------|-------------|----------------|-------------|-------------|
|                                            |                  |             |             | Min            | 135.2       | 157.3       |
|                                            |                  |             |             | Diff           | -5.0        | -7.9        |
| <b>Calculation of X-axis movements(cm)</b> |                  |             |             | <b>Trial 5</b> | x(shell)-   | x(shell)-   |
| Frame(0.017s)                              | Event            | X(ltfrtcam) | X(rtfrtcam) | X(shell)       | x(ltfrtcam) | x(rtfrtcam) |
| 1                                          |                  | -30.7       | -71.8       | 104.2          | 134.9       | 176.0       |
| 2                                          |                  | -21.5       | -59.1       | 115.2          | 136.7       | 174.3       |
| 3                                          |                  | -13.4       | -52.7       | 122.5          | 135.9       | 175.2       |
| 4                                          |                  | -4.4        | -43.6       | 131.4          | 135.8       | 174.9       |
| 5                                          |                  | 4.8         | -34.4       | 139.7          | 134.9       | 174.1       |
| 6                                          |                  | 11.9        | -27.1       | 147.1          | 135.3       | 174.2       |
| 7                                          |                  | 21.6        | -19.0       | 155.7          | 134.2       | 174.7       |
| 8                                          |                  | 30.8        | -10.3       | 164.4          | 133.6       | 174.6       |
| 9                                          |                  | 37.4        | -3.6        | 170.6          | 133.2       | 174.2       |
| 10                                         | Catch            | 46.0        | 6.6         | 179.6          | 133.6       | 173.0       |
| 11                                         |                  | 53.2        | 14.5        | 186.4          | 133.2       | 171.9       |
| 12                                         |                  | 59.2        | 20.3        | 193.7          | 134.6       | 173.4       |
| 13                                         |                  | 66.2        | 28.3        | 200.9          | 134.7       | 172.6       |
| 14                                         |                  | 74.0        | 36.1        | 208.0          | 134.1       | 171.9       |
| 15                                         |                  | 79.6        | 40.9        | 212.6          | 133.0       | 171.7       |
| 16                                         |                  | 87.3        | 49.3        | 220.8          | 133.5       | 171.5       |
| 17                                         |                  | 93.5        | 55.2        | 225.8          | 132.4       | 170.7       |
| 18                                         |                  | 100.5       | 61.4        | 232.8          | 132.3       | 171.4       |
| 19                                         |                  | 105.5       | 66.9        | 238.2          | 132.7       | 171.3       |
| 20                                         |                  | 112.4       | 73.6        | 245.0          | 132.6       | 171.4       |
| 21                                         |                  | 118.1       | 79.2        | 249.3          | 131.2       | 170.1       |
| 22                                         |                  | 124.3       | 86.5        | 257.3          | 133.0       | 170.8       |
| 23                                         |                  | 130.5       | 91.9        | 263.6          | 133.1       | 171.8       |
| 24                                         |                  | 134.7       | 97.8        | 268.1          | 133.4       | 170.3       |
| 25                                         |                  | 141.3       | 103.6       | 274.2          | 132.9       | 170.6       |
| 26                                         |                  | 150.6       | 112.0       | 282.8          | 132.2       | 170.8       |
| 27                                         |                  | 156.3       | 118.0       | 288.4          | 132.1       | 170.4       |
| 28                                         |                  | 163.8       | 124.9       | 295.2          | 131.5       | 170.3       |
| 29                                         |                  | 171.5       | 133.4       | 302.3          | 130.8       | 168.8       |
| 30                                         |                  | 177.5       | 140.3       | 308.9          | 131.4       | 168.6       |
| 31                                         |                  | 182.6       | 146.4       | 314.1          | 131.5       | 167.7       |
| 32                                         |                  | 191.2       | 153.4       | 322.5          | 131.3       | 169.1       |
| 33                                         |                  | 196.4       | 159.2       | 328.3          | 131.9       | 169.1       |
| 34                                         |                  | 204.4       | 167.4       | 336.4          | 132.0       | 169.0       |
| 35                                         |                  | 210.8       | 173.9       | 342.4          | 131.7       | 168.5       |
| 36                                         | End of Leg Drive | 218.2       | 181.4       | 349.8          | 131.6       | 168.4       |
| 37                                         |                  | 224.6       | 189.1       | 357.0          | 132.4       | 167.9       |
| 38                                         |                  | 233.9       | 196.7       | 364.9          | 131.0       | 168.2       |
| 39                                         |                  | 238.8       | 202.8       | 371.2          | 132.5       | 168.5       |
| 40                                         |                  | 247.0       | 210.8       | 378.7          | 131.6       | 167.8       |
| 41                                         |                  | 253.4       | 218.5       | 386.1          | 132.7       | 167.6       |
| 42                                         |                  | 263.5       | 227.7       | 394.6          | 131.0       | 166.8       |
| 43                                         |                  | 269.1       | 232.9       | 399.5          | 130.5       | 166.7       |
| 44                                         |                  | 277.4       | 242.2       | 409.6          | 132.2       | 167.4       |

| 45                                  |        | 284.6       | 248.6       | 415.7    | 131.1       | 167.1       |
|-------------------------------------|--------|-------------|-------------|----------|-------------|-------------|
| 46                                  |        | 292.3       | 256.7       | 423.8    | 131.5       | 167.0       |
| 47                                  |        | 300.4       | 265.9       | 431.4    | 131.0       | 165.5       |
| 48                                  |        | 307.6       | 273.3       | 439.5    | 131.9       | 166.2       |
| 49                                  |        | 315.0       | 280.2       | 446.0    | 131.1       | 165.8       |
| 50                                  |        | 324.8       | 289.7       | 455.6    | 130.8       | 166.0       |
| 51                                  |        | 330.9       | 296.0       | 460.9    | 130.1       | 164.9       |
| 52                                  |        | 338.0       | 305.2       | 470.1    | 132.0       | 164.9       |
| 53                                  |        | 348.0       | 314.2       | 479.2    | 131.2       | 165.0       |
| 54                                  |        | 355.8       | 322.2       | 486.1    | 130.3       | 163.9       |
| 55                                  |        | 362.5       | 328.2       | 494.3    | 131.8       | 166.1       |
| 56                                  |        | 372.2       | 338.3       | 502.8    | 130.5       | 164.5       |
| 57                                  |        | 379.4       | 345.6       | 509.8    | 130.4       | 164.1       |
| 58                                  |        | 387.6       | 354.3       | 518.5    | 130.9       | 164.2       |
| 59                                  |        | 396.2       | 362.2       | 526.6    | 131.4       | 164.5       |
| 60                                  | Finish | 403.8       | 370.9       | 533.9    | 130.1       | 162.9       |
| 61                                  |        | 411.3       | 378.1       | 542.6    | 131.3       | 164.6       |
| 62                                  |        | 420.1       | 387.7       | 551.1    | 131.0       | 163.4       |
| 63                                  |        | 427.9       | 394.6       | 558.2    | 130.2       | 163.6       |
| 64                                  |        | 436.7       | 403.0       | 566.1    | 130.4       | 163.1       |
| 65                                  |        | 444.0       | 411.4       | 575.6    | 131.6       | 164.2       |
| 66                                  |        | 452.2       | 418.5       | 583.0    | 130.8       | 164.5       |
| 67                                  |        | 460.2       | 427.7       | 590.2    | 130.0       | 162.4       |
| 68                                  |        | 469.5       | 437.8       | 600.1    | 130.6       | 162.3       |
| 69                                  |        | 478.6       | 446.5       | 608.6    | 130.0       | 162.2       |
| 70                                  |        | 486.4       | 453.5       | 615.4    | 129.0       | 162.0       |
|                                     |        |             |             | Max      | 136.7       | 176.0       |
|                                     |        |             |             | Min      | 129.0       | 162.0       |
|                                     |        |             |             | Diff     | -7.6        | -14.0       |
| Calculation of X-axis movements(cm) |        |             |             | Trial 6  | x(shell)-   | x(shell)-   |
| Frame(0.017s)                       | Event  | X(lrtftcam) | X(rtrftcam) | X(shell) | x(lrtftcam) | x(rtrftcam) |
| 1                                   |        | 44.6        | 7.4         | 173.0    | 128.5       | 165.6       |
| 2                                   |        | 50.6        | 15.6        | 179.9    | 129.3       | 164.3       |
| 3                                   |        | 58.6        | 23.2        | 186.1    | 128.5       | 165.0       |
| 4                                   |        | 65.8        | 28.7        | 194.1    | 128.4       | 165.4       |
| 5                                   |        | 74.6        | 38.8        | 204.7    | 130.0       | 165.9       |
| 6                                   |        | 80.2        | 45.7        | 210.7    | 130.5       | 165.0       |
| 7                                   |        | 89.5        | 55.0        | 219.5    | 130.0       | 164.6       |
| 8                                   |        | 97.5        | 62.1        | 228.7    | 131.2       | 166.6       |
| 9                                   |        | 103.7       | 69.3        | 234.4    | 130.7       | 165.1       |
| 10                                  | Finish | 110.2       | 76.9        | 241.2    | 131.0       | 164.3       |
| 11                                  |        | 120.0       | 86.2        | 250.0    | 130.0       | 164.8       |
| 12                                  |        | 127.2       | 92.5        | 257.3    | 130.1       | 164.8       |
| 13                                  |        | 134.7       | 100.4       | 266.5    | 131.8       | 166.1       |
| 14                                  |        | 142.6       | 108.5       | 274.0    | 131.4       | 165.5       |
| 15                                  |        | 148.9       | 115.4       | 281.1    | 131.2       | 165.7       |
| 16                                  |        | 156.9       | 123.6       | 290.0    | 131.1       | 166.5       |
| 17                                  |        | 167.5       | 132.7       | 297.8    | 130.4       | 165.1       |

|    |                 |       |       |       |       |       |
|----|-----------------|-------|-------|-------|-------|-------|
| 18 |                 | 174.9 | 139.6 | 305.3 | 130.4 | 165.7 |
| 19 |                 | 182.8 | 147.6 | 313.3 | 130.5 | 165.7 |
| 20 |                 | 191.3 | 155.8 | 322.3 | 131.0 | 166.5 |
| 21 |                 | 199.4 | 163.1 | 329.5 | 130.1 | 166.5 |
| 22 |                 | 205.8 | 170.8 | 338.7 | 132.9 | 167.9 |
| 23 |                 | 215.9 | 180.2 | 346.6 | 130.8 | 166.4 |
| 24 |                 | 223.9 | 188.7 | 355.1 | 131.2 | 166.4 |
| 25 |                 | 230.5 | 195.7 | 363.3 | 132.8 | 167.6 |
| 26 |                 | 239.5 | 206.0 | 372.3 | 132.9 | 166.3 |
| 27 |                 | 246.7 | 211.7 | 380.1 | 133.4 | 168.4 |
| 28 | Beg. Seat Movt. | 255.5 | 220.5 | 389.2 | 133.7 | 168.7 |
| 29 |                 | 265.4 | 229.4 | 399.0 | 133.5 | 169.5 |
| 30 |                 | 273.0 | 238.0 | 406.9 | 132.9 | 167.9 |
| 31 |                 | 280.5 | 246.9 | 414.8 | 134.3 | 167.8 |
| 32 |                 | 291.3 | 256.5 | 425.2 | 133.9 | 168.7 |
| 33 |                 | 300.5 | 264.1 | 433.4 | 133.0 | 169.3 |
| 34 |                 | 307.7 | 273.1 | 440.8 | 133.2 | 167.7 |
| 35 |                 | 317.3 | 281.3 | 450.6 | 133.3 | 169.3 |
| 36 |                 | 328.1 | 290.6 | 460.5 | 134.4 | 169.8 |
| 37 |                 | 335.8 | 299.9 | 469.3 | 133.6 | 169.4 |
| 38 |                 | 346.2 | 309.5 | 479.9 | 133.7 | 170.4 |
| 39 |                 | 353.9 | 317.6 | 487.4 | 133.5 | 169.8 |
| 40 |                 | 363.2 | 326.5 | 496.7 | 133.5 | 170.2 |
| 41 |                 | 373.1 | 335.6 | 506.1 | 133.0 | 170.5 |
| 42 |                 | 380.9 | 344.9 | 515.5 | 134.6 | 170.7 |
| 43 |                 | 390.8 | 353.4 | 525.4 | 134.5 | 171.9 |
| 44 |                 | 400.0 | 362.4 | 534.3 | 134.3 | 171.9 |
| 45 |                 | 407.2 | 370.7 | 542.4 | 135.3 | 171.7 |
| 46 |                 | 418.3 | 381.1 | 553.2 | 134.9 | 172.2 |
| 47 |                 | 427.0 | 390.3 | 563.9 | 136.9 | 173.6 |
| 48 |                 | 435.9 | 398.7 | 571.5 | 135.6 | 172.8 |
| 49 |                 | 444.7 | 407.3 | 580.8 | 136.1 | 173.5 |
| 50 |                 | 452.1 | 416.3 | 588.7 | 136.6 | 172.4 |
| 51 |                 | 463.0 | 424.2 | 597.9 | 134.9 | 173.7 |
| 52 |                 | 470.8 | 432.8 | 606.8 | 136.0 | 174.0 |
| 53 |                 | 480.3 | 442.6 | 616.5 | 136.2 | 173.9 |
| 54 |                 | 489.7 | 449.6 | 624.2 | 134.6 | 174.6 |
| 55 |                 | 498.4 | 458.0 | 632.9 | 134.5 | 174.9 |
| 56 |                 | 505.0 | 465.8 | 640.8 | 135.8 | 174.9 |
| 57 |                 | 514.2 | 474.0 | 649.8 | 135.6 | 175.7 |
| 58 |                 | 521.9 | 482.4 | 657.1 | 135.1 | 174.7 |
| 59 |                 | 529.4 | 491.3 | 666.3 | 136.9 | 175.0 |
| 60 |                 | 536.1 | 497.1 | 673.2 | 137.1 | 176.1 |
| 61 |                 | 543.2 | 506.2 | 682.5 | 139.3 | 176.3 |
| 62 |                 | 550.0 | 512.0 | 689.2 | 139.2 | 177.2 |
| 63 |                 | 557.7 | 519.4 | 697.3 | 139.6 | 177.9 |
| 64 |                 | 564.8 | 526.5 | 703.2 | 138.3 | 177.7 |
| 65 |                 | 572.4 | 533.4 | 711.8 | 139.4 | 178.4 |
| 66 | Catch           | 577.4 | 539.8 | 716.0 | 138.6 | 176.2 |



|    |  |       |       |       |       |       |
|----|--|-------|-------|-------|-------|-------|
| 67 |  | 586.4 | 546.5 | 725.0 | 138.6 | 178.5 |
| 68 |  | 592.1 | 553.6 | 731.3 | 139.1 | 177.7 |
| 69 |  | 597.9 | 559.9 | 738.0 | 140.1 | 178.1 |
| 70 |  | 603.5 | 565.1 | 743.4 | 139.9 | 178.3 |
| 71 |  | 611.4 | 571.8 | 750.5 | 139.1 | 178.7 |
| 72 |  | 617.1 | 576.4 | 754.9 | 137.9 | 178.5 |
| 73 |  | 624.3 | 582.7 | 763.1 | 138.8 | 180.4 |
| 74 |  | 628.4 | 588.6 | 768.7 | 140.3 | 180.1 |
| 75 |  | 633.4 | 594.7 | 774.7 | 141.3 | 180.0 |
| 76 |  | 640.8 | 601.3 | 783.0 | 142.2 | 181.7 |
|    |  |       |       | Max   | 142.2 | 181.7 |
|    |  |       |       | Min   | 128.4 | 164.3 |
|    |  |       |       | Diff  | -13.8 | -17.4 |

## APPENDIX D

### Calculations of y axis movements of the Mobile Video Platform

| Calculation of Y-axis movements(c |               |                | Trial 1        |
|-----------------------------------|---------------|----------------|----------------|
| Frame(0.017s)                     | Event         | Y(lftrcam)(cm) | Y(rttrcam)(cm) |
| 1                                 |               | 45.3           | 45.1           |
| 2                                 |               | 46.4           | 46.5           |
| 3                                 |               | 45.6           | 45.4           |
| 4                                 |               | 46.2           | 46.1           |
| 5                                 |               | 47.1           | 46.4           |
| 6                                 |               | 46.0           | 45.5           |
| 7                                 |               | 47.0           | 47.0           |
| 8                                 |               | 46.2           | 45.8           |
| 9                                 |               | 45.4           | 46.6           |
| 10                                | Catch         | 47.4           | 47.2           |
| 11                                |               | 44.6           | 45.5           |
| 12                                |               | 46.1           | 46.1           |
| 13                                |               | 44.0           | 45.2           |
| 14                                |               | 44.8           | 46.4           |
| 15                                |               | 44.1           | 45.0           |
| 16                                |               | 44.7           | 46.8           |
| 17                                |               | 43.1           | 45.3           |
| 18                                |               | 42.7           | 45.9           |
| 19                                |               | 43.3           | 46.3           |
| 20                                |               | 44.7           | 46.3           |
| 21                                |               | 43.6           | 46.5           |
| 22                                |               | 43.5           | 45.5           |
| 23                                |               | 44.4           | 47.2           |
| 24                                |               | 43.3           | 46.6           |
| 25                                |               | 43.7           | 44.8           |
| 26                                |               | 43.4           | 45.9           |
| 27                                |               | 43.7           | 45.7           |
| 28                                |               | 43.6           | 46.2           |
| 29                                |               | 42.7           | 45.2           |
| 30                                |               | 43.9           | 45.4           |
| 31                                |               | 44.1           | 47.4           |
| 32                                | End Leg Drive | 44.0           | 45.8           |
| 33                                |               | 44.0           | 47.2           |
| 34                                |               | 44.8           | 46.4           |
| 35                                |               | 44.0           | 45.4           |
| 36                                |               | 44.1           | 45.3           |
| 37                                |               | 43.9           | 44.9           |
| 38                                |               | 44.6           | 46.0           |
| 39                                |               | 42.8           | 43.9           |
| 40                                |               | 44.4           | 45.8           |
| 41                                |               | 44.0           | 45.3           |
| 42                                |               | 46.3           | 46.6           |
| 43                                |               | 44.9           | 45.6           |
| 44                                |               | 45.7           | 46.2           |
| 45                                |               | 45.3           | 45.5           |
| 46                                |               | 46.5           | 47.0           |
| 47                                |               | 46.0           | 45.4           |

| 48                                |        | 46.3           | 47.3           |
|-----------------------------------|--------|----------------|----------------|
| 49                                |        | 46.8           | 45.9           |
| 50                                |        | 47.2           | 47.3           |
| 51                                |        | 46.4           | 46.1           |
| 52                                |        | 46.7           | 47.0           |
| 53                                |        | 46.4           | 46.3           |
| 54                                | Finish | 46.7           | 46.2           |
| 55                                |        | 46.5           | 47.4           |
| 56                                |        | 46.9           | 46.5           |
| 57                                |        | 45.6           | 46.6           |
| 58                                |        | 47.2           | 46.9           |
| 59                                |        | 45.8           | 46.7           |
| 60                                |        | 46.2           | 47.5           |
| 61                                |        | 46.4           | 47.3           |
| 62                                |        | 46.1           | 47.8           |
|                                   |        | 45.2           | 47.0           |
|                                   |        | 47.3           | 49.0           |
|                                   | Max    | 47.4           | 49.0           |
|                                   | Min    | 42.7           | 43.9           |
|                                   | Diff   | 4.7            | 5.1            |
|                                   |        |                |                |
| Calculation of Y-axis movements(c |        |                | Trial 2        |
| Frame(0.017s)                     | Event  | Y(ltftcam)(cm) | Y(rtftcam)(cm) |
| 1                                 |        | 43.8           | 42.7           |
| 2                                 |        | 46.1           | 44.1           |
| 3                                 | Finish | 45.2           | 43.9           |
| 4                                 |        | 45.9           | 44.7           |
| 5                                 |        | 45.6           | 43.5           |
| 6                                 |        | 44.8           | 44.0           |
| 7                                 |        | 46.5           | 44.4           |
| 8                                 |        | 46.2           | 44.7           |
| 9                                 |        | 46.8           | 44.2           |
| 10                                | Finish | 44.6           | 44.6           |
| 11                                |        | 46.7           | 44.7           |
| 12                                |        | 46.4           | 46.0           |
| 13                                |        | 46.8           | 44.8           |
| 14                                |        | 47.3           | 46.4           |
| 15                                |        | 46.3           | 45.1           |
| 16                                |        | 45.3           | 44.6           |
| 17                                |        | 46.0           | 45.9           |
| 18                                |        | 46.1           | 46.0           |
| 19                                |        | 45.9           | 45.7           |
| 20                                |        | 44.7           | 45.3           |
| 21                                |        | 46.0           | 45.0           |
| 22                                |        | 44.5           | 44.7           |
| 23                                |        | 45.3           | 44.0           |
| 24                                |        | 44.1           | 43.5           |
| 25                                |        | 44.9           | 44.5           |
| 26                                |        | 45.5           | 44.6           |

|    |               |      |      |
|----|---------------|------|------|
| 27 |               | 45.0 | 44.8 |
| 28 |               | 44.9 | 44.3 |
| 29 |               | 44.8 | 44.0 |
| 30 | Beg Seat Movt | 45.9 | 46.0 |
| 31 |               | 45.0 | 44.2 |
| 32 |               | 45.4 | 45.3 |
| 33 |               | 45.8 | 44.2 |
| 34 |               | 45.5 | 45.1 |
| 35 |               | 44.9 | 44.2 |
| 36 |               | 45.3 | 44.2 |
| 37 |               | 45.1 | 44.7 |
| 38 |               | 45.0 | 43.9 |
| 39 |               | 44.9 | 44.6 |
| 40 |               | 45.4 | 45.2 |
| 41 |               | 44.5 | 44.3 |
| 42 |               | 44.1 | 44.6 |
| 43 |               | 45.1 | 44.4 |
| 44 |               | 45.1 | 44.5 |
| 45 |               | 47.2 | 45.9 |
| 46 |               | 44.6 | 43.7 |
| 47 |               | 46.8 | 45.9 |
| 48 |               | 46.4 | 45.2 |
| 49 |               | 47.2 | 46.0 |
| 50 |               | 45.5 | 44.3 |
| 51 |               | 46.0 | 44.5 |
| 52 |               | 47.1 | 45.5 |
| 53 |               | 46.9 | 45.7 |
| 54 |               | 47.0 | 45.3 |
| 55 |               | 46.7 | 45.7 |
| 56 |               | 47.3 | 45.7 |
| 57 |               | 47.0 | 46.2 |
| 58 |               | 46.5 | 44.4 |
| 59 |               | 47.1 | 46.3 |
| 60 |               | 47.1 | 45.7 |
| 61 |               | 47.0 | 46.3 |
| 62 |               | 47.6 | 46.3 |
| 63 |               | 47.0 | 46.6 |
| 64 |               | 45.8 | 45.9 |
| 65 |               | 46.5 | 46.5 |
| 66 | Catch         | 46.8 | 47.1 |
| 67 |               | 46.4 | 46.9 |
| 68 |               | 46.7 | 47.4 |
| 69 |               | 46.6 | 46.3 |
| 70 |               | 46.0 | 47.3 |
| 71 |               | 46.7 | 45.9 |
| 72 |               | 44.8 | 45.9 |
| 73 |               | 46.9 | 45.9 |
| 74 |               | 45.6 | 45.4 |
| 75 |               | 45.9 | 45.2 |

|                                          | Max              | 47.6            | 47.4           |
|------------------------------------------|------------------|-----------------|----------------|
|                                          | Min              | 43.8            | 42.7           |
|                                          | Diff             | 3.8             | 4.8            |
|                                          |                  |                 |                |
| <b>Calculation of Y-axis movements(c</b> |                  |                 | <b>Trial 5</b> |
| Frame(0.017s)                            | Event            | Y(lftrtcam)(cm) | Y(rtrtcam)(cm) |
| 1                                        |                  | 41.6            | 42.6           |
| 2                                        |                  | 40.8            | 42.2           |
| 3                                        |                  | 42.0            | 42.5           |
| 4                                        |                  | 42.6            | 42.7           |
| 5                                        |                  | 42.4            | 43.3           |
| 6                                        |                  | 43.0            | 43.6           |
| 7                                        |                  | 41.9            | 42.3           |
| 8                                        |                  | 42.9            | 42.8           |
| 9                                        |                  | 42.9            | 42.9           |
| 10                                       | Catch            | 42.5            | 43.3           |
| 11                                       |                  | 42.5            | 42.9           |
| 12                                       |                  | 43.3            | 43.4           |
| 13                                       |                  | 43.9            | 43.8           |
| 14                                       |                  | 43.4            | 43.5           |
| 15                                       |                  | 43.1            | 43.6           |
| 16                                       |                  | 43.5            | 44.0           |
| 17                                       |                  | 43.2            | 43.6           |
| 18                                       |                  | 43.3            | 43.8           |
| 19                                       |                  | 42.6            | 42.6           |
| 20                                       |                  | 42.5            | 44.2           |
| 21                                       |                  | 42.9            | 43.9           |
| 22                                       |                  | 42.6            | 44.9           |
| 23                                       |                  | 42.0            | 44.4           |
| 24                                       |                  | 41.8            | 44.5           |
| 25                                       |                  | 42.8            | 44.8           |
| 26                                       |                  | 42.6            | 44.7           |
| 27                                       |                  | 41.6            | 45.2           |
| 28                                       |                  | 42.8            | 45.0           |
| 29                                       |                  | 42.2            | 45.8           |
| 30                                       |                  | 42.6            | 45.2           |
| 31                                       |                  | 40.8            | 45.1           |
| 32                                       |                  | 41.8            | 45.5           |
| 33                                       |                  | 40.9            | 44.7           |
| 34                                       |                  | 41.8            | 45.4           |
| 35                                       |                  | 42.0            | 45.3           |
| 36                                       | End of Leg Drive | 41.8            | 45.3           |
| 37                                       |                  | 40.8            | 44.7           |
| 38                                       |                  | 41.9            | 45.4           |
| 39                                       |                  | 41.1            | 45.4           |
| 40                                       |                  | 41.9            | 44.8           |
| 41                                       |                  | 41.0            | 45.3           |
| 42                                       |                  | 41.5            | 45.6           |
| 43                                       |                  | 40.9            | 44.4           |

|                                          | Max              | 47.6            | 47.4           |
|------------------------------------------|------------------|-----------------|----------------|
|                                          | Min              | 43.8            | 42.7           |
|                                          | Diff             | 3.8             | 4.8            |
|                                          |                  |                 |                |
| <b>Calculation of Y-axis movements(c</b> |                  |                 | <b>Trial 5</b> |
| Frame(0.017s)                            | Event            | Y(lftrtcam)(cm) | Y(rtrtcam)(cm) |
| 1                                        |                  | 41.6            | 42.6           |
| 2                                        |                  | 40.8            | 42.2           |
| 3                                        |                  | 42.0            | 42.5           |
| 4                                        |                  | 42.6            | 42.7           |
| 5                                        |                  | 42.4            | 43.3           |
| 6                                        |                  | 43.0            | 43.6           |
| 7                                        |                  | 41.9            | 42.3           |
| 8                                        |                  | 42.9            | 42.8           |
| 9                                        |                  | 42.9            | 42.9           |
| 10                                       | Catch            | 42.5            | 43.3           |
| 11                                       |                  | 42.5            | 42.9           |
| 12                                       |                  | 43.3            | 43.4           |
| 13                                       |                  | 43.9            | 43.8           |
| 14                                       |                  | 43.4            | 43.5           |
| 15                                       |                  | 43.1            | 43.6           |
| 16                                       |                  | 43.5            | 44.0           |
| 17                                       |                  | 43.2            | 43.6           |
| 18                                       |                  | 43.3            | 43.8           |
| 19                                       |                  | 42.6            | 42.6           |
| 20                                       |                  | 42.5            | 44.2           |
| 21                                       |                  | 42.9            | 43.9           |
| 22                                       |                  | 42.6            | 44.9           |
| 23                                       |                  | 42.0            | 44.4           |
| 24                                       |                  | 41.8            | 44.5           |
| 25                                       |                  | 42.8            | 44.8           |
| 26                                       |                  | 42.6            | 44.7           |
| 27                                       |                  | 41.6            | 45.2           |
| 28                                       |                  | 42.8            | 45.0           |
| 29                                       |                  | 42.2            | 45.8           |
| 30                                       |                  | 42.6            | 45.2           |
| 31                                       |                  | 40.8            | 45.1           |
| 32                                       |                  | 41.8            | 45.5           |
| 33                                       |                  | 40.9            | 44.7           |
| 34                                       |                  | 41.8            | 45.4           |
| 35                                       |                  | 42.0            | 45.3           |
| 36                                       | End of Leg Drive | 41.8            | 45.3           |
| 37                                       |                  | 40.8            | 44.7           |
| 38                                       |                  | 41.9            | 45.4           |
| 39                                       |                  | 41.1            | 45.4           |
| 40                                       |                  | 41.9            | 44.8           |
| 41                                       |                  | 41.0            | 45.3           |
| 42                                       |                  | 41.5            | 45.6           |
| 43                                       |                  | 40.9            | 44.4           |

| 44                                        |        | 41.4           | 44.6           |
|-------------------------------------------|--------|----------------|----------------|
| 45                                        |        | 41.9           | 45.2           |
| 46                                        |        | 42.4           | 45.1           |
| 47                                        |        | 42.7           | 45.3           |
| 48                                        |        | 42.4           | 45.0           |
| 49                                        |        | 43.4           | 44.9           |
| 50                                        |        | 42.5           | 45.2           |
| 51                                        |        | 43.5           | 44.7           |
| 52                                        |        | 43.8           | 45.1           |
| 53                                        |        | 42.9           | 45.0           |
| 54                                        |        | 43.9           | 45.5           |
| 55                                        |        | 44.1           | 44.4           |
| 56                                        |        | 44.0           | 45.4           |
| 57                                        |        | 43.6           | 45.1           |
| 58                                        |        | 44.5           | 46.0           |
| 59                                        |        | 44.0           | 45.7           |
| 60                                        | Finish | 44.6           | 46.6           |
| 61                                        |        | 43.9           | 46.3           |
| 62                                        |        | 45.4           | 46.0           |
| 63                                        |        | 44.1           | 46.1           |
| 64                                        |        | 44.9           | 46.1           |
| 65                                        |        | 43.9           | 45.3           |
| 66                                        |        | 43.3           | 46.6           |
| 67                                        |        | 43.6           | 45.4           |
| 68                                        |        | 43.9           | 47.0           |
| 69                                        |        | 43.4           | 46.1           |
| 70                                        |        | 43.6           | 46.9           |
|                                           | Max    | 45.4           | 47.0           |
|                                           | Min    | 40.8           | 42.2           |
|                                           | Diff   | 4.7            | 4.9            |
| Calculation of Y-axis movements(c Trial 6 |        |                |                |
| Frame(0.017s)                             | Event  | Y(ltrtoam)(cm) | Y(rtrtoam)(cm) |
| 1                                         |        | 40.2           | 39.2           |
| 2                                         |        | 40.1           | 37.4           |
| 3                                         |        | 39.9           | 38.7           |
| 4                                         |        | 41.7           | 38.9           |
| 5                                         |        | 40.7           | 39.2           |
| 6                                         |        | 41.3           | 38.7           |
| 7                                         |        | 41.3           | 39.3           |
| 8                                         |        | 41.5           | 39.1           |
| 9                                         |        | 42.6           | 39.3           |
| 10                                        | Finish | 42.8           | 41.1           |
| 11                                        |        | 43.2           | 39.7           |
| 12                                        |        | 43.4           | 40.8           |
| 13                                        |        | 44.2           | 41.0           |
| 14                                        |        | 44.1           | 41.3           |
| 15                                        |        | 43.4           | 40.7           |
| 16                                        |        | 44.7           | 42.1           |



|    |                 |      |      |
|----|-----------------|------|------|
| 17 |                 | 43.8 | 41.4 |
| 18 |                 | 45.0 | 42.2 |
| 19 |                 | 44.0 | 43.5 |
| 20 |                 | 43.6 | 41.9 |
| 21 |                 | 43.5 | 42.5 |
| 22 |                 | 44.2 | 43.1 |
| 23 |                 | 43.6 | 42.1 |
| 24 |                 | 43.5 | 42.5 |
| 25 |                 | 43.7 | 42.8 |
| 26 |                 | 44.1 | 42.3 |
| 27 |                 | 42.5 | 42.9 |
| 28 | Beg. Sent Movt. | 45.6 | 43.3 |
| 29 |                 | 43.4 | 43.5 |
| 30 |                 | 44.3 | 43.1 |
| 31 |                 | 44.6 | 43.9 |
| 32 |                 | 45.2 | 44.2 |
| 33 |                 | 44.1 | 43.5 |
| 34 |                 | 45.3 | 43.3 |
| 35 |                 | 43.7 | 43.4 |
| 36 |                 | 45.3 | 43.5 |
| 37 |                 | 44.1 | 44.4 |
| 38 |                 | 45.4 | 43.6 |
| 39 |                 | 44.1 | 43.5 |
| 40 |                 | 45.3 | 43.9 |
| 41 |                 | 45.1 | 43.8 |
| 42 |                 | 45.4 | 43.5 |
| 43 |                 | 44.5 | 44.2 |
| 44 |                 | 45.0 | 42.7 |
| 45 |                 | 44.8 | 44.5 |
| 46 |                 | 45.1 | 43.5 |
| 47 |                 | 45.0 | 43.6 |
| 48 |                 | 45.4 | 43.6 |
| 49 |                 | 46.4 | 44.0 |
| 50 |                 | 46.0 | 43.5 |
| 51 |                 | 48.0 | 45.8 |
| 52 |                 | 46.7 | 43.6 |
| 53 |                 | 47.8 | 45.2 |
| 54 |                 | 46.0 | 43.3 |
| 55 |                 | 48.0 | 44.7 |
| 56 |                 | 47.4 | 44.2 |
| 57 |                 | 47.9 | 44.8 |
| 58 |                 | 48.0 | 45.8 |
| 59 |                 | 47.6 | 45.2 |
| 60 |                 | 47.9 | 45.1 |
| 61 |                 | 48.5 | 45.7 |
| 62 |                 | 48.6 | 45.1 |
| 63 |                 | 48.7 | 45.9 |
| 64 |                 | 49.4 | 44.9 |
| 65 |                 | 48.2 | 46.6 |

## APPENDIX E

### Calculations of z axis movements of the Mobile Video Platform

| Z-axis movements(cm) |               |            |            |          | Trial 1   |             |             |              |
|----------------------|---------------|------------|------------|----------|-----------|-------------|-------------|--------------|
|                      |               |            |            |          |           |             |             | dz(lftrcam)+ |
| Frame(0.017s)        | Event         | Z(lftrcam) | Z(rftrcam) | Z(shell) | dz(shell) | dz(lftrcam) | dz(rftrcam) | dz(rftrcam)  |
| 1                    |               | 216.6      | 518.1      | 385.2    |           |             |             |              |
| 2                    |               | 217.1      | 520.4      | 385.7    | 0.5       | 0.6         | 2.3         | 2.8          |
| 3                    |               | 220.2      | 521.7      | 385.3    | -0.4      | 3.0         | 1.3         | 4.4          |
| 4                    |               | 219.2      | 522.5      | 386.4    | 1.2       | -1.0        | 0.8         | -0.2         |
| 5                    |               | 222.5      | 525.4      | 390.5    | 4.1       | 3.4         | 2.9         | 6.3          |
| 6                    |               | 223.4      | 526.7      | 389.7    | -0.9      | 0.8         | 1.4         | 2.2          |
| 7                    |               | 223.3      | 526.8      | 390.3    | 0.7       | -0.1        | 0.1         | 0.0          |
| 8                    |               | 225.7      | 528.3      | 391.5    | 1.2       | 2.5         | 1.5         | 4.0          |
| 9                    |               | 224.9      | 527.9      | 390.9    | -0.6      | -0.6        | -0.4        | -1.2         |
| 10                   | Catch         | 226.9      | 531.2      | 394.3    | 3.4       | 2.0         | 3.3         | 5.2          |
| 11                   |               | 228.2      | 530.4      | 393.1    | -1.2      | 1.3         | -0.8        | 0.6          |
| 12                   |               | 228.0      | 529.5      | 393.6    | 0.5       | -0.2        | -0.8        | -1.0         |
| 13                   |               | 228.3      | 530.9      | 394.8    | 1.2       | 0.3         | 1.3         | 1.7          |
| 14                   |               | 229.8      | 534.5      | 397.5    | 2.7       | 1.5         | 3.6         | 5.1          |
| 15                   |               | 232.1      | 535.3      | 396.5    | -1.0      | 2.3         | 0.8         | 3.1          |
| 16                   |               | 232.5      | 536.8      | 397.1    | 0.6       | 0.4         | 1.5         | 1.9          |
| 17                   |               | 230.5      | 533.1      | 396.1    | -1.0      | -2.0        | -3.7        | -5.7         |
| 18                   |               | 231.5      | 536.9      | 398.2    | 2.1       | 1.0         | 3.8         | 4.9          |
| 19                   |               | 232.8      | 536.8      | 399.0    | 0.8       | 1.3         | -0.2        | 1.1          |
| 20                   |               | 234.1      | 537.2      | 400.0    | 1.0       | 1.3         | 0.4         | 1.8          |
| 21                   |               | 234.7      | 539.9      | 400.6    | 0.7       | 0.6         | 2.7         | 3.3          |
| 22                   |               | 235.9      | 540.2      | 401.2    | 0.6       | 1.1         | 0.3         | 1.4          |
| 23                   |               | 236.7      | 542.6      | 400.8    | -0.4      | 0.8         | 2.4         | 3.2          |
| 24                   |               | 238.3      | 544.1      | 403.1    | 2.4       | 2.6         | 1.4         | 4.1          |
| 25                   |               | 240.0      | 544.0      | 403.1    | 0.0       | 0.7         | -0.1        | 0.6          |
| 26                   |               | 238.3      | 544.1      | 402.7    | -0.5      | -1.8        | 0.2         | -1.6         |
| 27                   |               | 239.6      | 544.1      | 402.5    | -0.1      | 1.3         | -0.1        | 1.2          |
| 28                   |               | 240.4      | 546.4      | 403.6    | 1.0       | 0.8         | 2.3         | 3.1          |
| 29                   |               | 240.6      | 546.2      | 403.4    | -0.2      | 0.3         | -0.2        | 0.0          |
| 30                   |               | 243.7      | 548.8      | 404.7    | 1.3       | 3.1         | 2.6         | 5.7          |
| 31                   |               | 244.2      | 551.5      | 404.7    | 0.0       | 0.5         | 2.8         | 3.2          |
| 32                   | END Lag Drive | 244.6      | 549.1      | 404.6    | -0.1      | 0.4         | -2.5        | -2.1         |
| 33                   |               | 244.2      | 549.4      | 404.4    | -0.2      | -0.3        | 0.4         | 0.0          |
| 34                   |               | 246.2      | 550.9      | 406.9    | 2.4       | 1.9         | 1.5         | 3.5          |
| 35                   |               | 248.0      | 552.7      | 408.1    | 1.3       | 1.9         | 1.7         | 3.6          |
| 36                   |               | 250.5      | 555.0      | 408.7    | 0.6       | 2.4         | 2.4         | 4.8          |
| 37                   |               | 249.8      | 555.1      | 408.1    | -0.6      | -0.6        | 0.1         | -0.6         |
| 38                   |               | 252.9      | 556.7      | 410.0    | 1.9       | 3.1         | 0.6         | 3.7          |
| 39                   |               | 251.1      | 556.5      | 408.6    | -1.4      | -1.9        | 0.8         | -1.1         |
| 40                   |               | 251.7      | 556.9      | 408.8    | 1.2       | 0.6         | 0.4         | 1.1          |
| 41                   |               | 253.1      | 558.9      | 410.1    | 0.3       | 1.4         | 2.0         | 3.4          |
| 42                   |               | 254.0      | 557.6      | 408.6    | -1.5      | 0.9         | -1.3        | -0.4         |
| 43                   |               | 253.0      | 558.9      | 410.0    | 1.5       | -1.0        | 1.4         | 0.3          |
| 44                   |               | 256.3      | 561.0      | 412.3    | 2.3       | 3.3         | 2.0         | 5.4          |
| 45                   |               | 256.1      | 561.8      | 412.3    | -0.1      | -0.2        | 0.9         | 0.6          |
| 46                   |               | 255.5      | 562.2      | 411.0    | -1.3      | -0.6        | 0.4         | -0.2         |

| 47                   |        | 255.6      | 562.9      | 409.8    | -1.2      | 0.1         | 0.7         | 0.8          |
|----------------------|--------|------------|------------|----------|-----------|-------------|-------------|--------------|
| 48                   |        | 258.0      | 563.3      | 411.8    | 2.0       | 2.4         | 0.4         | 2.8          |
| 49                   |        | 258.6      | 564.7      | 411.2    | -0.6      | 0.6         | 1.4         | 2.0          |
| 50                   |        | 258.1      | 564.9      | 413.3    | 2.0       | -0.5        | 0.2         | -0.3         |
| 51                   |        | 259.3      | 565.0      | 414.8    | 1.5       | 1.2         | 0.1         | 1.3          |
| 52                   |        | 260.5      | 564.5      | 413.4    | -1.4      | 1.1         | -0.4        | 0.7          |
| 53                   |        | 261.4      | 566.4      | 413.5    | 0.1       | 1.0         | 1.8         | 2.8          |
| 54                   | Finish | 260.8      | 566.6      | 413.9    | 0.4       | -0.7        | 0.2         | -0.4         |
| 55                   |        | 261.2      | 567.3      | 413.6    | -0.2      | 0.5         | 0.7         | 1.2          |
| 56                   |        | 262.1      | 567.9      | 414.0    | 0.4       | 0.9         | 0.6         | 1.6          |
| 57                   |        | 260.7      | 568.7      | 412.2    | -1.8      | -1.5        | -1.2        | -2.7         |
| 58                   |        | 261.8      | 567.7      | 413.5    | 1.2       | 1.1         | 1.0         | 2.1          |
| 59                   |        | 261.0      | 568.0      | 413.3    | -0.1      | -0.8        | 0.3         | -0.5         |
| 60                   |        | 262.5      | 569.6      | 413.4    | 0.1       | 1.6         | 1.6         | 3.2          |
| 61                   |        | 263.8      | 569.1      | 413.9    | 0.4       | 1.3         | -0.5        | 0.7          |
| 62                   |        | 264.2      | 571.4      | 413.9    | 0.0       | 0.4         | 2.3         | 2.6          |
|                      |        |            |            |          |           |             | Max         | 6.3          |
|                      |        |            |            |          |           |             | Min         | -5.7         |
|                      |        |            |            |          |           |             | Diff        | 11.9         |
| Z-axis movements(cm) |        |            |            |          |           | Trial 2     |             |              |
|                      |        |            |            |          |           |             |             | dz(lfrtoam)→ |
| Frame(0.017s)        | Event  | Z(lfrtoam) | Z(rfrtoam) | Z(shell) | dz(shell) | dz(lfrtoam) | dz(rfrtoam) | dz(rfrtoam)  |
| 1                    |        | -92.8      | 212.6      | 61.6     |           |             |             |              |
| 2                    |        | -96.3      | 212.3      | 59.2     | -2.4      | -3.6        | -0.3        | -3.9         |
| 3                    |        | -92.1      | 216.1      | 61.8     | 2.6       | 4.3         | 3.8         | 8.1          |
| 4                    |        | -93.6      | 214.0      | 61.2     | -0.6      | -1.5        | -2.1        | -3.6         |
| 5                    |        | -91.9      | 215.6      | 61.6     | 0.4       | 1.6         | 1.6         | 3.2          |
| 6                    |        | -94.6      | 213.3      | 58.0     | -3.6      | -2.7        | -2.3        | -5.0         |
| 7                    |        | -92.2      | 215.7      | 62.6     | 4.6       | 2.5         | 2.5         | 4.9          |
| 8                    |        | -90.6      | 214.2      | 61.2     | -1.4      | 1.6         | -1.5        | 0.0          |
| 9                    |        | -91.4      | 215.9      | 61.6     | 0.4       | -0.8        | 1.6         | 0.8          |
| 10                   | Finish | -93.9      | 215.9      | 60.9     | -0.7      | -2.5        | 0.0         | -2.5         |
| 11                   |        | -91.2      | 215.3      | 60.6     | -0.3      | 2.8         | -0.5        | 2.3          |
| 12                   |        | -94.7      | 213.2      | 58.1     | -2.5      | -3.5        | -2.1        | -5.7         |
| 13                   |        | -91.7      | 214.8      | 61.0     | 2.9       | 3.0         | 1.6         | 4.6          |
| 14                   |        | -90.9      | 216.2      | 61.9     | 1.0       | 0.9         | 1.4         | 2.3          |
| 15                   |        | -98.8      | 217.3      | 62.8     | 0.8       | 2.0         | 1.1         | 3.1          |
| 16                   |        | -93.2      | 213.3      | 59.3     | -3.5      | -4.4        | -4.1        | -8.5         |
| 17                   |        | -91.7      | 216.2      | 61.9     | 2.6       | 1.6         | 2.9         | 4.5          |
| 18                   |        | -91.1      | 216.0      | 61.2     | -0.7      | 0.6         | -1.2        | -0.6         |
| 19                   |        | -92.6      | 215.1      | 61.8     | 0.6       | -1.5        | 0.0         | -1.5         |
| 20                   |        | -92.8      | 212.9      | 59.9     | -1.8      | -0.2        | -2.2        | -2.4         |
| 21                   |        | -92.0      | 214.1      | 61.4     | 1.5       | 0.8         | 1.2         | 2.0          |
| 22                   |        | -91.9      | 215.1      | 61.8     | 0.4       | 0.1         | 1.0         | 1.1          |
| 23                   |        | -90.2      | 217.3      | 61.8     | 0.0       | 1.6         | 2.2         | 3.9          |
| 24                   |        | -92.9      | 212.7      | 60.1     | -1.7      | -2.7        | -4.6        | -7.3         |
| 25                   |        | -91.7      | 218.7      | 63.3     | 3.2       | 1.3         | 6.0         | 7.3          |
| 26                   |        | -90.6      | 216.6      | 62.5     | -0.8      | 1.1         | -2.1        | -1.0         |

|    |                  |       |       |      |      |      |      |      |
|----|------------------|-------|-------|------|------|------|------|------|
| 27 |                  | -90.8 | 215.9 | 63.4 | 0.9  | -0.2 | -0.7 | -0.9 |
| 28 |                  | -89.7 | 216.7 | 64.0 | 0.5  | 1.1  | 0.8  | 1.9  |
| 29 |                  | -90.5 | 216.2 | 62.4 | -1.6 | -0.8 | -0.5 | -1.4 |
| 30 | Bag Seat<br>Movt | -90.3 | 216.4 | 63.3 | 1.0  | 0.2  | 0.3  | 0.4  |
| 31 |                  | -90.3 | 217.2 | 64.3 | 1.0  | 0.1  | 0.8  | 0.8  |
| 32 |                  | -90.0 | 217.1 | 62.7 | -1.6 | 0.3  | -0.1 | 0.1  |
| 33 |                  | -88.3 | 216.0 | 63.8 | 1.1  | 1.7  | -1.1 | 0.6  |
| 34 |                  | -90.6 | 219.4 | 64.5 | 0.7  | -2.3 | 3.4  | 1.1  |
| 35 |                  | -87.7 | 219.6 | 63.9 | -0.6 | 2.9  | 0.2  | 3.1  |
| 36 |                  | -88.5 | 218.1 | 63.5 | -0.4 | -0.8 | -1.5 | -2.3 |
| 37 |                  | -88.8 | 217.2 | 65.2 | 1.7  | -0.3 | -0.9 | -1.2 |
| 38 |                  | -88.9 | 216.5 | 65.3 | 0.1  | -0.1 | -0.7 | -0.8 |
| 39 |                  | -89.0 | 218.1 | 65.9 | 0.6  | -0.1 | 1.6  | 1.5  |
| 40 |                  | -87.9 | 219.8 | 64.6 | -1.3 | 1.1  | 1.7  | 2.8  |
| 41 |                  | -88.7 | 219.6 | 65.8 | 1.3  | -0.7 | -0.2 | -0.9 |
| 42 |                  | -86.9 | 220.1 | 66.5 | 0.7  | 1.8  | 0.5  | 2.2  |
| 43 |                  | -88.3 | 219.7 | 67.8 | 1.3  | -1.4 | -0.4 | -1.7 |
| 44 |                  | -85.1 | 220.2 | 68.5 | 0.7  | 3.2  | 0.5  | 3.7  |
| 45 |                  | -84.5 | 221.1 | 68.0 | -0.5 | 0.7  | 0.9  | 1.5  |
| 46 |                  | -87.9 | 218.7 | 67.7 | -0.3 | -3.5 | -2.4 | -5.9 |
| 47 |                  | -86.4 | 220.3 | 68.8 | 1.0  | 1.5  | 1.6  | 3.2  |
| 48 |                  | -84.1 | 221.6 | 66.8 | -2.0 | 2.3  | 1.3  | 3.5  |
| 49 |                  | -84.7 | 221.8 | 71.3 | 4.5  | -0.5 | 0.2  | -0.3 |
| 50 |                  | -84.2 | 219.8 | 69.0 | -2.4 | 0.4  | -2.0 | -1.6 |
| 51 |                  | -82.5 | 223.5 | 76.6 | 7.6  | 1.7  | 3.7  | 5.5  |
| 52 |                  | -82.8 | 221.5 | 71.4 | -5.2 | -0.3 | -2.0 | -2.3 |
| 53 |                  | -80.8 | 225.2 | 75.8 | 4.4  | 2.0  | 3.7  | 5.7  |
| 54 |                  | -81.3 | 224.1 | 71.5 | -4.2 | -0.5 | -1.1 | -1.6 |
| 55 |                  | -82.9 | 224.3 | 73.9 | 2.3  | -1.6 | 0.2  | -1.4 |
| 56 |                  | -81.3 | 224.8 | 71.8 | -2.0 | 1.7  | 0.5  | 2.1  |
| 57 |                  | -80.7 | 226.7 | 76.7 | 4.9  | 0.6  | 1.9  | 2.5  |
| 58 |                  | -81.0 | 225.1 | 74.8 | -1.9 | -0.3 | -1.6 | -1.8 |
| 59 |                  | -80.2 | 226.9 | 79.3 | 4.5  | 0.7  | 1.8  | 2.5  |
| 60 |                  | -78.4 | 227.2 | 75.1 | -4.2 | 1.8  | 0.2  | 2.1  |
| 61 |                  | -78.3 | 227.9 | 76.1 | 1.0  | 0.1  | 0.8  | 0.9  |
| 62 |                  | -79.6 | 227.7 | 76.2 | 0.1  | -1.3 | -0.3 | -1.6 |
| 63 |                  | -80.7 | 227.4 | 75.5 | -0.8 | -1.2 | -0.3 | -1.4 |
| 64 |                  | -76.7 | 229.0 | 76.8 | 1.3  | 4.0  | 1.6  | 5.5  |
| 65 |                  | -76.8 | 228.5 | 77.5 | 0.7  | 0.0  | -0.5 | -0.5 |
| 66 | Catch            | -79.1 | 226.9 | 75.5 | -2.1 | -2.3 | -1.6 | -3.9 |
| 67 |                  | -76.4 | 231.0 | 79.1 | 3.6  | 2.7  | 4.2  | 6.8  |
| 68 |                  | -77.4 | 231.0 | 79.3 | 0.2  | -1.0 | -0.1 | -1.1 |
| 69 |                  | -76.2 | 229.8 | 81.0 | 1.7  | 1.2  | -1.2 | 0.0  |
| 70 |                  | -75.5 | 231.4 | 78.3 | -2.7 | 0.7  | 1.7  | 2.4  |
| 71 |                  | -74.9 | 229.8 | 80.3 | 2.0  | 0.7  | -1.6 | -0.9 |
| 72 |                  | -75.4 | 233.2 | 80.2 | 0.0  | -0.5 | 3.3  | 2.8  |
| 73 |                  | -74.1 | 232.0 | 80.7 | 0.5  | 1.2  | -1.2 | 0.1  |
| 74 |                  | -73.6 | 232.0 | 80.0 | -0.7 | 0.6  | 0.1  | 0.6  |
| 75 |                  | -75.8 | 231.8 | 79.5 | -0.5 | -2.2 | -0.3 | -2.5 |

|                                            |                  |                   |                  |                 |                  |                    |                   |                   |
|--------------------------------------------|------------------|-------------------|------------------|-----------------|------------------|--------------------|-------------------|-------------------|
|                                            |                  |                   |                  |                 |                  |                    | Max               | 8.1               |
|                                            |                  |                   |                  |                 |                  |                    | Min               | -8.5              |
|                                            |                  |                   |                  |                 |                  |                    | Diff              | 16.6              |
| <b>Calculation of Z-axis movements(cm)</b> |                  |                   |                  |                 | <b>Trial 5</b>   |                    |                   |                   |
|                                            |                  |                   |                  |                 |                  |                    |                   | dz(lftrcam)+      |
| <b>Frame(0.017s)</b>                       | <b>Event</b>     | <b>Z(lftrcam)</b> | <b>Z(rtrcam)</b> | <b>Z(shell)</b> | <b>dz(shell)</b> | <b>dz(lftrcam)</b> | <b>dz(rtrcam)</b> | <b>dz(rtrcam)</b> |
| 1                                          |                  | 210.5             | 516.9            | 392.9           |                  |                    |                   |                   |
| 2                                          |                  | 213.7             | 519.6            | 395.6           | 2.7              | 3.2                | 2.7               | 5.9               |
| 3                                          |                  | 216.2             | 521.7            | 395.6           | 0.0              | 2.4                | 2.1               | 4.5               |
| 4                                          |                  | 219.0             | 524.0            | 397.9           | 2.3              | 2.9                | 2.4               | 5.2               |
| 5                                          |                  | 221.7             | 528.6            | 400.6           | 2.7              | 2.6                | 4.5               | 7.2               |
| 6                                          |                  | 223.3             | 529.0            | 400.3           | -0.3             | 1.6                | 0.4               | 2.0               |
| 7                                          |                  | 226.2             | 531.2            | 402.4           | 2.0              | 3.0                | 2.2               | 5.2               |
| 8                                          |                  | 227.1             | 532.6            | 403.6           | 1.2              | 0.9                | 1.4               | 2.3               |
| 9                                          |                  | 228.3             | 534.3            | 405.1           | 1.5              | 1.2                | 1.7               | 2.9               |
| 10                                         | Catch            | 229.6             | 536.0            | 406.0           | 0.9              | 1.3                | 1.7               | 3.0               |
| 11                                         |                  | 233.2             | 539.1            | 407.7           | 1.7              | 3.6                | 3.1               | 6.7               |
| 12                                         |                  | 232.7             | 540.0            | 408.5           | 0.8              | -0.4               | 0.9               | 0.4               |
| 13                                         |                  | 234.1             | 541.1            | 410.0           | 1.5              | 1.4                | 1.2               | 2.6               |
| 14                                         |                  | 235.4             | 542.0            | 410.9           | 0.9              | 1.2                | 0.9               | 2.1               |
| 15                                         |                  | 237.5             | 543.4            | 412.2           | 1.3              | 2.2                | 1.4               | 3.5               |
| 16                                         |                  | 239.1             | 547.5            | 415.1           | 2.9              | 1.6                | 4.1               | 5.7               |
| 17                                         |                  | 238.7             | 547.1            | 414.1           | -1.0             | -0.4               | -0.4              | -0.8              |
| 18                                         |                  | 241.0             | 548.8            | 417.2           | 3.1              | 2.4                | 1.7               | 4.1               |
| 19                                         |                  | 240.0             | 548.1            | 414.9           | -2.3             | -1.0               | -0.7              | -1.8              |
| 20                                         |                  | 243.5             | 550.4            | 416.7           | 1.8              | 3.5                | 2.3               | 5.8               |
| 21                                         |                  | 243.6             | 551.9            | 418.2           | 1.5              | 0.2                | 1.5               | 1.7               |
| 22                                         |                  | 245.7             | 555.0            | 419.2           | 1.0              | 2.1                | 3.0               | 5.1               |
| 23                                         |                  | 246.7             | 554.6            | 419.3           | 0.1              | 1.1                | -0.4              | 0.6               |
| 24                                         |                  | 247.2             | 555.6            | 420.4           | 1.2              | 0.5                | 1.1               | 1.5               |
| 25                                         |                  | 251.3             | 558.2            | 421.3           | 0.9              | 4.1                | 2.5               | 6.6               |
| 26                                         |                  | 250.4             | 558.6            | 421.4           | 0.1              | -0.9               | 0.5               | -0.4              |
| 27                                         |                  | 253.1             | 562.4            | 423.8           | 2.4              | 2.7                | 3.8               | 6.6               |
| 28                                         |                  | 253.2             | 562.5            | 424.9           | 1.1              | 0.1                | 0.0               | 0.1               |
| 29                                         |                  | 253.8             | 563.4            | 424.9           | 0.0              | 0.7                | 0.9               | 1.6               |
| 30                                         |                  | 255.3             | 563.3            | 425.6           | 0.7              | 1.5                | -0.1              | 1.4               |
| 31                                         |                  | 255.2             | 565.8            | 426.7           | 1.2              | -0.1               | 2.5               | 2.4               |
| 32                                         |                  | 256.9             | 567.4            | 427.0           | 0.2              | 1.7                | 1.7               | 3.4               |
| 33                                         |                  | 257.2             | 568.0            | 427.8           | 0.8              | 0.2                | 0.6               | 0.8               |
| 34                                         |                  | 258.3             | 570.3            | 428.4           | 0.7              | 2.1                | 2.2               | 4.3               |
| 35                                         |                  | 261.2             | 572.3            | 430.3           | 1.8              | 1.9                | 2.0               | 4.0               |
| 36                                         | END OF LOG Drive | 263.6             | 573.6            | 431.3           | 1.0              | 2.4                | 1.3               | 3.7               |
| 37                                         |                  | 264.0             | 575.1            | 431.5           | 0.2              | 0.4                | 1.6               | 2.0               |
| 38                                         |                  | 267.1             | 575.7            | 431.4           | -0.1             | 3.1                | 0.6               | 3.7               |
| 39                                         |                  | 265.9             | 577.0            | 432.8           | 1.4              | -1.2               | 1.3               | 0.1               |
| 40                                         |                  | 265.9             | 576.3            | 432.5           | -0.4             | 0.0                | -0.8              | -0.8              |
| 41                                         |                  | 268.9             | 579.8            | 433.7           | 1.2              | 3.0                | 3.5               | 6.6               |
| 42                                         |                  | 271.0             | 582.7            | 436.8           | 3.2              | 2.1                | 2.9               | 5.0               |
| 43                                         |                  | 271.2             | 582.2            | 434.8           | -2.1             | 0.2                | -0.5              | -0.3              |

|                                     |        |            |            |          |           |             |             |              |
|-------------------------------------|--------|------------|------------|----------|-----------|-------------|-------------|--------------|
| 44                                  |        | 272.4      | 582.0      | 436.2    | 1.4       | 1.2         | -0.2        | 0.9          |
| 45                                  |        | 274.5      | 585.7      | 437.9    | 1.8       | 2.1         | 3.7         | 5.8          |
| 46                                  |        | 274.2      | 586.2      | 438.6    | 0.6       | -0.3        | 0.5         | 0.1          |
| 47                                  |        | 276.3      | 586.9      | 438.3    | -0.3      | 2.1         | 0.7         | 2.8          |
| 48                                  |        | 277.1      | 587.1      | 438.5    | 0.2       | 0.8         | 0.2         | 1.0          |
| 49                                  |        | 276.8      | 587.9      | 438.3    | -0.2      | -0.3        | 0.9         | 0.5          |
| 50                                  |        | 280.7      | 591.5      | 440.0    | 1.7       | 3.9         | 3.5         | 7.4          |
| 51                                  |        | 281.0      | 593.1      | 440.4    | 0.4       | 0.4         | 1.7         | 2.0          |
| 52                                  |        | 279.3      | 591.2      | 438.1    | -2.2      | -1.7        | -1.9        | -3.7         |
| 53                                  |        | 283.8      | 596.0      | 443.4    | 5.2       | 4.5         | 4.8         | 9.3          |
| 54                                  |        | 281.8      | 594.9      | 441.5    | -1.8      | -1.9        | -1.2        | -3.1         |
| 55                                  |        | 284.8      | 596.8      | 443.4    | 1.9       | 3.0         | 1.9         | 4.9          |
| 56                                  |        | 286.0      | 598.0      | 443.7    | 0.3       | 1.1         | 1.2         | 2.3          |
| 57                                  |        | 285.7      | 597.4      | 443.5    | -0.2      | -0.3        | -0.6        | -0.9         |
| 58                                  |        | 285.5      | 598.4      | 442.3    | -1.2      | -0.2        | 1.0         | 0.9          |
| 59                                  |        | 286.0      | 598.8      | 444.7    | 2.4       | 0.6         | 1.5         | 1.9          |
| 60                                  | Finish | 286.2      | 601.8      | 443.4    | -1.3      | 0.2         | 1.9         | 2.1          |
| 61                                  |        | 287.2      | 601.5      | 444.9    | 1.5       | 1.0         | -0.3        | 0.7          |
| 62                                  |        | 288.1      | 604.1      | 443.6    | -1.3      | 0.9         | 2.7         | 3.6          |
| 63                                  |        | 289.6      | 604.0      | 443.7    | 0.1       | 1.5         | -0.1        | 1.4          |
| 64                                  |        | 290.1      | 604.0      | 443.6    | -0.1      | 0.4         | 0.0         | 0.4          |
| 65                                  |        | 289.3      | 604.5      | 443.0    | -0.6      | -0.8        | 0.5         | -0.3         |
| 66                                  |        | 287.9      | 603.1      | 442.0    | -1.0      | -1.4        | -1.4        | -2.8         |
| 67                                  |        | 291.5      | 606.0      | 442.6    | 0.6       | 3.6         | 2.9         | 6.5          |
| 68                                  |        | 289.1      | 605.0      | 441.8    | -0.9      | -2.4        | -1.0        | -3.4         |
| 69                                  |        | 291.1      | 606.9      | 441.9    | 0.2       | 2.0         | 1.9         | 3.9          |
| 70                                  |        | 289.6      | 606.2      | 443.3    | 1.3       | -1.5        | -1.7        | -3.2         |
|                                     |        |            |            |          |           |             | Max         | 9.3          |
|                                     |        |            |            |          |           |             | Min         | -3.7         |
|                                     |        |            |            |          |           |             | DW          | 12.9         |
| Calculation of Z-axis movements(cm) |        |            |            |          | Trial 6   |             |             |              |
|                                     |        |            |            |          |           |             |             | dz(lfrtoam)* |
| Frame(0.017s)                       | Event  | Z(lfrtoam) | Z(rfrtoam) | Z(shell) | dz(shell) | dz(lfrtoam) | dz(rfrtoam) | dz(rfrtoam)  |
| 1                                   |        | 58.1       | 356.0      | 228.8    |           |             |             |              |
| 2                                   |        | 58.9       | 357.3      | 229.2    | 0.4       | 0.8         | 2.4         | 3.2          |
| 3                                   |        | 60.9       | 358.1      | 231.0    | 1.7       | 2.1         | 0.8         | 2.9          |
| 4                                   |        | 63.0       | 360.5      | 232.3    | 1.3       | 2.1         | 2.4         | 4.4          |
| 5                                   |        | 62.8       | 361.6      | 232.3    | 0.0       | -0.2        | 1.1         | 1.0          |
| 6                                   |        | 62.3       | 361.2      | 231.7    | -0.6      | -0.6        | -0.4        | -1.0         |
| 7                                   |        | 66.3       | 365.4      | 233.7    | 2.1       | 4.1         | 4.1         | 8.2          |
| 8                                   |        | 69.0       | 368.8      | 235.5    | 1.7       | 2.6         | 1.5         | 4.1          |
| 9                                   |        | 69.9       | 369.5      | 236.1    | 0.7       | 1.0         | 2.7         | 3.7          |
| 10                                  | Finish | 70.9       | 370.2      | 235.9    | -0.2      | 1.0         | 0.7         | 1.7          |
| 11                                  |        | 73.2       | 372.2      | 237.7    | 1.8       | 2.3         | 2.0         | 4.2          |
| 12                                  |        | 74.5       | 373.7      | 239.4    | 1.7       | 1.3         | 1.5         | 2.8          |
| 13                                  |        | 75.0       | 375.5      | 241.5    | 2.1       | 0.5         | 1.9         | 2.3          |
| 14                                  |        | 76.2       | 376.5      | 241.5    | 0.0       | 1.2         | 0.9         | 2.2          |
| 15                                  |        | 78.1       | 377.3      | 243.2    | 1.7       | 1.9         | 0.8         | 2.7          |
| 16                                  |        | 79.4       | 379.5      | 243.9    | 0.7       | 1.3         | 2.2         | 3.5          |

|    |                    |       |       |       |      |      |      |      |
|----|--------------------|-------|-------|-------|------|------|------|------|
| 17 |                    | 80.2  | 379.5 | 244.8 | 1.0  | 0.8  | 0.0  | 0.8  |
| 18 |                    | 82.6  | 381.8 | 245.2 | 0.4  | 2.4  | 2.3  | 4.7  |
| 19 |                    | 82.2  | 383.7 | 246.8 | 1.6  | -0.4 | 1.9  | 1.6  |
| 20 |                    | 83.0  | 384.1 | 247.5 | 0.6  | 0.8  | 0.4  | 1.2  |
| 21 |                    | 84.2  | 384.5 | 246.5 | -0.9 | 1.2  | 0.4  | 1.6  |
| 22 |                    | 85.0  | 386.5 | 249.4 | 2.9  | 0.8  | 1.9  | 2.8  |
| 23 |                    | 87.3  | 386.5 | 249.4 | -0.1 | 2.3  | 0.1  | 2.4  |
| 24 |                    | 89.7  | 390.6 | 249.9 | 0.6  | 2.4  | 4.0  | 6.4  |
| 25 |                    | 88.5  | 390.2 | 250.4 | 0.5  | -1.2 | -0.3 | -1.6 |
| 26 |                    | 90.6  | 392.2 | 251.2 | 0.8  | 2.1  | 2.0  | 4.1  |
| 27 |                    | 89.7  | 392.8 | 251.0 | -0.1 | -0.9 | 0.6  | -0.3 |
| 28 | Bag. Seat<br>Movt. | 91.0  | 395.6 | 253.6 | 2.5  | 1.3  | 2.8  | 4.2  |
| 29 |                    | 92.3  | 393.1 | 251.2 | -2.4 | 1.2  | -2.6 | -1.3 |
| 30 |                    | 92.0  | 394.1 | 251.9 | 0.7  | -0.2 | 1.0  | 0.8  |
| 31 |                    | 93.6  | 397.1 | 255.4 | 3.5  | 1.5  | 3.0  | 4.6  |
| 32 |                    | 96.7  | 399.3 | 256.8 | 1.4  | 3.2  | 2.1  | 5.3  |
| 33 |                    | 96.5  | 398.2 | 255.9 | -1.0 | 1.8  | -1.1 | 0.7  |
| 34 |                    | 98.4  | 401.5 | 254.8 | -1.1 | -0.2 | 3.3  | 3.2  |
| 35 |                    | 100.2 | 401.6 | 255.9 | 1.2  | 1.8  | 0.1  | 1.9  |
| 36 |                    | 99.5  | 403.7 | 257.7 | 1.8  | -0.6 | 2.1  | 1.5  |
| 37 |                    | 100.3 | 403.3 | 256.9 | -0.8 | 0.8  | -0.4 | 0.4  |
| 38 |                    | 102.9 | 405.2 | 258.1 | 1.2  | 2.5  | 1.8  | 4.4  |
| 39 |                    | 103.5 | 405.3 | 260.2 | 2.1  | 0.6  | 0.1  | 0.7  |
| 40 |                    | 104.3 | 406.3 | 259.3 | -0.9 | 0.8  | 1.0  | 1.8  |
| 41 |                    | 104.5 | 408.3 | 260.3 | 1.0  | 0.3  | 2.1  | 2.4  |
| 42 |                    | 104.3 | 407.9 | 260.2 | -0.1 | -0.3 | -0.4 | -0.7 |
| 43 |                    | 104.9 | 408.2 | 260.0 | -0.3 | 0.6  | 0.3  | 0.9  |
| 44 |                    | 106.3 | 410.0 | 260.0 | 0.1  | 1.4  | 1.8  | 3.2  |
| 45 |                    | 106.6 | 410.2 | 259.8 | -0.3 | 0.3  | 0.2  | 0.5  |
| 46 |                    | 106.8 | 412.4 | 262.6 | 2.8  | -0.8 | 2.2  | 1.4  |
| 47 |                    | 107.2 | 411.5 | 261.3 | -1.2 | 1.4  | -0.8 | 0.6  |
| 48 |                    | 108.6 | 412.8 | 262.6 | 1.2  | 1.3  | 1.3  | 2.6  |
| 49 |                    | 110.5 | 413.9 | 262.8 | 0.2  | 1.9  | 1.1  | 3.0  |
| 50 |                    | 107.3 | 414.4 | 261.3 | -1.5 | -3.2 | 0.5  | -2.7 |
| 51 |                    | 110.1 | 415.0 | 264.4 | 3.1  | 2.9  | 0.6  | 3.5  |
| 52 |                    | 106.2 | 414.3 | 261.5 | -2.9 | -2.0 | -0.7 | -2.7 |
| 53 |                    | 110.0 | 416.1 | 263.1 | 1.6  | 1.8  | 1.8  | 3.6  |
| 54 |                    | 110.2 | 416.5 | 261.8 | -1.3 | 0.2  | 0.4  | 0.5  |
| 55 |                    | 111.1 | 416.2 | 262.8 | 1.0  | 0.9  | -0.3 | 0.6  |
| 56 |                    | 109.4 | 416.0 | 261.9 | -0.9 | -1.7 | -0.2 | -1.9 |
| 57 |                    | 113.2 | 417.3 | 263.6 | 1.7  | 3.8  | 1.3  | 6.2  |
| 58 |                    | 112.5 | 417.1 | 262.0 | -1.6 | -0.7 | -0.2 | -0.9 |
| 59 |                    | 110.4 | 418.3 | 263.4 | 1.5  | -2.1 | 1.1  | -1.0 |
| 60 |                    | 114.5 | 420.0 | 264.0 | 0.6  | 4.1  | 1.8  | 5.9  |
| 61 |                    | 112.9 | 420.8 | 263.0 | -1.1 | -1.7 | 0.8  | -0.9 |
| 62 |                    | 111.9 | 420.1 | 262.4 | -0.6 | -1.0 | -0.7 | -1.7 |
| 63 |                    | 113.7 | 421.6 | 264.7 | 2.4  | 1.8  | 1.5  | 3.3  |
| 64 |                    | 112.2 | 420.1 | 261.0 | -3.8 | -1.6 | -1.4 | -3.0 |
| 65 |                    | 112.9 | 422.1 | 263.8 | 2.8  | 0.7  | 2.0  | 2.7  |





## **APPENDIX F**

### **Calculations of xz Plane movements of the Mobile Video Platform**

| Calculation of $\theta$ (movements in the xz plane) Trial 1 |                        |                        |                          |                              |                        |                        |                          |                              |                        |                        |                          |                          |      |
|-------------------------------------------------------------|------------------------|------------------------|--------------------------|------------------------------|------------------------|------------------------|--------------------------|------------------------------|------------------------|------------------------|--------------------------|--------------------------|------|
| Frame                                                       | $\alpha_x(\text{mrq})$ | $\alpha_x(\text{mrq})$ | $\alpha_x(\text{shali})$ | $\alpha_x(\text{shali}) + 1$ | $\alpha_z(\text{mrq})$ | $\alpha_z(\text{mrq})$ | $\alpha_z(\text{shali})$ | $\alpha_z(\text{shali}) + 1$ | $\alpha_z(\text{mrq})$ | $\alpha_z(\text{mrq})$ | $\alpha_z(\text{shali})$ | $\alpha_z(\text{shali})$ |      |
|                                                             | $X(\text{fricam})$     | $X(\text{fricam})$     | $X(\text{shali})$        | $X(\text{shali})$            | $Z(\text{fricam})$     | $Z(\text{fricam})$     | $Z(\text{shali})$        | $Z(\text{shali})$            | degrees                | degrees                | degrees                  | degrees                  |      |
| $0.017\%$                                                   | (cm)                   | (cm)                   | (cm)                     | (cm)                         | (cm)                   | (cm)                   | (cm)                     | (cm)                         |                        |                        |                          |                          |      |
| 2                                                           | 6.1                    | 7.3                    | 7.6                      | 0.6                          | 2.3                    | 0.5                    |                          |                              | 1.5                    | 1.3                    | 1.5                      | 0.0                      | 0.2  |
| 3                                                           | 5.3                    | 4.3                    | 5.5                      | 3.0                          | 1.3                    | -0.4                   |                          |                              | 1.0                    | 1.3                    | -1.5                     | -2.5                     | -2.8 |
| 4                                                           | 8.5                    | 8.5                    | 7.6                      | -1.0                         | 0.8                    | 1.2                    |                          |                              | -1.5                   | 1.5                    | 1.4                      | 2.9                      | -0.1 |
| 5                                                           | 7.2                    | 7.5                    | 8.0                      | 3.4                          | 2.9                    | 4.1                    |                          |                              | 1.1                    | 1.2                    | 1.1                      | 0.0                      | -0.1 |
| 6                                                           | 6.4                    | 6.1                    | 5.7                      | 0.8                          | 1.4                    | -0.9                   |                          |                              | 1.4                    | 1.4                    | -1.4                     | -2.9                     | -0.1 |
| 7                                                           | 6.0                    | 5.4                    | 4.7                      | -0.1                         | 0.1                    | 0.7                    |                          |                              | -1.6                   | 1.6                    | 1.4                      | 3.0                      | -0.1 |
| 8                                                           | 5.5                    | 6.3                    | 7.2                      | 2.5                          | 1.5                    | 1.2                    |                          |                              | 1.1                    | 1.3                    | 1.4                      | 0.3                      | 0.1  |
| 9                                                           | 6.4                    | 4.7                    | 5.2                      | -0.8                         | -0.4                   | -0.6                   |                          |                              | -1.4                   | -1.5                   | -1.4                     | 0.0                      | 0.0  |
| 10                                                          | 4.9                    | 6.8                    | 6.7                      | 2.0                          | 3.3                    | 3.4                    |                          |                              | 1.2                    | 1.1                    | 1.1                      | -0.1                     | 0.0  |
| 11                                                          | 8.6                    | 7.3                    | 6.5                      | 1.3                          | -0.8                   | -1.2                   |                          |                              | 1.4                    | -1.5                   | -1.4                     | -2.8                     | 0.1  |
| 12                                                          | 4.1                    | 4.3                    | 5.4                      | -0.2                         | 0.5                    | 0.5                    |                          |                              | -1.5                   | -1.4                   | 1.5                      | 3.0                      | 2.9  |
| 13                                                          | 6.4                    | 5.9                    | 5.7                      | 0.3                          | 1.3                    | 1.2                    |                          |                              | 1.5                    | 1.3                    | 1.4                      | -0.2                     | 0.0  |
| 14                                                          | 3.8                    | 4.2                    | 4.1                      | 1.5                          | 3.6                    | 2.7                    |                          |                              | 1.2                    | 0.9                    | 1.0                      | -0.2                     | 0.1  |
| 15                                                          | 5.2                    | 6.6                    | 5.9                      | 2.3                          | 0.8                    | -1.0                   |                          |                              | 1.2                    | 1.4                    | -1.4                     | -2.5                     | -2.8 |
| 16                                                          | 5.0                    | 5.3                    | 4.6                      | 0.4                          | 1.5                    | 0.6                    |                          |                              | 1.5                    | 1.3                    | 1.4                      | 0.0                      | 0.1  |
| 17                                                          | 7.1                    | 6.1                    | 7.4                      | -2.0                         | -3.7                   | -1.0                   |                          |                              | -1.3                   | -1.0                   | -1.4                     | -0.1                     | -0.4 |
| 18                                                          | 5.2                    | 3.9                    | 4.5                      | 1.0                          | 3.8                    | 2.1                    |                          |                              | 1.4                    | 0.8                    | 1.1                      | -0.2                     | 0.3  |
| 19                                                          | 4.7                    | 6.2                    | 5.2                      | 1.3                          | -0.2                   | 0.8                    |                          |                              | 1.3                    | -1.5                   | 1.4                      | 0.1                      | 3.0  |
| 20                                                          | 5.8                    | 5.6                    | 6.3                      | 1.3                          | 0.4                    | 1.0                    |                          |                              | 1.3                    | 1.5                    | 1.4                      | 0.1                      | -0.1 |
| 21                                                          | 6.4                    | 6.6                    | 6.2                      | 0.6                          | 2.7                    | 0.7                    |                          |                              | 1.5                    | 1.2                    | 1.5                      | 0.0                      | 0.3  |
| 22                                                          | 5.9                    | 6.3                    | 7.1                      | 1.1                          | 0.3                    | 0.6                    |                          |                              | 1.4                    | 1.5                    | 1.5                      | 0.1                      | 0.0  |
| 23                                                          | 4.9                    | 4.6                    | 5.1                      | 0.8                          | 2.4                    | -0.4                   |                          |                              | 1.4                    | 1.1                    | -1.5                     | -2.9                     | -2.6 |
| 24                                                          | 5.9                    | 6.0                    | 6.1                      | 2.6                          | 1.4                    | 2.4                    |                          |                              | 1.2                    | 1.3                    | 1.2                      | 0.0                      | -0.1 |
| 25                                                          | 5.5                    | 6.7                    | 5.7                      | 0.7                          | -0.1                   | 0.0                    |                          |                              | -1.6                   | -1.6                   | -3.0                     | 0.0                      | 0.0  |
| 26                                                          | 5.6                    | 5.2                    | 5.4                      | -1.8                         | 0.2                    | -0.5                   |                          |                              | -1.3                   | 1.5                    | -1.5                     | -0.2                     | -3.0 |
| 27                                                          | 7.0                    | 5.3                    | 5.8                      | 1.3                          | -0.1                   | -0.1                   |                          |                              | 1.4                    | -1.6                   | -1.5                     | -2.9                     | 0.0  |
| 28                                                          | 6.6                    | 8.4                    | 7.2                      | 0.8                          | 2.3                    | 1.0                    |                          |                              | 1.5                    | 1.3                    | 1.4                      | 0.0                      | 0.1  |

|    |     |     |     |      |      |      |      |      |      |      |
|----|-----|-----|-----|------|------|------|------|------|------|------|
| 29 | 5.2 | 4.7 | 6.9 | 0.3  | -0.2 | -0.2 | 1.5  | -1.5 | -3.1 | 0.0  |
| 30 | 5.9 | 6.7 | 4.1 | 3.1  | 2.6  | 1.3  | 1.1  | 1.2  | 0.2  | 0.1  |
| 31 | 6.8 | 7.4 | 6.5 | 0.5  | 2.8  | 0.0  | 1.5  | 1.2  | -3.1 | -2.8 |
| 32 | 6.7 | 5.4 | 6.9 | 0.4  | -2.6 | -0.1 | 1.5  | -1.1 | -3.1 | -0.4 |
| 33 | 6.1 | 7.0 | 5.6 | -0.3 | 0.4  | -0.2 | -1.5 | 1.5  | 0.0  | -3.1 |
| 34 | 6.8 | 6.6 | 6.7 | 1.9  | 1.5  | 2.4  | 1.3  | 1.3  | -0.1 | -0.1 |
| 35 | 7.4 | 6.2 | 7.6 | 1.9  | 1.7  | 1.3  | 1.3  | 1.3  | 0.1  | 0.1  |
| 36 | 8.6 | 7.2 | 6.0 | 2.4  | 2.4  | 0.6  | 1.3  | 1.3  | 0.2  | 0.2  |
| 37 | 4.5 | 6.0 | 6.6 | -0.6 | 0.1  | -0.6 | -1.4 | 1.6  | -0.1 | -3.0 |
| 38 | 6.7 | 6.8 | 6.3 | 3.1  | 0.6  | 1.9  | 1.1  | 1.5  | 0.1  | -0.2 |
| 39 | 6.7 | 7.6 | 8.7 | -1.9 | 0.8  | -1.4 | -1.3 | 1.5  | -0.1 | -2.9 |
| 40 | 6.6 | 6.1 | 5.5 | 0.6  | 0.4  | 1.2  | 1.5  | 1.5  | -0.1 | -0.1 |
| 41 | 7.1 | 7.7 | 8.2 | 1.4  | 2.0  | 0.3  | 1.4  | 1.3  | 0.2  | 0.2  |
| 42 | 5.7 | 6.0 | 6.4 | 0.9  | -1.3 | -1.5 | 1.4  | -1.4 | -2.8 | 0.0  |
| 43 | 8.0 | 8.1 | 7.1 | -1.0 | 1.4  | 1.5  | -1.4 | 1.4  | 2.8  | 0.0  |
| 44 | 8.4 | 7.1 | 7.8 | 3.3  | 2.0  | 2.3  | 1.2  | 1.3  | 0.1  | 0.0  |
| 45 | 6.0 | 6.4 | 5.5 | -0.2 | 0.9  | -0.1 | -1.5 | 1.4  | 0.0  | -3.0 |
| 46 | 8.9 | 8.7 | 8.3 | -0.6 | 0.4  | -1.3 | -1.5 | 1.5  | 0.1  | -3.0 |
| 47 | 7.5 | 7.7 | 4.8 | 0.1  | 0.7  | -1.2 | 1.6  | 1.5  | -2.9 | -2.8 |
| 48 | 6.7 | 5.8 | 9.1 | 2.4  | 0.4  | 2.0  | 1.2  | 1.5  | 0.1  | -0.1 |
| 49 | 7.1 | 7.3 | 5.1 | 0.6  | 1.4  | -0.6 | 1.6  | 1.4  | -2.9 | -2.8 |
| 50 | 7.1 | 7.8 | 9.3 | -0.5 | 0.2  | 2.0  | -1.5 | 1.5  | 2.9  | -0.2 |
| 51 | 7.6 | 7.6 | 8.3 | 1.2  | 0.1  | 1.5  | 1.4  | 1.6  | 0.0  | -0.2 |
| 52 | 7.4 | 7.4 | 6.7 | 1.1  | -0.4 | -1.4 | 1.4  | -1.5 | -2.8 | 0.1  |
| 53 | 7.1 | 7.6 | 8.1 | 1.0  | 1.8  | 0.1  | 1.4  | 1.3  | 0.1  | 0.2  |
| 54 | 7.3 | 7.6 | 6.9 | -0.7 | 0.2  | 0.4  | -1.5 | 1.5  | 3.0  | 0.0  |
| 55 | 7.0 | 8.2 | 8.9 | 0.5  | 0.7  | -0.2 | 1.5  | 1.5  | -3.0 | -3.0 |
| 56 | 9.2 | 8.0 | 7.3 | 0.9  | 0.6  | 0.4  | 1.6  | 1.5  | 0.0  | 0.0  |
| 57 | 7.5 | 7.0 | 7.0 | -1.5 | -1.2 | -1.8 | -1.4 | -1.4 | 0.1  | 0.1  |
| 58 | 6.7 | 6.6 | 7.5 | 1.1  | 1.0  | 1.2  | 1.4  | 1.4  | 0.0  | 0.0  |
| 59 | 6.7 | 7.7 | 8.1 | -0.8 | 0.3  | -0.1 | -1.4 | 1.5  | -0.1 | -3.1 |
| 60 | 7.8 | 7.2 | 7.1 | 1.6  | 1.8  | 0.1  | 1.4  | 1.3  | 0.2  | 0.2  |
| 61 | 7.5 | 7.0 | 8.0 | 1.3  | -0.5 | 0.4  | 1.4  | -1.5 | 0.1  | 3.0  |

|                                                                       |                      |                      |                      |                      |                      |                      |                               |                               |                               |                               |      |
|-----------------------------------------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|------|
| 62                                                                    | 8.8                  | 8.6                  | 8.3                  | 0.4                  | 2.3                  | 0.0                  | 1.5                           | 1.3                           | -1.6                          | -3.1                          | -2.9 |
| 63                                                                    | 7.4                  | 8.2                  | 7.6                  | -1.7                 | -1.1                 | -0.7                 | -1.4                          | -1.4                          | -1.5                          | -0.1                          | 0.0  |
| 64                                                                    | 8.0                  | 7.4                  | 5.2                  | 2.5                  | 2.0                  | 2.5                  | 1.3                           | 1.3                           | 1.2                           | -0.1                          | -0.1 |
| Max                                                                   | 9.2                  | 8.7                  | 9.3                  | 3.4                  | 3.8                  | 4.1                  | 1.6                           | 1.6                           | 1.6                           | 3.0                           | 3.0  |
| Min                                                                   | 3.9                  | 3.9                  | 4.1                  | -2.0                 | -3.7                 | -1.8                 | -1.6                          | -1.6                          | -1.6                          | -3.1                          | -3.1 |
| Diff                                                                  | 5.4                  | 4.7                  | 5.2                  | 5.4                  | 7.5                  | 5.9                  | 3.1                           | 3.1                           | 3.1                           | 6.1                           | 6.1  |
| <b>Calculation of <math>\theta</math> (movements in the xz plane)</b> |                      |                      |                      |                      |                      |                      |                               |                               |                               |                               |      |
| Frame                                                                 | $\alpha(\text{trq})$ | $\alpha(\text{she})$ | $\alpha(\text{trq})$ | $\alpha(\text{she})$ | $\alpha(\text{trq})$ | $\alpha(\text{she})$ | $\alpha(\text{trq})$          | $\alpha(\text{she})$          | $\alpha(\text{trq})$          | $\alpha(\text{she})$          |      |
|                                                                       | $X(\text{trcam}), -$ | $X(\text{trcam}), -$ | $X(\text{she}) + 1$  | $Z(\text{trcam}), -$ | $Z(\text{trcam}), -$ | $Z(\text{she}) + 1$  | $\arctan(\alpha(\text{trq}))$ | $\arctan(\alpha(\text{she}))$ | $\arctan(\alpha(\text{trq}))$ | $\arctan(\alpha(\text{she}))$ |      |
|                                                                       | $X(\text{trcam})$    | $X(\text{trcam})$    | $X(\text{she})$      | $Z(\text{trcam})$    | $Z(\text{trcam})$    | $Z(\text{she})$      | $\text{d}(\text{trq})$        | $\text{d}(\text{she})$        | $\text{d}(\text{trq})$        | $\text{d}(\text{she})$        |      |
|                                                                       | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | degrees                       | degrees                       | degrees                       | degrees                       |      |
| 0.017s                                                                |                      |                      |                      |                      |                      |                      |                               |                               |                               |                               |      |
| 2                                                                     | 9.0                  | 8.0                  | 7.3                  | -3.6                 | -0.3                 | -2.4                 | -1.2                          | -1.5                          | -1.3                          | -0.1                          | 0.3  |
| 3                                                                     | 6.4                  | 6.9                  | 6.5                  | 4.3                  | 3.8                  | 2.6                  | 1.0                           | 1.1                           | 1.2                           | 0.2                           | 0.1  |
| 4                                                                     | 8.5                  | 7.2                  | 7.4                  | -1.5                 | -2.1                 | -0.5                 | -1.3                          | -1.3                          | -1.5                          | -0.2                          | -0.2 |
| 5                                                                     | 8.3                  | 7.6                  | 8.0                  | 1.6                  | 1.6                  | 0.4                  | 1.4                           | 1.4                           | 1.5                           | 0.1                           | 0.2  |
| 6                                                                     | 5.0                  | 6.1                  | 5.4                  | -2.7                 | -2.3                 | -3.6                 | -1.1                          | -1.2                          | -1.0                          | 0.1                           | 0.2  |
| 7                                                                     | 9.2                  | 6.8                  | 8.9                  | 2.5                  | 2.5                  | 4.6                  | 1.3                           | 1.2                           | 1.1                           | -0.2                          | -0.1 |
| 8                                                                     | 7.2                  | 7.5                  | 7.0                  | 1.6                  | -1.5                 | -1.4                 | 1.4                           | -1.4                          | -1.4                          | -2.7                          | 0.0  |
| 9                                                                     | 7.7                  | 7.1                  | 8.0                  | -0.8                 | 1.6                  | 0.4                  | -1.5                          | 1.4                           | 1.5                           | 3.0                           | 0.2  |
| 10                                                                    | 5.9                  | 6.6                  | 5.2                  | -2.5                 | 0.0                  | -0.7                 | -1.2                          | 1.6                           | -1.4                          | -0.3                          | -3.0 |
| 11                                                                    | 8.1                  | 7.4                  | 8.2                  | 2.8                  | -0.5                 | -0.3                 | 1.2                           | -1.5                          | -1.5                          | -2.8                          | 0.0  |
| 12                                                                    | 6.9                  | 6.5                  | 6.6                  | -3.5                 | -2.1                 | -2.5                 | -1.1                          | -1.3                          | -1.2                          | -0.1                          | 0.0  |
| 13                                                                    | 7.3                  | 7.1                  | 7.7                  | 3.0                  | 1.6                  | 2.9                  | 1.2                           | 1.3                           | 1.2                           | 0.0                           | -0.1 |
| 14                                                                    | 7.4                  | 8.3                  | 7.5                  | 0.9                  | 1.4                  | 1.0                  | 1.5                           | 1.4                           | 1.4                           | 0.0                           | 0.0  |
| 15                                                                    | 8.6                  | 6.9                  | 8.5                  | 2.0                  | 1.1                  | 0.8                  | 1.3                           | 1.4                           | 1.5                           | 0.1                           | 0.1  |
| 16                                                                    | 6.9                  | 7.2                  | 5.9                  | -4.4                 | -4.1                 | -3.5                 | -1.0                          | -1.1                          | -1.0                          | 0.0                           | 0.0  |
| 17                                                                    | 6.9                  | 7.2                  | 7.7                  | 1.6                  | 2.9                  | 2.6                  | 1.3                           | 1.2                           | 1.2                           | -0.1                          | 0.1  |
| 18                                                                    | 6.5                  | 7.0                  | 6.8                  | 0.6                  | -1.2                 | -0.7                 | 1.5                           | -1.4                          | -1.5                          | -2.9                          | -0.1 |
| 19                                                                    | 7.5                  | 7.3                  | 7.7                  | -1.5                 | 0.0                  | 0.6                  | -1.4                          | 1.6                           | 1.5                           | 2.9                           | -0.1 |
| 20                                                                    | 7.0                  | 6.5                  | 6.5                  | -0.2                 | -2.2                 | -1.8                 | -1.5                          | -1.2                          | -1.3                          | 0.2                           | 0.0  |
| 21                                                                    | 7.2                  | 7.8                  | 7.4                  | 0.8                  | 1.2                  | 1.5                  | 1.5                           | 1.4                           | 1.4                           | -0.1                          | -0.1 |

|    |      |      |      |      |      |      |      |      |      |      |      |
|----|------|------|------|------|------|------|------|------|------|------|------|
| 22 | 7.2  | 6.6  | 7.2  | 0.1  | 1.0  | 0.4  | 1.6  | 1.4  | 1.5  | 0.0  | 0.1  |
| 23 | 9.2  | 9.7  | 9.7  | 1.6  | 2.2  | 0.0  | 1.4  | 1.3  | 1.6  | 0.2  | 0.2  |
| 24 | 9.1  | 7.4  | 6.7  | -2.7 | -4.6 | -1.7 | -1.3 | -1.0 | -1.3 | 0.0  | -0.3 |
| 25 | 6.3  | 8.2  | 8.0  | 1.3  | 6.0  | 3.2  | 1.4  | 0.9  | 1.2  | -0.2 | 0.3  |
| 26 | 7.9  | 8.3  | 8.5  | 1.1  | -2.1 | -0.8 | 1.4  | -1.3 | -1.5 | -2.9 | -0.2 |
| 27 | 8.0  | 7.0  | 7.7  | -0.2 | -0.7 | 0.9  | -1.5 | -1.5 | 1.5  | 3.0  | 2.9  |
| 28 | 7.8  | 7.5  | 8.4  | 1.1  | 0.8  | 0.5  | 1.4  | 1.5  | 1.5  | 0.1  | 0.0  |
| 29 | 7.8  | 8.1  | 6.7  | -0.8 | -0.5 | -1.6 | -1.5 | -1.5 | -1.3 | 0.1  | 0.2  |
| 30 | 7.4  | 7.4  | 8.9  | 0.2  | 0.3  | 1.0  | 1.5  | 1.5  | 1.5  | -0.1 | -0.1 |
| 31 | 8.9  | 8.4  | 8.0  | 0.1  | 0.8  | 1.0  | 1.6  | 1.5  | 1.5  | -0.1 | 0.0  |
| 32 | 7.7  | 8.2  | 7.6  | 0.3  | -0.1 | -1.6 | 1.5  | -1.6 | -1.4 | -2.9 | 0.2  |
| 33 | 7.5  | 7.5  | 8.9  | 1.7  | -1.1 | 1.1  | 1.4  | -1.4 | 1.5  | 0.1  | 2.9  |
| 34 | 8.5  | 8.1  | 8.1  | -2.3 | 3.4  | 0.7  | -1.3 | 1.2  | 1.5  | 2.8  | 0.3  |
| 35 | 9.9  | 10.1 | 9.7  | 2.9  | 0.2  | -0.6 | 1.3  | 1.6  | -1.5 | -2.8 | -3.1 |
| 36 | 6.6  | 6.4  | 7.1  | -0.8 | -1.5 | -0.4 | -1.5 | -1.3 | -1.5 | -0.1 | -0.2 |
| 37 | 8.4  | 8.1  | 8.0  | -0.3 | -0.9 | 1.7  | -1.5 | -1.5 | 1.4  | 2.9  | 2.8  |
| 38 | 9.2  | 8.5  | 9.8  | -0.1 | -0.7 | 0.1  | -1.6 | -1.5 | 1.6  | 3.1  | 3.0  |
| 39 | 7.8  | 7.7  | 6.5  | -0.1 | 1.6  | 0.6  | -1.6 | 1.4  | 1.5  | 3.0  | 0.1  |
| 40 | 8.1  | 8.2  | 9.0  | 1.1  | 1.7  | -1.3 | 1.4  | 1.4  | -1.4 | -2.9 | -2.8 |
| 41 | 9.0  | 9.9  | 8.9  | -0.7 | -0.2 | 1.3  | -1.5 | -1.6 | 1.4  | 2.9  | 3.0  |
| 42 | 7.8  | 7.2  | 7.7  | 1.8  | 0.5  | 0.7  | 1.3  | 1.5  | 1.5  | 0.1  | 0.0  |
| 43 | 9.7  | 8.7  | 9.9  | -1.4 | -0.4 | 1.3  | -1.4 | -1.5 | 1.4  | 2.9  | 3.0  |
| 44 | 7.3  | 7.9  | 6.7  | 3.2  | 0.5  | 0.7  | 1.2  | 1.5  | 1.5  | 0.3  | 0.0  |
| 45 | 8.5  | 8.3  | 9.3  | 0.7  | 0.9  | -0.5 | 1.5  | 1.5  | -1.5 | -3.0 | -3.0 |
| 46 | 8.1  | 8.1  | 7.3  | -3.5 | -2.4 | -0.3 | -1.2 | -1.3 | -1.5 | -0.4 | -0.3 |
| 47 | 8.2  | 9.6  | 9.3  | 1.5  | 1.6  | 1.0  | 1.4  | 1.4  | 1.5  | 0.1  | 0.1  |
| 48 | 7.6  | 7.7  | 8.0  | 2.3  | 1.3  | -2.0 | 1.3  | 1.4  | -1.3 | -2.6 | -2.7 |
| 49 | 10.2 | 8.1  | 7.2  | -0.5 | 0.2  | 4.5  | -1.5 | 1.5  | 1.0  | 2.5  | -0.5 |
| 50 | 7.0  | 7.0  | 8.2  | 0.4  | -2.0 | -2.4 | 1.5  | -1.3 | -1.3 | -2.8 | 0.0  |
| 51 | 7.9  | 8.6  | 10.6 | 1.7  | 3.7  | 7.6  | 1.4  | 1.2  | 0.9  | -0.4 | -0.2 |
| 52 | 7.5  | 6.8  | 5.1  | -0.3 | -2.0 | -6.2 | -1.5 | -1.3 | -0.8 | 0.8  | 0.5  |
| 53 | 8.4  | 9.1  | 10.5 | 2.0  | 3.7  | 4.4  | 1.3  | 1.2  | 1.2  | -0.2 | 0.0  |
| 54 | 7.3  | 5.6  | 3.9  | -0.5 | -1.1 | -4.2 | -1.5 | -1.4 | -0.7 | 0.8  | 0.6  |

|                                                      |                                                 |                                                      |                                                      |                   |                    |                    |                   |                    |                    |                   |                    |
|------------------------------------------------------|-------------------------------------------------|------------------------------------------------------|------------------------------------------------------|-------------------|--------------------|--------------------|-------------------|--------------------|--------------------|-------------------|--------------------|
| 56                                                   | 6.8                                             | 8.7                                                  | 8.0                                                  | -1.6              | 0.2                | 2.3                | -1.3              | 1.5                | 1.3                | 2.6               | -0.3               |
| 56                                                   | 7.8                                             | 7.5                                                  | 7.5                                                  | 1.7               | 0.5                | -2.0               | 1.4               | 1.5                | -1.3               | -2.7              | -2.8               |
| 57                                                   | 7.3                                             | 6.9                                                  | 8.0                                                  | 0.6               | 1.9                | 4.9                | 1.5               | 1.3                | 1.0                | -0.5              | -0.3               |
| 58                                                   | 6.8                                             | 5.9                                                  | 5.8                                                  | -0.3              | -1.6               | -1.9               | -1.5              | -1.3               | -1.3               | 0.3               | 0.1                |
| 58                                                   | 5.9                                             | 7.1                                                  | 5.1                                                  | 0.7               | 1.8                | 4.5                | 1.4               | 1.3                | 0.9                | -0.6              | -0.5               |
| 60                                                   | 7.4                                             | 6.9                                                  | 9.2                                                  | 1.8               | 0.2                | -4.2               | 1.3               | 1.5                | -1.1               | -2.5              | -2.7               |
| 61                                                   | 7.0                                             | 6.5                                                  | 6.6                                                  | 0.1               | 0.8                | 1.0                | 1.6               | 1.4                | 1.4                | -0.1              | 0.0                |
| 62                                                   | 6.0                                             | 6.7                                                  | 6.2                                                  | -1.3              | -0.3               | 0.1                | -1.4              | -1.5               | 1.6                | 2.9               | 3.1                |
| 63                                                   | 5.8                                             | 5.7                                                  | 6.2                                                  | -1.2              | -0.3               | -0.8               | -1.4              | -1.5               | -1.4               | -0.1              | 0.1                |
| 64                                                   | 7.4                                             | 6.9                                                  | 7.3                                                  | 4.0               | 1.6                | 1.3                | 1.1               | 1.3                | 1.4                | 0.3               | 0.0                |
| 65                                                   | 6.7                                             | 6.1                                                  | 5.8                                                  | 0.0               | -0.5               | 0.7                | -1.6              | -1.5               | 1.5                | 3.0               | 2.9                |
| 66                                                   | 4.8                                             | 5.5                                                  | 5.0                                                  | -2.3              | -1.6               | -2.1               | -1.1              | -1.3               | -1.2               | -0.1              | 0.1                |
| 67                                                   | 7.3                                             | 6.8                                                  | 6.6                                                  | 2.7               | 4.2                | 3.6                | 1.2               | 1.0                | 1.1                | -0.2              | 0.0                |
| 68                                                   | 4.6                                             | 4.8                                                  | 5.6                                                  | -1.0              | -0.1               | 0.2                | -1.4              | -1.6               | 1.5                | 2.9               | 3.1                |
| 69                                                   | 5.3                                             | 4.0                                                  | 5.8                                                  | 1.2               | -1.2               | 1.7                | 1.3               | -1.3               | 1.3                | -0.1              | 2.6                |
| 70                                                   | 7.4                                             | 8.5                                                  | 5.3                                                  | 0.7               | 1.7                | -2.7               | 1.5               | 1.4                | -1.1               | -2.6              | -2.5               |
| 71                                                   | 3.9                                             | 3.3                                                  | 4.7                                                  | 0.7               | -1.6               | 2.0                | 1.4               | -1.1               | 1.2                | -0.2              | 2.3                |
| 72                                                   | 4.4                                             | 6.4                                                  | 4.6                                                  | -0.5              | 3.3                | 0.0                | -1.5              | 1.0                | -1.6               | -0.1              | -2.6               |
| 73                                                   | 6.2                                             | 5.2                                                  | 7.6                                                  | 1.2               | -1.2               | 0.5                | 1.4               | -1.3               | 1.5                | 0.1               | 2.9                |
| 74                                                   | 5.9                                             | 5.1                                                  | 4.6                                                  | 0.6               | 0.1                | -0.7               | 1.5               | 1.6                | -1.4               | -2.9              | -3.0               |
| 75                                                   | 4.3                                             | 6.2                                                  | 6.1                                                  | -2.2              | -0.3               | -0.5               | -1.1              | -1.5               | -1.5               | -0.4              | 0.0                |
| Max                                                  | 10.2                                            | 10.1                                                 | 10.5                                                 | 4.3               | 6.0                | 7.6                | 1.6               | 1.6                | 1.6                | 3.1               | 3.1                |
| Min                                                  | 3.9                                             | 3.3                                                  | 3.9                                                  | -4.4              | -4.6               | -6.2               | -1.6              | -1.6               | -1.6               | -3.0              | -3.1               |
| Diff                                                 | -6.3                                            | -6.8                                                 | -6.5                                                 | -8.7              | -10.7              | -12.9              | -3.1              | -3.1               | -3.1               | -6.1              | -6.2               |
| Calculation of $\theta$ (movements in the xz plane)  |                                                 |                                                      |                                                      |                   |                    |                    |                   |                    |                    |                   |                    |
| Trial 5                                              |                                                 |                                                      |                                                      |                   |                    |                    |                   |                    |                    |                   |                    |
| Frame                                                | $dx(\text{left})$                               | $dx(\text{right})$                                   | $dx(\text{shell})$                                   | $dz(\text{left})$ | $dz(\text{right})$ | $dz(\text{shell})$ | $xz(\text{left})$ | $xz(\text{right})$ | $xz(\text{shell})$ |                   |                    |
| $X(\text{leftcam})_{k-1} - X(\text{rightcam})_{k-1}$ | $X(\text{shell})_{k-1} - X(\text{shell})_{k-1}$ | $Z(\text{leftcam})_{k-1} - Z(\text{rightcam})_{k-1}$ | $Z(\text{leftcam})_{k-1} - Z(\text{rightcam})_{k-1}$ | $dz(\text{left})$ | $dz(\text{right})$ | $dz(\text{shell})$ | $dz(\text{left})$ | $dz(\text{right})$ | $dz(\text{shell})$ | $xz(\text{left})$ | $xz(\text{right})$ |
| $X(\text{leftcam})_k - X(\text{rightcam})_k$         | $X(\text{shell})_k - X(\text{shell})_k$         | $Z(\text{leftcam})_k - Z(\text{rightcam})_k$         | $Z(\text{leftcam})_k - Z(\text{rightcam})_k$         | $dz(\text{left})$ | $dz(\text{right})$ | $dz(\text{shell})$ | $dz(\text{left})$ | $dz(\text{right})$ | $dz(\text{shell})$ | $xz(\text{left})$ | $xz(\text{right})$ |
| 0.017s                                               | (cm)                                            | (cm)                                                 | (cm)                                                 | (cm)              | (cm)               | (cm)               | degrees           | degrees            | degrees            |                   |                    |
| 2                                                    | 9.2                                             | 12.7                                                 | 10.9                                                 | 3.2               | 2.7                | 2.7                | 1.2               | 1.4                | 1.3                | 0.1               | 0.0                |
| 3                                                    | 8.1                                             | 6.4                                                  | 7.3                                                  | 2.4               | 2.1                | 0.0                | 1.3               | 1.3                | 1.6                | 0.3               | 0.3                |

|    |     |      |     |      |      |      |      |      |      |      |      |
|----|-----|------|-----|------|------|------|------|------|------|------|------|
| 4  | 9.0 | 9.1  | 8.9 | 2.9  | 2.4  | 2.3  | 1.3  | 1.3  | 1.3  | 0.1  | 0.0  |
| 5  | 9.2 | 9.1  | 8.3 | 2.6  | 4.5  | 2.7  | 1.3  | 1.3  | 1.3  | 0.0  | 0.1  |
| 6  | 7.1 | 7.4  | 7.5 | 1.6  | 0.4  | -0.3 | 1.3  | 1.3  | -1.5 | -2.9 | -3.1 |
| 7  | 9.7 | 8.1  | 8.6 | 3.0  | 2.2  | 2.0  | 1.3  | 1.3  | 1.3  | 0.1  | 0.0  |
| 8  | 9.2 | 8.7  | 8.7 | 0.9  | 1.4  | 1.2  | 1.5  | 1.4  | 1.4  | 0.0  | 0.0  |
| 9  | 8.6 | 6.7  | 6.3 | 1.2  | 1.7  | 1.5  | 1.4  | 1.3  | 1.3  | -0.1 | 0.0  |
| 10 | 8.6 | 10.2 | 8.9 | 1.3  | 1.7  | 0.9  | 1.4  | 1.4  | 1.5  | 0.0  | 0.1  |
| 11 | 7.2 | 7.9  | 6.8 | 3.6  | 3.1  | 1.7  | 1.1  | 1.2  | 1.3  | 0.2  | 0.1  |
| 12 | 6.0 | 5.8  | 7.3 | -0.4 | 0.9  | 0.8  | -1.5 | 1.4  | 1.5  | 3.0  | 0.0  |
| 13 | 7.0 | 8.0  | 7.2 | 1.4  | 1.2  | 1.5  | 1.4  | 1.4  | 1.4  | 0.0  | -0.1 |
| 14 | 7.8 | 7.8  | 7.1 | 1.2  | 0.9  | 0.9  | 1.4  | 1.5  | 1.4  | 0.0  | 0.0  |
| 15 | 5.6 | 4.8  | 4.6 | 2.2  | 1.4  | 1.3  | 1.2  | 1.3  | 1.3  | 0.1  | 0.0  |
| 16 | 7.7 | 8.4  | 8.2 | 1.6  | 4.1  | 2.9  | 1.4  | 1.1  | 1.2  | -0.1 | 0.1  |
| 17 | 6.2 | 5.8  | 5.0 | -0.4 | -0.4 | -1.0 | -1.5 | -1.5 | -1.4 | 0.1  | 0.1  |
| 18 | 7.1 | 6.2  | 6.9 | 2.4  | 1.7  | 3.1  | 1.2  | 1.3  | 1.1  | -0.1 | -0.2 |
| 19 | 5.0 | 5.5  | 5.4 | -1.0 | -0.7 | -2.3 | -1.4 | -1.4 | -1.2 | 0.2  | 0.3  |
| 20 | 7.0 | 6.7  | 6.8 | 3.5  | 2.3  | 1.8  | 1.1  | 1.2  | 1.3  | 0.2  | 0.1  |
| 21 | 5.7 | 5.6  | 4.3 | 0.2  | 1.5  | 1.5  | 1.5  | 1.3  | 1.2  | -0.3 | -0.1 |
| 22 | 6.2 | 7.3  | 8.0 | 2.1  | 3.0  | 1.0  | 1.3  | 1.2  | 1.4  | 0.2  | 0.3  |
| 23 | 6.2 | 5.3  | 6.3 | 1.1  | -0.4 | 0.1  | 1.4  | -1.5 | 1.6  | 0.2  | 3.1  |
| 24 | 4.2 | 6.0  | 4.5 | 0.6  | 1.1  | 1.2  | 1.5  | 1.4  | 1.3  | -0.1 | -0.1 |
| 25 | 6.6 | 5.8  | 6.1 | 4.1  | 2.5  | 0.9  | 1.0  | 1.2  | 1.4  | 0.4  | 0.3  |
| 26 | 9.3 | 8.3  | 8.5 | -0.9 | 0.5  | 0.1  | -1.5 | 1.5  | 1.6  | 3.0  | 0.0  |
| 27 | 5.7 | 6.1  | 5.7 | 2.7  | 3.8  | 2.4  | 1.1  | 1.0  | 1.2  | 0.1  | 0.2  |
| 28 | 7.4 | 6.9  | 6.8 | 0.1  | 0.0  | 1.1  | 1.6  | 1.6  | 1.4  | -0.2 | -0.2 |
| 29 | 7.7 | 8.5  | 7.0 | 0.7  | 0.9  | 0.0  | 1.5  | 1.5  | -1.6 | -3.0 | -3.0 |
| 30 | 6.1 | 6.9  | 6.6 | 1.5  | -0.1 | 0.7  | 1.3  | -1.6 | 1.5  | 0.1  | 3.0  |
| 31 | 5.0 | 6.1  | 5.2 | -0.1 | 2.5  | 1.2  | -1.5 | 1.2  | 1.4  | 2.9  | 0.2  |
| 32 | 8.6 | 7.0  | 8.4 | 1.7  | 1.7  | 0.2  | 1.4  | 1.3  | 1.5  | 0.2  | 0.2  |
| 33 | 5.2 | 5.8  | 5.8 | 0.2  | 0.6  | 0.8  | 1.5  | 1.5  | 1.4  | -0.1 | 0.0  |
| 34 | 8.0 | 8.2  | 8.1 | 2.1  | 2.2  | 0.7  | 1.3  | 1.3  | 1.5  | 0.2  | 0.2  |
| 35 | 6.4 | 6.6  | 6.0 | 1.9  | 2.0  | 1.8  | 1.3  | 1.3  | 1.3  | 0.0  | 0.0  |
| 36 | 7.4 | 7.5  | 7.4 | 2.4  | 1.3  | 1.0  | 1.3  | 1.4  | 1.4  | 0.2  | 0.0  |



|    |      |      |      |      |      |      |      |      |      |      |      |
|----|------|------|------|------|------|------|------|------|------|------|------|
| 37 | 6.4  | 7.7  | 7.2  | 0.4  | 1.6  | 0.2  | 1.5  | 1.4  | 1.5  | 0.0  | 0.2  |
| 38 | 9.3  | 7.6  | 7.9  | 3.1  | 0.6  | -0.1 | 1.2  | 1.5  | -1.6 | -2.8 | -3.1 |
| 39 | 4.9  | 6.1  | 6.3  | -1.2 | 1.3  | 1.4  | -1.3 | 1.4  | 1.4  | 2.7  | 0.0  |
| 40 | 8.3  | 8.1  | 7.4  | 0.0  | -0.8 | -0.4 | -1.6 | -1.5 | -1.5 | 0.0  | 0.0  |
| 41 | 6.4  | 7.7  | 7.5  | 3.0  | 3.5  | 1.2  | 1.1  | 1.1  | 1.4  | 0.3  | 0.3  |
| 42 | 10.1 | 9.2  | 8.4  | 2.1  | 2.9  | 3.2  | 1.4  | 1.3  | 1.2  | -0.2 | -0.1 |
| 43 | 6.5  | 6.2  | 5.0  | 0.2  | -0.5 | -2.1 | 1.5  | -1.5 | -1.2 | -2.7 | 0.3  |
| 44 | 8.3  | 9.3  | 10.1 | 1.2  | -0.2 | 1.4  | 1.4  | -1.5 | 1.4  | 0.0  | 3.0  |
| 45 | 7.2  | 6.4  | 6.1  | 2.1  | 3.7  | 1.8  | 1.3  | 1.0  | 1.3  | 0.0  | 0.2  |
| 46 | 7.6  | 8.1  | 8.1  | -0.3 | 0.5  | 0.6  | -1.5 | 1.5  | 1.5  | 3.0  | 0.0  |
| 47 | 8.1  | 9.2  | 7.6  | 2.1  | 0.7  | -0.3 | 1.3  | 1.5  | -1.5 | -2.9 | -3.0 |
| 48 | 7.2  | 7.4  | 8.2  | 0.8  | 0.2  | 0.2  | 1.5  | 1.6  | 1.5  | 0.1  | 0.0  |
| 49 | 7.3  | 6.9  | 6.5  | -0.3 | 0.9  | -0.2 | -1.5 | 1.4  | -1.5 | 0.0  | -3.0 |
| 50 | 9.9  | 9.5  | 9.6  | 3.9  | 3.5  | 1.7  | 1.2  | 1.2  | 1.4  | 0.2  | 0.2  |
| 51 | 6.0  | 6.4  | 5.3  | 0.4  | 1.7  | 0.4  | 1.5  | 1.3  | 1.5  | 0.0  | 0.2  |
| 52 | 7.2  | 9.1  | 9.1  | -1.7 | -1.9 | -2.2 | -1.3 | -1.4 | -1.3 | 0.0  | 0.0  |
| 53 | 10.0 | 9.0  | 9.1  | 4.5  | 4.8  | 6.2  | 1.2  | 1.1  | 1.0  | -0.1 | 0.0  |
| 54 | 7.7  | 8.0  | 6.9  | -1.9 | -1.2 | -1.8 | -1.3 | -1.4 | -1.3 | 0.0  | 0.1  |
| 55 | 6.7  | 6.0  | 8.2  | 3.0  | 1.9  | 1.9  | 1.2  | 1.3  | 1.3  | 0.2  | 0.1  |
| 56 | 9.7  | 10.1 | 8.5  | 1.1  | 1.2  | 0.3  | 1.5  | 1.5  | 1.5  | 0.1  | 0.1  |
| 57 | 7.1  | 7.3  | 7.0  | -0.3 | -0.6 | -0.2 | -1.5 | -1.5 | -1.5 | 0.0  | -0.1 |
| 58 | 8.2  | 8.6  | 8.7  | -0.2 | 1.0  | -1.2 | -1.6 | 1.5  | -1.4 | 0.1  | -2.9 |
| 59 | 7.6  | 7.9  | 8.2  | 0.5  | 1.5  | 2.4  | 1.5  | 1.4  | 1.3  | -0.2 | -0.1 |
| 60 | 8.6  | 8.8  | 7.3  | 0.2  | 1.9  | -1.3 | 1.5  | 1.4  | -1.4 | -2.9 | -2.7 |
| 61 | 7.5  | 7.1  | 8.7  | 1.0  | -0.3 | 1.5  | 1.4  | -1.5 | 1.4  | 0.0  | 2.9  |
| 62 | 8.8  | 9.7  | 8.5  | 0.9  | 2.7  | -1.3 | 1.5  | 1.3  | -1.4 | -2.9 | -2.7 |
| 63 | 7.8  | 6.8  | 7.0  | 1.5  | -0.1 | 0.1  | 1.4  | -1.6 | 1.6  | 0.2  | 3.1  |
| 64 | 7.8  | 8.4  | 8.0  | 0.4  | 0.0  | -0.1 | 1.5  | -1.6 | -1.6 | -3.1 | 0.0  |
| 65 | 9.3  | 8.4  | 9.5  | -0.8 | 0.5  | -0.6 | -1.5 | 1.5  | -1.5 | 0.0  | -3.0 |
| 66 | 8.2  | 7.1  | 7.4  | -1.4 | -1.4 | -1.0 | -1.4 | -1.4 | -1.4 | 0.0  | -0.1 |
| 67 | 8.0  | 9.2  | 7.1  | 3.6  | 2.9  | 0.6  | 1.1  | 1.3  | 1.5  | 0.3  | 0.2  |
| 68 | 9.3  | 10.1 | 10.0 | -2.4 | -1.0 | -0.9 | -1.3 | -1.5 | -1.5 | -0.2 | 0.0  |
| 69 | 9.1  | 8.6  | 8.6  | 2.0  | 1.9  | 0.2  | 1.4  | 1.4  | 1.6  | 0.2  | 0.2  |

|                                                     |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
|-----------------------------------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| 70                                                  | 7.8                  | 7.6                  | 6.8                  | -1.5                 | -1.7                 | 1.3                  | -1.4                 | -1.3                 | 1.4                  | 2.8                  | 2.7                  |
|                                                     | 10.1                 | 12.7                 | 10.9                 | 4.5                  | 4.8                  | 5.2                  | 1.6                  | 1.6                  | 1.6                  | 3.0                  | 3.1                  |
|                                                     | 4.2                  | 4.6                  | 4.3                  | -2.4                 | -1.9                 | -2.3                 | -1.6                 | -1.6                 | -1.6                 | -3.1                 | -3.1                 |
|                                                     | -5.9                 | -7.9                 | -6.7                 | -6.9                 | -6.7                 | -7.5                 | -3.1                 | -3.1                 | -3.1                 | -6.1                 | -6.2                 |
| Calculation of $\theta$ (movements in the xz plane) |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| Trial 6                                             |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |                      |
| Frame                                               | $\Delta x(\text{m})$ | $\Delta y(\text{m})$ | $\Delta z(\text{m})$ | $\Delta x(\text{m})$ | $\Delta y(\text{m})$ | $\Delta z(\text{m})$ | $\Delta x(\text{m})$ | $\Delta y(\text{m})$ | $\Delta z(\text{m})$ | $\Delta x(\text{m})$ | $\Delta y(\text{m})$ |
| $X(\text{rfcam}), 1$                                | $X(\text{rfcam}), 1$ | $X(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ |
| $X(\text{rfcam}), 1$                                | $X(\text{rfcam}), 1$ | $X(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ | $Z(\text{rfcam}), 1$ |
| $0.017\%$                                           | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 | (cm)                 |
| 2                                                   | 6.1                  | 6.1                  | 6.9                  | 0.8                  | 2.4                  | 0.4                  | 1.4                  | 1.3                  | 1.5                  | 0.1                  | 0.2                  |
| 3                                                   | 9.0                  | 7.6                  | 8.2                  | 2.1                  | 0.8                  | 1.7                  | 1.3                  | 1.5                  | 1.4                  | 0.0                  | -0.1                 |
| 4                                                   | 6.1                  | 5.6                  | 6.0                  | 2.1                  | 2.4                  | 1.3                  | 1.2                  | 1.2                  | 1.4                  | 0.1                  | 0.2                  |
| 5                                                   | 8.9                  | 10.0                 | 10.5                 | -0.2                 | 1.1                  | 0.0                  | -1.6                 | 1.5                  | 1.6                  | 3.1                  | 0.1                  |
| 6                                                   | 5.6                  | 6.9                  | 6.0                  | -0.6                 | -0.4                 | -0.6                 | -1.5                 | -1.5                 | -1.5                 | 0.0                  | 0.0                  |
| 7                                                   | 9.3                  | 9.3                  | 8.8                  | 4.1                  | 4.1                  | 2.1                  | 1.2                  | 1.2                  | 1.3                  | 0.2                  | 0.2                  |
| 8                                                   | 8.0                  | 7.1                  | 9.1                  | 2.6                  | 1.5                  | 1.7                  | 1.3                  | 1.4                  | 1.4                  | 0.1                  | 0.0                  |
| 9                                                   | 6.2                  | 7.2                  | 5.7                  | 1.0                  | 2.7                  | 0.7                  | 1.4                  | 1.2                  | 1.5                  | 0.0                  | 0.2                  |
| 10                                                  | 6.5                  | 7.6                  | 6.7                  | 1.0                  | 0.7                  | -0.2                 | 1.4                  | 1.5                  | -1.5                 | -3.0                 | -3.0                 |
| 11                                                  | 9.9                  | 8.3                  | 8.9                  | 2.3                  | 2.0                  | 1.8                  | 1.3                  | 1.3                  | 1.4                  | 0.0                  | 0.0                  |
| 12                                                  | 7.2                  | 7.3                  | 7.3                  | 1.3                  | 1.5                  | 1.7                  | 1.4                  | 1.4                  | 1.3                  | 0.0                  | 0.0                  |
| 13                                                  | 7.5                  | 7.9                  | 9.2                  | 0.5                  | 1.9                  | 2.1                  | 1.5                  | 1.3                  | 1.3                  | -0.2                 | 0.0                  |
| 14                                                  | 7.9                  | 8.1                  | 7.5                  | 1.2                  | 0.9                  | 0.0                  | 1.4                  | 1.5                  | -1.6                 | -3.0                 | -3.0                 |
| 15                                                  | 7.3                  | 6.9                  | 7.1                  | 1.9                  | 0.8                  | 1.7                  | 1.3                  | 1.4                  | 1.3                  | 0.0                  | -0.1                 |
| 16                                                  | 9.0                  | 8.1                  | 9.0                  | 1.3                  | 2.2                  | 0.7                  | 1.4                  | 1.3                  | 1.5                  | 0.1                  | 0.2                  |
| 17                                                  | 8.5                  | 9.1                  | 7.8                  | 0.8                  | 0.0                  | 1.0                  | 1.5                  | -1.6                 | 1.4                  | 0.0                  | 3.0                  |
| 18                                                  | 7.4                  | 6.9                  | 7.5                  | 2.4                  | 2.3                  | 0.4                  | 1.3                  | 1.3                  | 1.5                  | 0.3                  | 0.3                  |
| 19                                                  | 7.9                  | 8.0                  | 7.9                  | -0.4                 | 1.9                  | 1.6                  | -1.5                 | 1.3                  | 1.4                  | 2.9                  | 0.0                  |
| 20                                                  | 8.5                  | 8.3                  | 9.0                  | 0.8                  | 0.4                  | 0.6                  | 1.5                  | 1.5                  | 1.5                  | 0.0                  | 0.0                  |
| 21                                                  | 8.1                  | 7.3                  | 7.3                  | 1.2                  | 0.4                  | -0.9                 | 1.4                  | 1.5                  | -1.4                 | -3.9                 | -3.0                 |
| 22                                                  | 6.4                  | 7.7                  | 9.2                  | 0.8                  | 1.9                  | 2.9                  | 1.4                  | 1.3                  | 1.3                  | -0.2                 | -0.1                 |
| 23                                                  | 10.1                 | 9.4                  | 7.9                  | 2.3                  | 0.1                  | -0.1                 | 1.3                  | 1.6                  | -1.6                 | -2.9                 | -3.1                 |

|    |      |      |      |      |      |      |      |      |      |      |      |      |
|----|------|------|------|------|------|------|------|------|------|------|------|------|
| 24 | 8.0  | 8.6  | 8.6  | 8.6  | 2.4  | 4.0  | 0.6  | 1.3  | 1.1  | 1.5  | 0.2  | 0.4  |
| 25 | 6.6  | 7.0  | 8.2  | 8.2  | -1.2 | -0.3 | 0.5  | -1.4 | -1.5 | 1.5  | 2.9  | 3.0  |
| 26 | 9.0  | 10.3 | 9.0  | 9.0  | 2.1  | 2.0  | 0.8  | 1.3  | 1.4  | 1.5  | 0.1  | 0.1  |
| 27 | 7.2  | 6.7  | 7.8  | 7.8  | -0.9 | 0.6  | -0.1 | -1.4 | 1.5  | -1.6 | -0.1 | -3.0 |
| 28 | 8.8  | 8.7  | 9.1  | 9.1  | 1.3  | 2.8  | 2.5  | 1.4  | 1.3  | 1.3  | -0.1 | 0.0  |
| 29 | 10.0 | 8.9  | 9.8  | 9.8  | 1.2  | -2.6 | -2.4 | 1.4  | -1.3 | -1.3 | -2.8 | 0.0  |
| 30 | 7.6  | 8.6  | 6.9  | 6.9  | -0.2 | 1.0  | 0.7  | -1.5 | 1.5  | 1.5  | 3.0  | 0.0  |
| 31 | 7.5  | 8.9  | 8.9  | 8.9  | 1.5  | 3.0  | 3.5  | 1.4  | 1.2  | 1.2  | -0.2 | -0.1 |
| 32 | 10.8 | 9.6  | 10.4 | 10.4 | 3.2  | 2.1  | 1.4  | 1.3  | 1.4  | 1.4  | 0.2  | 0.1  |
| 33 | 9.2  | 7.6  | 8.2  | 8.2  | 1.8  | -1.1 | -1.0 | 1.4  | -1.4 | -1.5 | -2.8 | 0.0  |
| 34 | 7.2  | 9.0  | 7.4  | 7.4  | -0.2 | 3.3  | -1.1 | -1.5 | 1.2  | -1.4 | 0.1  | -2.6 |
| 35 | 9.6  | 8.2  | 9.7  | 9.7  | 1.8  | 0.1  | 1.2  | 1.4  | 1.6  | 1.5  | 0.1  | -0.1 |
| 36 | 8.8  | 9.3  | 9.9  | 9.9  | -0.6 | 2.1  | 1.8  | -1.5 | 1.3  | 1.4  | 2.9  | 0.0  |
| 37 | 9.7  | 9.3  | 8.9  | 8.9  | 0.8  | -0.4 | -0.8 | 1.5  | -1.5 | -1.5 | -3.0 | 0.0  |
| 38 | 10.4 | 9.6  | 10.5 | 10.5 | 2.5  | 1.8  | 1.2  | 1.3  | 1.4  | 1.5  | 0.1  | 0.1  |
| 39 | 7.7  | 8.2  | 7.6  | 7.6  | 0.6  | 0.1  | 2.1  | 1.5  | 1.6  | 1.3  | -0.2 | -0.3 |
| 40 | 9.3  | 8.9  | 9.3  | 9.3  | 0.8  | 1.0  | -0.9 | 1.5  | 1.5  | -1.5 | -3.0 | -2.9 |
| 41 | 9.8  | 9.1  | 9.4  | 9.4  | 0.3  | 2.1  | 1.0  | 1.5  | 1.3  | 1.5  | -0.1 | 0.1  |
| 42 | 7.8  | 9.3  | 9.4  | 9.4  | -0.3 | -0.4 | -0.1 | -1.5 | -1.5 | -1.6 | 0.0  | 0.0  |
| 43 | 9.9  | 8.6  | 9.9  | 9.9  | 0.6  | 0.3  | -0.3 | 1.5  | 1.5  | -1.5 | -3.1 | -3.1 |
| 44 | 9.2  | 8.9  | 8.9  | 8.9  | 1.4  | 1.8  | 0.1  | 1.4  | 1.4  | 1.6  | 0.1  | 0.2  |
| 45 | 7.2  | 8.3  | 8.1  | 8.1  | 0.3  | 0.2  | -0.3 | 1.5  | 1.6  | -1.5 | -3.1 | -3.1 |
| 46 | 11.1 | 10.4 | 10.8 | 10.8 | -0.8 | 2.2  | 2.8  | -1.5 | 1.4  | 1.3  | 2.8  | 0.0  |
| 47 | 8.7  | 9.2  | 10.7 | 10.7 | 1.4  | -0.8 | -1.2 | 1.4  | -1.5 | -1.5 | -2.9 | 0.0  |
| 48 | 8.9  | 8.4  | 7.6  | 7.6  | 1.3  | 1.3  | 1.2  | 1.4  | 1.4  | 1.4  | 0.0  | 0.0  |
| 49 | 8.8  | 8.6  | 9.2  | 9.2  | 1.9  | 1.1  | 0.2  | 1.4  | 1.4  | 1.5  | 0.2  | 0.1  |
| 50 | 7.3  | 9.1  | 7.9  | 7.9  | -3.2 | 0.6  | -1.5 | -1.2 | 1.5  | -1.4 | -0.2 | -2.9 |
| 51 | 11.0 | 7.9  | 9.3  | 9.3  | 2.9  | 0.6  | 3.1  | 1.3  | 1.5  | 1.2  | -0.1 | -0.2 |
| 52 | 7.8  | 8.6  | 8.9  | 8.9  | -2.0 | -0.7 | -2.9 | -1.3 | -1.5 | -1.3 | 0.1  | 0.2  |
| 53 | 9.5  | 9.9  | 9.7  | 9.7  | 1.8  | 1.8  | 1.6  | 1.4  | 1.4  | 1.4  | 0.0  | 0.0  |
| 54 | 9.4  | 7.0  | 7.7  | 7.7  | 0.2  | 0.4  | -1.3 | 1.6  | 1.5  | -1.4 | -3.0 | -2.9 |
| 55 | 8.7  | 8.4  | 8.6  | 8.6  | 0.9  | -0.3 | 1.0  | 1.5  | -1.5 | 1.5  | 0.0  | 3.0  |
| 56 | 6.6  | 7.8  | 7.9  | 7.9  | -1.7 | -0.2 | -0.9 | -1.3 | -1.5 | -1.5 | -0.1 | 0.1  |

|     |      |      |      |      |      |      |      |      |      |      |      |
|-----|------|------|------|------|------|------|------|------|------|------|------|
| 57  | 9.2  | 8.2  | 9.0  | 3.8  | 1.3  | 1.7  | 1.2  | 1.4  | 1.4  | 0.2  | 0.0  |
| 58  | 7.7  | 8.3  | 7.3  | -0.7 | -0.2 | -1.6 | -1.5 | -1.6 | -1.4 | 0.1  | 0.2  |
| 59  | 7.5  | 8.9  | 9.2  | -2.1 | 1.1  | 1.5  | -1.3 | 1.4  | 1.4  | 2.7  | 0.0  |
| 60  | 6.8  | 5.8  | 6.9  | 4.1  | 1.8  | 0.6  | 1.0  | 1.3  | 1.5  | 0.5  | 0.2  |
| 61  | 7.1  | 9.2  | 9.3  | -1.7 | 0.8  | -1.1 | -1.3 | 1.5  | -1.5 | -0.1 | -2.9 |
| 62  | 6.8  | 6.7  | 6.6  | -1.0 | -0.7 | -0.6 | -1.4 | -1.4 | -1.5 | -0.1 | 0.0  |
| 63  | 7.7  | 7.4  | 8.1  | 1.8  | 1.5  | 2.4  | 1.3  | 1.4  | 1.3  | 0.0  | -0.1 |
| 64  | 7.2  | 6.1  | 5.9  | -1.6 | -1.4 | -3.8 | -1.4 | -1.3 | -1.0 | 0.4  | 0.3  |
| 65  | 7.5  | 7.9  | 8.7  | 0.7  | 2.0  | 2.8  | 1.5  | 1.3  | 1.3  | -0.2 | -0.1 |
| 66  | 5.0  | 6.4  | 4.2  | -1.2 | -1.5 | -2.6 | -1.3 | -1.3 | -1.0 | 0.3  | 0.3  |
| 67  | 9.0  | 6.6  | 9.0  | 2.6  | 0.8  | 3.3  | 1.3  | 1.5  | 1.2  | -0.1 | -0.2 |
| 68  | 5.8  | 7.0  | 6.3  | -0.2 | -0.5 | -4.2 | -1.5 | -1.5 | -1.0 | 0.6  | 0.5  |
| 69  | 5.7  | 6.3  | 6.7  | 1.3  | 2.1  | 3.7  | 1.3  | 1.3  | 1.1  | -0.3 | -0.2 |
| 70  | 5.6  | 5.2  | 5.4  | -1.9 | -0.2 | -2.6 | -1.3 | -1.5 | -1.1 | 0.1  | 0.4  |
| 71  | 8.0  | 6.7  | 7.1  | -0.1 | 0.6  | 0.7  | -1.6 | 1.5  | 1.5  | 3.0  | 0.0  |
| 72  | 5.6  | 4.6  | 4.4  | -1.0 | -3.2 | -1.6 | -1.4 | -1.0 | -1.2 | 0.2  | -0.3 |
| 73  | 7.2  | 6.3  | 8.2  | 0.4  | 0.9  | 0.6  | 1.5  | 1.4  | 1.5  | 0.0  | 0.1  |
| 74  | 4.0  | 5.8  | 5.6  | 0.0  | 0.5  | -1.8 | 1.6  | 1.5  | -1.3 | -2.8 | -2.8 |
| 75  | 5.0  | 6.2  | 6.0  | 1.3  | 2.1  | 1.4  | 1.3  | 1.2  | 1.3  | 0.0  | 0.1  |
| 76  | 7.4  | 6.6  | 8.3  | -0.9 | -2.6 | -0.6 | -1.5 | -1.2 | -1.5 | 0.0  | -0.3 |
| Max | 11.1 | 10.4 | 10.8 | 4.1  | 4.1  | 3.7  | 1.6  | 1.6  | 1.6  | 3.1  | 3.0  |
| Min | 4.0  | 4.6  | 4.2  | -3.2 | -3.2 | -4.2 | -1.6 | -1.6 | -1.6 | -3.1 | -3.1 |
| DIF | -7.1 | -6.8 | -6.7 | -7.4 | -7.3 | -7.9 | -3.1 | -3.1 | -3.1 | -6.2 | -6.2 |

## **APPENDIX G**

### **Calculations of yz Plane movements of the Mobile Video Platform**

| Calculation of $\phi$ (movements in the yz plane) |       |               |                |               |                |               |                |               |                | Trial 1       |                |               |                |
|---------------------------------------------------|-------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|---------------|----------------|
| Frame                                             | Event | Y(rfbcam) [m] | Z(rfbcam) [cm] | Y(rfbcam) [m] | Z(rfbcam) [cm] | Y(rfbcam) [m] | Z(rfbcam) [cm] | Y(rfbcam) [m] | Z(rfbcam) [cm] | Y(rfbcam) [m] | Z(rfbcam) [cm] | Y(rfbcam) [m] | Z(rfbcam) [cm] |
| [U0178]                                           |       |               |                |               |                |               |                |               |                |               |                |               |                |
| 1                                                 |       | 46.3          | 216.6          | 44.9          | 218.6          | 45.1          | 518.1          | 45.0          | 517.2          | -30.5         | -301.5         | -30.5         | -303.6         |
| 2                                                 |       | 46.4          | 217.1          | 46.0          | 214.9          | 46.5          | 520.4          | 46.2          | 517.5          | -33.0         | -303.2         | -33.0         | -302.6         |
| 3                                                 |       | 46.5          | 220.2          | 45.2          | 215.0          | 45.4          | 521.7          | 44.9          | 517.6          | -31.0         | -301.5         | -31.0         | -302.5         |
| 4                                                 |       | 46.2          | 219.2          | 45.8          | 217.0          | 46.1          | 522.5          | 45.6          | 518.8          | -32.4         | -303.3         | -32.4         | -301.8         |
| 5                                                 |       | 47.1          | 222.5          | 47.0          | 220.7          | 46.4          | 525.4          | 46.0          | 522.0          | -33.5         | -302.8         | -33.5         | -301.3         |
| 6                                                 |       | 46.0          | 223.4          | 45.7          | 221.2          | 45.5          | 526.7          | 44.9          | 521.5          | -31.5         | -303.4         | -31.5         | -300.3         |
| 7                                                 |       | 47.0          | 223.3          | 46.5          | 220.2          | 47.0          | 526.8          | 46.7          | 523.4          | -34.0         | -303.5         | -34.0         | -303.2         |
| 8                                                 |       | 46.2          | 225.7          | 45.9          | 221.1          | 45.8          | 528.3          | 45.5          | 524.0          | -32.1         | -302.6         | -32.1         | -302.9         |
| 9                                                 |       | 45.4          | 224.9          | 45.0          | 221.7          | 46.6          | 527.9          | 46.4          | 526.6          | -32.0         | -303.0         | -32.0         | -304.9         |
| 10                                                | Catch | 47.4          | 226.9          | 47.3          | 223.6          | 47.2          | 531.2          | 46.9          | 526.6          | -34.7         | -304.3         | -34.7         | -303.0         |
| 11                                                |       | 44.6          | 228.2          | 44.6          | 226.5          | 45.5          | 530.4          | 45.2          | 527.5          | -30.1         | -302.1         | -30.1         | -301.0         |
| 12                                                |       | 46.1          | 226.0          | 45.9          | 226.2          | 46.1          | 529.5          | 45.8          | 528.3          | -32.2         | -301.5         | -32.2         | -301.0         |
| 13                                                |       | 44.0          | 226.3          | 43.6          | 226.5          | 45.2          | 530.9          | 44.8          | 529.2          | -35.1         | -302.6         | -35.1         | -303.6         |
| 14                                                |       | 44.6          | 229.8          | 44.2          | 229.3          | 46.4          | 534.5          | 46.3          | 531.3          | -31.2         | -304.7         | -31.2         | -302.0         |
| 15                                                |       | 44.1          | 232.1          | 44.0          | 229.5          | 45.0          | 535.3          | 44.7          | 531.3          | -35.1         | -303.2         | -35.1         | -301.8         |
| 16                                                |       | 44.7          | 232.5          | 44.4          | 230.5          | 46.8          | 536.8          | 46.5          | 533.1          | -31.4         | -304.3         | -31.4         | -302.6         |
| 17                                                |       | 43.1          | 235.5          | 43.0          | 231.4          | 45.3          | 533.1          | 45.4          | 534.9          | -38.4         | -302.6         | -38.4         | -303.4         |
| 18                                                |       | 42.7          | 231.5          | 42.5          | 230.7          | 45.9          | 536.9          | 45.8          | 535.5          | -38.7         | -305.4         | -38.7         | -304.8         |
| 19                                                |       | 43.3          | 232.8          | 43.0          | 232.2          | 46.3          | 536.8          | 45.7          | 535.0          | -48.0         | -304.0         | -48.0         | -302.8         |
| 20                                                |       | 44.7          | 234.1          | 44.6          | 234.1          | 46.3          | 537.2          | 46.0          | 536.3          | -31.0         | -303.1         | -31.0         | -302.2         |
| 21                                                |       | 43.6          | 234.7          | 43.5          | 235.1          | 46.5          | 533.9          | 46.3          | 537.8          | -30.1         | -305.2         | -30.1         | -302.8         |
| 22                                                |       | 43.5          | 235.9          | 43.4          | 236.8          | 45.5          | 540.2          | 45.5          | 538.9          | -39.0         | -304.4         | -39.0         | -302.1         |
| 23                                                |       | 44.4          | 236.7          | 44.3          | 236.8          | 47.2          | 542.6          | 46.9          | 540.5          | -31.7         | -306.0         | -31.7         | -304.0         |
| 24                                                |       | 43.3          | 235.3          | 43.2          | 240.3          | 46.6          | 544.1          | 46.0          | 540.5          | -30.0         | -304.8         | -30.0         | -302.0         |
| 25                                                |       | 43.7          | 240.0          | 43.5          | 239.3          | 44.8          | 544.0          | 44.5          | 541.7          | -38.5         | -303.9         | -38.5         | -302.3         |
| 26                                                |       | 43.4          | 238.3          | 43.2          | 236.3          | 45.9          | 544.1          | 45.8          | 541.9          | -35.2         | -305.8         | -35.2         | -305.6         |
| 27                                                |       | 43.7          | 235.6          | 43.1          | 239.6          | 45.7          | 544.1          | 45.6          | 542.3          | -39.4         | -304.5         | -39.4         | -302.8         |
| 28                                                |       | 43.6          | 240.4          | 43.2          | 238.0          | 46.2          | 546.4          | 45.8          | 542.8          | -35.8         | -306.0         | -35.8         | -304.9         |
| 29                                                |       | 42.7          | 240.6          | 42.6          | 240.5          | 45.2          | 546.2          | 45.1          | 544.8          | -37.9         | -305.6         | -37.9         | -304.3         |
| 30                                                |       | 43.9          | 243.7          | 43.8          | 242.2          | 45.4          | 546.8          | 45.0          | 546.0          | -35.3         | -305.1         | -35.3         | -303.8         |

|    |        |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
|----|--------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|------|
| 31 |        | 44.1 | 244.2 | 44.3 | 244.7 | 47.4 | 551.5 | 46.8 | 546.7 | -91.5 | -307.4 | 16.6 | -2.6 | -302.0 | 0.5  |
| 32 | Drive  | 44.0 | 244.6 | 43.7 | 242.7 | 45.9 | 549.1 | 45.2 | 547.0 | -89.8 | -304.5 | 16.4 | -1.5 | -304.3 | 0.3  |
| 33 |        | 44.0 | 244.2 | 43.7 | 243.5 | 47.2 | 549.4 | 47.2 | 549.5 | -91.2 | -305.2 | 16.6 | -3.4 | -306.1 | 0.6  |
| 34 |        | 44.8 | 246.2 | 44.6 | 245.7 | 46.4 | 550.9 | 45.8 | 549.8 | -91.1 | -304.8 | 16.7 | -1.2 | -304.1 | 0.2  |
| 35 |        | 44.0 | 248.0 | 43.7 | 246.6 | 45.4 | 552.7 | 45.1 | 551.0 | -89.5 | -304.6 | 16.4 | -1.5 | -304.4 | 0.3  |
| 36 |        | 44.1 | 250.5 | 43.9 | 249.2 | 45.3 | 555.0 | 44.9 | 552.8 | -89.4 | -304.6 | 16.4 | -1.0 | -303.6 | 0.2  |
| 37 |        | 43.9 | 249.8 | 43.6 | 248.0 | 44.9 | 555.1 | 44.5 | 552.4 | -88.8 | -304.3 | 16.2 | -0.9 | -304.4 | 0.2  |
| 38 |        | 44.6 | 252.9 | 44.2 | 250.1 | 46.0 | 555.7 | 45.7 | 555.0 | -90.6 | -302.7 | 16.7 | -1.5 | -304.8 | 0.3  |
| 39 |        | 42.8 | 251.1 | 42.6 | 249.2 | 43.9 | 556.5 | 43.6 | 553.3 | -86.7 | -305.4 | 15.9 | -1.1 | -304.1 | 0.2  |
| 40 |        | 44.4 | 251.7 | 44.2 | 251.3 | 45.8 | 556.9 | 45.5 | 556.5 | -90.2 | -305.2 | 16.5 | -1.3 | -305.2 | 0.2  |
| 41 |        | 44.0 | 253.1 | 43.7 | 252.5 | 45.3 | 558.9 | 44.5 | 556.2 | -89.3 | -305.8 | 16.3 | -0.8 | -303.6 | 0.2  |
| 42 |        | 46.3 | 254.0 | 45.8 | 252.0 | 46.6 | 557.6 | 46.1 | 555.8 | -92.8 | -303.6 | 17.0 | -0.3 | -303.8 | 0.1  |
| 43 |        | 44.9 | 253.0 | 45.2 | 253.5 | 45.6 | 558.9 | 45.3 | 557.5 | -90.5 | -306.0 | 16.5 | -0.2 | -304.0 | 0.0  |
| 44 |        | 45.7 | 256.3 | 45.3 | 253.4 | 46.2 | 561.0 | 46.3 | 560.9 | -91.9 | -304.7 | 16.8 | -1.0 | -307.5 | 0.2  |
| 45 |        | 45.3 | 256.1 | 45.0 | 254.8 | 45.5 | 561.8 | 45.3 | 561.3 | -90.8 | -305.7 | 16.6 | -0.3 | -306.4 | 0.1  |
| 46 |        | 46.5 | 255.5 | 46.4 | 253.6 | 47.0 | 562.2 | 46.8 | 561.2 | -90.5 | -306.7 | 17.0 | -0.3 | -307.6 | 0.1  |
| 47 |        | 46.0 | 255.6 | 45.7 | 256.5 | 45.4 | 562.9 | 45.0 | 560.7 | -91.4 | -307.3 | 16.6 | 0.8  | -304.2 | -0.1 |
| 48 |        | 46.3 | 258.0 | 46.3 | 257.7 | 47.3 | 563.3 | 46.5 | 562.3 | -93.6 | -305.3 | 17.1 | -0.3 | -304.6 | 0.1  |
| 49 |        | 46.8 | 258.6 | 46.8 | 258.2 | 45.9 | 564.7 | 45.6 | 564.4 | -92.7 | -306.1 | 16.9 | 1.3  | -306.2 | -0.2 |
| 50 |        | 47.2 | 258.1 | 47.0 | 258.0 | 47.3 | 564.9 | 47.2 | 565.5 | -94.5 | -306.8 | 17.1 | -0.1 | -307.5 | 0.0  |
| 51 |        | 46.4 | 259.3 | 46.3 | 260.1 | 46.1 | 565.0 | 45.7 | 564.9 | -92.4 | -305.7 | 16.8 | 0.8  | -304.9 | -0.1 |
| 52 |        | 46.7 | 260.5 | 46.5 | 259.8 | 47.0 | 564.5 | 47.0 | 565.0 | -93.8 | -304.1 | 17.1 | -0.5 | -306.2 | 0.1  |
| 53 |        | 46.4 | 261.4 | 46.4 | 261.3 | 46.3 | 566.4 | 46.1 | 566.9 | -92.7 | -305.0 | 16.9 | 0.2  | -305.6 | 0.0  |
| 54 | Finish | 46.7 | 260.8 | 46.7 | 260.0 | 46.2 | 566.6 | 46.0 | 567.8 | -92.9 | -305.8 | 16.9 | 0.7  | -307.9 | -0.1 |
| 55 |        | 46.5 | 261.2 | 46.3 | 260.3 | 47.4 | 567.3 | 47.3 | 569.3 | -94.0 | -306.0 | 17.1 | -1.0 | -309.0 | 0.2  |
| 56 |        | 46.9 | 262.1 | 46.8 | 261.4 | 46.5 | 567.9 | 46.7 | 570.0 | -93.4 | -305.8 | 17.0 | 0.2  | -306.6 | 0.0  |
| 57 |        | 45.6 | 260.7 | 45.2 | 259.7 | 46.6 | 566.7 | 46.5 | 567.3 | -92.3 | -306.0 | 16.8 | -1.3 | -307.6 | 0.2  |
| 58 |        | 47.2 | 261.8 | 46.7 | 261.7 | 46.9 | 567.7 | 46.4 | 567.1 | -94.1 | -306.9 | 17.1 | 0.3  | -305.4 | -0.1 |
| 59 |        | 46.8 | 261.0 | 45.5 | 261.3 | 46.7 | 568.0 | 46.8 | 568.7 | -92.6 | -307.0 | 16.8 | -1.2 | -305.4 | 0.2  |
| 60 |        | 46.2 | 262.5 | 46.0 | 260.9 | 47.5 | 569.8 | 47.2 | 568.7 | -93.7 | -307.1 | 17.0 | -1.2 | -307.8 | 0.2  |
| 61 |        | 46.4 | 263.8 | 46.1 | 263.1 | 47.3 | 569.1 | 47.2 | 569.7 | -93.7 | -305.3 | 17.1 | -1.0 | -306.6 | 0.2  |
| 62 |        | 46.1 | 264.2 | 46.0 | 263.4 | 47.8 | 571.4 | 47.4 | 569.6 | -93.9 | -307.2 | 17.0 | -1.4 | -306.2 | 0.3  |
| 63 |        | 45.2 | 262.5 | 44.9 | 262.8 | 47.0 | 570.2 | 46.9 | 571.0 | -92.2 | -307.7 | 16.7 | -2.0 | -306.2 | 0.4  |
| 64 |        | 47.3 | 265.0 | 47.0 | 264.8 | 49.0 | 572.2 | 48.8 | 572.7 | -96.2 | -307.2 | 17.4 | -1.8 | -307.9 | 0.3  |
|    |        |      |       |      |       |      |       |      | max   | -86.7 | -301.5 | 17.4 | 1.3  | -300.2 | 0.6  |
|    |        |      |       |      |       |      |       |      | min   | -96.2 | -307.7 | 15.9 | -3.4 | -309.0 | -0.2 |
|    |        |      |       |      |       |      |       |      | diff  | 9.5   | 6.2    | 1.5  | 4.7  | 8.8    | 0.9  |

| Calculation of $\phi$ (movements in the yz plane) |        |                |                |                 |                 |                 |                 |                        |                        |                        |                        |                        |                        | Trial 2 |  |  |  |
|---------------------------------------------------|--------|----------------|----------------|-----------------|-----------------|-----------------|-----------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|---------|--|--|--|
| Frame                                             | Event  | Y(ft/sec<br>m) | Z(ft/sec<br>m) | Y(ft/sec<br>an) | Z(ft/sec<br>an) | Y(ft/sec<br>an) | Z(ft/sec<br>an) | Y(ft/sec<br>an)        | Z(ft/sec<br>an)        | Y(ft/sec<br>an)        | Z(ft/sec<br>an)        | Y(ft/sec<br>an)        | Z(ft/sec<br>an)        |         |  |  |  |
| 0.0715                                            |        |                |                |                 |                 |                 |                 | Y(ft/sec)<br>Z(ft/sec) | Y(ft/sec)<br>Z(ft/sec) | Y(ft/sec)<br>Z(ft/sec) | Y(ft/sec)<br>Z(ft/sec) | Y(ft/sec)<br>Z(ft/sec) | Y(ft/sec)<br>Z(ft/sec) |         |  |  |  |
|                                                   |        |                |                |                 |                 |                 |                 | (cm)                   | (cm)                   | (cm)                   | (cm)                   | (cm)                   | (cm)                   |         |  |  |  |
|                                                   | 1      | 43.8           | -92.8          | 44.0            | -89.6           | 42.7            | 212.6           | 42.6                   | 215.9                  | -86.5                  | -305.3                 | 15.8                   | 1.4                    |         |  |  |  |
|                                                   | 2      | 46.1           | -96.3          | 45.1            | -90.7           | 44.1            | 212.3           | 44.2                   | 215.7                  | -90.2                  | -305.6                 | 16.3                   | 1.9                    |         |  |  |  |
|                                                   | 3      | 45.2           | -92.1          | 44.9            | -89.4           | 43.9            | 216.1           | 43.6                   | 216.6                  | -89.1                  | -305.2                 | 16.1                   | 1.3                    |         |  |  |  |
|                                                   | 4      | 45.9           | -93.6          | 45.9            | -89.7           | 44.7            | 214.0           | 44.4                   | 215.8                  | -90.6                  | -307.6                 | 16.4                   | 1.5                    |         |  |  |  |
|                                                   | 5      | 45.6           | -91.9          | 45.7            | -88.1           | 43.5            | 215.6           | 43.4                   | 217.4                  | -89.1                  | -307.5                 | 16.2                   | 2.4                    |         |  |  |  |
|                                                   | 6      | 44.8           | -94.6          | 44.6            | -93.0           | 44.0            | 213.3           | 43.5                   | 214.6                  | -88.7                  | -307.9                 | 16.1                   | 1.1                    |         |  |  |  |
|                                                   | 7      | 46.5           | -92.2          | 46.2            | -91.5           | 44.4            | 215.7           | 44.3                   | 216.7                  | -90.9                  | -307.9                 | 16.5                   | 1.9                    |         |  |  |  |
|                                                   | 8      | 46.2           | -90.6          | 46.0            | -90.5           | 44.7            | 214.2           | 44.4                   | 217.4                  | -90.8                  | -304.8                 | 16.6                   | 1.6                    |         |  |  |  |
| 9                                                 | 46.8   | -91.4          | 46.4           | -90.7           | 44.2            | 215.8           | 44.2            | 215.2                  | -91.0                  | -307.2                 | 16.5                   | 2.2                    |                        |         |  |  |  |
| 10                                                | Finish | 44.6           | -93.9          | 44.6            | -90.7           | 44.6            | 215.8           | 44.3                   | 215.5                  | -89.1                  | -309.7                 | 16.1                   | 0.3                    |         |  |  |  |
| 11                                                |        | 46.7           | -91.2          | 46.6            | -89.9           | 44.7            | 215.3           | 44.6                   | 216.6                  | -91.4                  | -306.5                 | 16.6                   | 2.0                    |         |  |  |  |
| 12                                                |        | 46.4           | -94.7          | 46.3            | -91.3           | 46.0            | 213.2           | 46.0                   | 215.8                  | -92.4                  | -307.9                 | 16.7                   | 0.3                    |         |  |  |  |
| 13                                                |        | 46.8           | -91.7          | 46.8            | -91.8           | 44.8            | 214.8           | 44.8                   | 216.9                  | -91.6                  | -306.5                 | 16.6                   | 2.0                    |         |  |  |  |
| 14                                                |        | 47.3           | -90.9          | 47.0            | -92.4           | 46.4            | 216.2           | 46.2                   | 216.9                  | -93.7                  | -307.1                 | 17.0                   | 0.8                    |         |  |  |  |
| 15                                                |        | 46.3           | -88.8          | 46.1            | -87.4           | 45.1            | 217.3           | 44.8                   | 217.7                  | -91.4                  | -306.2                 | 16.6                   | 1.3                    |         |  |  |  |
| 16                                                |        | 45.3           | -93.2          | 45.0            | -92.0           | 44.6            | 213.3           | 44.4                   | 214.8                  | -90.0                  | -306.5                 | 16.4                   | 0.6                    |         |  |  |  |
| 17                                                |        | 46.0           | -91.7          | 45.8            | -91.1           | 45.9            | 216.2           | 45.7                   | 216.6                  | -91.9                  | -307.9                 | 16.6                   | 0.1                    |         |  |  |  |
| 18                                                |        | 46.1           | -91.1          | 45.9            | -91.6           | 46.0            | 215.0           | 45.8                   | 214.9                  | -92.1                  | -306.2                 | 16.8                   | 0.2                    |         |  |  |  |
| 19                                                |        | 45.9           | -92.6          | 45.8            | -92.5           | 45.7            | 215.1           | 45.8                   | 217.2                  | -91.6                  | -307.6                 | 16.6                   | -0.1                   |         |  |  |  |
| 20                                                |        | 44.7           | -92.8          | 44.7            | -90.5           | 45.3            | 212.9           | 45.1                   | 213.7                  | -90.0                  | -305.7                 | 16.4                   | -0.3                   |         |  |  |  |
| 21                                                |        | 46.0           | -92.0          | 45.7            | -91.4           | 45.0            | 214.1           | 44.9                   | 215.6                  | -91.1                  | -306.0                 | 16.6                   | 0.8                    |         |  |  |  |
| 22                                                |        | 44.5           | -91.9          | 44.3            | -90.5           | 44.7            | 215.1           | 44.8                   | 215.5                  | -89.2                  | -306.9                 | 16.2                   | -0.5                   |         |  |  |  |
| 23                                                |        | 45.3           | -90.2          | 45.1            | -91.4           | 44.0            | 217.3           | 43.8                   | 215.2                  | -89.4                  | -307.5                 | 16.2                   | 1.3                    |         |  |  |  |
| 24                                                |        | 44.1           | -92.9          | 43.9            | -94.6           | 43.5            | 212.7           | 43.5                   | 213.6                  | -87.6                  | -305.6                 | 16.0                   | 0.4                    |         |  |  |  |
| 25                                                |        | 44.9           | -91.7          | 44.6            | -89.5           | 44.5            | 216.7           | 44.2                   | 216.8                  | -89.4                  | -310.4                 | 16.1                   | 0.4                    |         |  |  |  |
| 26                                                |        | 45.5           | -90.6          | 44.8            | -91.7           | 44.6            | 216.6           | 44.1                   | 215.6                  | -90.1                  | -307.2                 | 16.4                   | 0.7                    |         |  |  |  |



|    |                  |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
|----|------------------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|------|
| 27 |                  | 45.0 | -90.8 | 44.9 | -90.2 | 44.8 | 215.9 | 44.8 | 219.1 | -89.8 | -306.7 | 16.3 | 0.1  | -309.3 | 0.0  |
| 28 |                  | 44.9 | -89.7 | 44.8 | -91.4 | 44.3 | 216.7 | 44.2 | 217.2 | -89.2 | -306.4 | 16.2 | 0.6  | -308.7 | -0.1 |
| 29 |                  | 44.8 | -90.5 | 44.4 | -91.3 | 44.0 | 216.2 | 43.5 | 215.0 | -89.6 | -306.7 | 16.2 | 0.9  | -306.3 | -0.2 |
| 30 | Bag Seet<br>Mort | 45.9 | -90.3 | 45.6 | -91.6 | 46.0 | 216.4 | 45.8 | 216.1 | -91.8 | -306.8 | 16.7 | -0.2 | -307.8 | 0.0  |
| 31 |                  | 45.0 | -90.3 | 44.8 | -89.8 | 44.2 | 217.2 | 43.9 | 216.7 | -89.2 | -307.5 | 16.2 | 1.0  | -306.6 | -0.2 |
| 32 |                  | 45.4 | -90.0 | 45.2 | -89.7 | 45.3 | 217.1 | 45.2 | 218.1 | -90.7 | -307.1 | 16.5 | 0.0  | -307.8 | 0.0  |
| 33 |                  | 45.8 | -88.3 | 45.5 | -90.4 | 44.2 | 216.0 | 44.0 | 216.5 | -90.0 | -304.4 | 16.5 | 1.5  | -306.9 | -0.3 |
| 34 |                  | 45.5 | -90.6 | 45.1 | -90.6 | 45.1 | 219.4 | 44.5 | 217.6 | -90.5 | -310.1 | 16.3 | 0.6  | -306.2 | -0.1 |
| 35 |                  | 44.9 | -87.7 | 44.5 | -89.1 | 44.2 | 219.6 | 43.7 | 218.6 | -89.0 | -307.3 | 16.2 | 0.7  | -305.8 | -0.1 |
| 36 |                  | 45.3 | -88.5 | 45.1 | -90.6 | 44.2 | 219.1 | 43.9 | 217.6 | -89.5 | -306.6 | 16.3 | 1.2  | -308.3 | -0.2 |
| 37 |                  | 46.1 | -88.8 | 45.0 | -89.5 | 44.7 | 217.2 | 44.4 | 218.6 | -89.8 | -306.0 | 16.4 | 0.6  | -306.0 | -0.1 |
| 38 |                  | 45.0 | -88.9 | 45.0 | -89.0 | 43.9 | 216.5 | 43.7 | 217.3 | -88.9 | -306.4 | 16.2 | 1.3  | -306.3 | -0.2 |
| 39 |                  | 44.9 | -89.0 | 44.5 | -89.7 | 44.6 | 216.1 | 44.6 | 218.1 | -89.5 | -307.1 | 16.3 | -0.1 | -307.8 | 0.0  |
| 40 |                  | 45.4 | -87.9 | 45.1 | -89.9 | 45.2 | 219.8 | 44.8 | 218.7 | -90.6 | -307.7 | 16.4 | 0.3  | -306.6 | -0.1 |
| 41 |                  | 44.5 | -88.7 | 44.0 | -90.6 | 44.3 | 219.6 | 44.0 | 218.1 | -88.8 | -308.3 | 16.1 | 0.0  | -308.7 | 0.0  |
| 42 |                  | 44.1 | -86.9 | 43.7 | -87.8 | 44.6 | 220.1 | 44.4 | 219.8 | -88.7 | -307.0 | 16.1 | -0.7 | -307.6 | 0.1  |
| 43 |                  | 45.1 | -88.3 | 44.8 | -87.3 | 44.4 | 219.7 | 44.1 | 220.7 | -88.6 | -308.0 | 16.2 | 0.7  | -307.9 | -0.1 |
| 44 |                  | 45.1 | -85.1 | 44.7 | -88.3 | 44.5 | 220.2 | 44.2 | 221.0 | -89.5 | -305.4 | 16.4 | 0.4  | -309.3 | -0.1 |
| 45 |                  | 47.2 | -94.5 | 47.1 | -85.2 | 45.9 | 221.1 | 45.7 | 221.0 | -83.1 | -305.6 | 17.0 | 1.4  | -306.1 | -0.3 |
| 46 |                  | 44.6 | -87.9 | 44.4 | -88.5 | 43.7 | 216.7 | 43.5 | 219.3 | -88.3 | -306.6 | 16.1 | 1.0  | -307.8 | -0.2 |
| 47 |                  | 48.8 | -86.4 | 46.5 | -88.6 | 45.9 | 220.3 | 45.4 | 219.8 | -92.7 | -306.7 | 16.8 | 1.1  | -308.4 | -0.2 |
| 48 |                  | 46.4 | -94.1 | 46.2 | -87.7 | 45.2 | 221.6 | 44.9 | 221.4 | -91.6 | -305.7 | 16.7 | 1.2  | -309.1 | -0.2 |
| 49 |                  | 47.2 | -94.7 | 46.9 | -86.8 | 46.0 | 221.8 | 45.7 | 223.6 | -93.2 | -306.4 | 16.9 | 1.2  | -310.4 | -0.2 |
| 50 |                  | 45.5 | -94.2 | 45.0 | -85.5 | 44.3 | 219.8 | 43.8 | 219.2 | -89.8 | -304.0 | 16.5 | 1.2  | -304.7 | -0.2 |
| 51 |                  | 46.0 | -82.5 | 45.6 | -85.7 | 44.5 | 223.5 | 44.2 | 223.1 | -90.5 | -306.0 | 16.5 | 1.4  | -306.8 | -0.3 |
| 52 |                  | 47.1 | -82.8 | 46.7 | -87.7 | 45.5 | 221.5 | 45.3 | 222.5 | -92.6 | -304.3 | 16.9 | 1.4  | -310.2 | -0.3 |
| 53 |                  | 48.9 | -90.8 | 46.7 | -87.7 | 45.7 | 225.2 | 45.2 | 223.2 | -92.6 | -306.0 | 16.8 | 1.5  | -311.0 | -0.3 |
| 54 |                  | 47.0 | -81.3 | 46.7 | -87.7 | 45.3 | 224.1 | 44.9 | 222.1 | -92.3 | -305.4 | 16.8 | 1.8  | -309.9 | -0.3 |
| 55 |                  | 46.7 | -82.9 | 46.4 | -83.0 | 45.7 | 224.3 | 45.5 | 222.7 | -92.3 | -307.2 | 16.7 | 0.9  | -305.7 | -0.2 |
| 56 |                  | 47.3 | -91.3 | 46.9 | -81.5 | 45.7 | 224.8 | 45.4 | 223.9 | -93.0 | -306.1 | 16.9 | 1.5  | -305.4 | -0.3 |
| 57 |                  | 47.0 | -80.7 | 46.7 | -81.0 | 46.2 | 226.7 | 45.7 | 224.3 | -93.2 | -307.4 | 16.9 | 1.0  | -305.3 | -0.2 |
| 58 |                  | 46.5 | -91.0 | 46.3 | -81.4 | 44.4 | 226.1 | 44.2 | 224.8 | -91.0 | -306.1 | 16.6 | 2.1  | -306.3 | -0.4 |

| 59                                                                 |        | 47.1            | -80.2           | 46.9             | -79.3            | 46.3            | 226.9            | 46.1             | 224.8            | -53.4            | -307.2           | 16.9      | 0.9              | -305.1           | -0.2      |
|--------------------------------------------------------------------|--------|-----------------|-----------------|------------------|------------------|-----------------|------------------|------------------|------------------|------------------|------------------|-----------|------------------|------------------|-----------|
| 60                                                                 |        | 47.1            | -78.4           | 46.7             | -81.7            | 46.7            | 227.2            | 45.1             | 224.8            | -52.8            | -305.6           | 16.9      | 1.6              | -306.5           | -0.3      |
| 61                                                                 |        | 47.0            | -78.3           | 46.4             | -80.9            | 46.3            | 227.9            | 45.9             | 227.7            | -53.4            | -306.2           | 17.0      | 0.5              | -308.7           | -0.1      |
| 62                                                                 |        | 47.6            | -79.6           | 47.3             | -82.2            | 46.3            | 227.7            | 46.0             | 227.0            | -53.9            | -307.2           | 17.0      | 1.2              | -309.2           | -0.2      |
| 63                                                                 |        | 47.0            | -80.7           | 46.6             | -80.1            | 46.6            | 227.4            | 46.0             | 225.5            | -53.6            | -308.1           | 16.9      | 0.5              | -308.6           | -0.1      |
| 64                                                                 |        | 45.8            | -76.7           | 45.3             | -79.0            | 45.9            | 225.0            | 45.6             | 228.5            | -51.7            | -305.7           | 16.7      | -0.2             | -307.5           | 0.0       |
| 65                                                                 |        | 46.5            | -76.8           | 46.2             | -78.7            | 46.5            | 226.5            | 45.9             | 227.5            | -53.0            | -305.2           | 16.9      | 0.3              | -306.2           | -0.1      |
| 66                                                                 | Catch  | 46.8            | -79.1           | 46.5             | -82.7            | 47.1            | 226.9            | 46.3             | 226.5            | -53.9            | -305.9           | 17.1      | 0.2              | -309.2           | 0.0       |
| 67                                                                 |        | 46.4            | -76.4           | 45.8             | -78.6            | 46.9            | 231.0            | 46.5             | 228.5            | -53.3            | -307.5           | 16.9      | -0.7             | -307.1           | 0.1       |
| 68                                                                 |        | 46.7            | -77.4           | 46.5             | -78.2            | 47.4            | 231.0            | 47.0             | 229.5            | -54.1            | -308.4           | 17.0      | -0.5             | -307.7           | 0.1       |
| 69                                                                 |        | 46.8            | -78.2           | 46.4             | -79.7            | 46.3            | 229.8            | 46.0             | 229.2            | -52.9            | -306.0           | 16.9      | 0.4              | -309.0           | -0.1      |
| 70                                                                 |        | 46.0            | -75.5           | 45.9             | -80.2            | 47.3            | 231.4            | 46.9             | 227.4            | -53.4            | -307.0           | 16.9      | -1.0             | -307.6           | 0.2       |
| 71                                                                 |        | 46.7            | -74.9           | 46.5             | -79.6            | 45.9            | 229.9            | 45.5             | 229.7            | -52.7            | -304.7           | 16.9      | 1.0              | -308.2           | -0.2      |
| 72                                                                 |        | 44.8            | -75.4           | 44.4             | -78.3            | 45.9            | 233.2            | 45.5             | 231.5            | -50.7            | -308.5           | 16.4      | -1.1             | -309.8           | 0.2       |
| 73                                                                 |        | 46.9            | -74.1           | 46.5             | -78.1            | 45.9            | 232.0            | 45.6             | 231.6            | -52.8            | -306.1           | 16.9      | 0.9              | -309.7           | -0.2      |
| 74                                                                 |        | 45.6            | -73.6           | 45.2             | -77.5            | 45.4            | 232.0            | 45.0             | 230.4            | -51.0            | -305.6           | 16.6      | 0.1              | -307.9           | 0.0       |
| 75                                                                 |        | 45.9            | -75.8           | 45.5             | -77.5            | 45.2            | 231.8            | 45.1             | 229.3            | -51.1            | -307.5           | 16.5      | 0.4              | -306.8           | -0.1      |
|                                                                    |        |                 |                 |                  |                  |                 |                  |                  | max              | -86.5            | -304.0           | 17.1      | 2.4              | -304.2           | 0.2       |
|                                                                    |        |                 |                 |                  |                  |                 |                  |                  | min              | -94.1            | -310.4           | 15.8      | -1.1             | -311.4           | -0.4      |
|                                                                    |        |                 |                 |                  |                  |                 |                  |                  | diff             | 7.7              | 6.4              | 1.3       | 3.5              | 7.2              | 0.6       |
| <b>Calculation of <math>\phi</math> movements in the yz plane)</b> |        |                 |                 |                  |                  |                 |                  |                  |                  |                  |                  |           |                  |                  |           |
| <b>Trial 5</b>                                                     |        |                 |                 |                  |                  |                 |                  |                  |                  |                  |                  |           |                  |                  |           |
| Frame                                                              | Event  | Y (ft/sec<br>m) | Z (ft/sec<br>m) | Y (ft/sec<br>an) | Z (ft/sec<br>an) | Y (ft/sec<br>m) | Z (ft/sec<br>an) | Y (ft/sec<br>an) | Z (ft/sec<br>an) | Y (ft/sec<br>an) | Z (ft/sec<br>an) | Arctan    | Y (ft/sec<br>an) | Z (ft/sec<br>an) | Arctan    |
|                                                                    |        |                 |                 |                  |                  |                 |                  |                  |                  | Y (ft/sec<br>an) | Z (ft/sec<br>an) | (degrees) | Y (ft/sec<br>an) | Z (ft/sec<br>an) | (degrees) |
| 1                                                                  | 0.0776 |                 |                 |                  |                  |                 |                  |                  |                  |                  |                  |           |                  |                  |           |
| 1                                                                  |        | 41.6            | 210.5           | 41.4             | 208.9            | 42.6            | 516.9            | 42.5             | 514.5            | -84.2            | -306.4           | 15.4      | -1.1             | -305.7           | 0.2       |
| 2                                                                  |        | 40.8            | 213.7           | 40.6             | 212.1            | 42.2            | 519.6            | 41.8             | 515.3            | -83.0            | -305.9           | 15.2      | -1.1             | -303.1           | 0.2       |
| 3                                                                  |        | 42.0            | 216.2           | 41.9             | 212.4            | 42.5            | 521.7            | 42.0             | 515.8            | -84.5            | -305.5           | 15.5      | -0.1             | -303.4           | 0.0       |
| 4                                                                  |        | 42.6            | 219.0           | 42.0             | 214.9            | 42.7            | 524.0            | 42.2             | 517.8            | -85.3            | -305.0           | 15.6      | -0.2             | -302.9           | 0.0       |
| 5                                                                  |        | 42.4            | 221.7           | 42.3             | 218.6            | 43.3            | 526.6            | 42.6             | 524.0            | -86.7            | -306.9           | 15.6      | -0.3             | -305.4           | 0.1       |

|    |                  |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
|----|------------------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|------|
| 6  |                  | 43.0 | 223.3 | 42.6 | 219.9 | 43.6 | 529.0 | 43.1 | 524.7 | -86.6 | -305.7 | 15.8 | -0.6 | -304.8 | 0.1  |
| 7  |                  | 41.9 | 226.2 | 41.6 | 222.7 | 42.3 | 531.2 | 41.8 | 527.6 | -84.2 | -305.0 | 15.4 | -0.2 | -304.9 | 0.0  |
| 8  |                  | 42.9 | 227.1 | 42.6 | 223.2 | 42.8 | 532.6 | 42.7 | 528.6 | -85.8 | -305.5 | 15.7 | -0.1 | -305.4 | 0.0  |
| 9  |                  | 42.9 | 228.3 | 42.5 | 223.9 | 42.9 | 534.3 | 42.7 | 531.6 | -85.8 | -306.0 | 15.7 | -0.2 | -307.8 | 0.0  |
| 10 | Catch            | 42.5 | 229.6 | 42.4 | 227.2 | 43.3 | 536.0 | 42.9 | 532.7 | -85.9 | -306.4 | 15.7 | -0.5 | -305.5 | 0.1  |
| 11 |                  | 42.5 | 233.2 | 42.5 | 231.1 | 42.9 | 539.1 | 42.7 | 536.4 | -85.4 | -305.9 | 15.6 | -0.1 | -305.3 | 0.0  |
| 12 |                  | 43.3 | 232.7 | 43.2 | 230.7 | 43.4 | 540.0 | 43.1 | 536.0 | -86.7 | -307.2 | 15.8 | 0.1  | -305.3 | 0.0  |
| 13 |                  | 43.9 | 234.1 | 43.8 | 232.4 | 43.8 | 541.1 | 43.3 | 537.1 | -87.7 | -307.0 | 15.9 | 0.5  | -304.7 | -0.1 |
| 14 |                  | 43.4 | 235.4 | 43.0 | 230.6 | 43.5 | 542.0 | 42.9 | 538.4 | -86.9 | -306.6 | 15.8 | 0.1  | -307.8 | 0.0  |
| 15 |                  | 43.1 | 237.5 | 42.7 | 232.5 | 43.6 | 543.4 | 43.1 | 539.8 | -86.6 | -306.9 | 15.8 | -0.5 | -307.3 | 0.1  |
| 16 |                  | 43.5 | 238.1 | 43.2 | 237.4 | 44.0 | 547.5 | 43.5 | 542.9 | -87.5 | -308.4 | 15.8 | -0.3 | -305.5 | 0.1  |
| 17 |                  | 43.2 | 238.7 | 42.8 | 236.9 | 43.6 | 547.1 | 43.2 | 542.6 | -86.8 | -308.4 | 15.7 | -0.4 | -306.7 | 0.1  |
| 18 |                  | 43.3 | 241.0 | 43.1 | 239.1 | 43.8 | 548.8 | 43.6 | 548.5 | -87.1 | -307.8 | 15.8 | -0.4 | -307.4 | 0.1  |
| 19 |                  | 42.6 | 240.0 | 42.3 | 238.1 | 42.6 | 548.1 | 42.2 | 545.3 | -85.2 | -308.1 | 15.5 | 0.1  | -307.1 | 0.0  |
| 20 |                  | 42.5 | 243.5 | 42.4 | 242.0 | 44.2 | 550.4 | 43.8 | 549.1 | -86.7 | -307.0 | 15.8 | -1.4 | -307.1 | 0.3  |
| 21 |                  | 42.9 | 243.6 | 42.7 | 241.9 | 43.9 | 551.9 | 43.3 | 548.2 | -86.8 | -308.3 | 15.7 | -0.6 | -306.3 | 0.1  |
| 22 |                  | 42.8 | 245.7 | 42.3 | 243.4 | 44.9 | 555.0 | 44.2 | 552.3 | -87.6 | -309.3 | 15.8 | -1.9 | -308.9 | 0.3  |
| 23 |                  | 42.0 | 246.7 | 41.7 | 244.4 | 44.4 | 554.6 | 43.9 | 550.2 | -86.4 | -307.8 | 15.7 | -2.2 | -305.9 | 0.4  |
| 24 |                  | 41.8 | 247.2 | 41.6 | 246.2 | 44.5 | 555.6 | 44.1 | 552.4 | -86.3 | -308.4 | 15.6 | -2.6 | -306.2 | 0.5  |
| 25 |                  | 42.8 | 251.3 | 42.6 | 247.6 | 44.8 | 558.2 | 44.4 | 555.7 | -87.6 | -308.9 | 15.9 | -1.8 | -308.1 | 0.3  |
| 26 |                  | 42.6 | 250.4 | 42.2 | 247.9 | 44.7 | 558.6 | 44.4 | 555.9 | -87.3 | -308.3 | 15.8 | -2.2 | -308.1 | 0.4  |
| 27 |                  | 41.6 | 253.1 | 41.2 | 251.2 | 45.2 | 562.4 | 44.8 | 559.1 | -86.8 | -309.3 | 15.7 | -3.6 | -307.9 | 0.7  |
| 28 |                  | 42.8 | 253.2 | 42.6 | 251.0 | 45.0 | 562.5 | 44.9 | 559.4 | -87.8 | -309.3 | 15.9 | -2.2 | -308.4 | 0.4  |
| 29 |                  | 42.2 | 253.8 | 41.8 | 252.1 | 45.8 | 563.4 | 45.5 | 559.5 | -88.0 | -309.5 | 15.9 | -3.7 | -307.4 | 0.7  |
| 30 |                  | 42.6 | 256.3 | 42.3 | 253.3 | 45.2 | 563.3 | 44.6 | 559.6 | -87.8 | -308.0 | 15.9 | -2.2 | -306.2 | 0.4  |
| 31 |                  | 40.8 | 255.2 | 40.7 | 254.1 | 45.1 | 563.8 | 44.6 | 561.5 | -86.0 | -310.6 | 15.5 | -3.9 | -307.4 | 0.7  |
| 32 |                  | 41.8 | 256.9 | 41.6 | 256.6 | 45.5 | 567.4 | 45.1 | 564.2 | -87.3 | -310.5 | 15.7 | -3.5 | -307.6 | 0.7  |
| 33 |                  | 40.9 | 257.2 | 40.6 | 256.4 | 44.7 | 566.0 | 44.3 | 564.8 | -85.6 | -310.9 | 15.4 | -3.6 | -308.3 | 0.7  |
| 34 |                  | 41.8 | 259.3 | 41.4 | 258.3 | 45.4 | 570.3 | 45.1 | 567.4 | -87.2 | -311.0 | 15.7 | -3.7 | -309.1 | 0.7  |
| 35 |                  | 42.0 | 261.2 | 41.9 | 260.2 | 45.3 | 572.3 | 45.0 | 568.9 | -87.4 | -311.0 | 15.7 | -3.1 | -308.7 | 0.6  |
| 36 | End of Leg Drive | 41.8 | 263.6 | 41.8 | 262.3 | 45.3 | 573.6 | 45.0 | 571.1 | -87.1 | -310.0 | 15.7 | -3.2 | -308.8 | 0.6  |
| 37 |                  | 40.8 | 264.0 | 40.8 | 263.0 | 44.7 | 575.1 | 44.2 | 572.1 | -85.5 | -311.1 | 15.4 | -3.4 | -309.1 | 0.6  |

|    |        |      |       |      |       |      |       |      |       |       |        |      |      |        |     |
|----|--------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|-----|
| 38 |        | 41.9 | 267.1 | 41.5 | 264.6 | 45.4 | 575.7 | 45.1 | 573.4 | -87.3 | -308.6 | 15.8 | -3.6 | -308.9 | 0.7 |
| 39 |        | 41.1 | 265.9 | 41.1 | 265.7 | 45.4 | 577.0 | 45.0 | 575.3 | -86.6 | -311.1 | 15.6 | -3.9 | -309.5 | 0.7 |
| 40 |        | 41.9 | 265.9 | 41.7 | 265.3 | 44.8 | 576.3 | 44.5 | 575.1 | -86.7 | -310.4 | 15.6 | -2.8 | -309.9 | 0.5 |
| 41 |        | 41.0 | 268.9 | 41.0 | 268.1 | 45.3 | 579.8 | 45.3 | 578.2 | -86.3 | -310.9 | 15.5 | -4.3 | -310.1 | 0.8 |
| 42 |        | 41.5 | 271.0 | 41.6 | 269.8 | 45.6 | 582.7 | 45.2 | 579.4 | -87.2 | -311.7 | 15.6 | -3.6 | -309.6 | 0.7 |
| 43 |        | 40.9 | 271.2 | 40.9 | 269.7 | 44.4 | 582.2 | 44.4 | 581.9 | -85.3 | -311.0 | 15.3 | -3.5 | -312.3 | 0.6 |
| 44 |        | 41.4 | 272.4 | 41.5 | 272.0 | 44.6 | 582.0 | 44.4 | 581.9 | -86.1 | -309.6 | 15.6 | -2.9 | -309.8 | 0.5 |
| 45 |        | 41.9 | 274.5 | 41.8 | 272.7 | 45.2 | 585.7 | 44.9 | 583.7 | -87.1 | -311.2 | 15.6 | -3.1 | -310.9 | 0.6 |
| 46 |        | 42.4 | 274.2 | 42.3 | 273.3 | 45.1 | 586.2 | 44.8 | 584.0 | -87.4 | -312.0 | 15.7 | -2.5 | -310.7 | 0.5 |
| 47 |        | 42.7 | 276.3 | 42.8 | 275.2 | 45.3 | 586.9 | 45.0 | 585.4 | -86.0 | -310.7 | 15.8 | -2.2 | -310.2 | 0.4 |
| 48 |        | 42.4 | 277.1 | 42.3 | 275.6 | 45.0 | 587.1 | 44.8 | 585.9 | -87.4 | -310.0 | 15.8 | -2.6 | -310.4 | 0.5 |
| 49 |        | 43.4 | 276.8 | 43.4 | 277.4 | 44.9 | 587.9 | 45.1 | 587.4 | -86.3 | -311.2 | 15.9 | -1.7 | -310.0 | 0.3 |
| 50 |        | 42.5 | 280.7 | 42.2 | 279.0 | 45.2 | 591.5 | 45.0 | 590.2 | -87.7 | -310.8 | 15.8 | -2.8 | -311.2 | 0.5 |
| 51 |        | 43.5 | 281.0 | 43.1 | 280.4 | 44.7 | 593.1 | 44.4 | 592.0 | -86.2 | -312.1 | 15.8 | -1.4 | -311.5 | 0.3 |
| 52 |        | 43.8 | 279.3 | 43.6 | 277.8 | 45.1 | 591.2 | 45.2 | 590.5 | -86.9 | -311.9 | 15.9 | -1.6 | -312.7 | 0.3 |
| 53 |        | 42.9 | 283.8 | 42.9 | 282.3 | 45.0 | 596.0 | 45.0 | 594.8 | -87.9 | -312.3 | 15.7 | -2.0 | -312.4 | 0.4 |
| 54 |        | 43.9 | 281.8 | 43.8 | 282.2 | 45.5 | 594.8 | 45.4 | 593.1 | -88.4 | -313.0 | 16.0 | -1.5 | -310.9 | 0.3 |
| 55 |        | 44.1 | 284.8 | 44.0 | 283.9 | 44.4 | 596.8 | 44.3 | 595.8 | -86.6 | -311.9 | 15.9 | -0.3 | -311.9 | 0.1 |
| 56 |        | 44.0 | 288.0 | 43.8 | 285.2 | 45.4 | 598.0 | 45.6 | 596.2 | -89.5 | -312.0 | 16.0 | -1.8 | -313.0 | 0.3 |
| 57 |        | 43.6 | 285.7 | 43.5 | 285.8 | 45.1 | 597.4 | 45.3 | 596.2 | -86.7 | -311.7 | 16.9 | -1.8 | -312.4 | 0.3 |
| 58 |        | 44.5 | 285.5 | 44.5 | 284.0 | 46.0 | 598.4 | 45.8 | 596.2 | -90.5 | -312.8 | 16.1 | -1.3 | -312.2 | 0.2 |
| 59 |        | 44.0 | 286.0 | 43.8 | 285.9 | 45.7 | 599.8 | 45.6 | 598.6 | -88.7 | -313.8 | 16.0 | -1.9 | -313.8 | 0.3 |
| 60 | Finish | 44.6 | 286.2 | 44.7 | 286.6 | 46.6 | 601.8 | 46.3 | 601.2 | -91.2 | -315.5 | 16.1 | -1.5 | -314.5 | 0.3 |
| 61 |        | 43.9 | 287.2 | 44.1 | 286.4 | 46.3 | 601.5 | 45.9 | 600.2 | -90.1 | -314.3 | 16.0 | -1.8 | -311.8 | 0.3 |
| 62 |        | 45.4 | 288.1 | 45.6 | 289.1 | 48.0 | 604.1 | 45.9 | 600.9 | -91.4 | -316.0 | 16.1 | -0.3 | -311.8 | 0.1 |
| 63 |        | 44.1 | 289.6 | 44.0 | 288.5 | 46.1 | 604.0 | 45.9 | 602.1 | -90.2 | -314.4 | 16.0 | -1.8 | -313.6 | 0.3 |
| 64 |        | 44.9 | 290.1 | 44.6 | 289.1 | 46.1 | 604.0 | 45.9 | 603.4 | -91.0 | -313.9 | 16.2 | -1.3 | -314.3 | 0.2 |
| 65 |        | 43.9 | 289.3 | 44.1 | 289.3 | 45.3 | 604.5 | 45.4 | 603.9 | -89.2 | -315.2 | 15.8 | -1.3 | -314.6 | 0.2 |
| 66 |        | 43.3 | 287.9 | 43.2 | 287.7 | 46.6 | 603.1 | 46.3 | 602.0 | -89.9 | -315.3 | 15.9 | -3.1 | -314.3 | 0.6 |
| 67 |        | 43.6 | 291.5 | 43.4 | 291.6 | 45.4 | 606.0 | 45.1 | 605.6 | -88.0 | -314.6 | 16.8 | -1.7 | -314.0 | 0.3 |
| 68 |        | 43.9 | 289.1 | 43.9 | 289.3 | 47.0 | 605.0 | 46.9 | 604.2 | -90.9 | -316.0 | 16.1 | -3.0 | -314.9 | 0.6 |
| 69 |        | 43.4 | 291.1 | 43.4 | 291.0 | 46.1 | 606.9 | 45.9 | 606.5 | -89.5 | -316.9 | 15.8 | -2.5 | -315.5 | 0.5 |
| 70 |        | 43.6 | 289.6 | 43.6 | 290.1 | 46.9 | 605.2 | 46.8 | 605.6 | -90.6 | -316.7 | 16.0 | -3.2 | -315.5 | 0.6 |

[illegible]

|    |                   |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
|----|-------------------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|------|
| 23 |                   | 43.6 | 87.3  | 43.1 | 84.9  | 42.1 | 386.5 | 41.6 | 383.4 | -85.7 | -299.2 | 16.0 | 1.6  | -298.6 | -0.3 |
| 24 |                   | 43.5 | 89.7  | 43.1 | 85.8  | 42.5 | 390.6 | 41.9 | 387.7 | -86.0 | -300.8 | 16.0 | 1.2  | -302.0 | -0.2 |
| 25 |                   | 43.7 | 88.5  | 43.3 | 87.9  | 42.8 | 390.2 | 42.3 | 386.8 | -86.5 | -301.7 | 16.0 | 1.0  | -298.9 | -0.2 |
| 26 |                   | 44.1 | 90.6  | 43.7 | 89.7  | 42.3 | 392.2 | 41.6 | 387.1 | -86.4 | -301.6 | 16.0 | 2.1  | -297.5 | -0.4 |
| 27 |                   | 42.5 | 89.7  | 42.1 | 89.5  | 42.9 | 392.8 | 42.0 | 388.3 | -85.4 | -303.1 | 15.7 | 0.0  | -298.9 | 0.0  |
|    | Reg. Seat<br>Movt |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
| 28 |                   | 45.6 | 91.0  | 45.2 | 91.5  | 43.3 | 395.6 | 42.6 | 391.3 | -88.9 | -304.6 | 16.3 | 2.6  | -299.8 | -0.5 |
| 29 |                   | 43.4 | 92.3  | 43.2 | 91.5  | 43.5 | 393.1 | 42.9 | 391.8 | -86.9 | -300.8 | 16.1 | 0.3  | -300.2 | -0.1 |
| 30 |                   | 44.3 | 92.0  | 44.1 | 93.1  | 43.1 | 394.1 | 42.3 | 390.4 | -87.4 | -302.1 | 16.1 | 1.8  | -297.3 | -0.4 |
| 31 |                   | 44.6 | 93.6  | 44.4 | 92.7  | 43.9 | 397.1 | 43.7 | 394.6 | -88.6 | -303.5 | 16.3 | 0.8  | -302.0 | -0.1 |
| 32 |                   | 45.2 | 96.7  | 45.0 | 95.3  | 44.2 | 399.3 | 43.4 | 396.1 | -89.4 | -302.5 | 16.5 | 1.6  | -300.8 | -0.3 |
| 33 |                   | 44.1 | 98.5  | 43.4 | 95.3  | 43.5 | 398.2 | 43.2 | 397.1 | -87.6 | -299.6 | 16.3 | 0.2  | -301.7 | 0.0  |
| 34 |                   | 45.3 | 98.4  | 44.9 | 96.8  | 43.3 | 401.5 | 42.3 | 396.7 | -88.7 | -303.2 | 16.3 | 2.5  | -300.9 | -0.5 |
| 35 |                   | 43.7 | 100.2 | 43.0 | 97.3  | 43.4 | 401.6 | 43.0 | 400.2 | -87.1 | -301.5 | 16.1 | 0.1  | -302.8 | 0.0  |
| 36 |                   | 45.3 | 99.5  | 44.9 | 98.7  | 43.5 | 403.7 | 43.0 | 399.5 | -88.8 | -304.2 | 16.3 | 1.9  | -300.8 | -0.4 |
| 37 |                   | 44.1 | 100.3 | 43.6 | 98.5  | 44.4 | 403.3 | 43.8 | 399.6 | -88.5 | -303.0 | 16.3 | -0.2 | -301.1 | 0.0  |
| 38 |                   | 45.4 | 102.9 | 45.0 | 101.5 | 43.6 | 405.2 | 43.3 | 403.1 | -89.0 | -302.3 | 16.4 | 1.8  | -301.5 | -0.3 |
| 39 |                   | 44.1 | 103.5 | 43.5 | 102.6 | 43.5 | 405.3 | 43.0 | 405.1 | -87.6 | -301.8 | 16.2 | 0.5  | -302.5 | -0.1 |
| 40 |                   | 45.3 | 104.3 | 44.8 | 102.5 | 43.9 | 406.3 | 43.4 | 403.8 | -89.3 | -302.0 | 16.5 | 1.4  | -301.4 | -0.3 |
| 41 |                   | 45.1 | 104.5 | 44.7 | 104.4 | 43.8 | 406.3 | 43.5 | 405.8 | -88.9 | -303.8 | 16.3 | 1.1  | -301.4 | -0.2 |
| 42 |                   | 45.4 | 104.3 | 44.9 | 103.0 | 43.5 | 407.9 | 43.1 | 405.4 | -88.9 | -303.6 | 16.3 | 1.9  | -302.4 | -0.4 |
| 43 |                   | 44.5 | 104.9 | 44.4 | 105.8 | 44.2 | 408.2 | 43.6 | 407.0 | -88.8 | -303.3 | 16.3 | 0.8  | -301.2 | -0.1 |
| 44 |                   | 45.0 | 106.3 | 44.8 | 105.9 | 42.7 | 410.0 | 42.2 | 408.6 | -87.7 | -303.7 | 16.1 | 2.6  | -302.6 | -0.5 |
| 45 |                   | 44.8 | 106.6 | 44.4 | 104.5 | 44.5 | 410.2 | 44.1 | 406.2 | -89.3 | -303.6 | 16.4 | 0.3  | -303.7 | -0.1 |
| 46 |                   | 45.1 | 105.8 | 45.0 | 106.5 | 43.5 | 412.4 | 42.7 | 409.3 | -88.5 | -306.5 | 16.1 | 2.3  | -302.8 | -0.4 |
| 47 |                   | 45.0 | 107.2 | 44.7 | 106.5 | 43.6 | 411.5 | 43.2 | 409.8 | -88.6 | -304.3 | 16.2 | 1.4  | -303.3 | -0.3 |
| 48 |                   | 45.4 | 108.6 | 44.9 | 107.2 | 43.6 | 412.8 | 42.9 | 409.8 | -88.9 | -304.3 | 16.3 | 1.9  | -302.6 | -0.4 |
| 49 |                   | 45.4 | 110.5 | 45.9 | 109.0 | 44.0 | 413.9 | 43.5 | 412.8 | -90.4 | -303.4 | 16.6 | 2.4  | -303.8 | -0.4 |
| 50 |                   | 46.0 | 107.3 | 45.8 | 108.2 | 43.5 | 414.4 | 42.8 | 412.9 | -89.6 | -307.2 | 16.3 | 3.0  | -304.8 | -0.6 |
| 51 |                   | 45.0 | 110.1 | 47.8 | 108.8 | 45.8 | 415.0 | 45.4 | 414.1 | -83.8 | -304.9 | 17.1 | 2.3  | -305.4 | -0.4 |
| 52 |                   | 46.7 | 108.2 | 46.4 | 108.0 | 43.6 | 414.3 | 43.2 | 412.7 | -90.4 | -306.1 | 16.5 | 3.2  | -304.6 | -0.6 |
| 53 |                   | 47.8 | 110.0 | 47.3 | 109.9 | 45.2 | 416.1 | 44.7 | 413.9 | -93.0 | -306.1 | 16.9 | 2.7  | -304.0 | -0.5 |
| 54 |                   | 45.0 | 110.2 | 45.8 | 109.3 | 43.3 | 416.5 | 42.7 | 414.9 | -89.3 | -306.3 | 16.3 | 3.0  | -305.6 | -0.6 |

|    |       |      |       |      |       |      |       |      |       |       |        |      |      |        |      |
|----|-------|------|-------|------|-------|------|-------|------|-------|-------|--------|------|------|--------|------|
| 55 |       | 48.0 | 111.1 | 47.9 | 110.9 | 44.7 | 415.2 | 44.4 | 415.0 | -92.7 | -305.1 | 16.9 | 3.5  | -304.1 | -0.7 |
| 56 |       | 47.4 | 109.4 | 47.1 | 110.0 | 44.2 | 415.0 | 43.8 | 415.0 | -91.6 | -306.6 | 16.6 | 3.3  | -305.0 | -0.6 |
| 57 |       | 47.9 | 113.2 | 47.4 | 113.3 | 44.8 | 417.3 | 44.3 | 417.2 | -92.7 | -304.1 | 17.0 | 3.1  | -303.9 | -0.6 |
| 58 |       | 48.0 | 112.6 | 47.5 | 110.3 | 45.8 | 417.1 | 45.2 | 416.6 | -93.7 | -304.6 | 17.1 | 2.3  | -306.4 | -0.4 |
| 59 |       | 47.6 | 110.4 | 47.3 | 111.6 | 45.2 | 415.3 | 44.6 | 417.7 | -92.8 | -307.9 | 16.8 | 2.7  | -306.1 | -0.5 |
| 60 |       | 47.9 | 114.5 | 47.4 | 112.9 | 45.1 | 420.0 | 44.6 | 418.7 | -93.0 | -305.5 | 16.9 | 2.8  | -305.8 | -0.5 |
| 61 |       | 48.6 | 112.9 | 48.0 | 112.6 | 45.7 | 420.8 | 45.5 | 419.4 | -94.1 | -308.0 | 17.0 | 2.6  | -306.9 | -0.5 |
| 62 |       | 48.6 | 111.9 | 48.1 | 113.3 | 45.1 | 420.1 | 45.0 | 420.6 | -93.7 | -308.2 | 16.9 | 3.1  | -307.3 | -0.6 |
| 63 |       | 48.7 | 113.7 | 48.4 | 114.6 | 45.9 | 421.6 | 45.7 | 420.9 | -94.6 | -307.8 | 17.1 | 2.6  | -306.3 | -0.5 |
| 64 |       | 49.4 | 112.2 | 48.9 | 112.2 | 44.9 | 420.1 | 44.6 | 419.1 | -94.2 | -308.0 | 17.0 | 4.2  | -306.9 | -0.8 |
| 65 |       | 48.2 | 112.8 | 47.9 | 113.4 | 46.6 | 422.1 | 46.3 | 420.2 | -94.8 | -309.2 | 17.0 | 1.7  | -306.9 | -0.3 |
| 66 | Catch | 48.1 | 111.7 | 48.0 | 114.6 | 45.8 | 420.6 | 45.2 | 418.5 | -93.9 | -308.9 | 16.9 | 2.8  | -303.9 | -0.5 |
| 67 |       | 48.9 | 114.2 | 48.4 | 113.5 | 47.4 | 421.4 | 47.0 | 420.7 | -96.4 | -307.3 | 17.4 | 1.4  | -307.2 | -0.3 |
| 68 |       | 47.8 | 114.0 | 47.4 | 113.0 | 44.8 | 421.0 | 44.3 | 420.2 | -92.6 | -307.0 | 16.8 | 3.1  | -307.2 | -0.6 |
| 69 |       | 49.4 | 115.3 | 49.2 | 116.0 | 47.4 | 423.0 | 46.9 | 422.3 | -96.8 | -307.7 | 17.5 | 2.3  | -306.3 | -0.4 |
| 70 |       | 48.6 | 113.4 | 48.4 | 114.4 | 45.9 | 422.8 | 45.6 | 421.5 | -94.5 | -309.3 | 17.0 | 2.8  | -307.0 | -0.5 |
| 71 |       | 48.0 | 113.4 | 47.7 | 113.3 | 46.2 | 423.4 | 45.7 | 422.4 | -94.1 | -310.1 | 16.9 | 2.1  | -309.0 | -0.4 |
| 72 |       | 49.1 | 112.4 | 48.9 | 112.4 | 47.0 | 420.2 | 46.6 | 423.1 | -96.1 | -307.8 | 17.3 | 2.2  | -310.7 | -0.4 |
| 73 |       | 48.2 | 112.8 | 47.7 | 114.6 | 46.4 | 421.1 | 45.9 | 422.5 | -94.6 | -308.3 | 17.1 | 1.8  | -307.9 | -0.3 |
| 74 |       | 47.9 | 112.9 | 47.4 | 112.8 | 46.5 | 421.6 | 46.2 | 422.5 | -94.5 | -308.7 | 17.0 | 1.3  | -309.8 | -0.2 |
| 75 |       | 48.7 | 114.1 | 48.4 | 115.1 | 46.7 | 423.6 | 45.9 | 423.3 | -95.4 | -309.5 | 17.1 | 2.4  | -308.2 | -0.4 |
| 76 |       | 47.1 | 113.2 | 47.0 | 114.0 | 45.3 | 421.1 | 45.0 | 421.9 | -92.4 | -307.8 | 16.7 | 2.1  | -307.9 | -0.4 |
|    |       |      |       |      |       |      |       |      | max   | -77.5 | -296.9 | 17.5 | 4.2  | -293.4 | 0.0  |
|    |       |      |       |      |       |      |       |      | min   | -96.8 | -310.1 | 14.6 | -0.2 | -310.7 | -0.8 |
|    |       |      |       |      |       |      |       |      | diff  | 19.3  | 13.2   | 2.9  | 4.5  | 17.2   | 0.8  |

## APPENDIX H

### Calculations of xy Plane movements of the Mobile Video Platform





|    |                  |       |      |       |      |       |      |       |      |      |      |      |      |      |      |
|----|------------------|-------|------|-------|------|-------|------|-------|------|------|------|------|------|------|------|
| 28 |                  | 123.9 | 43.6 | 107.2 | 43.2 | 90.3  | 46.2 | 71.4  | 45.8 | 16.7 | 0.4  | 1.3  | 18.9 | 0.4  | 1.3  |
| 29 |                  | 129.1 | 42.7 | 112.8 | 42.6 | 96.0  | 45.2 | 77.9  | 45.1 | 16.3 | 0.1  | 0.3  | 17.1 | 0.1  | 0.3  |
| 30 |                  | 135.0 | 43.9 | 118.8 | 43.8 | 101.7 | 45.4 | 83.3  | 45.0 | 16.2 | 0.1  | 0.5  | 18.4 | 0.3  | 1.1  |
| 31 |                  | 141.8 | 44.1 | 125.1 | 44.3 | 109.1 | 47.4 | 90.1  | 46.8 | 16.7 | -0.1 | -0.5 | 19.0 | 0.6  | 1.9  |
|    | END LOG<br>Drive |       |      |       |      |       |      |       |      |      |      |      |      |      |      |
| 32 |                  | 147.5 | 44.0 | 132.0 | 43.7 | 114.5 | 45.8 | 96.8  | 45.2 | 15.5 | 0.4  | 1.5  | 18.0 | 0.6  | 2.0  |
| 33 |                  | 153.6 | 44.0 | 138.1 | 43.7 | 121.6 | 47.2 | 102.8 | 47.2 | 15.5 | 0.2  | 0.9  | 18.8 | 0.1  | 0.2  |
| 34 |                  | 160.4 | 44.8 | 144.3 | 44.6 | 128.2 | 46.4 | 110.6 | 45.8 | 16.1 | 0.2  | 0.5  | 17.5 | 0.5  | 1.7  |
| 35 |                  | 167.8 | 44.0 | 152.2 | 43.7 | 134.4 | 45.4 | 118.0 | 45.1 | 15.6 | 0.4  | 1.3  | 16.4 | 0.3  | 1.0  |
| 36 |                  | 176.5 | 44.1 | 159.7 | 43.9 | 141.6 | 46.3 | 124.7 | 44.9 | 16.8 | 0.2  | 0.5  | 16.9 | 0.4  | 1.4  |
| 37 |                  | 181.0 | 43.9 | 165.3 | 43.6 | 147.6 | 44.9 | 129.7 | 44.5 | 15.7 | 0.4  | 1.3  | 17.9 | 0.4  | 1.3  |
| 38 |                  | 187.8 | 44.6 | 171.4 | 44.2 | 154.4 | 46.0 | 137.3 | 45.7 | 16.4 | 0.5  | 1.6  | 17.1 | 0.3  | 0.9  |
| 39 |                  | 194.4 | 42.8 | 179.6 | 42.6 | 161.9 | 43.9 | 145.3 | 43.6 | 14.8 | 0.3  | 1.0  | 16.7 | 0.2  | 0.8  |
| 40 |                  | 201.0 | 44.4 | 185.1 | 44.2 | 168.0 | 45.8 | 150.2 | 45.5 | 15.9 | 0.2  | 0.7  | 17.8 | 0.2  | 0.8  |
| 41 |                  | 208.1 | 44.0 | 192.6 | 43.7 | 175.7 | 46.3 | 158.0 | 44.5 | 15.6 | 0.3  | 1.2  | 17.6 | 0.7  | 2.4  |
| 42 |                  | 213.8 | 46.3 | 197.6 | 45.8 | 181.7 | 46.6 | 164.1 | 46.1 | 16.0 | 0.4  | 1.6  | 17.6 | 0.4  | 1.4  |
| 43 |                  | 221.8 | 44.8 | 205.8 | 45.2 | 188.7 | 45.6 | 171.0 | 45.3 | 16.0 | -0.3 | -1.0 | 18.7 | 0.3  | 0.9  |
| 44 |                  | 230.2 | 45.7 | 212.7 | 45.3 | 196.8 | 46.2 | 178.8 | 46.3 | 17.5 | 0.4  | 1.3  | 18.0 | -0.1 | -0.4 |
| 45 |                  | 236.2 | 45.3 | 219.6 | 45.0 | 203.2 | 45.5 | 184.6 | 45.3 | 16.6 | 0.3  | 1.0  | 18.6 | 0.2  | 0.7  |
| 46 |                  | 245.0 | 46.5 | 227.4 | 46.4 | 211.9 | 47.0 | 193.5 | 46.8 | 17.7 | 0.1  | 0.4  | 18.4 | 0.2  | 0.6  |
| 47 |                  | 252.5 | 46.0 | 235.0 | 45.7 | 219.6 | 45.4 | 200.7 | 45.0 | 17.5 | 0.2  | 0.7  | 18.9 | 0.4  | 1.3  |
| 48 |                  | 259.2 | 46.3 | 241.3 | 46.3 | 225.4 | 47.3 | 207.2 | 46.5 | 17.8 | 0.0  | 0.1  | 18.2 | 0.8  | 2.5  |
| 49 |                  | 266.2 | 46.8 | 249.2 | 46.8 | 232.8 | 45.9 | 213.8 | 45.6 | 17.0 | 0.0  | 0.0  | 19.0 | 0.4  | 1.1  |
| 50 |                  | 273.3 | 47.2 | 256.3 | 47.0 | 240.6 | 47.3 | 222.3 | 47.2 | 15.0 | 0.1  | 0.5  | 18.3 | 0.1  | 0.5  |
| 51 |                  | 280.9 | 46.4 | 264.1 | 46.3 | 248.2 | 46.1 | 230.8 | 45.7 | 16.8 | 0.1  | 0.3  | 17.4 | 0.4  | 1.3  |
| 52 |                  | 288.3 | 46.7 | 273.3 | 46.5 | 255.6 | 47.0 | 237.4 | 47.0 | 15.0 | 0.3  | 1.0  | 18.2 | 0.0  | 0.0  |
| 53 |                  | 295.4 | 46.4 | 279.1 | 46.4 | 263.2 | 46.3 | 245.3 | 46.1 | 16.3 | 0.0  | 0.1  | 17.9 | 0.2  | 0.6  |
| 54 | Finish           | 302.7 | 46.7 | 286.4 | 46.7 | 270.7 | 46.2 | 252.5 | 46.0 | 16.3 | 0.0  | 0.0  | 18.3 | 0.3  | 0.9  |
| 55 |                  | 309.8 | 46.5 | 293.9 | 46.3 | 278.9 | 47.4 | 260.3 | 47.3 | 15.9 | 0.2  | 0.8  | 18.6 | 0.1  | 0.4  |
| 56 |                  | 319.0 | 46.9 | 302.7 | 46.8 | 287.0 | 46.5 | 267.7 | 46.7 | 16.3 | 0.0  | 0.2  | 19.3 | -0.1 | -0.4 |
| 57 |                  | 326.5 | 45.6 | 310.8 | 45.2 | 294.0 | 46.6 | 275.9 | 46.5 | 15.8 | 0.4  | 1.4  | 18.0 | 0.1  | 0.5  |
| 58 |                  | 333.2 | 47.2 | 316.8 | 46.7 | 300.6 | 46.9 | 283.2 | 46.4 | 16.4 | 0.4  | 1.5  | 17.4 | 0.5  | 1.5  |
| 59 |                  | 339.9 | 45.8 | 324.9 | 45.5 | 306.3 | 46.7 | 290.2 | 46.8 | 15.0 | 0.3  | 1.2  | 18.1 | 0.0  | -0.1 |
| 60 |                  | 347.7 | 46.2 | 332.1 | 46.0 | 315.6 | 47.5 | 297.8 | 47.2 | 15.6 | 0.2  | 0.8  | 17.7 | 0.3  | 0.9  |
| 61 |                  | 355.2 | 46.4 | 339.3 | 46.1 | 322.5 | 47.3 | 305.6 | 47.2 | 16.0 | 0.2  | 0.8  | 17.0 | 0.1  | 0.5  |
| 62 |                  | 364.0 | 46.1 | 347.9 | 46.0 | 331.1 | 47.8 | 313.1 | 47.4 | 16.1 | 0.1  | 0.4  | 18.0 | 0.4  | 1.3  |
| 63 |                  | 371.5 | 45.2 | 355.3 | 44.9 | 339.4 | 47.0 | 321.3 | 46.9 | 16.2 | 0.2  | 0.8  | 18.0 | 0.1  | 0.4  |



|    |                 |       |      |       |      |       |      |       |      |      |     |     |      |     |     |
|----|-----------------|-------|------|-------|------|-------|------|-------|------|------|-----|-----|------|-----|-----|
| 24 |                 | 236.9 | 44.1 | 221.0 | 43.9 | 214.5 | 43.5 | 195.5 | 43.5 | 17.8 | 0.2 | 0.8 | 18.9 | 0.0 | 0.0 |
| 25 |                 | 246.1 | 44.9 | 228.3 | 44.6 | 222.8 | 44.5 | 204.0 | 44.2 | 18.8 | 0.2 | 0.8 | 18.6 | 0.3 | 0.9 |
| 26 |                 | 253.1 | 45.5 | 236.3 | 44.8 | 231.0 | 44.6 | 211.4 | 44.1 | 18.8 | 0.7 | 2.3 | 19.6 | 0.5 | 1.3 |
| 27 |                 | 261.1 | 45.0 | 244.1 | 44.9 | 238.0 | 44.8 | 220.0 | 44.8 | 17.0 | 0.1 | 0.5 | 17.9 | 0.0 | 0.1 |
| 28 |                 | 268.9 | 44.9 | 250.9 | 44.8 | 245.5 | 44.3 | 226.9 | 44.2 | 18.0 | 0.1 | 0.3 | 18.5 | 0.1 | 0.4 |
| 29 |                 | 276.7 | 44.8 | 258.1 | 44.4 | 253.5 | 44.0 | 234.4 | 43.5 | 18.6 | 0.4 | 1.3 | 19.1 | 0.6 | 1.7 |
|    | 943 SAR<br>Movt |       |      |       |      |       |      |       |      |      |     |     |      |     |     |
| 30 |                 | 284.2 | 45.9 | 267.7 | 45.6 | 260.9 | 46.0 | 243.5 | 45.8 | 18.5 | 0.3 | 0.9 | 17.4 | 0.2 | 0.7 |
| 31 |                 | 293.0 | 46.0 | 276.7 | 44.8 | 269.3 | 44.2 | 250.7 | 43.9 | 18.4 | 0.2 | 0.6 | 18.6 | 0.3 | 1.0 |
| 32 |                 | 300.7 | 45.4 | 283.8 | 45.2 | 277.5 | 45.3 | 259.2 | 45.2 | 18.9 | 0.2 | 0.5 | 18.2 | 0.1 | 0.3 |
| 33 |                 | 308.2 | 45.8 | 292.0 | 45.5 | 285.0 | 44.2 | 266.1 | 44.0 | 18.2 | 0.3 | 1.2 | 18.9 | 0.2 | 0.5 |
| 34 |                 | 316.8 | 45.5 | 299.4 | 45.1 | 293.1 | 45.1 | 274.5 | 44.5 | 17.4 | 0.3 | 1.1 | 18.7 | 0.5 | 1.7 |
| 35 |                 | 326.7 | 44.9 | 309.5 | 44.5 | 303.2 | 44.2 | 283.5 | 43.7 | 17.2 | 0.4 | 1.2 | 19.7 | 0.4 | 1.2 |
| 36 |                 | 333.2 | 45.3 | 316.6 | 45.1 | 309.7 | 44.2 | 291.0 | 43.9 | 16.6 | 0.2 | 0.7 | 18.6 | 0.3 | 1.0 |
| 37 |                 | 341.6 | 46.1 | 324.5 | 45.0 | 317.8 | 44.7 | 298.5 | 44.4 | 17.1 | 0.1 | 0.4 | 19.2 | 0.3 | 0.8 |
| 38 |                 | 350.8 | 45.0 | 333.5 | 45.0 | 326.3 | 43.9 | 309.4 | 43.7 | 17.3 | 0.1 | 0.2 | 16.9 | 0.2 | 0.7 |
| 39 |                 | 358.6 | 44.9 | 340.4 | 44.5 | 333.9 | 44.6 | 316.6 | 44.6 | 18.2 | 0.4 | 1.4 | 17.4 | 0.0 | 0.2 |
| 40 |                 | 366.7 | 45.4 | 349.2 | 45.1 | 342.1 | 45.2 | 323.6 | 44.8 | 17.5 | 0.3 | 1.0 | 18.5 | 0.4 | 1.1 |
| 41 |                 | 375.7 | 44.5 | 358.4 | 44.0 | 352.0 | 44.3 | 333.1 | 44.0 | 17.3 | 0.5 | 1.8 | 18.8 | 0.4 | 1.1 |
| 42 |                 | 383.4 | 44.1 | 366.2 | 43.7 | 359.2 | 44.6 | 339.9 | 44.4 | 17.3 | 0.4 | 1.4 | 19.3 | 0.2 | 0.6 |
| 43 |                 | 393.1 | 45.1 | 376.7 | 44.8 | 367.9 | 44.4 | 349.2 | 44.1 | 16.4 | 0.3 | 1.1 | 18.7 | 0.3 | 1.0 |
| 44 |                 | 400.4 | 46.1 | 383.1 | 44.7 | 375.6 | 44.5 | 357.7 | 44.2 | 17.3 | 0.4 | 1.5 | 18.1 | 0.2 | 0.7 |
| 45 |                 | 408.9 | 47.2 | 391.5 | 47.1 | 384.1 | 45.9 | 365.0 | 45.7 | 17.3 | 0.1 | 0.3 | 19.0 | 0.2 | 0.5 |
| 46 |                 | 416.9 | 44.6 | 399.7 | 44.4 | 392.2 | 43.7 | 373.3 | 43.5 | 17.2 | 0.2 | 0.6 | 18.9 | 0.3 | 0.8 |
| 47 |                 | 425.1 | 46.8 | 409.0 | 46.5 | 401.8 | 45.9 | 382.6 | 45.4 | 16.1 | 0.3 | 1.1 | 19.2 | 0.4 | 1.3 |
| 48 |                 | 432.7 | 46.4 | 416.8 | 46.2 | 409.4 | 45.2 | 390.9 | 44.9 | 15.9 | 0.3 | 1.0 | 18.5 | 0.3 | 0.8 |
| 49 |                 | 442.9 | 47.2 | 425.6 | 46.9 | 417.5 | 46.0 | 396.8 | 45.7 | 17.3 | 0.3 | 1.1 | 20.7 | 0.3 | 0.8 |
| 50 |                 | 449.8 | 45.5 | 432.8 | 45.0 | 424.6 | 44.3 | 405.9 | 43.8 | 17.1 | 0.5 | 1.6 | 18.6 | 0.5 | 1.6 |
| 51 |                 | 457.8 | 46.0 | 441.6 | 45.6 | 433.3 | 44.5 | 414.7 | 44.2 | 16.2 | 0.4 | 1.6 | 18.7 | 0.2 | 0.7 |
| 52 |                 | 465.4 | 47.1 | 449.1 | 46.7 | 440.1 | 45.5 | 423.0 | 45.3 | 16.2 | 0.4 | 1.5 | 17.1 | 0.2 | 0.6 |
| 53 |                 | 473.8 | 46.9 | 449.1 | 46.7 | 449.2 | 45.7 | 429.1 | 45.2 | 24.6 | 0.2 | 0.4 | 20.2 | 0.5 | 1.4 |
| 54 |                 | 481.1 | 47.0 | 449.1 | 46.7 | 464.9 | 46.3 | 435.7 | 44.9 | 31.9 | 0.3 | 0.5 | 19.2 | 0.4 | 1.2 |
| 55 |                 | 487.9 | 46.7 | 471.4 | 46.4 | 463.6 | 45.7 | 444.6 | 45.5 | 18.4 | 0.3 | 0.9 | 19.0 | 0.2 | 0.6 |
| 56 |                 | 495.7 | 47.3 | 478.9 | 46.9 | 471.1 | 45.7 | 451.0 | 45.4 | 16.8 | 0.4 | 1.4 | 20.1 | 0.3 | 0.9 |

|                                                   |       |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
|---------------------------------------------------|-------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 57                                                |       | 503.0     | 47.0      | 485.3     | 46.7      | 478.0     | 46.2      | 488.0     | 45.7      | 17.7      | 0.3       | 0.9       | 20.0      | 0.4       | 1.3       |
| 58                                                |       | 509.8     | 46.5      | 491.7     | 46.3      | 483.9     | 44.4      | 485.6     | 44.2      | 18.0      | 0.2       | 0.8       | 18.3      | 0.3       | 0.8       |
| 59                                                |       | 515.7     | 47.1      | 496.4     | 46.9      | 491.1     | 46.3      | 471.8     | 46.1      | 17.3      | 0.2       | 0.6       | 19.2      | 0.3       | 0.8       |
| 60                                                |       | 523.1     | 47.1      | 505.6     | 46.7      | 498.0     | 45.7      | 478.9     | 45.1      | 17.6      | 0.4       | 1.4       | 19.0      | 0.6       | 1.9       |
| 61                                                |       | 530.2     | 47.0      | 512.6     | 46.4      | 504.5     | 46.3      | 486.0     | 45.9      | 17.6      | 0.6       | 2.0       | 18.5      | 0.4       | 1.3       |
| 62                                                |       | 536.2     | 47.6      | 519.1     | 47.3      | 511.2     | 46.3      | 491.9     | 46.0      | 17.0      | 0.3       | 1.1       | 19.3      | 0.3       | 0.8       |
| 63                                                |       | 542.0     | 47.0      | 523.7     | 46.6      | 517.0     | 46.6      | 496.3     | 46.0      | 18.2      | 0.4       | 1.4       | 18.6      | 0.5       | 1.7       |
| 64                                                |       | 549.3     | 45.8      | 531.0     | 45.3      | 523.9     | 45.9      | 504.8     | 45.6      | 18.3      | 0.5       | 1.5       | 19.1      | 0.3       | 0.9       |
| 65                                                |       | 556.1     | 46.5      | 537.7     | 46.2      | 529.9     | 46.5      | 510.9     | 45.9      | 17.4      | 0.3       | 0.8       | 19.0      | 0.5       | 1.6       |
| 66                                                | Catch | 559.8     | 46.8      | 542.1     | 46.5      | 535.5     | 47.1      | 516.4     | 46.3      | 17.7      | 0.3       | 1.0       | 19.0      | 0.7       | 2.2       |
| 67                                                |       | 567.2     | 46.4      | 550.2     | 45.8      | 542.2     | 46.9      | 523.3     | 46.5      | 17.0      | 0.6       | 2.1       | 18.9      | 0.3       | 1.0       |
| 68                                                |       | 571.7     | 46.7      | 555.5     | 46.5      | 547.1     | 47.4      | 528.4     | 47.0      | 16.3      | 0.2       | 0.8       | 18.7      | 0.4       | 1.2       |
| 69                                                |       | 577.1     | 46.6      | 559.9     | 46.4      | 551.1     | 46.3      | 532.9     | 46.0      | 17.1      | 0.3       | 0.9       | 18.2      | 0.3       | 1.1       |
| 70                                                |       | 584.4     | 46.0      | 566.2     | 45.9      | 559.6     | 47.3      | 538.7     | 46.9      | 18.2      | 0.1       | 0.3       | 20.8      | 0.4       | 1.2       |
| 71                                                |       | 588.3     | 46.7      | 570.2     | 46.5      | 562.9     | 46.9      | 544.0     | 45.5      | 18.1      | 0.2       | 0.6       | 18.9      | 0.4       | 1.3       |
| 72                                                |       | 592.8     | 44.8      | 575.8     | 44.4      | 568.3     | 45.9      | 549.5     | 45.5      | 17.0      | 0.4       | 1.4       | 18.8      | 0.3       | 1.0       |
| 73                                                |       | 599.0     | 46.9      | 581.3     | 46.5      | 573.5     | 45.9      | 555.0     | 45.6      | 17.7      | 0.3       | 1.1       | 18.5      | 0.3       | 1.0       |
| 74                                                |       | 604.9     | 45.6      | 586.4     | 45.2      | 578.6     | 45.4      | 560.2     | 45.0      | 18.5      | 0.5       | 1.5       | 18.3      | 0.3       | 1.0       |
| 75                                                |       | 609.2     | 45.9      | 591.3     | 45.5      | 584.7     | 45.2      | 564.5     | 45.1      | 17.9      | 0.4       | 1.2       | 20.2      | 0.1       | 0.2       |
|                                                   |       |           |           |           |           |           |           |           | Max       | 31.9      | 0.7       | 2.3       | 20.8      | 0.7       | 2.2       |
|                                                   |       |           |           |           |           |           |           |           | Min       | 14.4      | -0.2      | -0.8      | 16.9      | -0.1      | -0.3      |
|                                                   |       |           |           |           |           |           |           |           | Diff      | 17.5      | 0.9       | 3.0       | 3.9       | 0.8       | 2.5       |
| Calculation of $\Psi$ (Movements in the xy plane) |       |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Trial 5                                           |       |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Frame                                             | Event | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | Arctan    |
|                                                   |       | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | Y(rtkcam) | X(rtkcam) | Y(rtkcam) | Arctan    |
| (0.017s)                                          |       | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (cm)      | (degrees) |
| 1                                                 |       | -30.7     | 41.6      | -49.2     | 41.4      | -71.8     | 42.6      | -92.6     | 42.5      | 18.6      | 23.6      | 51.8      | 20.8      | 0.0       | 0.1       |
| 2                                                 |       | -21.5     | 40.8      | -37.8     | 40.6      | -59.1     | 42.2      | -90.8     | 41.8      | 16.3      | 21.3      | 52.6      | 21.7      | 0.4       | 1.1       |
| 3                                                 |       | -13.4     | 42.0      | -30.0     | 41.9      | -52.7     | 42.5      | -73.0     | 42.0      | 16.6      | 21.7      | 52.5      | 20.3      | 0.5       | 1.4       |
| 4                                                 |       | -4.4      | 42.6      | -21.8     | 42.0      | -43.6     | 42.7      | -63.8     | 42.2      | 17.4      | 22.4      | 52.2      | 20.3      | 0.5       | 1.5       |
| 5                                                 |       | 4.8       | 42.4      | -11.9     | 42.3      | -34.4     | 43.3      | -53.1     | 42.6      | 16.7      | 21.4      | 52.1      | 18.6      | 0.7       | 2.0       |

|    |                  |       |      |       |      |       |      |       |      |      |      |      |      |     |     |
|----|------------------|-------|------|-------|------|-------|------|-------|------|------|------|------|------|-----|-----|
| 6  |                  | 11.9  | 43.0 | -5.1  | 42.6 | -27.1 | 43.6 | -46.4 | 43.1 | 17.0 | 21.6 | 51.7 | 19.3 | 0.5 | 1.5 |
| 7  |                  | 21.6  | 41.9 | 4.3   | 41.6 | -19.0 | 42.3 | -37.1 | 41.8 | 17.2 | 22.4 | 52.5 | 18.2 | 0.5 | 1.5 |
| 8  |                  | 30.8  | 42.9 | 13.9  | 42.6 | -10.3 | 42.8 | -29.6 | 42.7 | 16.8 | 21.5 | 52.0 | 19.3 | 0.2 | 0.4 |
| 9  |                  | 37.4  | 42.9 | 20.7  | 42.5 | -3.6  | 42.9 | -21.5 | 42.7 | 16.7 | 21.3 | 52.0 | 18.0 | 0.3 | 0.8 |
| 10 | Catch            | 46.0  | 42.5 | 28.9  | 42.4 | 6.6   | 43.3 | -12.4 | 42.9 | 16.1 | 20.5 | 52.0 | 19.0 | 0.5 | 1.4 |
| 11 |                  | 53.2  | 42.5 | 37.8  | 42.5 | 14.5  | 42.9 | -4.4  | 42.7 | 15.4 | 19.9 | 52.2 | 18.9 | 0.3 | 0.8 |
| 12 |                  | 59.2  | 43.3 | 43.4  | 43.2 | 20.3  | 43.4 | 1.7   | 43.1 | 15.8 | 20.1 | 51.9 | 18.6 | 0.3 | 0.9 |
| 13 |                  | 66.2  | 43.9 | 50.7  | 43.8 | 28.3  | 43.8 | 8.5   | 43.3 | 15.4 | 19.6 | 51.9 | 19.8 | 0.5 | 1.5 |
| 14 |                  | 74.0  | 43.4 | 58.1  | 43.0 | 36.1  | 43.5 | 16.6  | 42.9 | 15.8 | 20.2 | 52.0 | 19.5 | 0.5 | 1.6 |
| 15 |                  | 79.6  | 43.1 | 63.8  | 42.7 | 40.9  | 43.6 | 22.3  | 43.1 | 15.8 | 20.1 | 51.9 | 18.6 | 0.4 | 1.4 |
| 16 |                  | 87.3  | 43.5 | 70.7  | 43.2 | 48.3  | 44.0 | 30.4  | 43.5 | 16.6 | 20.9 | 51.6 | 18.9 | 0.5 | 1.5 |
| 17 |                  | 93.5  | 43.2 | 76.3  | 42.8 | 56.2  | 43.6 | 36.0  | 43.2 | 17.2 | 21.7 | 51.6 | 19.2 | 0.4 | 1.1 |
| 18 |                  | 100.5 | 43.3 | 83.6  | 43.1 | 61.4  | 43.8 | 43.1  | 43.6 | 16.9 | 21.2 | 51.5 | 18.3 | 0.2 | 0.6 |
| 19 |                  | 105.5 | 42.6 | 89.1  | 42.3 | 66.9  | 42.6 | 48.5  | 42.2 | 16.3 | 21.2 | 52.4 | 18.4 | 0.4 | 1.3 |
| 20 |                  | 112.4 | 42.6 | 95.0  | 42.4 | 73.6  | 44.2 | 54.6  | 43.8 | 17.5 | 21.8 | 51.3 | 19.0 | 0.5 | 1.4 |
| 21 |                  | 118.1 | 42.9 | 100.2 | 42.7 | 79.2  | 43.9 | 59.2  | 43.3 | 18.0 | 22.5 | 51.5 | 20.0 | 0.6 | 1.8 |
| 22 |                  | 124.3 | 42.6 | 107.1 | 42.3 | 86.5  | 44.9 | 66.7  | 44.2 | 17.2 | 21.3 | 51.1 | 19.8 | 0.8 | 2.2 |
| 23 |                  | 130.5 | 42.0 | 113.1 | 41.7 | 91.9  | 44.4 | 73.8  | 43.9 | 17.4 | 21.7 | 51.2 | 18.1 | 0.5 | 1.6 |
| 24 |                  | 134.7 | 41.8 | 118.6 | 41.6 | 97.8  | 44.5 | 78.7  | 44.1 | 16.1 | 20.1 | 51.3 | 19.1 | 0.4 | 1.2 |
| 25 |                  | 141.3 | 42.8 | 124.8 | 42.6 | 103.6 | 44.8 | 84.5  | 44.4 | 16.5 | 20.4 | 51.0 | 19.1 | 0.4 | 1.1 |
| 26 |                  | 150.6 | 42.6 | 133.7 | 42.2 | 112.0 | 44.7 | 93.1  | 44.4 | 16.9 | 20.8 | 51.0 | 18.9 | 0.3 | 0.9 |
| 27 |                  | 156.3 | 41.6 | 140.2 | 41.2 | 118.0 | 45.2 | 98.9  | 44.8 | 16.2 | 19.9 | 50.9 | 19.1 | 0.4 | 1.3 |
| 28 |                  | 163.8 | 42.8 | 146.8 | 42.6 | 124.9 | 45.0 | 108.0 | 44.9 | 16.9 | 20.7 | 50.7 | 17.0 | 0.1 | 0.5 |
| 29 |                  | 171.5 | 42.2 | 155.0 | 41.8 | 133.4 | 45.8 | 114.2 | 45.5 | 16.5 | 19.9 | 50.4 | 19.2 | 0.3 | 1.0 |
| 30 |                  | 177.5 | 42.6 | 161.0 | 42.3 | 140.3 | 46.2 | 120.4 | 44.6 | 16.5 | 20.3 | 51.0 | 19.9 | 0.7 | 1.9 |
| 31 |                  | 182.6 | 40.8 | 166.6 | 40.7 | 146.4 | 46.1 | 127.1 | 44.6 | 15.9 | 19.7 | 51.0 | 19.2 | 0.6 | 1.7 |
| 32 |                  | 191.2 | 41.8 | 175.2 | 41.6 | 153.4 | 45.5 | 135.9 | 45.1 | 15.9 | 19.5 | 50.7 | 17.5 | 0.5 | 1.5 |
| 33 |                  | 196.4 | 40.9 | 180.3 | 40.6 | 159.2 | 44.7 | 141.3 | 44.3 | 16.1 | 20.0 | 51.2 | 17.9 | 0.4 | 1.3 |
| 34 |                  | 204.4 | 41.8 | 186.3 | 41.4 | 167.4 | 45.4 | 149.7 | 45.1 | 16.1 | 19.7 | 50.7 | 17.7 | 0.4 | 1.1 |
| 35 |                  | 210.8 | 42.0 | 194.9 | 41.9 | 173.9 | 46.3 | 156.3 | 45.0 | 15.9 | 19.5 | 50.8 | 18.6 | 0.3 | 1.1 |
| 36 | End of Leg Drive | 219.2 | 41.8 | 203.0 | 41.8 | 181.4 | 46.3 | 163.0 | 45.0 | 16.2 | 18.7 | 50.9 | 18.4 | 0.4 | 1.1 |
| 37 |                  | 224.6 | 40.8 | 209.0 | 40.8 | 189.1 | 44.7 | 170.1 | 44.2 | 15.6 | 19.5 | 51.3 | 18.9 | 0.5 | 1.5 |

|    |        |       |      |       |      |       |      |       |      |      |      |      |      |      |      |
|----|--------|-------|------|-------|------|-------|------|-------|------|------|------|------|------|------|------|
| 38 |        | 233.9 | 41.9 | 216.9 | 41.5 | 196.7 | 45.4 | 179.7 | 45.1 | 17.0 | 20.7 | 50.6 | 17.0 | 0.3  | 1.0  |
| 39 |        | 238.8 | 41.1 | 224.0 | 41.1 | 202.8 | 45.4 | 194.3 | 45.0 | 14.8 | 18.2 | 51.0 | 18.5 | 0.4  | 1.4  |
| 40 |        | 247.0 | 41.9 | 232.5 | 41.7 | 210.8 | 44.8 | 192.8 | 44.5 | 14.5 | 19.1 | 51.3 | 18.0 | 0.3  | 1.0  |
| 41 |        | 253.4 | 41.0 | 239.0 | 41.0 | 218.5 | 45.3 | 200.7 | 45.3 | 14.4 | 17.6 | 50.8 | 17.8 | 0.0  | 0.1  |
| 42 |        | 263.5 | 41.5 | 247.6 | 41.6 | 227.7 | 45.6 | 209.7 | 45.2 | 16.0 | 19.5 | 50.7 | 18.0 | 0.5  | 1.5  |
| 43 |        | 269.1 | 40.9 | 253.4 | 40.9 | 232.9 | 44.4 | 214.6 | 44.4 | 15.7 | 19.5 | 51.2 | 18.3 | 0.0  | 0.1  |
| 44 |        | 277.4 | 41.4 | 261.6 | 41.5 | 242.2 | 44.6 | 223.1 | 44.4 | 15.8 | 19.6 | 51.2 | 19.1 | 0.3  | 0.8  |
| 45 |        | 284.6 | 41.9 | 268.3 | 41.8 | 248.6 | 45.2 | 230.3 | 44.9 | 16.3 | 20.0 | 50.8 | 18.3 | 0.3  | 0.8  |
| 46 |        | 292.3 | 42.4 | 276.6 | 42.3 | 256.7 | 45.1 | 238.9 | 44.8 | 15.7 | 19.3 | 50.9 | 17.9 | 0.3  | 0.9  |
| 47 |        | 300.4 | 42.7 | 283.8 | 42.8 | 265.9 | 46.3 | 247.9 | 45.0 | 16.6 | 20.3 | 50.7 | 18.0 | 0.3  | 1.0  |
| 48 |        | 307.6 | 42.4 | 291.3 | 42.3 | 273.3 | 45.0 | 255.0 | 44.8 | 16.3 | 20.0 | 50.8 | 18.3 | 0.2  | 0.6  |
| 49 |        | 315.0 | 43.4 | 299.4 | 43.4 | 280.2 | 44.9 | 262.4 | 45.1 | 15.6 | 19.1 | 50.8 | 17.8 | -0.2 | -0.6 |
| 50 |        | 324.8 | 42.5 | 308.5 | 42.2 | 289.7 | 45.2 | 271.5 | 45.0 | 16.3 | 19.9 | 50.7 | 18.2 | 0.2  | 0.6  |
| 51 |        | 330.9 | 43.5 | 314.9 | 43.1 | 296.0 | 44.7 | 277.3 | 44.4 | 16.0 | 19.8 | 51.1 | 18.7 | 0.3  | 0.9  |
| 52 |        | 338.0 | 43.8 | 323.3 | 43.6 | 305.2 | 45.1 | 286.5 | 45.2 | 14.7 | 19.0 | 50.8 | 18.6 | -0.1 | -0.3 |
| 53 |        | 348.0 | 42.9 | 331.6 | 42.9 | 314.2 | 45.0 | 297.3 | 45.0 | 16.4 | 20.0 | 50.8 | 16.9 | 0.1  | 0.3  |
| 54 |        | 356.8 | 43.9 | 340.5 | 43.8 | 322.2 | 45.5 | 303.7 | 45.4 | 15.2 | 18.6 | 50.7 | 18.5 | 0.2  | 0.5  |
| 55 |        | 362.5 | 44.1 | 346.6 | 44.0 | 328.2 | 44.4 | 311.1 | 44.3 | 15.9 | 19.7 | 51.2 | 17.1 | 0.2  | 0.5  |
| 56 |        | 372.2 | 44.0 | 356.5 | 43.8 | 338.3 | 45.4 | 320.7 | 45.6 | 15.8 | 19.1 | 50.4 | 17.6 | -0.2 | -0.7 |
| 57 |        | 379.4 | 43.6 | 363.3 | 43.5 | 345.6 | 45.1 | 328.1 | 45.3 | 16.1 | 19.6 | 50.6 | 17.5 | -0.1 | -0.4 |
| 58 |        | 387.6 | 44.5 | 372.2 | 44.5 | 354.3 | 46.0 | 336.7 | 45.8 | 15.4 | 18.7 | 50.4 | 17.6 | 0.3  | 0.9  |
| 59 |        | 395.2 | 44.0 | 380.1 | 43.8 | 362.2 | 45.7 | 345.0 | 45.6 | 15.1 | 19.3 | 50.5 | 17.2 | 0.1  | 0.2  |
| 60 | Finish | 403.8 | 44.6 | 388.4 | 44.7 | 370.9 | 46.6 | 353.2 | 46.3 | 15.4 | 18.4 | 50.1 | 17.8 | 0.3  | 1.1  |
| 61 |        | 411.3 | 43.9 | 395.4 | 44.1 | 378.1 | 46.3 | 360.3 | 45.9 | 15.9 | 19.1 | 50.3 | 17.7 | 0.3  | 1.1  |
| 62 |        | 420.1 | 45.4 | 404.3 | 45.6 | 387.7 | 46.0 | 368.5 | 45.9 | 15.8 | 19.0 | 50.3 | 19.2 | 0.1  | 0.3  |
| 63 |        | 427.9 | 44.1 | 412.3 | 44.0 | 394.6 | 46.1 | 377.0 | 45.9 | 15.6 | 18.8 | 50.3 | 17.6 | 0.3  | 0.8  |
| 64 |        | 435.7 | 44.9 | 419.7 | 44.6 | 403.0 | 46.1 | 385.2 | 45.9 | 16.1 | 19.3 | 50.3 | 17.8 | 0.2  | 0.7  |
| 65 |        | 444.0 | 43.9 | 429.1 | 44.1 | 411.4 | 45.3 | 393.2 | 45.4 | 14.9 | 18.1 | 50.7 | 18.2 | -0.1 | -0.2 |
| 66 |        | 452.2 | 43.3 | 436.2 | 43.2 | 418.5 | 46.6 | 401.2 | 46.3 | 16.0 | 19.1 | 50.0 | 17.3 | 0.3  | 1.0  |
| 67 |        | 460.2 | 43.6 | 444.1 | 43.4 | 427.7 | 45.4 | 410.9 | 45.1 | 16.0 | 19.6 | 50.7 | 16.8 | 0.3  | 1.1  |
| 68 |        | 469.5 | 43.9 | 454.4 | 43.9 | 437.8 | 47.0 | 419.5 | 46.9 | 15.1 | 17.8 | 49.8 | 18.3 | 0.1  | 0.4  |
| 69 |        | 478.6 | 43.4 | 463.3 | 43.4 | 446.5 | 46.1 | 427.9 | 45.9 | 15.3 | 18.4 | 50.3 | 18.5 | 0.2  | 0.6  |
| 70 |        | 486.4 | 43.6 | 470.7 | 43.6 | 453.5 | 46.9 | 436.3 | 46.8 | 15.7 | 18.6 | 49.8 | 17.2 | 0.1  | 0.5  |
|    |        |       |      |       |      |       |      |       | Max  | 18.6 | 23.6 | 52.6 | 21.7 | 0.8  | 2.2  |
|    |        |       |      |       |      |       |      |       | Min  | 14.4 | 17.6 | 49.8 | 16.8 | -0.2 | -0.7 |
|    |        |       |      |       |      |       |      |       | Diff | 4.2  | 6.0  | 2.9  | 4.9  | 1.0  | 2.9  |

| Calculation of $\Psi$ (Movements in the xy plane) |        |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|---------------------------------------------------|--------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Frame                                             | Event  | Trial 6           |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                   |        |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |                   |
|                                                   |        | $X(\text{rfcam})$ | $Y(\text{rfcam})$ | $X(\text{rfbcm})$ | $Y(\text{rfbcm})$ | $X(\text{rfcam})$ | $Y(\text{rfcam})$ | $X(\text{rfbcm})$ | $Y(\text{rfbcm})$ | $X(\text{rfcam})$ | $Y(\text{rfcam})$ | $X(\text{rfbcm})$ | $Y(\text{rfbcm})$ |
| [ 0.017s]                                         | (cm)   | (cm)              | (cm)              | (cm)              | (cm)              | (cm)              | (cm)              | (cm)              | $X(\text{rfbcm})$ | $Y(\text{rfbcm})$ | $X(\text{rfbcm})$ | $Y(\text{rfbcm})$ |                   |
| 1                                                 |        | 44.5              | 40.2              | 26.2              | 39.7              | 7.4               | 39.2              | -11.1             | 38.7              | 16.3              | 22.9              | 18.5              | 0.4               |
| 2                                                 |        | 50.6              | 40.1              | 36.7              | 39.7              | 15.6              | 37.4              | -2.5              | 36.7              | 14.0              | 20.8              | 18.1              | 0.7               |
| 3                                                 |        | 59.6              | 39.9              | 43.5              | 39.5              | 23.2              | 38.7              | 6.1               | 38.0              | 16.1              | 23.1              | 55.0              | 17.1              |
| 4                                                 |        | 65.8              | 41.7              | 48.9              | 41.1              | 29.7              | 38.9              | 11.9              | 38.2              | 15.8              | 22.6              | 54.9              | 16.8              |
| 5                                                 |        | 74.6              | 40.7              | 59.6              | 40.3              | 38.8              | 39.2              | 21.1              | 38.6              | 15.1              | 21.3              | 54.8              | 17.6              |
| 6                                                 |        | 80.2              | 41.3              | 66.1              | 41.0              | 45.7              | 38.7              | 28.2              | 38.3              | 14.1              | 20.3              | 55.1              | 17.5              |
| 7                                                 |        | 89.5              | 41.3              | 74.6              | 40.8              | 55.0              | 39.3              | 36.8              | 38.8              | 14.9              | 21.0              | 54.7              | 18.2              |
| 8                                                 |        | 97.5              | 41.5              | 82.1              | 41.0              | 62.1              | 39.1              | 44.9              | 38.5              | 15.4              | 21.8              | 54.8              | 17.2              |
| 9                                                 |        | 103.7             | 42.6              | 88.4              | 42.3              | 69.3              | 39.3              | 51.7              | 38.7              | 15.3              | 21.6              | 54.7              | 17.6              |
| 10                                                | Finish | 110.2             | 42.8              | 94.8              | 42.1              | 76.9              | 41.1              | 58.7              | 40.7              | 15.4              | 20.7              | 53.4              | 18.2              |
| 11                                                |        | 120.0             | 43.2              | 104.2             | 42.6              | 86.2              | 39.7              | 67.5              | 39.1              | 15.8              | 22.0              | 54.3              | 17.8              |
| 12                                                |        | 127.2             | 43.4              | 111.1             | 43.0              | 92.5              | 40.8              | 74.0              | 40.3              | 16.0              | 21.7              | 53.6              | 18.5              |
| 13                                                |        | 134.7             | 44.2              | 119.2             | 43.7              | 100.4             | 41.0              | 82.7              | 40.4              | 15.5              | 21.0              | 53.6              | 17.7              |
| 14                                                |        | 142.6             | 44.1              | 127.3             | 43.8              | 108.5             | 41.3              | 90.6              | 40.7              | 15.3              | 20.6              | 53.5              | 17.9              |
| 15                                                |        | 149.9             | 43.4              | 135.3             | 42.8              | 115.4             | 40.7              | 98.0              | 40.1              | 14.5              | 19.9              | 53.9              | 17.4              |
| 16                                                |        | 158.9             | 44.7              | 143.4             | 44.5              | 123.6             | 42.1              | 106.3             | 41.5              | 15.6              | 20.5              | 52.9              | 17.2              |
| 17                                                |        | 167.5             | 43.8              | 151.3             | 43.3              | 132.7             | 41.4              | 114.9             | 40.7              | 16.1              | 21.6              | 53.3              | 17.8              |
| 18                                                |        | 174.9             | 45.0              | 159.4             | 44.5              | 139.6             | 42.2              | 123.3             | 41.7              | 15.5              | 20.5              | 52.8              | 17.3              |
| 19                                                |        | 182.8             | 44.0              | 168.5             | 43.7              | 147.6             | 43.5              | 129.1             | 42.8              | 14.3              | 18.5              | 52.3              | 18.4              |
| 20                                                |        | 191.3             | 43.6              | 177.2             | 43.2              | 155.8             | 41.9              | 138.2             | 41.5              | 14.1              | 18.8              | 53.1              | 17.6              |
| 21                                                |        | 199.4             | 43.5              | 185.8             | 43.3              | 163.1             | 42.5              | 146.0             | 42.0              | 13.8              | 20.6              | 52.6              | 18.1              |
| 22                                                |        | 205.8             | 44.2              | 191.2             | 44.1              | 170.8             | 43.1              | 153.6             | 42.7              | 14.6              | 18.9              | 52.3              | 17.3              |
| 23                                                |        | 215.9             | 43.6              | 200.2             | 43.1              | 180.2             | 42.1              | 163.1             | 41.6              | 15.7              | 20.7              | 52.9              | 17.1              |
| 24                                                |        | 223.9             | 43.5              | 208.2             | 43.1              | 188.7             | 42.5              | 170.3             | 41.9              | 15.7              | 20.5              | 52.6              | 18.4              |
| 25                                                |        | 230.5             | 43.7              | 214.6             | 43.3              | 196.7             | 42.8              | 177.9             | 42.3              | 16.0              | 20.7              | 52.4              | 17.9              |
| 26                                                |        | 239.5             | 44.1              | 224.8             | 43.7              | 206.0             | 42.3              | 187.0             | 41.6              | 14.7              | 19.4              | 53.0              | 19.0              |
| 27                                                |        | 246.7             | 42.5              | 231.7             | 42.1              | 211.7             | 42.9              | 194.3             | 42.0              | 15.0              | 19.7              | 52.7              | 17.4              |



|    |                    |       |      |       |      |       |      |       |      |      |      |      |      |     |     |
|----|--------------------|-------|------|-------|------|-------|------|-------|------|------|------|------|------|-----|-----|
| 28 | Beg. Seet<br>Movt. | 265.5 | 45.6 | 240.0 | 45.2 | 220.5 | 43.3 | 203.0 | 42.6 | 15.5 | 20.0 | 52.3 | 17.5 | 0.7 | 2.4 |
| 29 |                    | 265.4 | 43.4 | 249.2 | 43.2 | 229.4 | 43.5 | 211.3 | 42.9 | 16.3 | 20.7 | 51.9 | 18.1 | 0.8 | 1.9 |
| 30 |                    | 273.0 | 44.3 | 256.5 | 44.1 | 238.0 | 43.1 | 219.8 | 42.3 | 16.5 | 21.3 | 52.3 | 18.2 | 0.8 | 2.5 |
| 31 |                    | 280.5 | 44.6 | 265.2 | 44.4 | 248.9 | 43.9 | 228.5 | 43.7 | 15.3 | 19.3 | 51.7 | 18.4 | 0.3 | 0.9 |
| 32 |                    | 291.3 | 45.2 | 275.7 | 45.0 | 256.5 | 44.2 | 238.1 | 43.4 | 15.6 | 19.7 | 51.8 | 18.5 | 0.8 | 2.5 |
| 33 |                    | 300.5 | 44.1 | 285.4 | 43.4 | 264.1 | 43.5 | 247.2 | 43.2 | 15.1 | 19.3 | 52.0 | 16.9 | 0.3 | 1.1 |
| 34 |                    | 307.7 | 45.3 | 292.9 | 44.9 | 273.1 | 43.3 | 254.5 | 42.3 | 14.8 | 19.3 | 52.5 | 18.6 | 1.0 | 3.0 |
| 35 |                    | 317.3 | 43.7 | 301.4 | 43.0 | 281.3 | 43.4 | 263.6 | 43.0 | 15.9 | 20.3 | 52.0 | 17.6 | 0.5 | 1.5 |
| 36 |                    | 325.1 | 45.3 | 311.0 | 44.9 | 290.5 | 43.5 | 272.8 | 43.0 | 15.1 | 19.3 | 52.1 | 17.8 | 0.6 | 1.8 |
| 37 |                    | 335.8 | 44.1 | 320.3 | 43.6 | 299.9 | 44.4 | 281.5 | 43.8 | 15.5 | 19.4 | 51.6 | 18.4 | 0.6 | 1.9 |
| 38 |                    | 346.2 | 45.4 | 329.7 | 45.0 | 308.5 | 43.6 | 292.0 | 43.3 | 16.5 | 20.9 | 51.7 | 17.5 | 0.3 | 1.1 |
| 39 |                    | 353.9 | 44.1 | 337.5 | 43.5 | 317.6 | 43.5 | 299.7 | 43.0 | 16.4 | 20.9 | 51.9 | 17.9 | 0.5 | 1.5 |
| 40 |                    | 363.2 | 45.3 | 347.3 | 44.8 | 326.5 | 43.9 | 306.2 | 43.4 | 15.9 | 20.1 | 51.7 | 18.3 | 0.5 | 1.7 |
| 41 |                    | 373.1 | 45.1 | 357.2 | 44.7 | 335.6 | 43.8 | 316.1 | 43.5 | 15.9 | 20.0 | 51.6 | 17.5 | 0.2 | 0.7 |
| 42 |                    | 380.9 | 45.4 | 365.2 | 44.9 | 344.9 | 43.5 | 326.9 | 43.1 | 15.7 | 20.1 | 51.9 | 18.0 | 0.4 | 1.4 |
| 43 |                    | 390.8 | 44.5 | 375.4 | 44.4 | 353.4 | 44.2 | 335.8 | 43.6 | 15.4 | 19.5 | 51.7 | 17.6 | 0.7 | 2.2 |
| 44 |                    | 400.0 | 45.0 | 384.9 | 44.8 | 362.4 | 42.7 | 344.8 | 42.2 | 15.1 | 19.7 | 52.5 | 17.5 | 0.5 | 1.5 |
| 45 |                    | 407.2 | 44.8 | 393.1 | 44.4 | 370.7 | 44.5 | 352.3 | 44.1 | 14.1 | 17.8 | 51.6 | 18.4 | 0.4 | 1.3 |
| 46 |                    | 416.3 | 45.1 | 402.5 | 45.0 | 381.1 | 43.5 | 362.6 | 42.7 | 15.8 | 20.3 | 52.1 | 18.5 | 0.7 | 2.3 |
| 47 |                    | 427.0 | 45.0 | 412.3 | 44.7 | 390.3 | 43.6 | 372.0 | 43.2 | 14.7 | 18.8 | 52.0 | 18.3 | 0.4 | 1.3 |
| 48 |                    | 435.9 | 45.4 | 419.8 | 44.9 | 398.7 | 43.6 | 379.5 | 42.9 | 16.1 | 20.6 | 52.0 | 19.2 | 0.6 | 1.9 |
| 49 |                    | 444.7 | 46.4 | 428.4 | 45.9 | 407.3 | 44.0 | 389.5 | 43.5 | 16.3 | 20.6 | 51.6 | 17.8 | 0.5 | 1.5 |
| 50 |                    | 452.1 | 46.0 | 436.5 | 45.8 | 416.3 | 43.5 | 397.8 | 42.8 | 15.5 | 19.9 | 52.1 | 18.5 | 0.7 | 2.2 |
| 51 |                    | 463.0 | 48.0 | 446.7 | 47.8 | 424.2 | 45.8 | 406.8 | 45.4 | 16.3 | 19.8 | 50.5 | 17.4 | 0.4 | 1.2 |
| 52 |                    | 470.8 | 46.7 | 456.2 | 46.4 | 432.8 | 43.6 | 415.1 | 43.2 | 14.7 | 18.7 | 52.0 | 17.7 | 0.4 | 1.4 |
| 53 |                    | 480.3 | 47.8 | 465.4 | 47.3 | 442.6 | 45.2 | 423.2 | 44.7 | 14.8 | 18.4 | 51.1 | 19.4 | 0.5 | 1.6 |
| 54 |                    | 489.7 | 46.0 | 473.1 | 45.8 | 449.6 | 43.3 | 431.2 | 42.7 | 16.6 | 21.2 | 52.0 | 18.4 | 0.6 | 1.8 |
| 55 |                    | 498.4 | 48.0 | 482.3 | 47.9 | 458.0 | 44.7 | 440.3 | 44.4 | 16.1 | 19.9 | 51.1 | 17.7 | 0.3 | 0.9 |
| 56 |                    | 505.0 | 47.4 | 489.9 | 47.1 | 465.8 | 44.2 | 448.0 | 43.8 | 15.1 | 19.0 | 51.6 | 17.8 | 0.4 | 1.3 |
| 57 |                    | 514.2 | 47.9 | 499.3 | 47.4 | 474.0 | 44.8 | 457.0 | 44.3 | 14.9 | 18.6 | 51.3 | 17.1 | 0.5 | 1.6 |
| 58 |                    | 521.8 | 48.0 | 505.6 | 47.5 | 482.4 | 45.8 | 464.7 | 45.2 | 16.4 | 19.9 | 50.6 | 17.6 | 0.6 | 1.9 |
| 59 |                    | 529.4 | 47.6 | 512.4 | 47.3 | 491.3 | 45.2 | 471.9 | 44.6 | 17.0 | 20.9 | 50.9 | 19.4 | 0.6 | 1.8 |

|    |       |       |      |       |      |       |      |       |      |      |      |      |      |     |     |
|----|-------|-------|------|-------|------|-------|------|-------|------|------|------|------|------|-----|-----|
| 60 |       | 536.1 | 47.9 | 519.2 | 47.4 | 497.1 | 46.1 | 477.4 | 44.6 | 16.9 | 20.8 | 50.9 | 19.7 | 0.5 | 1.5 |
| 61 |       | 543.2 | 48.5 | 528.2 | 48.0 | 506.2 | 45.7 | 486.8 | 45.5 | 15.0 | 18.3 | 50.6 | 19.5 | 0.2 | 0.6 |
| 62 |       | 550.0 | 48.6 | 535.0 | 48.1 | 512.0 | 45.1 | 494.1 | 45.0 | 15.0 | 18.4 | 50.9 | 17.9 | 0.1 | 0.3 |
| 63 |       | 557.7 | 48.7 | 542.4 | 48.4 | 519.4 | 45.9 | 501.8 | 45.7 | 15.3 | 18.5 | 50.4 | 17.7 | 0.2 | 0.6 |
| 64 |       | 564.8 | 49.4 | 548.3 | 48.9 | 525.5 | 44.9 | 507.1 | 44.6 | 16.5 | 20.3 | 50.9 | 18.4 | 0.3 | 0.8 |
| 65 |       | 572.4 | 49.2 | 556.5 | 47.9 | 533.4 | 46.6 | 515.1 | 46.3 | 15.9 | 19.0 | 50.1 | 18.4 | 0.3 | 1.1 |
| 66 | Catch | 577.4 | 48.1 | 561.1 | 48.0 | 539.8 | 45.8 | 521.6 | 45.2 | 16.3 | 19.9 | 50.6 | 18.2 | 0.6 | 2.0 |
| 67 |       | 586.4 | 48.9 | 570.1 | 48.4 | 546.5 | 47.4 | 528.4 | 47.0 | 16.3 | 19.1 | 49.6 | 18.1 | 0.4 | 1.3 |
| 68 |       | 592.1 | 47.8 | 578.0 | 47.4 | 553.6 | 44.8 | 534.9 | 44.3 | 16.1 | 20.0 | 51.2 | 18.7 | 0.5 | 1.7 |
| 69 |       | 597.9 | 49.4 | 582.9 | 49.2 | 559.9 | 47.4 | 541.4 | 46.9 | 15.0 | 17.8 | 49.8 | 18.5 | 0.5 | 1.6 |
| 70 |       | 603.5 | 49.6 | 588.3 | 48.4 | 565.1 | 45.9 | 546.5 | 45.6 | 15.2 | 18.4 | 50.5 | 18.6 | 0.3 | 1.0 |
| 71 |       | 611.4 | 48.0 | 594.5 | 47.7 | 571.8 | 46.2 | 553.0 | 45.7 | 16.9 | 20.4 | 50.3 | 18.8 | 0.5 | 1.6 |
| 72 |       | 617.1 | 49.1 | 599.7 | 48.9 | 578.4 | 47.0 | 556.1 | 46.6 | 17.4 | 20.5 | 49.7 | 20.3 | 0.3 | 0.9 |
| 73 |       | 624.3 | 48.2 | 606.6 | 47.7 | 582.7 | 46.4 | 563.3 | 45.9 | 17.7 | 21.1 | 50.0 | 19.4 | 0.5 | 1.5 |
| 74 |       | 628.4 | 47.9 | 609.7 | 47.4 | 586.6 | 46.5 | 569.0 | 46.2 | 18.6 | 22.0 | 49.8 | 19.6 | 0.4 | 1.2 |
| 75 |       | 633.4 | 48.7 | 618.3 | 48.4 | 594.7 | 46.7 | 576.1 | 45.9 | 15.1 | 18.2 | 50.3 | 19.6 | 0.8 | 2.2 |
| 76 |       | 640.8 | 47.1 | 624.5 | 47.0 | 601.3 | 45.3 | 582.8 | 45.0 | 16.3 | 19.9 | 50.8 | 18.5 | 0.4 | 1.2 |
|    |       |       |      |       |      |       |      |       | Max  | 18.6 | 23.1 | 56.2 | 20.3 | 1.0 | 3.0 |
|    |       |       |      |       |      |       |      |       | Min  | 14.0 | 17.8 | 49.6 | 16.8 | 0.1 | 0.3 |
|    |       |       |      |       |      |       |      |       | Diff | 4.7  | 5.3  | 6.6  | 3.5  | 0.9 | 2.7 |

## APPENDIX I

### Table of Movements of the Mobile Video Platform

|                                                                     |                    |                    |               |                    |                    |               |             |             |
|---------------------------------------------------------------------|--------------------|--------------------|---------------|--------------------|--------------------|---------------|-------------|-------------|
| <b>Movements of the MVP.</b>                                        |                    |                    |               |                    |                    |               |             |             |
| <b>Bold values were the values used as the movement of the MVP.</b> |                    |                    |               |                    |                    |               |             |             |
| <b>Digitizing error</b>                                             |                    |                    |               |                    |                    |               |             |             |
|                                                                     | <b>Trial 1</b>     |                    |               |                    |                    |               |             |             |
|                                                                     | X(lfcamLen)        | Y(lfcamLen)        | Z(lfcamLen)   | lfcamLen           | X(rtcamLen)        | Y(rtcamLen)   | Z(rtcamLen) | rtcamLen    |
|                                                                     | (cm)               | (cm)               | (cm)          | (cm)               | (cm)               | (cm)          | (cm)        | (cm)        |
| <b>Maximum</b>                                                      | <b>17.8</b>        | <b>0.6</b>         | <b>5.1</b>    | <b>17.8</b>        | <b>19.4</b>        | <b>0.8</b>    | <b>5.2</b>  | <b>19.6</b> |
| <b>Minimum</b>                                                      | <b>14.6</b>        | <b>-0.3</b>        | <b>-1.0</b>   | <b>14.7</b>        | <b>16.4</b>        | <b>-0.1</b>   | <b>-2.1</b> | <b>16.5</b> |
| <b>Difference</b>                                                   | <b>3.2</b>         | <b>0.9</b>         | <b>6.1</b>    | <b>3.1</b>         | <b>3.0</b>         | <b>0.9</b>    | <b>7.3</b>  | <b>3.1</b>  |
|                                                                     | <b>Trial 2</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>31.9</b>        | <b>0.7</b>         | <b>7.0</b>    | <b>32.6</b>        | <b>20.8</b>        | <b>0.7</b>    | <b>4.0</b>  | <b>21.2</b> |
| <b>Minimum</b>                                                      | <b>14.4</b>        | <b>-0.2</b>        | <b>-6.7</b>   | <b>14.5</b>        | <b>16.9</b>        | <b>-0.1</b>   | <b>-3.4</b> | <b>16.9</b> |
| <b>Difference</b>                                                   | <b>17.5</b>        | <b>0.9</b>         | <b>12.6</b>   | <b>18.1</b>        | <b>3.9</b>         | <b>0.8</b>    | <b>7.5</b>  | <b>4.3</b>  |
|                                                                     | <b>Trial 5</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>18.6</b>        | <b>0.6</b>         | <b>5.0</b>    | <b>24.3</b>        | <b>21.7</b>        | <b>0.8</b>    | <b>6.3</b>  | <b>22.2</b> |
| <b>Minimum</b>                                                      | <b>14.4</b>        | <b>-0.3</b>        | <b>-1.2</b>   | <b>16.4</b>        | <b>16.8</b>        | <b>-0.2</b>   | <b>-0.9</b> | <b>16.8</b> |
| <b>Difference</b>                                                   | <b>4.2</b>         | <b>0.9</b>         | <b>6.2</b>    | <b>7.9</b>         | <b>4.9</b>         | <b>1.0</b>    | <b>7.1</b>  | <b>5.4</b>  |
|                                                                     | <b>Trial 6</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>18.6</b>        | <b>0.7</b>         | <b>4.0</b>    | <b>25.3</b>        | <b>20.3</b>        | <b>1.0</b>    | <b>5.9</b>  | <b>20.5</b> |
| <b>Minimum</b>                                                      | <b>14.0</b>        | <b>0.1</b>         | <b>-2.9</b>   | <b>17.9</b>        | <b>16.8</b>        | <b>0.1</b>    | <b>-2.9</b> | <b>17.0</b> |
| <b>Difference</b>                                                   | <b>4.7</b>         | <b>0.6</b>         | <b>6.9</b>    | <b>7.4</b>         | <b>3.5</b>         | <b>0.9</b>    | <b>8.8</b>  | <b>3.5</b>  |
| <b>Movements of the MVP in the YZ plane</b>                         |                    |                    |               |                    |                    |               |             |             |
|                                                                     | <b>Trial 1</b>     |                    |               |                    |                    |               |             |             |
|                                                                     | Y(fr) <sup>o</sup> | Z(fr) <sup>o</sup> | Arctan        | Y(bk) <sup>o</sup> | Z(bk) <sup>o</sup> | Arctan        |             |             |
|                                                                     | Y(lfrtcaml)-       | Z(lfrtcaml)-       | (Y(fr)/Z(fr)) | Y(lfbkcaml)-       | Z(lfbkcaml)-       | (Y(bk)/Z(bk)) |             |             |
|                                                                     | Y(rtrtcaml)        | Z(rtrtcaml)        |               | Y(rtbkcaml)        | Z(rtbkcaml)        |               |             |             |
|                                                                     | (cm)               | (cm)               | (degrees)     | (cm)               | (cm)               | (degrees)     |             |             |
| <b>Maximum</b>                                                      | <b>-86.7</b>       | <b>-301.6</b>      | <b>17.4</b>   | <b>1.3</b>         | <b>-300.2</b>      | <b>0.6</b>    |             |             |
| <b>Minimum</b>                                                      | <b>-96.2</b>       | <b>-307.7</b>      | <b>15.9</b>   | <b>-3.4</b>        | <b>-309.0</b>      | <b>-0.2</b>   |             |             |
| <b>Differenc</b>                                                    | <b>9.5</b>         | <b>6.2</b>         | <b>1.5</b>    | <b>4.7</b>         | <b>8.8</b>         | <b>0.9</b>    |             |             |
|                                                                     | <b>Trial 2</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>-86.5</b>       | <b>-304.0</b>      | <b>17.1</b>   | <b>2.4</b>         | <b>-304.2</b>      | <b>0.2</b>    |             |             |
| <b>Minimum</b>                                                      | <b>-94.1</b>       | <b>-310.4</b>      | <b>15.8</b>   | <b>-1.1</b>        | <b>-311.4</b>      | <b>-0.4</b>   |             |             |
| <b>Differenc</b>                                                    | <b>7.7</b>         | <b>6.4</b>         | <b>1.3</b>    | <b>3.5</b>         | <b>7.2</b>         | <b>0.6</b>    |             |             |
|                                                                     | <b>Trial 5</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>-83.0</b>       | <b>-305.0</b>      | <b>16.2</b>   | <b>0.5</b>         | <b>-302.9</b>      | <b>0.8</b>    |             |             |
| <b>Minimum</b>                                                      | <b>-91.4</b>       | <b>-316.0</b>      | <b>15.2</b>   | <b>-4.3</b>        | <b>-315.5</b>      | <b>-0.1</b>   |             |             |
| <b>Differenc</b>                                                    | <b>8.5</b>         | <b>11.0</b>        | <b>1.0</b>    | <b>4.8</b>         | <b>12.7</b>        | <b>0.9</b>    |             |             |
|                                                                     | <b>Trial 6</b>     |                    |               |                    |                    |               |             |             |
| <b>Maximum</b>                                                      | <b>-77.5</b>       | <b>-296.9</b>      | <b>17.5</b>   | <b>4.2</b>         | <b>-293.4</b>      | <b>0.0</b>    |             |             |
| <b>Minimum</b>                                                      | <b>-96.8</b>       | <b>-310.1</b>      | <b>14.6</b>   | <b>-0.2</b>        | <b>-310.7</b>      | <b>-0.8</b>   |             |             |
| <b>Differenc</b>                                                    | <b>19.3</b>        | <b>13.2</b>        | <b>2.9</b>    | <b>4.5</b>         | <b>17.2</b>        | <b>0.8</b>    |             |             |

| Movements of the MVP with respect to the shell in the XZ plane  |                                             |             |                            |             |             |              |
|-----------------------------------------------------------------|---------------------------------------------|-------------|----------------------------|-------------|-------------|--------------|
|                                                                 |                                             |             |                            |             |             |              |
| x-axis movement                                                 | 17.4                                        | cm          |                            |             |             |              |
| z-axis movement                                                 | 16.6                                        | cm          | f MVP to camera = 128.3 cm |             |             |              |
|                                                                 | a change of 16.6 cm changes this to 111.8cm |             |                            |             |             |              |
| arctan (x-axis movement/z-axis movement =                       |                                             |             |                            |             |             |              |
|                                                                 |                                             |             |                            | 8.9         | degrees     |              |
| Movements of the MVP in the XY plane                            |                                             |             |                            |             |             |              |
|                                                                 |                                             |             | Trial 1                    |             |             |              |
|                                                                 | X(lf)=                                      | Y(lf)=      | Arctan                     | X(rt)=      | Y(rt)=      | Arctan       |
|                                                                 | X(lftrcam)-                                 | Y(lftrcam)- | (Y(lf)/X(lf))              | X(rftrcam)- | Y(rftrcam)- | (Y(rt)/X(rt) |
|                                                                 | X(lfbkcam)                                  | Y(lfbkcam)  | degrees                    | X(rfbkcam)  | Y(rfbkcam)  | degrees      |
|                                                                 | (cm)                                        | (cm)        | (degrees)                  | (cm)        | (cm)        | (degrees)    |
| Maximum                                                         | 17.8                                        | 0.6         | 2.2                        | 19.4        | 0.8         | 2.5          |
| Minimum                                                         | 14.6                                        | -0.3        | -1.0                       | 16.4        | -0.1        | -0.4         |
| Differenc                                                       | 3.2                                         | 0.9         | 3.2                        | 3.0         | 0.9         | 3.0          |
|                                                                 |                                             |             | Trial 2                    |             |             |              |
| Maximum                                                         | 31.9                                        | 0.7         | 2.3                        | 20.8        | 0.7         | 2.2          |
| Minimum                                                         | 14.4                                        | -0.2        | -0.8                       | 16.9        | -0.1        | -0.3         |
| Differenc                                                       | 17.5                                        | 0.9         | 3.0                        | 3.9         | 0.8         | 2.5          |
|                                                                 |                                             |             | Trial 5                    |             |             |              |
| Maximum                                                         | 18.6                                        | 23.6        | 52.6                       | 21.7        | 0.8         | 2.2          |
| Minimum                                                         | 14.4                                        | 17.6        | 49.8                       | 16.8        | -0.2        | -0.7         |
| Differenc                                                       | 4.2                                         | 6.0         | 2.9                        | 4.9         | 1.0         | 2.9          |
|                                                                 |                                             |             | Trial 6                    |             |             |              |
| Maximum                                                         | 18.6                                        | 23.1        | 56.2                       | 20.3        | 1.0         | 3.0          |
| Minimum                                                         | 14.0                                        | 17.8        | 49.6                       | 16.8        | 0.1         | 0.3          |
| Differenc                                                       | 4.7                                         | 6.3         | 6.6                        | 3.5         | 0.9         | 2.7          |
|                                                                 |                                             |             |                            |             |             |              |
| Movements of the MVP with respect to the shell along the x axis |                                             |             |                            |             |             |              |
|                                                                 | Trial 1                                     |             |                            |             |             |              |
|                                                                 | x(shell)-                                   | x(shell)-   |                            |             |             |              |
|                                                                 | x(lftrtoam)                                 | x(rftrtoam) |                            |             |             |              |
|                                                                 | (cm)                                        | (cm)        |                            |             |             |              |
| Maximum                                                         | 133.3                                       | 165.8       |                            |             |             |              |
| Minimum                                                         | 127.2                                       | 161.0       |                            |             |             |              |
| Differenc                                                       | -6.1                                        | -4.8        |                            |             |             |              |
|                                                                 | Trial 2                                     |             |                            |             |             |              |
| Maximum                                                         | 140.2                                       | 166.2       |                            |             |             |              |
| Minimum                                                         | 135.2                                       | 157.3       |                            |             |             |              |
| Differenc                                                       | -5.0                                        | -7.9        |                            |             |             |              |
|                                                                 | Trial 5                                     |             |                            |             |             |              |
| Maximum                                                         | 136.7                                       | 176.0       |                            |             |             |              |
| Minimum                                                         | 129.0                                       | 162.0       |                            |             |             |              |
| Differenc                                                       | -7.6                                        | -14.0       |                            |             |             |              |
|                                                                 | Trial 6                                     |             |                            |             |             |              |
| Maximum                                                         | 142.2                                       | 181.7       |                            |             |             |              |
| Minimum                                                         | 128.4                                       | 164.3       |                            |             |             |              |
| Differenc                                                       | -13.8                                       | -17.4       |                            |             |             |              |

|                                                                        |                |            |  |  |  |  |  |  |
|------------------------------------------------------------------------|----------------|------------|--|--|--|--|--|--|
|                                                                        |                |            |  |  |  |  |  |  |
| <b>Movements of the MVP along the y axis</b>                           |                |            |  |  |  |  |  |  |
|                                                                        | <b>Trial 1</b> |            |  |  |  |  |  |  |
|                                                                        | Y(lrtcam)      | Y(rtrtcam) |  |  |  |  |  |  |
|                                                                        | (cm)           | (cm)       |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 47.4           | 49.0       |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | 42.7           | 43.9       |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 4.7            | 5.1        |  |  |  |  |  |  |
|                                                                        | <b>Trial 2</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 47.6           | 47.4       |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | 43.8           | 42.7       |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 3.8            | 4.8        |  |  |  |  |  |  |
|                                                                        | <b>Trial 5</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 45.4           | 47.0       |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | 40.8           | 42.2       |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 4.7            | 4.9        |  |  |  |  |  |  |
|                                                                        | <b>Trial 6</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 49.4           | 47.4       |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | 39.9           | 37.4       |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 9.5            | 10.0       |  |  |  |  |  |  |
| <b>Movements of the MVP with respect to the shell along the z axis</b> |                |            |  |  |  |  |  |  |
|                                                                        | <b>Trial 1</b> |            |  |  |  |  |  |  |
|                                                                        | dz(lrtcam)→    |            |  |  |  |  |  |  |
|                                                                        | dz(rtrtcam)    |            |  |  |  |  |  |  |
|                                                                        | (cm)           |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 6.3            |            |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | -5.7           |            |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 11.9           |            |  |  |  |  |  |  |
|                                                                        | <b>Trial 2</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 8.1            |            |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | -8.5           |            |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 16.6           |            |  |  |  |  |  |  |
|                                                                        | <b>Trial 5</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 9.3            |            |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | -3.7           |            |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 12.9           |            |  |  |  |  |  |  |
|                                                                        | <b>Trial 6</b> |            |  |  |  |  |  |  |
| <b>Maximum</b>                                                         | 8.2            |            |  |  |  |  |  |  |
| <b>Minimum</b>                                                         | -4.1           |            |  |  |  |  |  |  |
| <b>Differenc</b>                                                       | 12.3           |            |  |  |  |  |  |  |

## APPENDIX J

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point A

| $\chi^2_{\text{total}} = 149.0$ cm, $X_{\text{center}} = 77.0$ cm, $Z_{\text{center}} = 76.2$ cm |  |       |       |       |       |       |       |       |       | Raw Coordinates |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|--------------------------------------------------------------------------------------------------|--|-------|-------|-------|-------|-------|-------|-------|-------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|-------|-------|----------|-------|-------|-----------|--|--|
| $Z$ (cm)                                                                                         |  | -18   |       |       | -14.4 |       |       | -10.8 |       |                 | -7.2  |       |       | -3.6  |       |       | 0     |       |       | 3.6   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$           | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 1                                                                                          |  | -14.4 | 5.4   | 6.7   | -15.6 | 5.3   | 8.2   | -16.0 | 5.0   | 9.1             | -13.4 | 4.8   | 10.7  | -8.4  | 5.1   | 12.6  | -3.5  | 4.1   | 15.0  | -4.8  | 4.3   | 15.9  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 2                                                                                          |  | -14.4 | 5.5   | 6.8   | -15.4 | 5.3   | 8.2   | -16.8 | 4.8   | 9.3             | -14.0 | 5.0   | 10.8  | -9.0  | 4.8   | 12.6  | -3.7  | 4.1   | 14.8  | -4.3  | 4.4   | 15.9  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 3                                                                                          |  | -14.7 | 5.4   | 6.8   | -16.0 | 5.5   | 8.3   | -16.2 | 5.1   | 9.3             | -13.3 | 5.0   | 10.8  | -8.8  | 5.1   | 12.6  | -3.7  | 4.1   | 15.1  | -5.0  | 4.1   | 15.5  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 4                                                                                          |  | -13.6 | 5.8   | 7.0   | -14.9 | 5.3   | 8.4   | -16.7 | 5.0   | 9.3             | -14.3 | 4.9   | 11.0  | -10.0 | 4.9   | 12.4  | -2.3  | 4.1   | 14.8  | -5.2  | 4.5   | 15.9  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 5                                                                                          |  | -14.8 | 5.2   | 6.9   | -15.7 | 5.6   | 8.6   | -16.6 | 5.0   | 9.4             | -13.4 | 5.0   | 10.8  | -9.2  | 5.0   | 12.5  | -3.6  | 4.0   | 15.0  | -4.4  | 4.4   | 15.7  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 6                                                                                          |  | -13.9 | 5.5   | 6.9   | -15.7 | 5.2   | 8.3   | -16.8 | 4.8   | 9.3             | -14.1 | 4.9   | 10.9  | -9.2  | 4.9   | 12.6  | -3.1  | 4.3   | 14.9  | -5.2  | 4.4   | 15.8  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 7                                                                                          |  | -14.7 | 5.5   | 6.9   | -15.6 | 5.5   | 8.3   | -16.7 | 5.0   | 9.2             | -13.3 | 5.0   | 10.8  | -8.4  | 5.0   | 12.7  | -3.9  | 4.0   | 14.9  | -5.1  | 4.3   | 15.5  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 8                                                                                          |  | -13.8 | 5.3   | 6.8   | -15.5 | 5.5   | 8.3   | -16.5 | 4.9   | 9.5             | -14.1 | 4.9   | 10.8  | -9.4  | 5.0   | 12.6  | -4.0  | 4.2   | 14.9  | -4.2  | 4.4   | 15.9  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 9                                                                                          |  | -14.4 | 5.3   | 6.8   | -16.0 | 5.5   | 8.4   | -15.4 | 4.8   | 9.3             | -13.5 | 4.9   | 10.7  | -8.4  | 5.1   | 12.6  | -4.4  | 4.1   | 15.0  | -4.7  | 4.2   | 15.7  |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 10                                                                                         |  | -14.0 | 5.8   | 6.9   | -15.4 | 5.3   | 8.2   | -16.9 | 4.9   | 9.2             | -13.9 | 4.8   | 10.9  | -9.0  | 4.9   | 12.5  | -3.0  | 4.0   | 14.8  | -4.6  | 4.4   | 15.7  |       |       |       |          |       |       |          |       |       |           |  |  |
| Average                                                                                          |  | -14.3 | 5.5   | 6.8   | -15.6 | 5.4   | 8.3   | -16.3 | 5.0   | 9.3             | -13.7 | 4.9   | 10.8  | -9.0  | 5.0   | 12.5  | -3.4  | 4.1   | 14.9  | -4.9  | 4.3   | 15.8  |       |       |       |          |       |       |          |       |       |           |  |  |
| St. Deviation                                                                                    |  | 0.4   | 0.18  | 0.07  | 0.33  | 0.13  | 0.10  | 0.52  | 0.07  | 0.12            | 0.36  | 0.07  | 0.07  | 0.50  | 0.06  | 0.12  | 0.57  | 0.09  | 0.10  | 0.36  | 0.11  | 0.13  |       |       |       |          |       |       |          |       |       |           |  |  |
| Raw Coordinates                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| $Z$ (cm)                                                                                         |  | 7.2   |       |       | 10.8  |       |       | 14.4  |       |                 | 18.0  |       |       | (w)   |       |       | $N_x$ |       |       | $N_y$ |       |       | $N_z$ |       |       | $N_{xy}$ |       |       | $N_{yz}$ |       |       | $N_{xyz}$ |  |  |
|                                                                                                  |  | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$           | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$ | $y_k$ | $z_k$ | $x_k$    | $y_k$ | $z_k$ | $x_k$    | $y_k$ | $z_k$ |           |  |  |
| Frame 1                                                                                          |  | -1.5  | 3.2   | 17.6  | 2.8   | 2.3   | 19.6  | 5.2   | 23    | 20.9            | 8.6   | 1.9   | 22.3  | -18.0 | -11.3 | 2.5   | -8.2  | 0.8   | -0.1  | 0.5   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 2                                                                                          |  | -1.2  | 3.1   | 17.6  | 2.7   | 2.6   | 19.7  | 5.0   | 23    | 20.9            | 8.7   | 2.1   | 22.3  | -10.8 | -13.3 | 2.0   | -5.7  | 1.2   | -0.2  | 0.5   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 3                                                                                          |  | -0.5  | 3.1   | 17.6  | 2.2   | 2.4   | 19.5  | 5.6   | 22    | 20.6            | 9.0   | 1.9   | 22.1  | -7.2  | -10.7 | 1.9   | -4.2  | 1.5   | -0.3  | 0.6   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 4                                                                                          |  | 5.4   | 14.0  | 2.5   | 2.4   | 19.5  | 6.2   | 2.1   | 21.1  | 9.7             | 2.1   | 22.2  | 0.0   | -0.4  | 1.1   | -0.1  |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 5                                                                                          |  | -0.7  | 2.5   | 17.6  | 2.2   | 2.4   | 19.6  | 5.1   | 23    | 20.9            | 8.7   | 2.0   | 22.2  | 3.6   | -1.9  | 1.3   | 0.8   | -0.5  | 0.4   | 0.2   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 6                                                                                          |  | 1.0   | 2.3   | 18.1  | 2.5   | 2.3   | 19.7  | 5.6   | 2.0   | 21.1            | 9.0   | 2.2   | 22.5  | 7.2   | -2.1  | 0.2   | -0.3  | 0.0   | 0.3   |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 7                                                                                          |  | -0.3  | 3.1   | 17.7  | 2.5   | 2.3   | 19.5  | 6.5   | 2.0   | 21.1            | 8.5   | 2.2   | 22.3  | 10.8  | 5.5   | -0.6  | 4.6   | 0.5   | -0.1  | 0.4   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 8                                                                                          |  | -1.8  | 3.1   | 17.7  | 2.8   | 2.6   | 19.5  | 6.2   | 2.0   | 21.1            | 8.8   | 2.2   | 22.4  | 14.4  | 8.6   | -0.8  | 5.9   | 0.6   | -0.1  | 0.4   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 9                                                                                          |  | -0.3  | 3.1   | 17.7  | 2.5   | 2.3   | 19.5  | 5.4   | 2.2   | 20.7            | 9.3   | 1.8   | 22.2  | 18.0  | 11.9  | -1.0  | 7.3   | 0.7   | -0.1  | 0.4   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Frame 10                                                                                         |  | -0.4  | 3.0   | 17.7  | 2.3   | 2.6   | 19.5  | 5.4   | 2.2   | 21.0            | 9.1   | 2.0   | 22.2  | 18.0  | 11.9  | -1.0  | 7.3   | 0.7   | -0.1  | 0.4   |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Average                                                                                          |  | -5.1  | 3.2   | 17.3  | 2.5   | 2.4   | 19.6  | 5.6   | 2.2   | 20.9            | 8.8   | 2.0   | 22.3  |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
| Deviation                                                                                        |  | 0.8   | 0.65  | 1.18  | 0.24  | 0.13  | 0.07  | 0.50  | 0.14  | 0.12            | 0.36  | 0.13  | 0.11  |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |
|                                                                                                  |  |       |       |       |       |       |       |       |       |                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |       |       |          |       |       |           |  |  |



| q <sub>center</sub> = -22.3 cm, y <sub>center</sub> = 76.4 cm, z <sub>center</sub> = 1.4 cm |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
|---------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--|--|--|--|
| ΔX (cm)                                                                                     |                |                | -18            |                |                | -14.4          |                |                | -10.8          |                |                | -7.2           |                |                | -3.6           |                |                | 0              |                |                | 3.6            |                |                |  |  |  |  |
|                                                                                             | x <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> | x <sub>s</sub> | y <sub>s</sub> | z <sub>s</sub> |  |  |  |  |
| Frame 1                                                                                     | -37.7          | 77.5           | 5.6            | -34.7          | 77.1           | 5.1            | 34.0           | 76.5           | 4.4            | -29.1          | 77.3           | 3.0            | -26.1          | 77.7           | 1.9            | -23.1          | 77.4           | 1.1            | -19.8          | 77.2           | 0.3            |                |                |  |  |  |  |
| Frame 2                                                                                     | -37.8          | 77.6           | 5.6            | -34.9          | 77.2           | 5.3            | 34.0           | 76.6           | 4.5            | -29.4          | 77.1           | 3.1            | -26.0          | 77.9           | 1.6            | -23.1          | 77.4           | 0.9            | -19.3          | 77.2           | 0.2            |                |                |  |  |  |  |
| Frame 3                                                                                     | -38.1          | 77.5           | 5.7            | -34.8          | 77.3           | 5.2            | 34.2           | 76.5           | 4.4            | -28.9          | 77.2           | 3.1            | -26.0          | 77.8           | 1.8            | -22.5          | 77.4           | 1.0            | -19.3          | 77.2           | 0.3            |                |                |  |  |  |  |
| Frame 4                                                                                     | -38.1          | 77.4           | 5.5            | -35.0          | 77.2           | 5.4            | 34.2           | 76.6           | 4.4            | -29.9          | 77.1           | 3.3            | -25.9          | 77.9           | 1.5            | -22.3          | 77.3           | 1.0            | -19.2          | 77.1           | 0.2            |                |                |  |  |  |  |
| Frame 5                                                                                     | -38.1          | 77.6           | 5.7            | -34.8          | 77.3           | 5.3            | 34.0           | 76.6           | 4.7            | -29.7          | 77.2           | 3.3            | -25.8          | 77.8           | 1.8            | -22.8          | 77.3           | 0.8            | -19.5          | 77.4           | 0.3            |                |                |  |  |  |  |
| Frame 6                                                                                     | -37.9          | 77.4           | 5.5            | -35.4          | 77.2           | 5.3            | 34.0           | 76.5           | 4.6            | -29.9          | 77.1           | 3.4            | -26.1          | 77.8           | 1.6            | -22.0          | 77.3           | 0.9            | -18.4          | 77.1           | 0.3            |                |                |  |  |  |  |
| Frame 7                                                                                     | -38.0          | 77.5           | 5.7            | -34.6          | 77.2           | 5.1            | 33.9           | 76.5           | 4.6            | -29.6          | 77.2           | 3.3            | -26.0          | 77.8           | 1.6            | -22.7          | 77.5           | 0.8            | -19.4          | 77.2           | 0.4            |                |                |  |  |  |  |
| Frame 8                                                                                     | -37.7          | 77.5           | 5.6            | -35.2          | 77.1           | 5.1            | 33.6           | 76.6           | 4.6            | -29.9          | 77.0           | 3.2            | -26.1          | 77.9           | 1.5            | -22.5          | 77.3           | 1.0            | -19.2          | 77.2           | 0.3            |                |                |  |  |  |  |
| Frame 9                                                                                     | -37.7          | 77.5           | 5.7            | -34.7          | 77.2           | 5.0            | 34.0           | 76.5           | 4.4            | -29.6          | 77.2           | 3.1            | -26.0          | 77.8           | 1.8            | -22.8          | 77.4           | 0.9            | -19.9          | 77.2           | 0.3            |                |                |  |  |  |  |
| Frame 10                                                                                    | -37.6          | 77.5           | 5.7            | -35.1          | 77.2           | 5.4            | 33.9           | 76.6           | 4.4            | -29.9          | 77.1           | 3.2            | -25.8          | 77.9           | 1.6            | -22.4          | 77.4           | 1.0            | -20.5          | 77.1           | -0.1           |                |                |  |  |  |  |
| Average                                                                                     | -37.9          | 77.5           | 5.6            | -34.9          | 77.2           | 5.2            | 34.0           | 76.6           | 4.5            | -29.7          | 77.2           | 3.2            | -26.0          | 77.8           | 1.7            | -22.5          | 77.4           | 0.9            | -19.5          | 77.2           | 0.2            |                |                |  |  |  |  |
| St. Deviation                                                                               | 0.2            | 0.08           | 0.06           | 0.26           | 0.07           | 0.13           | 0.16           | 0.03           | 0.11           | 0.27           | 0.10           | 0.12           | 0.10           | 0.07           | 0.15           | 0.33           | 0.08           | 0.09           | 0.40           | 0.08           | 0.12           |                |                |  |  |  |  |
| Raw Coordinates                                                                             |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
| ΔX (cm)                                                                                     |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
| 18.0                                                                                        |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
| x <sub>s</sub> y <sub>s</sub> z <sub>s</sub>                                                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
| Frame 1                                                                                     | -105           | 78.9           | -2.8           | -11.8          | 76.8           | -1.4           | -1.3           | 78.7           | -5.3           | 4.1            | 77.4           | -4.4           | -14.4          | -12.7          | 0.8            | 3.8            | 0.9            | -0.1           | -0.3           |                |                |                |                |  |  |  |  |
| Frame 2                                                                                     | -15.6          | 77.4           | -0.7           | -12.2          | 76.9           | -1.4           | -1.7           | 79.0           | -5.4           | 4.6            | 77.2           | -4.1           | -10.8          | -11.8          | 0.2            | 3.1            | 1.0            | 0.0            | -0.3           |                |                |                |                |  |  |  |  |
| Frame 3                                                                                     | -14.3          | 77.1           | -1.1           | -12.7          | 76.7           | -1.4           | -1.5           | 78.8           | -5.3           | 5.0            | 77.4           | -4.2           | -7.2           | -7.5           | 0.8            | 1.8            | 1.0            | -0.1           | -0.3           |                |                |                |                |  |  |  |  |
| Frame 4                                                                                     | -15.8          | 77.4           | -0.7           | -12.5          | 76.9           | -1.4           | -1.6           | 79.0           | -5.3           | 4.1            | 77.2           | -4.3           | -3.6           | -3.8           | 1.4            | 0.3            | 1.0            | -0.4           | -0.1           |                |                |                |                |  |  |  |  |
| Frame 5                                                                                     | -16.3          | 77.2           | -0.6           | -12.6          | 76.6           | -1.6           | -1.6           | 78.8           | -5.5           | 4.6            | 77.4           | -4.3           | 0.0            | -0.3           | 1.0            | -0.5           |                |                |                |                |                |                |                |  |  |  |  |
| Frame 6                                                                                     | -15.4          | 77.3           | -0.6           | -12.7          | 77.0           | -1.4           | -2.1           | 79.0           | -5.3           | 4.7            | 77.3           | -4.2           | 3.6            | 2.7            | 0.8            | -1.2           | 0.7            | 0.2            | -0.3           |                |                |                |                |  |  |  |  |
| Frame 7                                                                                     | -16.1          | 77.2           | -0.6           | -12.7          | 76.8           | -1.5           | -1.3           | 78.8           | -5.5           | 4.8            | 77.3           | -4.3           | 7.2            | 7.1            | 1.2            | -2.3           | 1.0            | 0.2            | -0.3           |                |                |                |                |  |  |  |  |
| Frame 8                                                                                     | -15.9          | 77.3           | -0.5           | -12.4          | 76.9           | -1.3           | -1.9           | 79.1           | -5.2           | 4.6            | 77.2           | -4.3           | 10.8           | 9.8            | 0.4            | -2.8           | 0.9            | 0.0            | -0.3           |                |                |                |                |  |  |  |  |
| Frame 9                                                                                     | -15.7          | 77.3           | -0.5           | -12.1          | 76.8           | -1.3           | -1.2           | 78.8           | -5.3           | 4.1            | 77.3           | -4.4           | 14.4           | 20.7           | 2.5            | -6.7           | 1.4            | 0.2            | -0.5           |                |                |                |                |  |  |  |  |
| Frame 10                                                                                    | -15.5          | 77.4           | -0.6           | -12.3          | 77.0           | -1.3           | -1.8           | 79.0           | -5.1           | 4.4            | 77.2           | -4.2           | 18.0           | 17.7           | 0.9            | -5.7           | 1.0            | 0.1            | -0.3           |                |                |                |                |  |  |  |  |
| Average                                                                                     | -15.1          | 77.6           | -0.9           | -12.4          | 76.8           | -1.4           | -1.5           | 78.9           | -5.3           | 4.5            | 77.3           | -4.3           |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
| Deviation                                                                                   | 1.7            | 0.82           | 0.69           | 0.30           | 0.11           | 0.09           | 0.27           | 0.13           | 0.11           | 0.30           | 0.08           | 0.08           |                |                |                |                |                |                |                |                |                |                |                |  |  |  |  |
|                                                                                             |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                | Ave.           | 1.00           | 0.00           | -0.28          |                |  |  |  |  |

|                         |       | Raw Coordinates |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
|-------------------------|-------|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----|--|--|--|--|--|
| $\Delta T \text{ (cm)}$ |       | -10.0           |       |       |       |       |       | -8.0  |       |       |       |       |       | -6.0  |       |       |       |       |       | -4.0  |       |       |       |       |       | -2.0  |       |       |       |       |       | 0.0   |       |       |       |       |       | 2.0 |  |  |  |  |  |
|                         |       | $x_a$           | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ |     |  |  |  |  |  |
| Frame 1                 | -20.6 | 72.5            | 0.7   | -22.9 | 73.4  | 0.6   | -20.4 | 74.4  | 0.6   | -21.7 | 75.2  | 1.5   | -22.8 | 76.7  | 1.6   | -22.5 | 77.4  | 0.9   | -21.8 | 78.2  | 1.3   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 2                 | -21.0 | 72.7            | 0.7   | -22.9 | 73.3  | 0.8   | -21.5 | 74.2  | 0.6   | -22.0 | 75.2  | 1.7   | -22.8 | 76.9  | 1.7   | -22.4 | 77.3  | 1.3   | -21.9 | 78.1  | 1.4   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 3                 | -20.8 | 72.5            | 0.8   | -22.5 | 73.4  | 0.9   | -21.1 | 74.5  | 1.0   | -22.0 | 75.3  | 1.6   | -22.6 | 76.8  | 1.8   | -22.4 | 77.3  | 1.3   | -22.2 | 78.1  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 4                 | -20.3 | 72.5            | 0.7   | -22.9 | 73.4  | 0.8   | -21.0 | 74.2  | 0.9   | -21.8 | 75.3  | 1.6   | -22.6 | 77.0  | 1.9   | -22.0 | 77.4  | 1.1   | -21.8 | 78.1  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 5                 | -20.5 | 72.6            | 0.7   | -22.7 | 73.5  | 1.0   | -20.7 | 74.5  | 0.9   | -22.1 | 75.2  | 1.8   | -22.5 | 76.8  | 1.8   | -22.1 | 77.3  | 1.3   | -22.0 | 78.2  | 1.6   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 6                 | -20.4 | 72.6            | 0.9   | -22.4 | 73.5  | 0.9   | -21.5 | 74.3  | 0.7   | -22.4 | 75.2  | 1.9   | -22.9 | 77.0  | 2.0   | -21.7 | 77.4  | 1.2   | -22.1 | 78.0  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 7                 | -20.6 | 72.6            | 0.7   | -22.5 | 73.5  | 1.1   | -21.1 | 74.6  | 0.7   | -22.1 | 75.2  | 1.6   | -23.1 | 76.8  | 1.9   | -22.7 | 77.4  | 1.3   | -22.1 | 78.3  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 8                 | -21.0 | 72.8            | 0.8   | -22.5 | 73.3  | 1.1   | -21.1 | 74.3  | 0.6   | -22.3 | 75.3  | 1.7   | -23.0 | 76.9  | 1.9   | -22.5 | 77.3  | 1.3   | -22.0 | 78.1  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 9                 | -21.3 | 72.5            | 0.9   | -22.7 | 73.5  | 0.6   | -21.2 | 74.5  | 0.8   | -22.5 | 75.2  | 1.8   | -22.9 | 76.6  | 1.8   | -23.0 | 77.4  | 1.3   | -22.2 | 78.3  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Frame 10                | -20.9 | 72.6            | 0.8   | -23.0 | 73.3  | 0.9   | -21.6 | 74.3  | 0.9   | -22.1 | 75.3  | 1.7   | -22.6 | 77.0  | 1.9   | -22.7 | 77.3  | 1.2   | -22.2 | 78.0  | 1.6   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| Average                 | -20.7 | 72.6            | 0.8   | -22.7 | 73.4  | 0.9   | -21.1 | 74.4  | 0.8   | -22.1 | 75.2  | 1.7   | -22.8 | 76.9  | 1.8   | -22.4 | 77.3  | 1.2   | -22.0 | 78.1  | 1.5   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |
| ST. Deviation           | 0.3   | 0.05            | 0.08  | 0.22  | 0.08  | 0.10  | 0.36  | 0.14  | 0.13  | 0.26  | 0.04  | 0.11  | 0.21  | 0.09  | 0.09  | 0.38  | 0.06  | 0.12  | 0.17  | 0.10  | 0.08  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |     |  |  |  |  |  |

|                         |  | Raw Coordinates |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |                         |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                      |       |       |       |       |       |                                       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |
|-------------------------|--|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|--------------------------------------|-------|-------|-------|-------|-------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|
| $\Delta Y \text{ (cm)}$ |  | 4.0             |       |       |       |       |       | 8.0   |       |       |       |       |       | 10.0  |       |       |       |       |       | $\Delta Y \text{ (cm)}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ Z^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ A^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ B^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ C^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ D^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ E^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ F^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ G^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ H^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ I^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ J^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ K^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ L^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ M^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ N^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ O^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ P^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ Q^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ R^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ S^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ T^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ U^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ V^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ W^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ X^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ Y^{\circ}$ |       |       |       |       |       | $\lambda^{\circ} / ^\circ \text{Avg}$ |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |          |
|                         |  | $x_a$           | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                   | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$                                 | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ | $z_b$ | $x_a$ | $y_a$ | $z_a$ | $x_b$ | $y_b$ </ |

| $q_{\text{control}} - X_{\text{a control}} = -149.0 \text{ cm}, Y_{\text{a control}} = 77.0 \text{ cm}, Z_{\text{a control}} = 78.2 \text{ cm}$ |              |        |        |                        |        |          |                        |        |        |                        |       |       |
|-------------------------------------------------------------------------------------------------------------------------------------------------|--------------|--------|--------|------------------------|--------|----------|------------------------|--------|--------|------------------------|-------|-------|
| Raw Coordinates                                                                                                                                 |              |        |        |                        |        |          |                        |        |        |                        |       |       |
| $Z \text{ (cm)}$                                                                                                                                | -18          |        |        | -14.4                  |        |          | -10.8                  |        |        | -7.2                   |       |       |
|                                                                                                                                                 | $x_a$        | $y_a$  | $z_a$  | $x_a$                  | $y_a$  | $z_a$    | $x_a$                  | $y_a$  | $z_a$  | $x_a$                  | $y_a$ | $z_a$ |
| Frame 1                                                                                                                                         | -34.2        | 76.898 | -5.193 | -33.5346               | 77.072 | -5.91306 | -35.81                 | 76.681 | -3.864 | -33.0                  | 76.9  | -1.8  |
| Frame 2                                                                                                                                         | -34.2        | 77.125 | -5.133 | -34.0705               | 77.2   | -4.06208 | -35.44                 | 76.972 | -3.376 | -33.4                  | 76.9  | -1.8  |
| Frame 3                                                                                                                                         | -34.4        | 76.853 | -5.162 | -34.1817               | 77.156 | -3.99504 | -34.87                 | 76.704 | -3.393 | -32.1                  | 77.7  | -1.1  |
| Frame 4                                                                                                                                         | -33.9        | 77.152 | -5.044 | -33.5462               | 77.155 | -4.01863 | -35.31                 | 76.466 | -3.342 | -33.8                  | 76.7  | -1.7  |
| Frame 5                                                                                                                                         | -34.3        | 76.897 | -5.148 | -33.6302               | 77.166 | -3.76845 | -34.86                 | 76.704 | -3.325 | -32.8                  | 76.8  | -1.8  |
| Frame 6                                                                                                                                         | -34.2        | 77.005 | -5.169 | -33.8609               | 76.931 | -4.03034 | -34.79                 | 76.719 | -3.235 | -33.6                  | 76.8  | -1.7  |
| Frame 7                                                                                                                                         | -34.6        | 76.917 | -5.151 | -33.8711               | 77.158 | -3.95643 | -34.69                 | 76.693 | -3.368 | -32.4                  | 76.8  | -1.9  |
| Frame 8                                                                                                                                         | -34.2        | 76.878 | -5.154 | -33.9834               | 77.287 | -4.18539 | -35.09                 | 76.678 | -3.179 | -33.6                  | 76.8  | -1.8  |
| Frame 9                                                                                                                                         | -34.2        | 76.829 | -5.189 | -34.5564               | 77.115 | -4.01869 | -35.12                 | 76.574 | -3.546 | -33.2                  | 76.8  | -1.7  |
| Frame 10                                                                                                                                        | -34.1        | 77.069 | -5.129 | -33.858                | 77.099 | -4.0029  | -35.34                 | 76.681 | -3.431 | -33.5                  | 76.8  | -1.7  |
| Average                                                                                                                                         | -34.2        | 77.0   | -5.1   | -33.9                  | 77.1   | -4.0     | -35.1                  | 76.6   | -3.4   | -33.1                  | 76.8  | -1.8  |
| St. Deviation                                                                                                                                   | 0.2          | 0.12   | 0.04   | 0.31                   | 0.09   | 0.12     | 0.35                   | 0.11   | 0.15   | 0.57                   | 0.05  | 0.08  |
| Raw Coordinates                                                                                                                                 |              |        |        |                        |        |          |                        |        |        |                        |       |       |
| $Z \text{ (cm)}$                                                                                                                                | 7.2          |        |        | 10.8                   |        |          | 14.4                   |        |        | 18.0                   |       |       |
|                                                                                                                                                 | $x_a$        | $y_a$  | $z_a$  | $x_a$                  | $y_a$  | $z_a$    | $x_a$                  | $y_a$  | $z_a$  | $x_a$                  | $y_a$ | $z_a$ |
| Frame 1                                                                                                                                         | -16.6        | 76.8   | 3.8    | -15.4                  | 77.2   | 5.6      | -12.0                  | 77.3   | 6.4    | -9.5                   | 77.5  | 7.2   |
| Frame 2                                                                                                                                         | -16.7        | 77.0   | 3.7    | -16.3                  | 77.4   | 5.4      | -12.5                  | 77.1   | 6.4    | -8.8                   | 77.8  | 7.2   |
| Frame 3                                                                                                                                         | -16.8        | 76.8   | 3.8    | -16.4                  | 77.1   | 5.4      | -12.6                  | 77.2   | 6.4    | -8.8                   | 77.5  | 7.2   |
| Frame 4                                                                                                                                         | -16.0        | 77.0   | 3.9    | -16.6                  | 77.0   | 5.3      | -12.0                  | 77.3   | 6.5    | -7.9                   | 77.7  | 6.9   |
| Frame 5                                                                                                                                         | -16.0        | 76.9   | 3.7    | -16.9                  | 77.2   | 5.3      | -12.7                  | 77.2   | 6.3    | -8.8                   | 77.5  | 7.3   |
| Frame 6                                                                                                                                         | -16.0        | 77.1   | 4.0    | -16.3                  | 77.2   | 5.4      | -12.0                  | 77.2   | 6.6    | -9.1                   | 77.6  | 7.4   |
| Frame 7                                                                                                                                         | -19.0        | 76.8   | 3.8    | -16.0                  | 77.1   | 5.6      | -12.1                  | 77.1   | 6.3    | -9.0                   | 77.8  | 7.2   |
| Frame 8                                                                                                                                         | -16.4        | 76.9   | 3.9    | -16.1                  | 77.3   | 5.4      | -12.1                  | 77.1   | 6.6    | -9.1                   | 77.6  | 7.2   |
| Frame 9                                                                                                                                         | -16.9        | 76.8   | 3.8    | -16.1                  | 77.1   | 5.3      | -12.8                  | 77.2   | 6.3    | -8.3                   | 77.6  | 7.2   |
| Frame 10                                                                                                                                        | -16.6        | 77.0   | 3.9    | -16.6                  | 77.1   | 5.3      | -12.4                  | 77.1   | 6.5    | -8.9                   | 77.6  | 7.0   |
| Average                                                                                                                                         | -16.5        | 76.9   | 3.8    | -16.5                  | 77.2   | 5.4      | -12.3                  | 77.2   | 6.4    | -8.6                   | 77.6  | 7.1   |
| Deviation                                                                                                                                       | 0.4          | 0.12   | 0.09   | 0.40                   | 0.11   | 0.10     | 0.31                   | 0.09   | 0.11   | 0.44                   | 0.07  | 0.14  |
| Uncertainty                                                                                                                                     |              |        |        |                        |        |          |                        |        |        |                        |       |       |
| $Z \text{ (cm)}$                                                                                                                                | $(\Delta Z)$ |        |        | $\frac{\Delta X}{X_a}$ |        |          | $\frac{\Delta Y}{Y_a}$ |        |        | $\frac{\Delta Z}{Z_a}$ |       |       |
|                                                                                                                                                 | $x_a$        | $y_a$  | $z_a$  | $x_a$                  | $y_a$  | $z_a$    | $x_a$                  | $y_a$  | $z_a$  | $x_a$                  | $y_a$ | $z_a$ |
| Frame 1                                                                                                                                         | -16.6        | 76.8   | 3.8    | -15.4                  | 77.2   | 5.6      | -12.0                  | 77.3   | 6.4    | -9.5                   | 77.5  | 7.2   |
| Frame 2                                                                                                                                         | -16.7        | 77.0   | 3.7    | -16.3                  | 77.4   | 6.4      | -12.5                  | 77.1   | 6.4    | -8.8                   | 77.8  | 7.2   |
| Frame 3                                                                                                                                         | -16.8        | 76.8   | 3.8    | -16.4                  | 77.1   | 5.4      | -12.6                  | 77.2   | 6.4    | -8.8                   | 77.5  | 7.2   |
| Frame 4                                                                                                                                         | -16.0        | 77.0   | 3.9    | -16.6                  | 77.0   | 5.3      | -12.0                  | 77.3   | 6.5    | -7.9                   | 77.7  | 6.9   |
| Frame 5                                                                                                                                         | -16.0        | 76.9   | 3.7    | -16.9                  | 77.2   | 5.3      | -12.7                  | 77.2   | 6.3    | -8.8                   | 77.5  | 7.3   |
| Frame 6                                                                                                                                         | -16.0        | 77.1   | 4.0    | -16.3                  | 77.2   | 5.4      | -12.0                  | 77.2   | 6.6    | -9.1                   | 77.6  | 7.4   |
| Frame 7                                                                                                                                         | -19.0        | 76.8   | 3.8    | -16.0                  | 77.1   | 5.6      | -12.1                  | 77.1   | 6.3    | -9.0                   | 77.8  | 7.2   |
| Frame 8                                                                                                                                         | -16.4        | 76.9   | 3.9    | -16.1                  | 77.3   | 5.4      | -12.1                  | 77.1   | 6.6    | -9.1                   | 77.6  | 7.2   |
| Frame 9                                                                                                                                         | -16.9        | 76.8   | 3.8    | -16.1                  | 77.1   | 5.3      | -12.8                  | 77.2   | 6.3    | -8.3                   | 77.6  | 7.2   |
| Frame 10                                                                                                                                        | -16.6        | 77.0   | 3.9    | -16.6                  | 77.1   | 5.3      | -12.4                  | 77.1   | 6.5    | -8.9                   | 77.6  | 7.0   |
| Average                                                                                                                                         | -16.5        | 76.9   | 3.8    | -16.5                  | 77.2   | 5.4      | -12.3                  | 77.2   | 6.4    | -8.6                   | 77.6  | 7.1   |
| Deviation                                                                                                                                       | 0.4          | 0.12   | 0.09   | 0.40                   | 0.11   | 0.10     | 0.31                   | 0.09   | 0.11   | 0.44                   | 0.07  | 0.14  |
|                                                                                                                                                 |              |        |        |                        |        |          |                        |        |        | Ave.                   |       |       |
|                                                                                                                                                 |              |        |        |                        |        |          |                        |        |        | 0.8077 0.016 0.3869    |       |       |

| $\theta_{\text{g control}} = -22.3 \text{ cm}$ , $Y_{\text{g control}} = 76.4 \text{ cm}$ , $Z_{\text{g control}} = 1.4 \text{ cm}$ |       |       |       |       |       |       |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |
|-------------------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--|--|
| 30(degrees)                                                                                                                         | -10.0 |       |       | -8.0  |       |       | -6.0           |                |                | -4.0           |                |                | -2.0           |                |                | 0.0            |                |                |                |                |                |                |  |  |
|                                                                                                                                     | $x_g$ | $y_g$ | $z_g$ | $x_g$ | $y_g$ | $z_g$ | $x_g$          | $y_g$          | $z_g$          | $x_g$          | $y_g$          | $z_g$          | $x_g$          | $y_g$          | $z_g$          | $x_g$          | $y_g$          | $z_g$          |                |                |                |                |  |  |
| Frame 1                                                                                                                             | -1.0  | 76.0  | -6.3  | -5.4  | 77.9  | -3.9  | -11.2          | 77.1           | -2.7           | -13.3          | 77.1           | -0.7           | -15.0          | 77.3           | 1.0            | -23.1          | 77.5           | 1.1            | -24.3          | 76.6           | 2.4            |                |  |  |
| Frame 2                                                                                                                             | -0.9  | 77.9  | -6.4  | -5.6  | 77.6  | -4.3  | -11.5          | 77.2           | -2.9           | -13.5          | 77.1           | -0.5           | -16.1          | 77.2           | 1.1            | -23.2          | 77.2           | 1.3            | -25.0          | 76.6           | 2.5            |                |  |  |
| Frame 3                                                                                                                             | -0.5  | 77.6  | -6.3  | -6.3  | 77.8  | -4.1  | -11.0          | 77.1           | -2.7           | -13.6          | 77.3           | -0.5           | -15.7          | 77.4           | 1.1            | -23.7          | 77.6           | 1.2            | -24.7          | 76.6           | 2.7            |                |  |  |
| Frame 4                                                                                                                             | -0.6  | 77.9  | -6.3  | -5.9  | 77.8  | -4.0  | -10.4          | 77.0           | -2.6           | -14.0          | 77.2           | -0.4           | -16.2          | 77.1           | 1.2            | -24.0          | 77.1           | 1.3            | -25.2          | 76.6           | 2.6            |                |  |  |
| Frame 5                                                                                                                             | -0.4  | 77.9  | -6.2  | -6.6  | 77.9  | -4.0  | -10.7          | 77.0           | -2.7           | -13.0          | 77.2           | -0.4           | -15.9          | 77.5           | 1.0            | -23.7          | 77.5           | 1.3            | -25.0          | 76.7           | 2.6            |                |  |  |
| Frame 6                                                                                                                             | -0.3  | 77.6  | -6.5  | -5.8  | 77.7  | -3.9  | -10.7          | 77.1           | -2.6           | -13.0          | 77.1           | -0.4           | -16.4          | 77.2           | 1.1            | -23.7          | 77.1           | 1.4            | -25.6          | 76.6           | 2.5            |                |  |  |
| Frame 7                                                                                                                             | -0.6  | 77.8  | -6.1  | -6.5  | 77.8  | -4.0  | -11.4          | 76.9           | -2.8           | -14.0          | 77.2           | -0.6           | -15.6          | 77.4           | 1.1            | -23.8          | 77.5           | 1.2            | -24.9          | 76.7           | 2.6            |                |  |  |
| Frame 8                                                                                                                             | -0.9  | 77.9  | -6.4  | -5.7  | 77.7  | -3.9  | -10.8          | 76.9           | -2.7           | -13.7          | 77.1           | -0.4           | -16.2          | 77.3           | 1.2            | -23.4          | 77.0           | 1.2            | -24.8          | 76.5           | 2.4            |                |  |  |
| Frame 9                                                                                                                             | -1.2  | 77.9  | -6.3  | -6.7  | 77.7  | -3.8  | -11.6          | 77.1           | -2.8           | -12.8          | 77.1           | -0.3           | -15.9          | 77.3           | 1.0            | -23.4          | 77.6           | 1.2            | -24.8          | 76.8           | 2.5            |                |  |  |
| Frame 10                                                                                                                            | -0.8  | 77.6  | -6.4  | -6.2  | 77.6  | -4.1  | -11.3          | 77.1           | -2.5           | -13.3          | 77.3           | -0.3           | -16.1          | 77.2           | 1.2            | -23.2          | 77.0           | 1.3            | -24.8          | 76.5           | 2.5            |                |  |  |
| Average                                                                                                                             | -0.7  | 77.9  | -6.3  | -6.1  | 77.7  | -4.0  | -11.1          | 77.1           | -2.7           | -13.4          | 77.2           | -0.4           | -15.9          | 77.3           | 1.1            | -23.5          | 77.3           | 1.2            | -24.9          | 76.6           | 2.5            |                |  |  |
| St. Deviation                                                                                                                       | 0.27  | 0.07  | 0.10  | 0.46  | 0.10  | 0.14  | 0.41           | 0.10           | 0.11           | 0.41           | 0.06           | 0.13           | 0.41           | 0.11           | 0.08           | 0.30           | 0.24           | 0.08           | 0.34           | 0.11           | 0.10           |                |  |  |
| Raw Coordinates                                                                                                                     |       |       |       |       |       |       |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |
| 30(degrees)                                                                                                                         | 4.0   |       |       | 6.0   |       |       | 8.0            |                |                | 10.0           |                |                | (degrees)      |                |                | $\sigma_{x_g}$ |                |                | $\sigma_{y_g}$ |                |                | $\sigma_{z_g}$ |  |  |
|                                                                                                                                     | $x_g$ | $y_g$ | $z_g$ | $x_g$ | $y_g$ | $z_g$ | $x_g$          | $y_g$          | $z_g$          | $x_g$          | $y_g$          | $z_g$          | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ |                |  |  |
| Frame 1                                                                                                                             | -30.0 | 76.5  | 3.4   | -34.5 | 76.6  | 2.6   | -35.2          | 76.3           | 3.1            | -40.0          | 76.3           | 4.1            | -8.0           | 16.1           | 1.3            | -5.4           | -2.02          | -0.17          | 0.68           |                |                |                |  |  |
| Frame 2                                                                                                                             | -30.3 | 76.3  | 3.5   | -34.0 | 76.7  | 2.5   | -35.5          | 76.0           | 3.3            | -40.0          | 75.9           | 4.0            | -6.0           | 11.1           | 0.7            | -4.1           | -1.85          | -0.11          | 0.68           |                |                |                |  |  |
| Frame 3                                                                                                                             | -29.9 | 76.4  | 3.4   | -34.7 | 76.6  | 2.5   | -35.2          | 76.3           | 3.1            | -40.3          | 75.8           | 3.9            | -4.0           | 8.8            | 0.8            | -1.8           | -2.19          | -0.19          | 0.46           |                |                |                |  |  |
| Frame 4                                                                                                                             | -29.9 | 76.4  | 3.6   | -33.9 | 76.8  | 2.7   | -35.5          | 76.0           | 3.1            | -40.4          | 75.9           | 3.9            | -2.0           | 6.3            | 0.9            | -0.3           | -3.14          | -0.45          | 0.15           |                |                |                |  |  |
| Frame 5                                                                                                                             | -29.5 | 76.4  | 3.6   | -34.4 | 76.8  | 2.6   | -35.2          | 76.3           | 3.2            | -40.0          | 76.2           | 4.2            | 0.0            | -1.3           | 0.9            | -0.2           |                |                |                |                |                |                |  |  |
| Frame 6                                                                                                                             | -29.3 | 76.5  | 3.4   | -34.3 | 76.9  | 2.6   | -35.4          | 75.9           | 3.1            | -40.0          | 75.9           | 4.0            | 2.0            | -2.7           | 0.2            | 1.1            | -1.36          | 0.12           | 0.66           |                |                |                |  |  |
| Frame 7                                                                                                                             | -28.5 | 76.6  | 3.6   | -34.4 | 76.6  | 2.6   | -35.5          | 76.3           | 3.3            | -40.3          | 76.3           | 4.1            | 4.0            | -7.5           | 0.0            | 2.1            | -1.89          | 0.00           | 0.53           |                |                |                |  |  |
| Frame 8                                                                                                                             | -29.9 | 76.1  | 3.4   | -34.6 | 76.7  | 2.5   | -35.4          | 76.0           | 3.3            | -40.6          | 76.1           | 4.0            | 6.0            | -12.2          | 0.3            | 1.2            | -2.03          | 0.05           | 0.20           |                |                |                |  |  |
| Frame 9                                                                                                                             | -30.6 | 76.7  | 3.6   | -34.5 | 76.6  | 2.5   | -34.9          | 76.4           | 3.2            | -40.1          | 76.2           | 3.9            | 8.0            | -13.2          | -0.2           | 1.8            | -1.65          | -0.03          | 0.22           |                |                |                |  |  |
| Frame 10                                                                                                                            | -29.5 | 76.3  | 3.6   | -34.4 | 76.9  | 2.6   | -35.8          | 76.0           | 3.2            | -40.1          | 75.9           | 4.0            | 10.0           | -18.0          | -0.3           | 2.6            | -1.80          | -0.03          | 0.26           |                |                |                |  |  |
| Average                                                                                                                             | -29.7 | 76.4  | 3.5   | -34.4 | 76.7  | 2.6   | -35.4          | 76.2           | 3.2            | -40.2          | 76.1           | 4.0            |                |                |                | Ave.           | -2.01          | -0.10          | 0.45           |                |                |                |  |  |
| St. Deviation                                                                                                                       | 0.59  | 0.15  | 0.08  | 0.26  | 0.11  | 0.06  | 0.22           | 0.19           | 0.09           | 0.21           | 0.16           | 0.11           |                |                |                |                |                |                |                |                |                |                |  |  |
| Raw Coordinates                                                                                                                     |       |       |       |       |       |       |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |
| 30(degrees)                                                                                                                         | 6.0   |       |       | 8.0   |       |       | 10.0           |                |                | (degrees)      |                |                | $\sigma_{x_g}$ |                |                | $\sigma_{y_g}$ |                |                | $\sigma_{z_g}$ |                |                |                |  |  |
|                                                                                                                                     | $x_g$ | $y_g$ | $z_g$ | $x_g$ | $y_g$ | $z_g$ | $x_g$          | $y_g$          | $z_g$          | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ |                |  |  |
| Frame 1                                                                                                                             | -30.0 | 76.5  | 3.4   | -34.5 | 76.6  | 2.6   | -35.2          | 76.3           | 3.1            | -40.0          | 76.3           | 4.1            | -8.0           | 16.1           | 1.3            | -5.4           | -2.02          | -0.17          | 0.68           |                |                |                |  |  |
| Frame 2                                                                                                                             | -30.3 | 76.3  | 3.5   | -34.0 | 76.7  | 2.5   | -35.5          | 76.0           | 3.3            | -40.0          | 75.9           | 4.0            | -6.0           | 11.1           | 0.7            | -4.1           | -1.85          | -0.11          | 0.68           |                |                |                |  |  |
| Frame 3                                                                                                                             | -29.9 | 76.4  | 3.4   | -34.7 | 76.6  | 2.5   | -35.2          | 76.3           | 3.1            | -40.3          | 75.8           | 3.9            | -4.0           | 8.8            | 0.8            | -1.8           | -2.19          | -0.19          | 0.46           |                |                |                |  |  |
| Frame 4                                                                                                                             | -29.9 | 76.4  | 3.6   | -33.9 | 76.8  | 2.7   | -35.5          | 76.0           | 3.1            | -40.4          | 75.9           | 3.9            | -2.0           | 6.3            | 0.9            | -0.3           | -3.14          | -0.45          | 0.15           |                |                |                |  |  |
| Frame 5                                                                                                                             | -29.5 | 76.4  | 3.6   | -34.4 | 76.8  | 2.6   | -35.2          | 76.3           | 3.2            | -40.0          | 76.2           | 4.2            | 0.0            | -1.3           | 0.9            | -0.2           |                |                |                |                |                |                |  |  |
| Frame 6                                                                                                                             | -29.3 | 76.5  | 3.4   | -34.3 | 76.9  | 2.6   | -35.4          | 75.9           | 3.1            | -40.0          | 75.9           | 4.0            | 2.0            | -2.7           | 0.2            | 1.1            | -1.36          | 0.12           | 0.66           |                |                |                |  |  |
| Frame 7                                                                                                                             | -28.5 | 76.6  | 3.6   | -34.4 | 76.6  | 2.6   | -35.5          | 76.3           | 3.3            | -40.3          | 76.3           | 4.1            | 4.0            | -7.5           | 0.0            | 2.1            | -1.89          | 0.00           | 0.53           |                |                |                |  |  |
| Frame 8                                                                                                                             | -29.9 | 76.1  | 3.4   | -34.6 | 76.7  | 2.5   | -35.4          | 76.0           | 3.3            | -40.6          | 76.1           | 4.0            | 6.0            | -12.2          | 0.3            | 1.2            | -2.03          | 0.05           | 0.20           |                |                |                |  |  |
| Frame 9                                                                                                                             | -30.6 | 76.7  | 3.6   | -34.5 | 76.6  | 2.5   | -34.9          | 76.4           | 3.2            | -40.1          | 76.2           | 3.9            | 8.0            | -13.2          | -0.2           | 1.8            | -1.65          | -0.03          | 0.22           |                |                |                |  |  |
| Frame 10                                                                                                                            | -29.5 | 76.3  | 3.6   | -34.4 | 76.9  | 2.6   | -35.8          | 76.0           | 3.2            | -40.1          | 75.9           | 4.0            | 10.0           | -18.0          | -0.3           | 2.6            | -1.80          | -0.03          | 0.26           |                |                |                |  |  |
| Average                                                                                                                             | -29.7 | 76.4  | 3.5   | -34.4 | 76.7  | 2.6   | -35.4          | 76.2           | 3.2            | -40.2          | 76.1           | 4.0            |                |                |                | Ave.           | -2.01          | -0.10          | 0.45           |                |                |                |  |  |
| St. Deviation                                                                                                                       | 0.59  | 0.15  | 0.08  | 0.26  | 0.11  | 0.06  | 0.22           | 0.19           | 0.09           | 0.21           | 0.16           | 0.11           |                |                |                |                |                |                |                |                |                |                |  |  |
| Raw Coordinates                                                                                                                     |       |       |       |       |       |       |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |
| 30(degrees)                                                                                                                         | 8.0   |       |       | 10.0  |       |       | (degrees)      |                |                | $\sigma_{x_g}$ |                |                | $\sigma_{y_g}$ |                |                | $\sigma_{z_g}$ |                |                |                |                |                |                |  |  |
|                                                                                                                                     | $x_g$ | $y_g$ | $z_g$ | $x_g$ | $y_g$ | $z_g$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ | $\sigma_{x_g}$ | $\sigma_{y_g}$ | $\sigma_{z_g}$ |                |  |  |
| Frame 1                                                                                                                             | -30.0 | 76.5  | 3.4   | -34.5 | 76.6  | 2.6   | -35.2          | 76.3           | 3.1            | -40.0          | 76.3           | 4.1            | -8.0           | 16.1           | 1.3            | -5.4           | -2.02          | -0.17          | 0.68           |                |                |                |  |  |
| Frame 2                                                                                                                             | -30.3 | 76.3  | 3.5   | -34.0 | 76.7  | 2.5   | -35.5          | 76.0           | 3.3            | -40.0          | 75.9           | 4.0            | -6.0           | 11.1           | 0.7            | -4.1           | -1.85          | -0.11          | 0.68           |                |                |                |  |  |
| Frame 3                                                                                                                             | -29.9 | 76.4  | 3.4   | -34.7 | 76.6  | 2.5   | -35.2          | 76.3           | 3.1            | -40.3          | 75.8           | 3.9            | -4.0           | 8.8            | 0.8            | -1.8           | -2.19          | -0.19          | 0.46           |                |                |                |  |  |
| Frame 4                                                                                                                             | -29.9 | 76.4  | 3.6   | -33.9 | 76.8  | 2.7   | -35.5          | 76.0           | 3.1            | -40.4          | 75.9           | 3.9            | -2.0           | 6.3            | 0.9            | -0.3           | -3.14          | -0.45          | 0.15           |                |                |                |  |  |
| Frame 5                                                                                                                             | -29.5 | 76.4  | 3.6   | -34.4 | 76.8  | 2.6   | -35.2          | 76.3           | 3.2            | -40.0          | 76.2           | 4.2            | 0.0            | -1.3           | 0.9            | -0.2           |                |                |                |                |                |                |  |  |
| Frame 6                                                                                                                             | -29.3 | 76.5  | 3.4   | -34.3 | 76.9  | 2.6   | -35.4          | 75.9           | 3.1            | -40.0          | 75.9           | 4.0            | 2.0            | -2.7           | 0.2            | 1.1            | -1.36          | 0.12           | 0.66           |                |                |                |  |  |
| Frame 7                                                                                                                             | -28.5 | 76.6  | 3.6   | -34.4 | 76.6  | 2.6   | -35.5          | 76.3           | 3.3            | -40.3          | 76.3           | 4.1            | 4.0            | -7.5           | 0.0            | 2.1            | -1.89          | 0.00           | 0.53           |                |                |                |  |  |
| Frame 8                                                                                                                             | -29.9 | 76.1  | 3.4   | -34.6 | 76.7  | 2.5   | -35.4          | 76.0           | 3.3            | -40.6          | 76.1           | 4.0            | 6.0            | -12.2          | 0.3            | 1.2            | -2.03          | 0.05           | 0.20           |                |                |                |  |  |
| Frame 9                                                                                                                             | -30.6 | 76.7  | 3.6   | -34.5 | 76.6  | 2.5   | -34.9          | 76.4           | 3.2            | -40.1          | 76.2           | 3.9            | 8.0            | -13.2          | -0.2           | 1.8            | -1.65          | -0.03          | 0.22           |                |                |                |  |  |
| Frame 10                                                                                                                            | -29.5 | 76.3  | 3.6   | -34.4 | 76.9  | 2.6   | -35.8          | 76.0           | 3.2            | -40.1          | 75.9           | 4.0            | 10.0           | -18.0          | -0.3           | 2.6            | -1.80          | -0.03          | 0.26           |                |                |                |  |  |
| Average                                                                                                                             | -29.7 | 76.4  | 3.5   | -34.4 | 76.7  | 2.6   | -35.4          | 76.2           | 3.2            | -40.2          | 76.1           | 4.0            |                |                |                | Ave.           | -2.01          | -0.10          | 0.45           |                |                |                |  |  |
| St. Deviation                                                                                                                       | 0.59  | 0.15  | 0.08  | 0.26  | 0.11  | 0.06  | 0.22           | 0.19           | 0.09           | 0.21           | 0.16           | 0.11           |                |                |                |                |                |                |                |                |                |                |  |  |

| Q <sub>1</sub> control: X <sub>0</sub> control = -22.3 cm, Y <sub>0</sub> control = 76.4 cm, Z <sub>0</sub> control = 1.4 cm |                 |                |                |                 |                |                |                 |                |                |                 |                |                |                 |                |                |
|------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------|----------------|-----------------|----------------|----------------|-----------------|----------------|----------------|-----------------|----------------|----------------|-----------------|----------------|----------------|
| λ(degrees)                                                                                                                   | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                |
|                                                                                                                              | x <sub>1</sub>  | y <sub>1</sub> | z <sub>1</sub> | x <sub>2</sub>  | y <sub>2</sub> | z <sub>2</sub> | x <sub>3</sub>  | y <sub>3</sub> | z <sub>3</sub> | x <sub>4</sub>  | y <sub>4</sub> | z <sub>4</sub> | x <sub>5</sub>  | y <sub>5</sub> | z <sub>5</sub> |
|                                                                                                                              | -8.3            |                |                | -5.9            |                |                | -3.9            |                |                | -1.9            |                |                | 0               |                | 1.9            |
| Frame 1                                                                                                                      | -242            | 72.0           | 5.6            | -20.6           | 72.6           | 5.4            | -23.7           | 74.1           | 3.3            | -21.1           | 78.1           | 2.0            | -21.1           | 76.8           | 0.7            |
| Frame 2                                                                                                                      | -24.8           | 72.1           | 5.7            | -20.8           | 72.5           | 5.2            | -24.4           | 74.3           | 3.2            | -21.2           | 75.7           | 2.1            | -21.4           | 76.9           | 0.8            |
| Frame 3                                                                                                                      | -24.3           | 72.1           | 5.6            | -20.9           | 72.5           | 5.4            | -24.1           | 74.2           | 3.1            | -21.4           | 78.1           | 2.0            | -21.2           | 76.9           | 0.7            |
| Frame 4                                                                                                                      | -24.4           | 72.1           | 5.6            | -20.8           | 72.5           | 5.4            | -24.5           | 74.3           | 3.1            | -21.4           | 75.8           | 2.0            | -21.8           | 76.6           | 0.7            |
| Frame 5                                                                                                                      | -24.0           | 72.1           | 5.7            | -20.7           | 72.4           | 5.4            | -24.1           | 74.1           | 3.1            | -21.0           | 78.1           | 2.2            | -21.3           | 76.8           | 0.8            |
| Frame 6                                                                                                                      | -24.2           | 72.1           | 5.7            | -20.5           | 72.6           | 5.3            | -24.1           | 74.1           | 3.2            | -21.3           | 75.7           | 2.2            | -21.6           | 76.8           | 0.9            |
| Frame 7                                                                                                                      | -24.5           | 72.1           | 5.7            | -20.6           | 72.4           | 5.3            | -23.9           | 74.1           | 3.3            | -21.2           | 78.1           | 2.1            | -21.3           | 76.8           | 0.7            |
| Frame 8                                                                                                                      | -24.5           | 72.1           | 5.7            | -20.4           | 72.5           | 5.4            | -23.7           | 74.2           | 3.3            | -21.0           | 75.7           | 2.1            | -21.7           | 76.8           | 0.8            |
| Frame 9                                                                                                                      | -24.4           | 72.1           | 5.6            | -20.2           | 72.5           | 5.3            | -24.3           | 74.0           | 3.4            | -21.0           | 78.1           | 2.0            | -21.2           | 76.9           | 0.7            |
| Frame 10                                                                                                                     | -24.1           | 72.2           | 5.6            | -20.6           | 72.5           | 5.3            | -24.4           | 74.1           | 3.2            | -21.1           | 75.7           | 2.1            | -21.5           | 76.9           | 0.7            |
| Average                                                                                                                      | -24.3           | 72.1           | 5.7            | -20.6           | 72.5           | 5.3            | -24.1           | 74.2           | 3.2            | -21.2           | 75.9           | 2.1            | -21.4           | 76.8           | 0.8            |
| St. Deviation                                                                                                                | 0.2             | 0.05           | 0.05           | 0.19            | 0.07           | 0.06           | 0.28            | 0.09           | 0.09           | 0.16            | 0.21           | 0.07           | 0.22            | 0.08           | 0.24           |
| Uncertainty                                                                                                                  |                 |                |                |                 |                |                |                 |                |                |                 |                |                |                 |                |                |
| λ(degrees)                                                                                                                   | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                | Raw Coordinates |                |                |
|                                                                                                                              | x <sub>1</sub>  | y <sub>1</sub> | z <sub>1</sub> | x <sub>2</sub>  | y <sub>2</sub> | z <sub>2</sub> | x <sub>3</sub>  | y <sub>3</sub> | z <sub>3</sub> | x <sub>4</sub>  | y <sub>4</sub> | z <sub>4</sub> | x <sub>5</sub>  | y <sub>5</sub> | z <sub>5</sub> |
| Frame 1                                                                                                                      | -24.6           | 81.9           | -0.6           | -28.2           | 84.9           | -0.3           | -25.4           | 87.2           | -0.5           | -5.9            | 1.6            | -3.9           | 3.9             | -0.27          | 0.662          |
| Frame 2                                                                                                                      | -24.9           | 82.2           | -0.6           | -28.7           | 84.7           | -0.3           | -26.2           | 87.0           | -0.5           | -3.9            | -1.9           | -2.2           | 1.8             | 0.489          | 0.573          |
| Frame 3                                                                                                                      | -25.5           | 82.0           | -0.4           | -28.2           | 84.8           | -0.3           | -25.5           | 87.3           | -0.5           | -1.9            | 1.0            | -0.5           | 0.7             | -0.54          | 0.252          |
| Frame 4                                                                                                                      | -25.0           | 82.1           | -0.5           | -28.3           | 84.8           | -0.3           | -25.8           | 87.0           | -0.4           | 0.0             | 0.8            | 0.4            | -0.6            |                |                |
| Frame 5                                                                                                                      | -25.3           | 81.9           | -0.4           | -28.4           | 84.8           | -0.4           | -25.4           | 87.3           | -0.5           | 1.9             | 0.8            | 3.1            | -1.7            | 0.41           | 1.633          |
| Frame 6                                                                                                                      | -24.8           | 82.2           | -0.5           | -28.7           | 84.8           | -0.3           | -25.8           | 87.0           | -0.6           | 3.9             | -2.9           | 5.6            | -1.9            | -0.75          | 1.444          |
| Frame 7                                                                                                                      | -25.4           | 81.9           | -0.5           | -28.2           | 84.8           | -0.5           | -25.4           | 87.3           | -0.5           | 5.9             | -4.3           | 8.4            | -1.7            | -0.73          | 1.419          |
| Frame 8                                                                                                                      | -25.3           | 82.1           | -0.4           | -28.7           | 84.7           | -0.3           | -25.8           | 87.0           | -0.5           | 9.3             | -3.5           | 10.7           | -1.9            | -0.37          | 1.153          |
| Frame 9                                                                                                                      | -25.5           | 81.9           | -0.4           | -28.5           | 84.9           | -0.3           | -25.6           | 87.2           | -0.5           |                 |                |                |                 | -0.19          | 0.95           |
| Frame 10                                                                                                                     | -24.9           | 82.2           | -0.5           | -28.8           | 84.7           | -0.2           | -25.8           | 87.0           | -0.5           |                 |                |                |                 |                |                |
| Average                                                                                                                      | -25.1           | 82.0           | -0.5           | -28.5           | 84.8           | -0.3           | -25.7           | 87.1           | -0.5           |                 |                |                |                 |                |                |
| St. Deviation                                                                                                                | 0.3             | 0.13           | 0.09           | 0.24            | 0.05           | 0.07           | 0.27            | 0.14           | 0.04           |                 |                |                |                 |                |                |

## APPENDIX K

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point B

| X <sub>0</sub> control = -3.0 cm, Y <sub>0</sub> control = -3.0 cm, Z <sub>0</sub> control = 15.0 cm |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |  |  |
|------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------|--|--|
| Raw Coordinates                                                                                      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |  |  |
| 3X (cm)                                                                                              | -18            |                |                | -14.4          |                |                | -10.8          |                |                | -7.2           |                |                | -3.6           |                |                | 0              |                |                | 3.6            |                |                |      |  |  |
|                                                                                                      | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> |      |  |  |
| Frame 1                                                                                              | -23.2          | 9.4            | 18.5           | -18.7          | 7.9            | 18.0           | -18.4          | 7.4            | 17.4           | -11.9          | 6.1            | 18.3           | -8.3           | 5.4            | 15.3           | -4.0           | 4.0            | 14.4           | 0.0            | 3.0            | 14.0           |      |  |  |
| Frame 2                                                                                              | -23.1          | 9.7            | 18.6           | -18.6          | -19.1          | 8.2            | -18.4          | -18.9          | 7.3            | -12.1          | 6.0            | 16.3           | -8.2           | 5.4            | 15.1           | -3.7           | 4.3            | 14.5           | 0.9            | 2.8            | 13.9           |      |  |  |
| Frame 3                                                                                              | -23.2          | 9.2            | 18.5           | -18.1          | 7.9            | 18.2           | -18.6          | 7.4            | 17.3           | -12.6          | 6.3            | 16.3           | -8.4           | 5.5            | 15.3           | -3.4           | 4.0            | 14.5           | 0.6            | 2.9            | 14.1           |      |  |  |
| Frame 4                                                                                              | -23.4          | 9.6            | 18.8           | -18.8          | 8.2            | 18.5           | -19.3          | 7.3            | 17.2           | -12.5          | 6.1            | 18.3           | -8.6           | 5.4            | 15.0           | -3.4           | 4.2            | 14.7           | -0.2           | 2.9            | 13.9           |      |  |  |
| Frame 5                                                                                              | -23.1          | 9.3            | 18.5           | -18.4          | 8.0            | 18.2           | -18.6          | 7.5            | 17.4           | -12.5          | 6.4            | 16.5           | -8.3           | 5.4            | 15.3           | -3.8           | 4.2            | 14.5           | 0.1            | 3.0            | 14.1           |      |  |  |
| Frame 6                                                                                              | -23.2          | 9.6            | 18.5           | -19.5          | 8.3            | 18.3           | -19.2          | 7.2            | 17.2           | -12.1          | 6.0            | 16.4           | -8.2           | 5.4            | 15.1           | -3.6           | 4.2            | 14.5           | 0.2            | 2.8            | 13.9           |      |  |  |
| Frame 7                                                                                              | -23.4          | 9.2            | 18.8           | -18.4          | 7.9            | 18.0           | -18.7          | 7.4            | 17.4           | -12.3          | 6.3            | 16.5           | -8.3           | 5.3            | 15.2           | -3.7           | 4.1            | 14.5           | 0.7            | 2.9            | 14.1           |      |  |  |
| Frame 8                                                                                              | -23.0          | 9.7            | 18.6           | -18.6          | -18.9          | 8.1            | -18.2          | -18.6          | 7.2            | -17.4          | -12.3          | 6.0            | -16.3          | -8.3           | 5.4            | 15.1           | -4.1           | 4.3            | 14.6           | 1.0            | 2.9            | 14.1 |  |  |
| Frame 9                                                                                              | -23.0          | 9.3            | 18.5           | -18.7          | 8.0            | 18.1           | -18.5          | 7.4            | 17.3           | -12.8          | 6.2            | 16.3           | -8.7           | 5.5            | 15.2           | -4.0           | 4.1            | 14.5           | 0.1            | 3.0            | 13.9           |      |  |  |
| Frame 10                                                                                             | -23.1          | 9.7            | 18.6           | -18.0          | 8.2            | 18.0           | -19.0          | 7.2            | 17.3           | -12.6          | 6.1            | 16.3           | -8.1           | 5.4            | 15.2           | -3.9           | 4.4            | 14.6           | -1.4           | 2.9            | 13.4           |      |  |  |
| Average                                                                                              | -23.2          | 9.5            | 18.5           | -18.8          | 8.1            | 18.2           | -18.6          | 7.3            | 17.3           | -12.4          | 6.1            | 16.4           | -8.3           | 5.4            | 15.2           | -3.6           | 4.2            | 14.5           | 0.2            | 2.8            | 13.9           |      |  |  |
| St. Deviation                                                                                        | 0.1            | 0.22           | 0.05           | 0.41           | 0.17           | 0.16           | 0.31           | 0.13           | 0.06           | 0.27           | 0.13           | 0.08           | 0.18           | 0.06           | 0.09           | 0.23           | 0.11           | 0.07           | 0.70           | 0.07           | 0.20           |      |  |  |

| Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                |                |         |                             |                                |                                |                                |                                |                                |                                |                                |  |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------|-----------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--|
| 3X (cm)         | 7.2            |                |                | 10.8           |                |                | 14.4           |                |                | 18.0           |                |                | 3X (cm) | x <sub>0</sub> <sup>2</sup> | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N | x <sub>0</sub> <sup>2</sup> /N |  |
|                 | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> | x <sub>0</sub> | y <sub>0</sub> | z <sub>0</sub> |         |                             |                                |                                |                                |                                |                                |                                |                                |  |
| Frame 1         | 3.8            | 1.8            | 13.5           | 8.4            | -0.5           | 12.3           | 15.6           | -1.7           | 10.4           | 17.5           | -1.9           | 10.1           | -14.4   | -15.8                       | 5.1                            | 3.2                            | 1.1                            | -0.4                           | -0.2                           |                                |                                |  |
| Frame 2         | 3.4            | 1.9            | 13.4           | 7.4            | -0.1           | 12.3           | 15.3           | -1.3           | 10.4           | 17.3           | -2.2           | 10.1           | -10.8   | -16.8                       | 4.3                            | 2.3                            | 1.5                            | -0.4                           | -0.2                           |                                |                                |  |
| Frame 3         | 4.0            | 1.5            | 13.3           | 7.5            | -0.4           | 12.3           | 15.6           | -1.7           | 10.6           | 17.1           | -1.9           | 10.1           | -7.2    | -8.4                        | 3.1                            | 1.4                            | 1.3                            | -0.4                           | -0.2                           |                                |                                |  |
| Frame 4         | 3.5            | 1.9            | 13.4           | 7.4            | 0.0            | 12.3           | 15.1           | -1.3           | 10.5           | 17.3           | -2.2           | 10.1           | -3.6    | 5.3                         | 2.4                            | 0.2                            | 1.5                            | -0.7                           | -0.1                           |                                |                                |  |
| Frame 5         | 3.5            | 1.8            | 13.4           | 7.9            | -0.5           | 12.2           | 15.7           | -1.7           | 10.4           | 17.1           | -2.0           | 10.1           | 0.0     | -0.8                        | 1.2                            | -0.5                           |                                |                                |                                |                                |                                |  |
| Frame 6         | 3.9            | 1.8            | 13.3           | 7.3            | 0.0            | 12.3           | 14.7           | -1.3           | 10.4           | 16.8           | -2.0           | 9.9            | 3.6     | 3.2                         | -0.1                           | -1.1                           | 0.9                            | 0.0                            | -0.3                           |                                |                                |  |
| Frame 7         | 3.8            | 1.9            | 13.4           | 7.1            | -0.3           | 12.1           | 15.7           | -1.8           | 10.4           | 17.6           | -2.0           | 10.1           | 7.2     | 6.8                         | -1.2                           | -1.6                           | 0.9                            | -0.2                           | -0.2                           |                                |                                |  |
| Frame 8         | 3.6            | 1.9            | 13.5           | 7.7            | -0.1           | 12.3           | 15.4           | -1.3           | 10.5           | 17.0           | -2.1           | 10.0           | 10.8    | 10.8                        | -3.2                           | -2.7                           | 1.0                            | -0.3                           | -0.3                           |                                |                                |  |
| Frame 9         | 3.9            | 1.9            | 13.5           | 7.6            | -0.4           | 12.3           | 15.6           | -1.7           | 10.6           | 18.0           | -2.1           | 10.3           | 14.4    | 18.4                        | 4.5                            | 4.5                            | 1.3                            | -0.3                           | -0.3                           |                                |                                |  |
| Frame 10        | 3.9            | 1.9            | 13.4           | 7.5            | 0.0            | 12.4           | 15.0           | -1.2           | 10.5           | 17.1           | -2.1           | 10.1           | 18.0    | 20.3                        | -5.1                           | -4.9                           | 1.1                            | -0.3                           | -0.3                           |                                |                                |  |
| Average         | 3.8            | 1.8            | 13.4           | 7.8            | -0.2           | 12.3           | 15.4           | -1.5           | 10.5           | 17.3           | -2.1           | 10.1           |         |                             |                                |                                | Ave                            | 1.17                           | -0.33                          | -0.22                          |                                |  |
| St. Deviation   | 0.2            | 0.14           | 0.05           | 0.36           | 0.20           | 0.07           | 0.33           | 0.22           | 0.06           | 0.34           | 0.10           | 0.10           |         |                             |                                |                                |                                |                                |                                |                                |                                |  |

| Q1 control: $x_0$ control = -22.3 cm, $y_0$ control = 76.4 cm, $z_0$ control = 1.4 cm |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|---------------------------------------------------------------------------------------|-------|--------|--------|----------|--------|---------|--------|--------|--------|-------|-------|-------|-------|------|------|-------|-------|------|------|------|------|------|--|
| Raw Coordinates                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
| 2 $\gamma$ (degrees)                                                                  | $x_0$ | $y_0$  | $z_0$  | $x_1$    | $y_1$  | $z_1$   | $x_2$  | $y_2$  | $z_2$  | $x_3$ | $y_3$ | $z_3$ | $x_4$ |      |      |       |       |      |      |      |      |      |  |
|                                                                                       | -10.3 |        |        | -5.9     |        |         | -3.2   |        |        | -3.0  |       |       | 0     |      |      |       |       |      |      |      |      |      |  |
| Frame 1                                                                               | -40.9 | 76.24  | 8.3872 | -34.6207 | 76.692 | 5.46203 | -34.62 | 76.692 | 5.462  | -27.9 | 76.9  | 3.7   | -27.1 | 77.1 | 2.1  | -22.2 | 77.5  | 0.9  |      |      |      |      |  |
| Frame 2                                                                               | -42.3 | 76.041 | 8.2003 | -34.6067 | 76.676 | 5.22481 | -34.81 | 76.679 | 5.2248 | -27.6 | 77.3  | 3.7   | -27.7 | 77.2 | 2.6  | -21.8 | 77.3  | 0.9  |      |      |      |      |  |
| Frame 3                                                                               | -41.4 | 76.202 | 8.2575 | -34.4235 | 76.669 | 5.26265 | -34.42 | 76.669 | 5.2626 | -27.6 | 76.9  | 3.6   | -27.8 | 77.1 | 2.6  | -21.8 | 77.4  | 1.0  |      |      |      |      |  |
| Frame 4                                                                               | -41.8 | 76.148 | 8.1868 | -35.2304 | 76.81  | 5.31462 | -35.23 | 76.81  | 5.3146 | -28.3 | 77.3  | 3.6   | -28.3 | 77.0 | 2.4  | -22.1 | 77.4  | 0.9  |      |      |      |      |  |
| Frame 5                                                                               | -41.9 | 76.167 | 8.2633 | -34.8323 | 76.727 | 5.26164 | -34.83 | 76.727 | 5.2616 | -27.9 | 76.9  | 3.7   | -27.8 | 77.0 | 2.6  | -21.9 | 77.4  | 0.9  |      |      |      |      |  |
| Frame 6                                                                               | -41.4 | 76.154 | 8.3933 | -34.9001 | 76.821 | 5.39921 | -34.9  | 76.821 | 5.3992 | -27.8 | 77.3  | 3.7   | -27.5 | 77.1 | 2.5  | -22.2 | 77.5  | 1.1  |      |      |      |      |  |
| Frame 7                                                                               | -42.0 | 76.174 | 8.2435 | -34.6693 | 76.603 | 5.31516 | -34.67 | 76.603 | 5.3152 | -27.9 | 76.9  | 3.6   | -27.4 | 77.1 | 2.3  | -21.6 | 77.4  | 0.8  |      |      |      |      |  |
| Frame 8                                                                               | -42.4 | 76.054 | 8.2367 | -34.6903 | 76.613 | 5.42433 | -34.69 | 76.613 | 5.4243 | -28.3 | 77.2  | 3.7   | -27.6 | 77.0 | 2.4  | -22.3 | 77.3  | 1.0  |      |      |      |      |  |
| Frame 9                                                                               | -42.0 | 76.167 | 8.2466 | -34.6315 | 76.643 | 5.26696 | -34.63 | 76.643 | 5.267  | -27.2 | 77.0  | 3.7   | -27.8 | 77.0 | 2.3  | -22.1 | 77.3  | 1.0  |      |      |      |      |  |
| Frame 10                                                                              | -41.6 | 76.136 | 8.2912 | -34.6913 | 76.633 | 5.43964 | -34.69 | 76.633 | 5.4396 | -27.6 | 77.4  | 3.6   | -27.6 | 77.1 | 2.4  | -22.2 | 77.3  | 1.1  |      |      |      |      |  |
| Average                                                                               | -41.8 | 76.2   | 8.3    | -34.8    | 76.8   | 5.3     | -34.8  | 76.8   | 5.3    | -27.8 | 77.1  | 3.7   | -27.7 | 77.1 | 2.4  | -22.0 | 77.4  | 1.0  |      |      |      |      |  |
| St. Deviation                                                                         | 0.4   | 0.06   | 0.07   | 0.22     | 0.11   | 0.09    | 0.22   | 0.11   | 0.09   | 0.33  | 0.22  | 0.07  | 0.32  | 0.05 | 0.15 | 0.24  | 0.06  | 0.06 |      |      |      |      |  |
| Raw Coordinates                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
| 2 $\gamma$ (degrees)                                                                  | $x_0$ | $y_0$  | $z_0$  | $x_1$    | $y_1$  | $z_1$   | $x_2$  | $y_2$  | $z_2$  | $x_3$ | $y_3$ | $z_3$ | $x_4$ |      |      |       |       |      |      |      |      |      |  |
|                                                                                       | 3.0   |        |        | 3.2      |        |         | 5.9    |        |        | 10.3  |       |       |       |      |      |       |       |      |      |      |      |      |  |
| Frame 1                                                                               | -17.4 | 76.8   | -0.3   | -16.3    | 76.2   | 0.1     | -12.8  | 76.6   | -1.3   | -8.3  | 80.6  | -2.8  | -4.3  | 81.6 | -3.4 | -4.6  | -12.5 | 0.4  | 3.9  | 1.5  | 0.0  | -0.3 |  |
| Frame 2                                                                               | -17.5 | 76.7   | -0.5   | -16.6    | 76.3   | 0.1     | -11.2  | 76.6   | -1.7   | -7.8  | 80.4  | -2.8  | -4.7  | 81.6 | -3.3 | -5.9  | -12.5 | 0.4  | 3.9  | 2.1  | -0.1 | -0.7 |  |
| Frame 3                                                                               | -17.8 | 76.8   | -0.2   | -16.2    | 76.3   | 0.1     | -12.7  | 76.5   | -1.3   | -8.4  | 80.6  | -2.7  | -4.3  | 81.6 | -3.4 | -3.2  | -5.5  | 0.7  | 2.3  | 1.7  | 0.2  | -0.7 |  |
| Frame 4                                                                               | -17.1 | 76.9   | -0.5   | -16.4    | 76.6   | -0.1    | -11.0  | 76.6   | -1.5   | -7.8  | 80.6  | -2.8  | -4.7  | 81.6 | -3.3 | 3.0   | -5.4  | 0.7  | 1.0  | -1.6 | 0.2  | 0.3  |  |
| Frame 5                                                                               | -17.1 | 76.8   | -0.3   | -16.2    | 76.4   | -0.1    | -12.0  | 76.6   | -1.5   | -8.3  | 80.6  | -2.8  | -4.6  | 81.5 | -3.5 | 0.0   | 0.3   | 1.0  | -0.4 |      |      |      |  |
| Frame 6                                                                               | -17.2 | 76.9   | -0.4   | -16.6    | 76.6   | 0.0     | -10.5  | 76.6   | -1.6   | -7.8  | 80.6  | -2.7  | -4.8  | 81.6 | -3.6 | 3.0   | 4.9   | 2.4  | -1.7 | 1.6  | 0.8  | -0.6 |  |
| Frame 7                                                                               | -17.6 | 76.8   | -0.1   | -16.0    | 76.3   | -0.2    | -12.8  | 76.7   | -1.2   | -8.0  | 80.6  | -2.8  | -4.2  | 81.6 | -3.7 | 3.2   | 3.9   | 2.0  | -1.4 | 1.2  | 0.6  | -0.4 |  |
| Frame 8                                                                               | -17.5 | 76.9   | -0.2   | -16.4    | 76.4   | 0.0     | -11.5  | 76.5   | -1.6   | -7.8  | 80.3  | -2.7  | -5.1  | 81.6 | -3.5 | 5.9   | 10.5  | 3.2  | -2.9 | 1.8  | 0.5  | -0.3 |  |
| Frame 9                                                                               | -16.9 | 76.8   | -0.3   | -16.7    | 76.3   | 0.0     | -12.4  | 76.5   | -1.6   | -8.2  | 80.6  | -2.8  | -3.9  | 81.7 | -3.5 | 6.6   | 14.3  | 4.2  | -4.2 | 1.7  | 0.5  | -0.5 |  |
| Frame 10                                                                              | -17.8 | 76.9   | -0.3   | -16.5    | 76.4   | 0.1     | -11.3  | 76.6   | -1.7   | -8.0  | 80.5  | -2.8  | -4.7  | 81.7 | -3.3 | 10.3  | 17.8  | 5.2  | -4.9 | 1.7  | 0.5  | -0.5 |  |
| Average                                                                               | -17.4 | 76.8   | -0.3   | -16.4    | 76.4   | 0.0     | -11.8  | 76.6   | -1.5   | -8.0  | 80.5  | -2.8  | -4.5  | 81.6 | -3.5 |       |       |      |      |      |      |      |  |
| St. Deviation                                                                         | 0.3   | 0.06   | 0.12   | 0.22     | 0.13   | 0.11    | 0.63   | 0.06   | 0.16   | 0.25  | 0.06  | 0.03  | 0.36  | 0.10 | 0.13 |       |       |      |      |      |      |      |  |
| Uncertainty                                                                           |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
| 2 $\gamma$ (degrees)                                                                  | $x_0$ | $y_0$  | $z_0$  | $x_1$    | $y_1$  | $z_1$   | $x_2$  | $y_2$  | $z_2$  | $x_3$ | $y_3$ | $z_3$ | $x_4$ |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |
|                                                                                       |       |        |        |          |        |         |        |        |        |       |       |       |       |      |      |       |       |      |      |      |      |      |  |





| Raw Coordinates |                |                |                |                |                |                |                |                |                |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Raw Coordinates |                |                |                |                |                |                |                |                |                |
| St(degrees)     | -10.0          |                |                | -8.0           |                |                | -6.0           |                |                |
|                 | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> |
| Frame 1         | 12.6           | 0.2            | 9.4            | 10.7           | 1.5            | 10.8           | 7.2            | 1.8            | 11.0           |
| Frame 2         | 13.5           | 0.0            | 9.2            | 10.3           | 1.3            | 10.7           | 7.0            | 1.8            | 11.0           |
| Frame 3         | 13.4           | -0.2           | 9.4            | 9.6            | 1.6            | 10.6           | 7.9            | 1.8            | 11.4           |
| Frame 4         | 13.6           | 0.0            | 9.1            | 9.2            | 1.5            | 10.7           | 8.6            | 1.6            | 11.2           |
| Frame 5         | 13.8           | -0.1           | 9.3            | 9.5            | 1.7            | 11.1           | 7.9            | 1.9            | 11.2           |
| Frame 6         | 13.3           | 0.0            | 9.3            | 9.0            | 1.6            | 10.9           | 7.5            | 1.7            | 11.4           |
| Frame 7         | 13.4           | -0.2           | 9.6            | 8.5            | 1.8            | 10.9           | 7.1            | 2.0            | 11.2           |
| Frame 8         | 12.3           | 0.3            | 9.5            | 9.7            | 1.5            | 11.0           | 7.8            | 1.7            | 11.4           |
| Frame 9         | 12.1           | 0.2            | 9.5            | 8.8            | 1.8            | 11.0           | 7.7            | 1.9            | 11.1           |
| Frame 10        | 12.6           | 0.2            | 9.4            | 10.7           | 1.2            | 10.9           | 7.8            | 1.8            | 11.2           |
| Average         | 13.0           | 0.0            | 9.4            | 9.6            | 1.5            | 10.9           | 7.6            | 1.8            | 11.2           |
| St. Deviation   | 0.57           | 0.15           | 0.15           | 0.77           | 0.20           | 0.15           | 0.46           | 0.12           | 0.15           |
| Raw Coordinates |                |                |                |                |                |                |                |                |                |
| Raw Coordinates |                |                |                |                |                |                |                |                |                |
| St(degrees)     | 4.0            |                |                | 6.0            |                |                | 8.0            |                |                |
|                 | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> |
| Frame 1         | -9.5           | 4.8            | 16.4           | -15.5          | 5.6            | 16.1           | -17.8          | 5.0            | 16.5           |
| Frame 2         | -10.2          | 4.6            | 16.5           | -15.1          | 5.3            | 16.1           | -18.1          | 4.8            | 16.5           |
| Frame 3         | -9.8           | 4.8            | 16.6           | -15.4          | 5.6            | 16.1           | -17.8          | 5.0            | 16.2           |
| Frame 4         | -10.0          | 4.7            | 16.6           | -15.7          | 5.5            | 16.1           | -18.6          | 4.8            | 16.3           |
| Frame 5         | -10.0          | 4.8            | 16.9           | -15.5          | 5.6            | 16.1           | -18.1          | 5.1            | 16.5           |
| Frame 6         | -10.0          | 4.4            | 16.7           | -15.4          | 5.6            | 16.1           | -18.3          | 4.5            | 16.4           |
| Frame 7         | -9.5           | 4.8            | 16.9           | -15.4          | 5.5            | 16.2           | -17.7          | 5.0            | 16.5           |
| Frame 8         | -11.0          | 4.4            | 16.4           | -15.2          | 5.5            | 16.0           | -18.3          | 4.8            | 16.4           |
| Frame 9         | -12.2          | 4.5            | 16.4           | -15.3          | 5.5            | 16.1           | -17.4          | 5.0            | 16.3           |
| Frame 10        | -9.8           | 4.1            | 16.7           | -15.0          | 5.5            | 16.2           | -18.3          | 4.8            | 16.4           |
| Average         | -10.2          | 4.6            | 16.6           | -15.3          | 5.5            | 16.1           | -18.1          | 4.9            | 16.4           |
| St. Deviation   | 0.82           | 0.24           | 0.20           | 0.20           | 0.07           | 0.07           | 0.41           | 0.16           | 0.10           |
| Uncertainty     |                |                |                |                |                |                |                |                |                |
| Uncertainty     |                |                |                |                |                |                |                |                |                |
| St(degrees)     | 10.0           |                |                | 10.0           |                |                | 10.0           |                |                |
|                 | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> | X <sub>0</sub> | Y <sub>0</sub> | Z <sub>0</sub> |
| Frame 1         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 2         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 3         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 4         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 5         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 6         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 7         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 8         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 9         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Frame 10        | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| Average         | -8.0           | 12.6           | -1.5           | -4.1           | -1.57          | 0.18           | 0.52           | -8.0           | 12.6           |
| St. Deviation   | 0.57           | 0.15           | 0.15           | 0.77           | 0.20           | 0.15           | 0.46           | 0.12           | 0.15           |

| $\theta_{\text{center}}^{\text{center}} = -3.0 \text{ cm}, y_{\text{center}} = 3.0 \text{ cm}, z_{\text{center}} = 15.0 \text{ cm}$ |       |       |       |       |       |       |       |       |       |         |       |             |       |       |       |       |       |       |       |       |       |  |
|-------------------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|-------|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--|
| Raw Coordinates                                                                                                                     |       |       |       |       |       |       |       |       |       |         |       |             |       |       |       |       |       |       |       |       |       |  |
| $\theta_z(\text{degrees})$                                                                                                          | -9.3  |       |       | -5.9  |       |       | -3.9  |       |       | -1.9    |       |             | 0     |       |       | 1.9   |       |       |       |       |       |  |
|                                                                                                                                     | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ | $x_0$   | $y_0$ | $z_0$       | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ |       |       |       |  |
| Frame 1                                                                                                                             | -9.3  | 1.7   | 25.1  | 0.6   | 0.4   | 25.1  | -6.1  | 2.1   | 20.0  | -2.6    | 2.2   | 17.3        | -2.9  | 3.3   | 14.4  | 0.8   | 5.1   | 12.3  |       |       |       |  |
| Frame 2                                                                                                                             | -9.7  | 1.8   | 25.1  | 0.8   | 0.7   | 25.2  | -6.9  | 2.1   | 20.1  | -2.6    | 2.2   | 17.4        | -3.6  | 3.1   | 14.3  | -0.8  | 5.3   | 12.4  |       |       |       |  |
| Frame 3                                                                                                                             | -9.2  | 1.8   | 25.0  | 0.0   | 0.4   | 25.1  | -6.6  | 2.2   | 19.9  | -2.9    | 2.1   | 17.3        | -3.1  | 3.3   | 14.3  | -0.7  | 5.1   | 12.5  |       |       |       |  |
| Frame 4                                                                                                                             | -9.5  | 1.8   | 25.1  | 0.4   | 0.8   | 25.0  | -6.2  | 2.0   | 20.3  | -2.8    | 2.3   | 17.3        | -3.8  | 2.9   | 14.3  | -0.8  | 5.1   | 12.3  |       |       |       |  |
| Frame 5                                                                                                                             | -9.1  | 1.8   | 25.0  | 0.1   | 0.6   | 25.1  | -6.1  | 2.1   | 20.2  | -2.5    | 2.1   | 17.4        | -3.4  | 3.3   | 14.3  | -0.8  | 5.1   | 12.4  |       |       |       |  |
| Frame 6                                                                                                                             | -9.4  | 1.8   | 25.1  | 0.1   | 0.7   | 24.8  | -7.2  | 2.1   | 20.0  | -2.8    | 2.3   | 17.4        | -4.0  | 3.1   | 14.2  | -0.6  | 5.2   | 12.6  |       |       |       |  |
| Frame 7                                                                                                                             | -9.6  | 1.8   | 25.1  | -0.2  | 0.6   | 25.0  | -6.3  | 2.2   | 20.0  | -2.5    | 2.1   | 17.5        | -3.0  | 3.3   | 14.3  | -0.8  | 5.1   | 12.4  |       |       |       |  |
| Frame 8                                                                                                                             | -9.7  | 1.8   | 25.0  | 0.5   | 0.6   | 25.0  | -6.3  | 2.1   | 20.2  | -2.1    | 2.1   | 17.4        | -3.3  | 3.0   | 14.5  | -0.8  | 5.0   | 12.4  |       |       |       |  |
| Frame 9                                                                                                                             | -9.6  | 1.7   | 25.1  | -0.2  | 0.6   | 24.9  | -6.8  | 2.1   | 20.2  | -2.9    | 2.1   | 17.3        | -2.3  | 3.2   | 14.5  | -1.0  | 5.2   | 12.4  |       |       |       |  |
| Frame 10                                                                                                                            | -9.5  | 1.8   | 25.1  | -0.2  | 0.8   | 24.9  | -6.3  | 2.0   | 20.3  | -3.0    | 2.3   | 17.2        | -3.9  | 3.1   | 14.4  | -1.1  | 5.1   | 12.5  |       |       |       |  |
| Average                                                                                                                             | -9.5  | 1.8   | 25.1  | 0.2   | 0.6   | 25.0  | -6.5  | 2.1   | 20.1  | -2.7    | 2.2   | 17.3        | -3.3  | 3.2   | 14.3  | -0.8  | 5.1   | 12.4  |       |       |       |  |
| St. Deviation                                                                                                                       | 0.2   | 0.04  | 0.05  | 0.36  | 0.13  | 0.10  | 0.37  | 0.07  | 0.14  | 0.28    | 0.08  | 0.07        | 0.52  | 0.15  | 0.09  | 0.14  | 0.07  | 0.07  |       |       |       |  |
| Raw Coordinates                                                                                                                     |       |       |       |       |       |       |       |       |       |         |       | Uncertainty |       |       |       |       |       |       |       |       |       |  |
| $\theta_z(\text{degrees})$                                                                                                          | 3.9   |       |       | 5.9   |       |       | 9.3   |       |       | degrees |       |             | $x_0$ |       |       | $y_0$ |       |       | $z_0$ |       |       |  |
|                                                                                                                                     | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ | $x_0$   | $y_0$ | $z_0$       | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ | $x_0$ | $y_0$ | $z_0$ |  |
| Frame 1                                                                                                                             | -5.2  | 8.8   | 10.5  | -6.0  | 11.9  | 9.3   | -6.4  | 14.5  | 7.7   | -5.9    | 3.2   | -2.4        | 10.0  | -0.55 | 0.403 | -1.7  |       |       |       |       |       |  |
| Frame 2                                                                                                                             | -5.0  | 8.8   | 10.6  | -6.0  | 11.8  | 9.4   | -6.4  | 14.3  | 7.5   | -3.9    | -3.5  | -0.9        | 5.1   | 0.865 | 0.233 | -1.31 |       |       |       |       |       |  |
| Frame 3                                                                                                                             | -5.5  | 8.9   | 10.6  | -5.7  | 11.9  | 9.3   | -5.7  | 14.4  | 7.8   | -1.9    | 0.3   | -0.8        | 2.3   | -0.16 | 0.422 | -1.23 |       |       |       |       |       |  |
| Frame 4                                                                                                                             | -4.7  | 8.8   | 10.6  | -5.9  | 11.9  | 9.3   | -6.2  | 14.3  | 7.6   | 0.0     | -0.3  | 0.2         | -0.7  |       |       |       |       |       |       |       |       |  |
| Frame 5                                                                                                                             | -5.3  | 8.8   | 10.7  | -6.0  | 11.9  | 9.2   | -5.8  | 14.4  | 7.8   | 1.9     | 2.2   | 2.1         | -2.6  | 1.137 | 1.111 | -1.35 |       |       |       |       |       |  |
| Frame 6                                                                                                                             | -4.5  | 8.8   | 10.8  | -6.3  | 11.9  | 9.2   | -5.8  | 14.1  | 7.4   | 3.9     | -2.1  | 5.8         | -4.4  | -0.55 | 1.486 | -1.12 |       |       |       |       |       |  |
| Frame 7                                                                                                                             | -5.7  | 8.8   | 10.6  | -5.9  | 11.9  | 9.2   | -5.9  | 14.4  | 7.5   | 5.9     | -3.0  | 8.9         | -3.7  | -0.5  | 1.505 | -0.97 |       |       |       |       |       |  |
| Frame 8                                                                                                                             | -5.0  | 8.9   | 10.7  | -5.9  | 11.9  | 9.3   | -6.4  | 14.3  | 7.7   | 9.3     | -3.1  | 11.4        | -7.4  | -0.33 | 1.22  | -0.6  |       |       |       |       |       |  |
| Frame 9                                                                                                                             | -5.3  | 8.9   | 10.6  | -5.7  | 11.9  | 9.3   | -5.8  | 14.4  | 7.7   |         |       |             |       | Ave   | 0.08  | 0.81  | -1.19 |       |       |       |       |  |
| Frame 10                                                                                                                            | -4.9  | 8.7   | 10.8  | -6.1  | 11.9  | 9.4   | -6.6  | 14.3  | 7.8   |         |       |             |       |       |       |       |       |       |       |       |       |  |
| Average                                                                                                                             | -5.1  | 8.8   | 10.6  | -6.0  | 11.9  | 9.3   | -6.1  | 14.4  | 7.6   |         |       |             |       |       |       |       |       |       |       |       |       |  |
| St. Deviation                                                                                                                       | 0.4   | 0.08  | 0.09  | 0.19  | 0.04  | 0.07  | 0.35  | 0.10  | 0.09  |         |       |             |       |       |       |       |       |       |       |       |       |  |

| $q_c$ control: $X_0$ control = -3.0 cm, $Y_0$ control = -3.0 cm, $Z_0$ control = 15.0 cm |              |              |              |              |              |              |              |              |              |              |              |              |
|------------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Raw Coordinates                                                                          |              |              |              |              |              |              |              |              |              |              |              |              |
| 2 $\gamma$ (degrees)                                                                     | -10.3        |              |              | -5.9         |              |              | -3.2         |              |              | 0            |              |              |
|                                                                                          | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        |
| Frame 1                                                                                  | 429          | 11.1         | 191          | -26.8        | 8.3          | 16.9         | -16.6        | 5.9          | 15.2         | -3.8         | 4.1          | 14.3         |
| Frame 2                                                                                  | 42.7         | 10.8         | 19.0         | -27.6        | 8.6          | 16.6         | -16.9        | 6.4          | 16.6         | -14.9        | 5.9          | 15.4         |
| Frame 3                                                                                  | 42.7         | 11.1         | 19.1         | -27.2        | 8.3          | 16.6         | -16.9        | 6.0          | 16.6         | -14.9        | 6.0          | 15.5         |
| Frame 4                                                                                  | 42.5         | 10.8         | 19.0         | -27.6        | 8.4          | 16.6         | -17.0        | 6.4          | 16.5         | -15.3        | 6.1          | 15.3         |
| Frame 5                                                                                  | 43.5         | 11.1         | 19.0         | -27.5        | 8.3          | 16.5         | -16.2        | 5.9          | 16.6         | -14.8        | 5.9          | 15.4         |
| Frame 6                                                                                  | 42.7         | 10.8         | 19.1         | -27.4        | 8.3          | 16.6         | -16.0        | 6.3          | 16.7         | -15.0        | 6.0          | 15.3         |
| Frame 7                                                                                  | 42.8         | 11.1         | 19.0         | -26.6        | 8.1          | 16.6         | -16.4        | 6.0          | 16.7         | -14.9        | 6.0          | 15.3         |
| Frame 8                                                                                  | 42.9         | 10.8         | 18.9         | -27.4        | 8.6          | 16.7         | -16.5        | 6.2          | 16.7         | -15.4        | 5.9          | 15.3         |
| Frame 9                                                                                  | 43.2         | 11.0         | 18.9         | -27.5        | 8.3          | 16.6         | -16.3        | 6.0          | 16.8         | -15.3        | 5.9          | 15.4         |
| Frame 10                                                                                 | 42.5         | 10.7         | 19.0         | -27.2        | 8.5          | 16.6         | -16.2        | 6.3          | 16.6         | -15.3        | 6.0          | 15.4         |
| Average                                                                                  | 42.8         | 10.9         | 19.0         | -27.3        | 8.4          | 16.7         | -16.5        | 6.1          | 16.6         | -15.0        | 6.0          | 15.4         |
| St. Deviation                                                                            | 0.3          | 0.15         | 0.07         | 0.35         | 0.14         | 0.11         | 0.34         | 0.19         | 0.10         | 0.29         | 0.07         | 0.10         |
| Raw Coordinates                                                                          |              |              |              |              |              |              |              |              |              |              |              |              |
| 2 $\gamma$ (degrees)                                                                     | 3.0          |              |              | 5.9          |              |              | 8.6          |              |              | 10.3         |              |              |
|                                                                                          | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        | $x_0$        | $y_0$        | $z_0$        |
| Frame 1                                                                                  | 6.7          | 3.9          | 13.6         | 7.5          | 3.3          | 14.1         | 19.4         | 2.2          | 13.4         | 27.7         | 1.8          | 12.6         |
| Frame 2                                                                                  | 6.6          | 4.1          | 13.6         | 6.7          | 3.9          | 14.1         | 19.4         | 2.0          | 13.4         | 27.7         | 1.6          | 12.6         |
| Frame 3                                                                                  | 6.6          | 3.9          | 13.6         | 7.4          | 3.4          | 14.1         | 19.6         | 2.1          | 13.7         | 28.1         | 1.8          | 12.7         |
| Frame 4                                                                                  | 7.1          | 4.1          | 13.7         | 7.3          | 3.9          | 13.9         | 21.0         | 1.8          | 13.5         | 27.9         | 1.6          | 12.6         |
| Frame 5                                                                                  | 8.0          | 3.7          | 13.6         | 6.6          | 3.5          | 14.0         | 20.1         | 2.1          | 13.8         | 28.0         | 1.8          | 12.8         |
| Frame 6                                                                                  | 7.6          | 4.0          | 13.7         | 6.8          | 3.7          | 14.1         | 20.8         | 1.9          | 13.4         | 27.7         | 1.7          | 12.7         |
| Frame 7                                                                                  | 7.4          | 3.7          | 13.6         | 6.7          | 3.4          | 13.9         | 19.9         | 2.2          | 13.6         | 28.1         | 1.8          | 12.6         |
| Frame 8                                                                                  | 7.2          | 4.0          | 14.0         | 6.7          | 3.8          | 13.7         | 19.7         | 1.9          | 13.3         | 27.6         | 1.7          | 12.6         |
| Frame 9                                                                                  | 7.4          | 3.8          | 13.9         | 6.4          | 3.5          | 13.8         | 18.6         | 1.9          | 13.7         | 27.5         | 1.9          | 12.8         |
| Frame 10                                                                                 | 6.7          | 4.0          | 13.9         | 6.5          | 4.0          | 14.2         | 20.1         | 2.0          | 13.5         | 28.0         | 1.6          | 12.7         |
| Average                                                                                  | 7.1          | 3.9          | 13.6         | 6.9          | 3.8          | 14.0         | 19.9         | 2.0          | 13.5         | 27.9         | 1.7          | 12.7         |
| St. Deviation                                                                            | 0.5          | 0.13         | 0.10         | 0.39         | 0.26         | 0.16         | 0.69         | 0.14         | 0.16         | 0.20         | 0.10         | 0.08         |
| Uncertainty                                                                              |              |              |              |              |              |              |              |              |              |              |              |              |
| 2 $\gamma$ (degrees)                                                                     | $\Delta x_0$ |              |              | $\Delta y_0$ |              |              | $\Delta z_0$ |              |              | $\Delta x_0$ |              |              |
|                                                                                          | $\Delta x_0$ | $\Delta y_0$ | $\Delta z_0$ | $\Delta x_0$ | $\Delta y_0$ | $\Delta z_0$ | $\Delta x_0$ | $\Delta y_0$ | $\Delta z_0$ | $\Delta x_0$ | $\Delta y_0$ | $\Delta z_0$ |
| Frame 1                                                                                  | 10.3         | 3.9          | 7.9          | 4.0          | 3.9          | 4.8          | 10.3         | 3.9          | 7.9          | 4.0          | 3.9          | 4.8          |
| Frame 2                                                                                  | 8.6          | 24.3         | 5.4          | 1.7          | 2.8          | 0.6          | 8.6          | 24.3         | 5.4          | 1.7          | 2.8          | 0.6          |
| Frame 3                                                                                  | 5.9          | 24.3         | 5.4          | 1.7          | 4.1          | -0.9         | 5.9          | 24.3         | 5.4          | 1.7          | 4.1          | -0.9         |
| Frame 4                                                                                  | 3.2          | 13.5         | 3.1          | 1.6          | 4.2          | -1.0         | 3.2          | 13.5         | 3.1          | 1.6          | 4.2          | -1.0         |
| Frame 5                                                                                  | 3.0          | 12.0         | 3.0          | 0.4          | 4.0          | 1.0          | 3.0          | 12.0         | 3.0          | 0.4          | 4.0          | 1.0          |
| Frame 6                                                                                  | 1.0          | 1.2          | -0.6         |              |              |              | 1.0          | 1.2          | -0.6         |              |              |              |
| Frame 7                                                                                  | 1.2          | 0.9          | -1.2         | 3.4          | 0.3          | -0.4         | 1.2          | 0.9          | -1.2         | 3.4          | 0.3          | -0.4         |
| Frame 8                                                                                  | 1.5          | 3.9          | -0.2         | 0.3          | 0.2          | -0.3         | 1.5          | 3.9          | -0.2         | 0.3          | 0.2          | -0.3         |
| Frame 9                                                                                  | 1.3          | 2.6          | -0.1         | 0.3          | 3.6          | -0.1         | 1.3          | 2.6          | -0.1         | 0.3          | 3.6          | -0.1         |
| Frame 10                                                                                 | 1.9          | 2.5          | 3.9          | -0.2         | 0.2          |              | 1.9          | 2.5          | 3.9          | -0.2         | 0.2          |              |
| Average                                                                                  | 2.88         | 4.25         | 0.27         |              |              |              | 2.88         | 4.25         | 0.27         |              |              |              |

## APPENDIX L

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point C

| 3X (cm)       |       | Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                | Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                | Raw Coordinates |  |  |  |  |  |  |  |  |  |  |  |
|---------------|-------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|--|--|--|--|--|--|--|--|--|--|--|
|               |       | -18             |                |                |                | -14.4          |                |                |                | -10.8          |                |                |                | -7.2            |                |                |                | -3.6           |                |                |                | 0              |                |                |                | 3.6             |  |  |  |  |  |  |  |  |  |  |  |
|               |       | X <sub>c</sub>  | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub>  | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 1       | -23.5 | 77.0            | 68.2           | -18.1          | 76.8           | 68.6           | -17.5          | 76.3           | 68.4           | -10.5          | 77.2           | 68.3           | -7.7           | 77.5            | 67.9           | -3.2           | 77.1           | 67.8           | 1.1            | 76.8           | 67.9           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 2       | -23.5 | 77.3            | 68.1           | -18.6          | 76.8           | 68.7           | -17.6          | 76.4           | 68.2           | -10.8          | 76.9           | 68.1           | -6.8           | 77.5            | 67.9           | -3.1           | 77.1           | 67.8           | 1.5            | 76.7           | 68.0           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 3       | -23.2 | 77.0            | 68.2           | -18.3          | 76.8           | 68.7           | -17.3          | 76.3           | 68.4           | -10.8          | 77.0           | 68.1           | -7.3           | 77.6            | 67.9           | -3.3           | 77.0           | 67.9           | 1.1            | 76.7           | 68.0           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 4       | -23.3 | 77.2            | 68.2           | -18.9          | 76.8           | 68.8           | -17.9          | 76.3           | 68.2           | -11.3          | 77.0           | 68.3           | -6.8           | 77.5            | 67.7           | -3.0           | 77.0           | 67.9           | 1.1            | 76.7           | 67.8           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 5       | -23.1 | 77.0            | 68.2           | -19.2          | 76.8           | 68.7           | -17.4          | 76.4           | 68.4           | -11.0          | 77.1           | 68.2           | -7.3           | 77.5            | 67.8           | -3.5           | 77.0           | 67.8           | 1.0            | 76.7           | 67.8           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 6       | -23.1 | 77.2            | 68.2           | -18.9          | 76.8           | 68.7           | -17.5          | 76.3           | 68.3           | -11.2          | 76.9           | 68.3           | -6.8           | 77.5            | 67.8           | -3.3           | 77.0           | 67.9           | 1.3            | 76.7           | 68.0           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 7       | -22.9 | 76.9            | 68.2           | -19.2          | 76.8           | 68.6           | -17.6          | 76.3           | 68.4           | -11.2          | 77.1           | 68.3           | -7.4           | 77.5            | 67.9           | -3.5           | 77.0           | 67.8           | 1.2            | 76.6           | 67.9           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 8       | -23.2 | 77.3            | 68.2           | -18.8          | 76.7           | 68.7           | -17.3          | 76.3           | 68.3           | -11.0          | 76.9           | 68.2           | -7.0           | 77.5            | 67.7           | -3.6           | 76.9           | 67.8           | 1.5            | 76.7           | 68.0           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 9       | -23.0 | 77.0            | 68.2           | -18.3          | 76.8           | 68.7           | -17.3          | 76.3           | 68.3           | -11.1          | 77.2           | 68.2           | -7.6           | 77.5            | 67.9           | -3.7           | 77.0           | 67.8           | 1.1            | 76.8           | 67.9           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Frame 10      | -23.3 | 77.3            | 68.2           | -19.1          | 76.7           | 68.7           | -17.5          | 76.3           | 68.3           | -11.5          | 76.9           | 68.2           | -6.6           | 77.5            | 67.9           | -3.1           | 77.0           | 67.9           | 0.9            | 76.8           | 67.7           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| Average       | -23.2 | 77.1            | 68.2           | -18.6          | 76.8           | 68.7           | -17.5          | 76.3           | 68.3           | -11.1          | 77.0           | 68.2           | -7.1           | 77.5            | 67.8           | -3.2           | 77.0           | 67.8           | 1.2            | 76.7           | 67.8           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |
| St. Deviation | 0.2   | 0.17            | 0.04           | 0.37           | 0.06           | 0.07           | 0.17           | 0.04           | 0.08           | 0.30           | 0.12           | 0.06           | 0.37           | 0.03            | 0.08           | 0.24           | 0.05           | 0.06           | 0.21           | 0.04           | 0.10           |                |                |                |                |                 |  |  |  |  |  |  |  |  |  |  |  |

| ΔX (cm)   |     | Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                | Raw Coordinates |                |                |                |                |                |                |                |                 |                |                |                | Raw Coordinates |                |                |  |                 |  |  |  |  |  |  |  |
|-----------|-----|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|-----------------|----------------|----------------|--|-----------------|--|--|--|--|--|--|--|
|           |     | 7.2             |                |                |                | 10.8           |                |                |                | 14.4           |                |                |                | 18.0            |                |                |                | ΔX (cm)        |                |                |                | ΔX <sub>1</sub> |                |                |                | ΔX <sub>2</sub> |                |                |  | ΔX <sub>3</sub> |  |  |  |  |  |  |  |
|           |     | X <sub>c</sub>  | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub>  | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub>  | X <sub>c</sub> | Y <sub>c</sub> | Z <sub>c</sub> | X <sub>c</sub>  | Y <sub>c</sub> | Z <sub>c</sub> |  |                 |  |  |  |  |  |  |  |
| Frame 1   | 6.1 | 76.9            | 68.0           | 11.6           | 76.5           | 68.2           | 16.9           | 77.6           | 67.8           | 21.8           | 77.1           | 67.7           | -14.4          | -21.0           | 0.3            | 2.1            | 1.2            | 0.0            | -0.1           |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 2   | 5.9 | 76.9            | 67.9           | 11.6           | 76.4           | 68.0           | 19.2           | 77.8           | 67.5           | 21.6           | 77.0           | 67.7           | -10.8          | -15.3           | -0.5           | 2.2            | 1.4            | 0.0            | -0.2           |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 3   | 6.3 | 76.7            | 68.1           | 10.9           | 76.5           | 68.0           | 19.0           | 77.6           | 67.6           | 21.7           | 77.1           | 67.9           | -7.2           | -8.9            | 0.2            | 2.1            | 1.2            | 0.0            | -0.3           |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 4   | 6.1 | 77.0            | 68.1           | 11.3           | 76.4           | 68.1           | 19.3           | 77.9           | 67.6           | 22.1           | 77.0           | 67.8           | -3.6           | -4.9            | 0.7            | 1.7            | 1.4            | -0.2           | -0.5           |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 5   | 5.9 | 76.8            | 67.9           | 11.3           | 76.4           | 68.1           | 19.2           | 77.7           | 67.7           | 22.2           | 77.0           | 67.9           | 0.0            | -1.1            | 0.2            | 1.7            | 1.6            | 0.0            | 0.0            | #####          | #####          | #####           | #####          | #####          | #####          | #####           | #####          | #####          |  |                 |  |  |  |  |  |  |  |
| Frame 6   | 6.5 | 76.8            | 68.0           | 11.2           | 76.4           | 68.0           | 18.6           | 77.9           | 67.7           | 21.9           | 77.1           | 67.9           | 3.6            | 3.4             | -0.1           | 1.8            | 0.9            | 0.0            | 0.5            |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 7   | 5.6 | 76.9            | 67.9           | 11.3           | 76.5           | 68.0           | 19.2           | 77.6           | 67.8           | 21.9           | 77.1           | 67.7           | 7.2            | 8.2             | 0.1            | 1.8            | 1.1            | 0.0            | 0.3            |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 8   | 5.9 | 77.0            | 67.9           | 11.2           | 76.4           | 68.1           | 19.1           | 77.9           | 67.6           | 22.1           | 77.0           | 67.8           | 10.8           | 13.5            | -0.4           | 2.0            | 1.3            | 0.0            | 0.2            |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 9   | 5.7 | 77.0            | 67.8           | 11.5           | 76.5           | 68.2           | 19.2           | 77.6           | 67.6           | 22.1           | 77.1           | 67.8           | 14.4           | 21.3            | 1.0            | 1.5            | 1.5            | 0.1            | 0.1            |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Frame 10  | 6.1 | 76.9            | 67.9           | 11.4           | 76.3           | 68.0           | 18.7           | 77.9           | 67.6           | 21.9           | 77.1           | 67.9           | 18.0           | 24.1            | 0.2            | 1.7            | 1.3            | 0.0            | 0.1            |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |
| Average   | 6.0 | 76.8            | 67.9           | 11.3           | 76.4           | 68.1           | 19.1           | 77.8           | 67.6           | 21.9           | 77.0           | 67.8           |                |                 |                |                |                |                |                | #####          | #####          | #####           | #####          | #####          | #####          | #####           | #####          | #####          |  |                 |  |  |  |  |  |  |  |
| Deviation | 0.3 | 0.09            | 0.08           | 0.20           | 0.06           | 0.06           | 0.25           | 0.16           | 0.04           | 0.21           | 0.05           | 0.07           |                |                 |                |                |                |                |                |                |                |                 |                |                |                |                 |                |                |  |                 |  |  |  |  |  |  |  |

| Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| St. Deviation   | -10.0          |                |                | -8.0           |                |                | -6.0           |                |                | -4.0           |                |                | -2.0           |                |                | 0.0            |                |                | 2.0            |                |                |
|                 | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> |
| Frame 1         | -0.7           | 71.6           | 67.8           | -2.18          | 74.3           | 71.1           | -0.9           | 73.4           | 68.0           | -2.1           | 74.6           | 68.6           | -2.7           | 76.4           | 68.4           | -3.5           | 77.9           | 67.8           | -2.0           | 79.5           | 71.0           |
| Frame 2         | -1.9           | 71.4           | 67.8           | -2.22          | 74.3           | 71.1           | -2.0           | 73.5           | 67.9           | -2.5           | 74.7           | 68.6           | -2.7           | 76.4           | 68.4           | -3.5           | 77.9           | 67.8           | -2.0           | 79.5           | 71.0           |
| Frame 3         | -1.4           | 71.6           | 68.0           | -2.18          | 74.4           | 71.1           | -2.2           | 73.5           | 68.1           | -3.1           | 74.6           | 68.6           | -2.8           | 76.3           | 68.2           | -4.2           | 76.8           | 67.7           | -2.2           | 79.5           | 71.1           |
| Frame 4         | -1.1           | 71.3           | 68.0           | -2.20          | 74.4           | 71.1           | -1.9           | 73.5           | 68.2           | -2.8           | 74.4           | 68.6           | -2.9           | 76.5           | 68.3           | -3.4           | 76.9           | 67.8           | -2.1           | 79.9           | 71.1           |
| Frame 5         | -1.3           | 71.6           | 68.0           | -2.16          | 74.3           | 71.2           | -1.8           | 73.6           | 68.2           | -3.4           | 74.6           | 68.6           | -2.6           | 76.4           | 68.3           | -3.7           | 76.8           | 67.9           | -2.2           | 79.5           | 71.1           |
| Frame 6         | -1.4           | 71.4           | 68.0           | -2.16          | 74.3           | 71.2           | -2.4           | 73.5           | 68.0           | -3.2           | 74.4           | 68.7           | -3.1           | 76.6           | 68.4           | -3.5           | 76.8           | 67.8           | -2.1           | 79.9           | 71.2           |
| Frame 7         | -1.5           | 71.6           | 67.9           | -2.16          | 74.2           | 71.3           | -2.1           | 73.7           | 68.1           | -3.2           | 74.6           | 68.6           | -2.9           | 76.4           | 68.4           | -3.9           | 77.0           | 67.8           | -2.2           | 79.5           | 71.2           |
| Frame 8         | -1.5           | 71.4           | 67.9           | -2.14          | 74.3           | 71.3           | -2.3           | 73.5           | 68.0           | -2.8           | 74.6           | 68.7           | -3.1           | 76.4           | 68.4           | -3.7           | 77.0           | 67.9           | -2.1           | 79.8           | 71.1           |
| Frame 9         | -1.4           | 71.6           | 67.9           | -2.15          | 74.4           | 71.1           | -2.1           | 73.5           | 68.1           | -3.0           | 74.6           | 68.7           | -2.9           | 76.3           | 68.4           | -4.1           | 76.9           | 67.7           | -2.2           | 79.7           | 71.1           |
| Frame 10        | -1.3           | 71.4           | 68.0           | -2.19          | 74.1           | 71.1           | -2.5           | 73.5           | 68.0           | -3.0           | 74.5           | 68.6           | -2.6           | 76.5           | 68.5           | -4.1           | 77.0           | 67.8           | -2.2           | 79.9           | 71.2           |
| Average         | -1.3           | 71.5           | 67.9           | -2.17          | 74.3           | 71.2           | -2.0           | 73.5           | 68.1           | -2.9           | 74.6           | 68.6           | -2.8           | 76.4           | 68.4           | -3.7           | 76.9           | 67.8           | -2.2           | 79.7           | 71.1           |
| St. Deviation   | 0.3            | 0.12           | 0.06           | 0.24           | 0.07           | 0.08           | 0.45           | 0.08           | 0.10           | 0.39           | 0.10           | 0.05           | 0.18           | 0.08           | 0.09           | 0.32           | 0.08           | 0.09           | 0.09           | 0.18           | 0.06           |

| Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                |                |         |         |         |       |       |       |      |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|---------|---------|---------|-------|-------|-------|------|
| St. Deviation   | 4.0            |                |                | 6.0            |                |                | 8.0            |                |                | 10.0           |                |                | ΔY (cm) | ΔX (cm) | ΔZ (cm) | ΔX/ΔY | ΔX/ΔZ | ΔY/ΔZ |      |
|                 | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> | X <sub>6</sub> | Y <sub>6</sub> | Z <sub>6</sub> |         |         |         |       |       |       |      |
| Frame 1         | -4.6           | 76.8           | 68.3           | -3.7           | 79.8           | 68.1           | -4.3           | 81.1           | 67.9           | -3.2           | 82.1           | 67.7           | -10.0   | 0.9     | -5.3    | 1.8   | -0.1  | 0.5   | -0.2 |
| Frame 2         | -4.6           | 78.4           | 68.2           | -3.7           | 79.8           | 68.1           | -4.6           | 81.0           | 68.1           | -3.6           | 82.2           | 67.7           | -6.0    | 0.2     | -3.3    | 2.0   | 0.3   | 0.3   | -0.8 |
| Frame 3         | -4.4           | 78.9           | 68.3           | -3.9           | 79.7           | 68.0           | -4.5           | 81.1           | 68.1           | -3.0           | 82.0           | 67.7           | -4.0    | -0.7    | -2.2    | 2.5   | 0.2   | 0.6   | -0.8 |
| Frame 4         | -5.0           | 78.4           | 68.3           | -3.5           | 79.9           | 68.1           | -4.3           | 81.0           | 68.1           | -3.2           | 82.2           | 67.7           | -2.0    | -0.6    | -0.4    | 2.3   | 0.3   | 0.2   | -1.1 |
| Frame 5         | -4.3           | 78.8           | 68.3           | -3.6           | 79.8           | 68.2           | -4.6           | 81.1           | 68.1           | -3.1           | 82.0           | 67.7           | 0.0     | -1.5    | 0.1     | 1.7   |       |       |      |
| Frame 6         | -4.9           | 78.5           | 68.3           | -3.6           | 79.8           | 68.1           | -4.7           | 80.9           | 68.1           | -3.1           | 82.3           | 67.7           | 2.0     | -19.9   | 2.9     | 5.0   | -10.0 | 1.5   | 2.5  |
| Frame 7         | -4.4           | 78.9           | 68.2           | -3.9           | 79.8           | 68.2           | -4.6           | 81.0           | 68.1           | -2.7           | 82.1           | 67.7           | 4.0     | -2.5    | 1.8     | 2.2   | -0.6  | 0.4   | 0.5  |
| Frame 8         | -4.6           | 78.3           | 68.3           | -4.1           | 79.8           | 68.0           | -4.5           | 80.8           | 68.1           | -3.0           | 82.2           | 67.8           | 6.0     | -1.6    | 3.0     | 2.0   | -0.3  | 0.5   | 0.3  |
| Frame 9         | -4.7           | 78.8           | 68.3           | -3.8           | 79.8           | 68.0           | -4.4           | 81.1           | 68.2           | -3.0           | 82.0           | 67.7           | 8.0     | -2.3    | 4.2     | 2.0   | -0.3  | 0.5   | 0.3  |
| Frame 10        | -5.0           | 78.3           | 68.2           | -3.6           | 79.8           | 68.1           | -4.6           | 80.9           | 68.1           | -3.2           | 82.2           | 67.8           | 10.0    | -0.9    | 5.3     | 1.6   | -0.1  | 0.5   | 0.2  |
| Average         | -4.7           | 78.6           | 68.3           | -3.8           | 79.8           | 68.1           | -4.5           | 81.0           | 68.1           | -3.1           | 82.1           | 67.7           |         |         |         | Ave.  | -0.64 | 0.96  | 0.09 |
| St. Deviation   | 0.2            | 0.23           | 0.05           | 0.18           | 0.05           | 0.07           | 0.18           | 0.09           | 0.06           | 0.23           | 0.10           | 0.05           |         |         |         |       |       |       |      |

| $q_0$ control: $X_0$ control = -148.0 cm, $Y_0$ control = 77.0 cm, $Z_0$ control = 78.2 cm |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |      |
|--------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|
| Raw Coordinates                                                                            |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |      |
| $\Delta Z$ (cm)                                                                            |       | -16   |       | -14.4 |       | -10.8 |       | -7.2  |       | -3.6  |       | 0     |       | 3.6   |       |       |       |       |       |       |      |
| $X_c$                                                                                      | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ |      |
| Frame 1                                                                                    | -25.5 | 78.6  | 62.7  | -26.5 | 78.6  | 64.2  | -8.1  | 76.6  | 62.6  | -26.5 | 78.6  | 67.2  | -4.5  | 77.6  | 65.6  | -3.8  | 76.9  | 67.9  | -3.3  | 77.5  | 69.3 |
| Frame 2                                                                                    | -25.4 | 78.8  | 62.7  | -28.7 | 78.6  | 64.1  | -8.6  | 76.6  | 62.5  | -26.5 | 78.0  | 67.1  | -4.4  | 77.2  | 65.6  | -2.8  | 77.0  | 68.0  | -2.7  | 77.8  | 69.2 |
| Frame 3                                                                                    | -25.8 | 78.6  | 62.7  | -27.3 | 78.9  | 64.2  | -9.0  | 76.8  | 62.7  | -26.6 | 78.7  | 67.2  | -4.5  | 77.4  | 65.8  | -2.7  | 77.0  | 68.2  | -3.6  | 77.6  | 69.1 |
| Frame 4                                                                                    | -25.2 | 78.6  | 62.8  | -26.4 | 78.9  | 64.2  | -8.9  | 76.6  | 62.5  | -26.9 | 78.6  | 67.2  | -5.6  | 77.2  | 65.6  | -2.7  | 76.9  | 68.0  | -4.0  | 77.5  | 69.2 |
| Frame 5                                                                                    | -25.6 | 78.6  | 62.7  | -27.1 | 78.8  | 64.3  | -8.7  | 76.8  | 62.8  | -26.5 | 78.8  | 67.2  | -4.4  | 77.5  | 65.7  | -2.9  | 76.9  | 68.2  | -3.4  | 77.8  | 69.2 |
| Frame 6                                                                                    | -24.9 | 78.7  | 62.9  | -27.1 | 78.6  | 64.0  | -8.9  | 76.5  | 62.3  | -26.8 | 78.8  | 67.2  | -4.4  | 77.3  | 65.8  | -3.0  | 78.9  | 68.0  | -4.0  | 77.5  | 69.1 |
| Frame 7                                                                                    | -26.7 | 78.7  | 62.7  | -27.0 | 78.9  | 64.2  | -8.2  | 76.8  | 62.6  | -26.5 | 78.7  | 67.2  | -4.0  | 77.4  | 65.8  | -3.3  | 76.9  | 68.1  | -3.5  | 77.5  | 69.1 |
| Frame 8                                                                                    | -25.4 | 78.9  | 62.8  | -28.5 | 78.9  | 64.2  | -8.7  | 76.6  | 62.8  | -26.7 | 78.8  | 67.2  | -4.3  | 77.3  | 65.6  | -3.1  | 76.9  | 67.9  | -3.7  | 77.5  | 69.2 |
| Frame 9                                                                                    | -25.6 | 78.5  | 62.7  | -27.2 | 78.7  | 64.3  | -8.3  | 76.7  | 62.7  | -26.5 | 78.7  | 67.2  | -4.2  | 77.4  | 65.7  | -3.6  | 78.9  | 68.0  | -3.1  | 77.6  | 69.2 |
| Frame 10                                                                                   | -25.5 | 78.0  | 62.7  | -26.6 | 78.7  | 64.1  | -9.0  | 76.7  | 62.5  | -26.7 | 78.7  | 67.2  | -4.3  | 77.3  | 65.7  | -3.0  | 76.9  | 67.9  | -3.5  | 77.5  | 69.2 |
| Average                                                                                    | -25.5 | 78.7  | 62.7  | -26.8 | 78.8  | 64.2  | -8.7  | 76.7  | 62.6  | -26.6 | 78.8  | 67.2  | -4.5  | 77.4  | 65.7  | -3.1  | 76.9  | 68.0  | -3.5  | 77.5  | 69.2 |
| St. Deviation                                                                              | 0.3   | 0.15  | 0.06  | 0.34  | 0.09  | 0.08  | 0.27  | 0.11  | 0.12  | 0.15  | 0.08  | 0.03  | 0.42  | 0.12  | 0.09  | 0.36  | 0.04  | 0.11  | 0.40  | 0.06  | 0.08 |

| Raw Coordinates |       |       |       |       |       |       |       |       |       | Uncertainty  |       |            |       |            |       |            |       |            |        |            |  |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------------|-------|------------|-------|------------|-------|------------|-------|------------|--------|------------|--|
| $\Delta Z$ (cm) |       | 7.2   |       | 10.8  |       | 14.4  |       | 18.0  |       | $(\Delta Z)$ |       | $\Delta X$ |       | $\Delta Y$ |       | $\Delta Z$ |       | $\Delta X$ |        | $\Delta Y$ |  |
| $X_c$           | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$ | $Z_c$ | $X_c$ | $Y_c$        | $Z_c$ | $X_c$      | $Y_c$ | $Z_c$      | $X_c$ | $Y_c$      | $Z_c$ | $X_c$      | $Y_c$  | $Z_c$      |  |
| Frame 1         | -1.1  | 78.9  | 71.5  | -1.1  | 78.8  | 73.5  | 2.6   | 76.8  | 73.2  | 2.1          | 77.0  | 76.8       | -14.4 | -24.6      | 2.0   | -1.9       | 1.7   | -0.1       | 0.1    |            |  |
| Frame 2         | -1.2  | 78.9  | 71.5  | -1.8  | 78.9  | 73.5  | 2.3   | 76.6  | 75.1  | 1.9          | 77.0  | 76.4       | -10.8 | -4.5       | -0.1  | -3.5       | 0.6   | 0.0        | 0.3    |            |  |
| Frame 3         | -0.5  | 78.7  | 71.8  | -1.3  | 78.7  | 73.4  | 1.7   | 77.0  | 75.1  | 2.9          | 77.0  | 76.5       | -7.2  | -24.4      | 2.0   | 1.1        | 3.4   | -0.3       | -0.2   |            |  |
| Frame 4         | -0.9  | 78.8  | 71.6  | -1.6  | 78.7  | 73.5  | 2.6   | 76.8  | 73.4  | 2.2          | 77.1  | 76.4       | -3.6  | -2.3       | 0.6   | -0.4       | 0.6   | -0.2       | 0.1    |            |  |
| Frame 5         | -0.9  | 78.6  | 71.5  | -1.5  | 78.6  | 73.6  | 1.7   | 77.0  | 75.0  | 2.6          | 77.0  | 76.5       | 0.0   | -0.9       | 0.1   | 1.9        |       |            |        |            |  |
| Frame 6         | -0.8  | 78.8  | 71.5  | -1.5  | 78.7  | 73.5  | 2.1   | 76.6  | 75.3  | 2.0          | 77.1  | 76.5       | 3.6   | -1.3       | 0.7   | 3.1        | -0.4  | 0.2        | 0.9    |            |  |
| Frame 7         | -0.7  | 78.8  | 71.6  | -1.5  | 78.8  | 73.6  | 2.5   | 77.0  | 73.2  | 1.9          | 77.0  | 76.4       | 7.2   | 1.3        | 0.0   | 5.4        | 0.2   | 0.0        | 0.8    |            |  |
| Frame 8         | -0.7  | 78.7  | 71.7  | -1.3  | 78.6  | 73.7  | 2.4   | 76.6  | 75.4  | 2.0          | 77.0  | 76.4       | 10.8  | 0.7        | 0.0   | 7.4        | 0.1   | 0.0        | 0.7    |            |  |
| Frame 9         | -1.2  | 78.9  | 71.5  | -1.1  | 78.7  | 73.4  | 1.7   | 76.9  | 75.1  | 2.5          | 77.1  | 76.4       | 14.4  | 4.3        | 0.0   | 9.1        | 0.3   | 0.0        | 0.6    |            |  |
| Frame 10        | -0.9  | 78.8  | 71.5  | -1.8  | 78.9  | 73.4  | 1.8   | 76.8  | 75.2  | 1.7          | 77.0  | 76.3       | 18.0  | 4.4        | 0.2   | 10.3       | 0.2   | 0.0        | 0.6    |            |  |
| Average         | -0.9  | 78.8  | 71.5  | -1.5  | 78.8  | 73.5  | 2.1   | 76.8  | 75.2  | 2.2          | 77.0  | 76.4       |       |            |       |            |       |            |        |            |  |
| St. Deviation   | 0.2   | 0.06  | 0.07  | 0.25  | 0.08  | 0.09  | 0.36  | 0.21  | 0.14  | 0.37         | 0.05  | 0.09       |       |            |       | Ave.       | 0.807 | 0.05       | 0.4104 |            |  |



| X <sub>c</sub> control = -2.2 cm, Y <sub>c</sub> control = 76.8 cm, Z <sub>c</sub> control = 66.1 cm |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |
|------------------------------------------------------------------------------------------------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------|
| lat (degrees)                                                                                        |                | Row Coordinates |                |                |                |                |                |                |                |                |                |                |                | Declinity      |                |                |                |                |                |                |                |                |                |      |
|                                                                                                      |                | -10.0           |                |                | -4.0           |                |                | 4.0            |                |                | -4.0           |                |                | -2.0           |                |                | 0.0            |                |                | 2.0            |                |                |                |      |
| x <sub>c</sub>                                                                                       | y <sub>c</sub> | z <sub>c</sub>  | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> |      |
| Frame 1                                                                                              | 7.1            | 77.2            | 63.0           | 4.6            | 77.3           | 64.4           | 3.0            | 77.0           | 65.0           | 1.6            | 77.1           | 66.4           | 0.9            | 76.9           | 66.2           | 3.8            | 77.1           | 66.0           | -2.0           | 76.8           | 66.5           |                |                |      |
| Frame 2                                                                                              | 8.9            | 77.2            | 62.9           | 4.1            | 77.2           | 64.1           | 2.6            | 77.1           | 65.0           | 1.0            | 76.7           | 66.6           | 0.2            | 76.7           | 66.2           | -3.6           | 76.7           | 66.2           | -3.6           | 76.7           | 66.2           | -3.6           | 76.8           | 69.4 |
| Frame 3                                                                                              | 7.3            | 77.3            | 63.1           | 3.5            | 77.3           | 64.1           | 3.2            | 77.0           | 65.0           | 1.5            | 77.0           | 66.5           | 0.8            | 76.8           | 66.2           | 4.3            | 77.1           | 67.9           | -1.6           | 76.8           | 69.4           |                |                |      |
| Frame 4                                                                                              | 7.6            | 77.1            | 63.0           | 3.5            | 77.1           | 64.3           | 4.1            | 77.1           | 65.3           | 0.8            | 76.8           | 66.7           | 0.4            | 76.7           | 66.4           | -4.4           | 76.8           | 66.1           | -3.0           | 76.7           | 69.2           |                |                |      |
| Frame 5                                                                                              | 7.5            | 77.2            | 63.2           | 3.5            | 77.1           | 64.4           | 3.5            | 77.0           | 65.0           | 1.3            | 77.0           | 66.6           | 0.4            | 76.8           | 66.3           | -4.3           | 77.1           | 68.1           | -2.5           | 76.8           | 69.3           |                |                |      |
| Frame 6                                                                                              | 7.9            | 77.2            | 62.9           | 3.5            | 77.2           | 64.2           | 2.6            | 76.9           | 65.1           | 1.7            | 76.5           | 66.5           | -0.5           | 76.5           | 66.4           | -4.2           | 76.7           | 66.1           | -2.9           | 76.8           | 69.2           |                |                |      |
| Frame 7                                                                                              | 8.7            | 77.2            | 63.2           | 3.2            | 77.3           | 64.2           | 2.6            | 77.0           | 64.8           | 1.4            | 76.9           | 66.3           | 0.3            | 77.0           | 66.2           | -4.0           | 77.1           | 68.0           | -1.5           | 76.8           | 69.4           |                |                |      |
| Frame 8                                                                                              | 6.7            | 77.2            | 63.0           | 4.0            | 77.3           | 64.3           | 2.9            | 77.0           | 65.1           | 0.9            | 76.7           | 66.6           | -0.1           | 76.7           | 66.2           | -3.7           | 76.8           | 66.1           | -3.0           | 76.9           | 69.3           |                |                |      |
| Frame 9                                                                                              | 6.5            | 77.1            | 63.2           | 3.4            | 77.3           | 64.3           | 2.8            | 77.0           | 65.0           | 2.4            | 77.1           | 66.5           | 0.3            | 76.8           | 66.4           | 3.5            | 77.1           | 67.9           | -2.1           | 76.9           | 69.3           |                |                |      |
| Frame 10                                                                                             | 7.0            | 77.1            | 62.9           | 4.3            | 77.1           | 64.1           | 3.0            | 77.2           | 65.3           | 1.3            | 76.8           | 66.7           | 0.3            | 76.7           | 66.4           | -3.9           | 76.8           | 66.0           | -2.6           | 76.5           | 69.4           |                |                |      |
| Average                                                                                              | 7.1            | 77.2            | 63.0           | 3.8            | 77.2           | 64.2           | 3.1            | 77.0           | 65.1           | 1.4            | 76.9           | 66.6           | 0.3            | 76.8           | 66.3           | -4.0           | 76.9           | 66.0           | -2.3           | 76.7           | 69.3           |                |                |      |
| Std. Deviation                                                                                       | 0.44           | 0.05            | 0.11           | 0.47           | 0.08           | 0.10           | 0.45           | 0.08           | 0.12           | 0.47           | 0.21           | 0.10           | 0.42           | 0.12           | 0.10           | 0.30           | 0.21           | 0.09           | 0.55           | 0.12           | 0.11           |                |                |      |
| lat (degrees)                                                                                        |                | Row Coordinates |                |                |                |                |                |                |                |                |                |                |                | Declinity      |                |                |                |                |                |                |                |                |                |      |
|                                                                                                      |                | -4.0            |                |                | 8.0            |                |                | 10.0           |                |                | lat (degrees)  |                |                | lat (degrees)  |                |                | lat (degrees)  |                |                | lat (degrees)  |                |                | lat (degrees)  |      |
| x <sub>c</sub>                                                                                       | y <sub>c</sub> | z <sub>c</sub>  | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> |      |
| Frame 1                                                                                              | -4.2           | 76.4            | 70.0           | -6.3           | 76.7           | 69.4           | -5.9           | 76.2           | 70.3           | -6.1           | 76.3           | 71.9           | -8.0           | 60.4           | -3.1           | -0.93          | -0.04          | 0.31           |                |                |                |                |                |      |
| Frame 2                                                                                              | -4.8           | 76.2            | 69.9           | -5.9           | 76.5           | 69.4           | -6.7           | 75.6           | 70.4           | -8.2           | 75.9           | 71.7           | -6.0           | 5.3            | 0.2            | -1.0           | -0.66          | 0.25           |                |                |                |                |                |      |
| Frame 3                                                                                              | -4.6           | 76.1            | 70.0           | -6.6           | 76.7           | 69.3           | -6.1           | 76.2           | 70.2           | -7.9           | 75.9           | 71.6           | -4.0           | 3.6            | 0.1            | 0.5            | -0.90          | -0.02          | -0.11          |                |                |                |                |      |
| Frame 4                                                                                              | -4.9           | 76.3            | 70.1           | -6.4           | 76.5           | 69.6           | -6.3           | 75.6           | 70.3           | -8.5           | 76.6           | 71.5           | -2.0           | 2.5            | 0.0            | 2.2            | -1.25          | 0.02           | -1.10          |                |                |                |                |      |
| Frame 5                                                                                              | -4.4           | 76.2            | 70.2           | -6.4           | 76.7           | 69.4           | -6.3           | 76.2           | 70.2           | -7.4           | 76.1           | 71.7           | 0.0            | -1.8           | 0.1            | 1.9            |                |                |                |                |                |                |                |      |
| Frame 6                                                                                              | -6.8           | 76.5            | 69.2           | -6.2           | 76.7           | 69.4           | -6.2           | 76.0           | 70.2           | -8.2           | 76.0           | 71.6           | 2.0            | -0.1           | -0.1           | 3.2            | -0.07          | -0.04          | 1.61           |                |                |                |                |      |
| Frame 7                                                                                              | -4.2           | 76.2            | 70.0           | -6.6           | 76.8           | 69.6           | -6.5           | 76.2           | 70.3           | -7.9           | 75.6           | 71.6           | 4.0            | -2.6           | -0.6           | 3.9            | -0.64          | -0.15          | 0.97           |                |                |                |                |      |
| Frame 8                                                                                              | -4.5           | 76.2            | 70.0           | -6.5           | 76.7           | 69.4           | -6.6           | 75.8           | 70.3           | -10.4          | 76.2           | 71.6           | 6.0            | -4.2           | -0.1           | 3.3            | -0.70          | -0.02          | 0.55           |                |                |                |                |      |
| Frame 9                                                                                              | -4.1           | 76.0            | 70.3           | -6.5           | 76.8           | 69.4           | -6.1           | 76.1           | 70.2           | -7.6           | 75.6           | 71.5           | 6.0            | -4.1           | -0.8           | 4.2            | -0.52          | -0.10          | 0.92           |                |                |                |                |      |
| Frame 10                                                                                             | -4.6           | 76.0            | 70.0           | -6.4           | 76.7           | 69.4           | -6.6           | 75.6           | 70.3           | -6.1           | 75.7           | 71.6           | 10.0           | -6.0           | -0.8           | 5.5            | -0.90          | -0.08          | 0.55           |                |                |                |                |      |
| Average                                                                                              | -4.8           | 76.2            | 70.0           | -6.4           | 76.7           | 69.4           | -6.3           | 76.0           | 70.3           | -8.2           | 76.0           | 71.6           |                |                |                |                |                |                |                |                |                |                |                |      |
| Deviation                                                                                            | 0.78           | 0.16            | 0.30           | 0.23           | 0.09           | 0.05           | 0.25           | 0.20           | 0.07           | 0.62           | 0.27           | 0.10           |                |                |                |                |                |                |                |                |                |                |                |      |



| q <sub>control</sub> |  | -76.8 cm, Y <sub>c</sub> control = 66.1cm |                |                |                |                |                |                |                |                |                | Raw Coordinates |                |                |                |                |                |                |                |                |                | Uncertainty    |                |                |                |                |                |                |                |                |                |                |                |                |  |
|----------------------|--|-------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--|
|                      |  | -10.3                                     |                | -5.9           |                | -5.9           |                | -5.9           |                | -3.2           |                | -3.0            |                | 0              |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| 2Y (degrees)         |  | x <sub>c</sub>                            | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub>  | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> |  |
| Frame 1              |  | -24.6                                     | 76.1           | 69.4           | -33.9          | 78.3           | 71.0           | -33.9          | 78.3           | 71.0           | -6.8           | 76.6            | 68.5           | -6.7           | 76.6           | 67.0           | -21.1          | 76.8           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 2              |  | -25.1                                     | 75.8           | 69.3           | -33.8          | 78.5           | 70.9           | -10.0          | 77.1           | 69.3           | -8.7           | 76.6            | 67.3           | -21.0          | 76.0           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 3              |  | -24.5                                     | 76.1           | 69.4           | -33.8          | 78.3           | 70.9           | -9.1           | 76.6           | 68.4           | -9.2           | 76.9            | 67.4           | -21.0          | 76.7           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 4              |  | -24.7                                     | 75.9           | 69.2           | -34.4          | 78.4           | 70.6           | -34.4          | 78.4           | 70.6           | -10.3          | 76.9            | 69.2           | -8.8           | 76.6           | 67.2           | -21.5          | 79.1           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 5              |  | -24.0                                     | 76.3           | 69.3           | -34.7          | 78.3           | 70.6           | -34.7          | 78.3           | 70.6           | -9.6           | 76.5            | 68.5           | -8.7           | 76.6           | 67.2           | -21.0          | 78.7           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 6              |  | -24.4                                     | 75.9           | 69.2           | -34.3          | 78.3           | 70.7           | -34.3          | 78.3           | 70.7           | -8.7           | 77.0            | 68.4           | -8.7           | 76.9           | 67.3           | -21.5          | 79.0           | 71.3           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 7              |  | -24.2                                     | 76.3           | 69.2           | -33.9          | 78.3           | 70.9           | -33.9          | 78.3           | 70.9           | -10.4          | 76.5            | 68.6           | -8.7           | 76.9           | 67.1           | -20.9          | 78.7           | 71.0           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 8              |  | -25.3                                     | 75.9           | 69.4           | -34.1          | 78.5           | 70.8           | -34.1          | 78.5           | 70.8           | -10.6          | 76.8            | 68.5           | -8.4           | 76.7           | 67.2           | -20.0          | 76.9           | 71.0           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 9              |  | -24.2                                     | 76.1           | 69.3           | -34.8          | 78.3           | 70.6           | -34.6          | 78.3           | 70.6           | -9.0           | 76.6            | 68.5           | -9.1           | 76.8           | 67.1           | -21.4          | 78.7           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 10             |  | -25.0                                     | 75.9           | 69.3           | -34.3          | 78.5           | 70.7           | -34.3          | 78.5           | 70.7           | -9.6           | 77.0            | 68.4           | -8.9           | 76.7           | 67.3           | -21.5          | 79.0           | 71.2           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Average              |  | -24.6                                     | 76.0           | 69.3           | -34.2          | 78.4           | 70.8           | -34.2          | 78.4           | 70.8           | -9.8           | 76.8            | 69.4           | -8.8           | 76.8           | 67.2           | -21.3          | 78.9           | 71.1           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Std. Deviation       |  | 0.4                                       | 0.16           | 0.06           | 0.33           | 0.10           | 0.14           | 0.33           | 0.10           | 0.14           | 0.53           | 0.22            | 0.11           | 0.23           | 0.09           | 0.11           | 0.36           | 0.16           | 0.08           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  | 3.0                                       |                | 3.2            |                | 5.9            |                | 5.9            |                | 8.6            |                | 10.3            |                |                |                | (degrees)      |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| 2Y (degrees)         |  | x <sub>c</sub>                            | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub>  | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> | x <sub>c</sub> | y <sub>c</sub> | z <sub>c</sub> |  |
| Frame 1              |  | 3.8                                       | 78.4           | 67.4           | 2.0            | 78.5           | 68.1           | 11.0           | 79.9           | 66.1           | 17.2           | 81.1            | 68.0           | 23.0           | 82.2           | 68.8           | -8.6           | -32.0          | 1.6            | 4.7            | 3.7            | -0.2           | -0.5           |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 2              |  | 4.3                                       | 78.7           | 67.4           | 3.0            | 78.3           | 67.9           | 11.5           | 79.9           | 68.2           | 17.3           | 80.8            | 67.9           | 22.8           | 82.7           | 68.6           | -5.9           | -32.0          | 1.6            | 4.7            | 3.4            | -0.3           | -0.8           |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 3              |  | 3.9                                       | 78.7           | 67.6           | 2.7            | 78.5           | 67.9           | 10.3           | 79.8           | 68.2           | 17.0           | 81.1            | 67.9           | 22.6           | 82.3           | 68.3           | -3.2           | -7.6           | 0.0            | 2.3            | 2.4            | 0.0            | -0.7           |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 4              |  | 3.9                                       | 79.0           | 67.4           | 3.4            | 78.4           | 67.9           | 11.4           | 79.8           | 68.3           | 17.5           | 80.8            | 68.0           | 22.9           | 82.8           | 68.6           | 3.0            | -6.6           | 0.0            | 1.1            | -2.2           | 0.0            | 0.4            |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 5              |  | 4.6                                       | 78.6           | 67.7           | 2.9            | 78.4           | 67.7           | 10.6           | 79.8           | 68.1           | 16.6           | 81.0            | 67.9           | 23.5           | 82.3           | 68.5           | 0.0            | -19.1          | 2.1            | 5.0            |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 6              |  | 4.3                                       | 79.0           | 67.4           | 2.7            | 78.4           | 67.9           | 11.6           | 79.8           | 68.2           | 17.1           | 80.9            | 68.0           | 22.9           | 82.8           | 68.3           | 3.0            | 6.4            | 2.0            | 1.4            | 2.1            | 0.7            | 0.5            |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 7              |  | 4.0                                       | 78.7           | 67.5           | 4.2            | 78.5           | 67.7           | 10.0           | 79.9           | 68.2           | 17.5           | 81.1            | 68.1           | 23.4           | 82.4           | 68.3           | 3.2            | 5.0            | 1.6            | 1.8            | 1.6            | 0.5            | 0.6            |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 8              |  | 4.5                                       | 79.0           | 67.8           | 2.6            | 78.3           | 67.9           | 11.1           | 79.7           | 68.2           | 17.1           | 80.8            | 68.1           | 23.3           | 82.6           | 68.6           | 5.9            | 13.1           | 3.0            | 2.1            | 2.2            | 0.5            | 0.4            |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 9              |  | 4.5                                       | 78.7           | 67.5           | 2.1            | 78.6           | 68.0           | 9.7            | 79.8           | 68.1           | 16.8           | 81.1            | 67.8           | 24.1           | 82.4           | 68.8           | 8.6            | 19.4           | 4.1            | 1.9            | 2.3            | 0.5            | 0.2            |                |                |                |                |                |                |                |                |                |                |                |  |
| Frame 10             |  | 4.3                                       | 79.0           | 67.4           | 2.8            | 78.3           | 68.0           | 11.8           | 79.9           | 68.1           | 17.4           | 80.8            | 68.1           | 22.5           | 82.7           | 68.4           | 10.3           | 25.3           | 5.8            | 2.4            | 2.5            | 0.6            | 0.2            |                |                |                |                |                |                |                |                |                |                |                |  |
| Average              |  | 4.2                                       | 78.8           | 67.5           | 2.8            | 78.4           | 67.9           | 10.9           | 79.8           | 68.2           | 17.2           | 80.9            | 68.0           | 23.1           | 82.6           | 68.5           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
| Std. Deviation       |  | 0.3                                       | 0.20           | 0.11           | 0.63           | 0.09           | 0.11           | 0.70           | 0.07           | 0.08           | 0.31           | 0.14            | 0.10           | 0.48           | 0.25           | 0.18           |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |
|                      |  |                                           |                |                |                |                |                |                |                |                |                |                 |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |

## APPENDIX M

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point D

[illegible]

| Raw Coordinates |                |                |                |                |                |                |                |                |                |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 3D (cm)         |                |                |                |                |                |                |                |                |                |
|                 | X <sub>1</sub> | X <sub>2</sub> | Z <sub>1</sub> | Z <sub>2</sub> | Y <sub>1</sub> | Y <sub>2</sub> | X <sub>1</sub> | X <sub>2</sub> | Z <sub>1</sub> |
|                 | -10.0          | -8.0           | -6.0           | -4.0           | -2.0           | 0.0            | 2.0            |                |                |
| Frame 1         | -27.6          | -0.6           | 78.8           | -28.6          | -0.1           | 78.9           | -28.4          | 1.1            | 78.7           |
| Frame 2         | -28.0          | -0.6           | 78.6           | -28.6          | 0.0            | 78.9           | -27.6          | 1.1            | 78.7           |
| Frame 3         | -27.8          | -0.5           | 78.7           | -29.5          | -0.2           | 79.0           | -27.4          | 1.3            | 78.8           |
| Frame 4         | -27.9          | -0.6           | 78.8           | -28.8          | 0.1            | 78.9           | -27.2          | 0.9            | 78.9           |
| Frame 5         | -27.7          | -0.6           | 78.7           | -28.2          | -0.2           | 79.0           | -27.0          | 1.2            | 78.9           |
| Frame 6         | -27.9          | -0.6           | 78.8           | -29.2          | 0.0            | 79.0           | -27.5          | 1.1            | 78.7           |
| Frame 7         | -27.6          | -0.5           | 78.8           | -28.5          | -0.2           | 79.0           | -27.5          | 1.3            | 78.8           |
| Frame 8         | -28.1          | -0.4           | 78.8           | -28.2          | 0.0            | 79.1           | -27.2          | 1.0            | 78.7           |
| Frame 9         | -28.3          | -0.5           | 78.7           | -28.4          | -0.1           | 78.8           | -27.6          | 1.3            | 79.0           |
| Frame 10        | -27.7          | -0.6           | 78.7           | -28.4          | -0.1           | 78.9           | -27.7          | 1.0            | 78.7           |
| Average         | -27.6          | -0.5           | 78.7           | -28.5          | -0.1           | 79.0           | -27.3          | 1.1            | 78.8           |
| St. Deviation   | 0.2            | 0.08           | 0.08           | 0.21           | 0.09           | 0.10           | 0.38           | 0.13           | 0.10           |
| Raw Coordinates |                |                |                |                |                |                |                |                |                |
| 3D' (cm)        |                |                |                |                |                |                |                |                |                |
|                 | X <sub>1</sub> | Y <sub>1</sub> | Z <sub>1</sub> | X <sub>2</sub> | Y <sub>2</sub> | Z <sub>2</sub> | X <sub>1</sub> | Y <sub>1</sub> | Z <sub>1</sub> |
|                 | 4.0            | 6.0            | 8.0            | 10.0           | 12.0           | 14.0           | 16.0           | 18.0           | 20.0           |
| Frame 1         | -30.1          | 6.3            | 78.6           | -29.1          | 6.9            | 78.6           | -29.0          | 7.9            | 78.6           |
| Frame 2         | -30.6          | 6.2            | 78.7           | -29.5          | 6.7            | 78.7           | -29.6          | 8.0            | 78.8           |
| Frame 3         | -30.2          | 6.3            | 78.7           | -29.4          | 6.9            | 78.7           | -29.3          | 8.1            | 78.8           |
| Frame 4         | -30.6          | 6.1            | 78.6           | -29.1          | 6.7            | 78.6           | -29.6          | 8.0            | 78.8           |
| Frame 5         | -29.9          | 6.1            | 78.9           | -29.6          | 7.0            | 78.6           | -29.3          | 8.0            | 78.8           |
| Frame 6         | -30.8          | 6.2            | 78.6           | -29.5          | 6.8            | 78.7           | -29.1          | 7.9            | 78.9           |
| Frame 7         | -30.1          | 6.3            | 78.7           | -29.9          | 7.0            | 78.6           | -29.2          | 8.0            | 78.7           |
| Frame 8         | -30.9          | 6.3            | 78.8           | -29.8          | 6.8            | 78.5           | -29.1          | 8.0            | 78.8           |
| Frame 9         | -30.1          | 6.3            | 78.8           | -29.4          | 6.8            | 78.7           | -29.0          | 8.0            | 78.8           |
| Frame 10        | -30.9          | 6.2            | 78.6           | -29.9          | 6.8            | 78.7           | -29.5          | 8.0            | 79.1           |
| Average         | -30.4          | 6.2            | 78.7           | -29.5          | 6.8            | 78.7           | -29.3          | 8.0            | 78.8           |
| St. Deviation   | 0.4            | 0.07           | 0.09           | 0.28           | 0.10           | 0.09           | 0.24           | 0.06           | 0.11           |
| Raw Coordinates |                |                |                |                |                |                |                |                |                |
| 3D'' (cm)       |                |                |                |                |                |                |                |                |                |
|                 | X <sub>1</sub> | Y <sub>1</sub> | Z <sub>1</sub> | X <sub>2</sub> | Y <sub>2</sub> | Z <sub>2</sub> | X <sub>1</sub> | Y <sub>1</sub> | Z <sub>1</sub> |
|                 | 4.0            | 6.0            | 8.0            | 10.0           | 12.0           | 14.0           | 16.0           | 18.0           | 20.0           |
| Frame 1         | -30.1          | 6.3            | 78.6           | -29.1          | 6.9            | 78.6           | -29.0          | 7.9            | 78.6           |
| Frame 2         | -30.6          | 6.2            | 78.7           | -29.5          | 6.7            | 78.7           | -29.6          | 8.0            | 78.8           |
| Frame 3         | -30.2          | 6.3            | 78.7           | -29.4          | 6.9            | 78.7           | -29.3          | 8.1            | 78.8           |
| Frame 4         | -30.6          | 6.1            | 78.6           | -29.1          | 6.7            | 78.6           | -29.6          | 8.0            | 78.8           |
| Frame 5         | -29.9          | 6.1            | 78.9           | -29.6          | 7.0            | 78.6           | -29.3          | 8.0            | 78.8           |
| Frame 6         | -30.8          | 6.2            | 78.6           | -29.5          | 6.8            | 78.7           | -29.1          | 7.9            | 78.9           |
| Frame 7         | -30.1          | 6.3            | 78.7           | -29.9          | 7.0            | 78.6           | -29.2          | 8.0            | 78.7           |
| Frame 8         | -30.9          | 6.3            | 78.8           | -29.8          | 6.8            | 78.5           | -29.1          | 8.0            | 78.8           |
| Frame 9         | -30.1          | 6.3            | 78.8           | -29.4          | 6.8            | 78.7           | -29.0          | 8.0            | 78.8           |
| Frame 10        | -30.9          | 6.2            | 78.6           | -29.9          | 6.8            | 78.7           | -29.5          | 8.0            | 79.1           |
| Average         | -30.4          | 6.2            | 78.7           | -29.5          | 6.8            | 78.7           | -29.3          | 8.0            | 78.8           |
| St. Deviation   | 0.4            | 0.07           | 0.09           | 0.28           | 0.10           | 0.09           | 0.24           | 0.06           | 0.11           |



| qd control - Xd control = -19.5 cm, Yd control = 2.8 cm, Zd control = 77.4 cm |       |      |      |       |      |      |       |      |      |       |      |      |           |                |                |                |                |                |                |                |                |                |
|-------------------------------------------------------------------------------|-------|------|------|-------|------|------|-------|------|------|-------|------|------|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Raw Coordinates                                                               |       |      |      |       |      |      |       |      |      |       |      |      |           |                |                |                |                |                |                |                |                |                |
| St(degrees)                                                                   | -10.0 |      |      | -8.0  |      |      | -6.0  |      |      | -4.0  |      |      | -2.0      |                |                | 0.0            |                |                | 2.0            |                |                |                |
|                                                                               | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   | Xd        | Yd             | Zd             | Xd             | Yd             | Zd             | Xd             | Yd             | Zd             |                |
| Frame 1                                                                       | -23.9 | 3.4  | 75.4 | -24.0 | 4.0  | 76.2 | -24.6 | 3.9  | 76.1 | -25.4 | 4.2  | 77.9 | -27.1     | 4.4            | 78.8           | -28.7          | 4.9            | 78.8           | -28.9          | 3.9            | 80.0           |                |
| Frame 2                                                                       | -23.7 | 3.2  | 75.4 | -23.6 | 3.6  | 76.1 | -24.4 | 4.1  | 76.2 | -25.4 | 4.2  | 78.2 | -27.2     | 4.1            | 78.6           | -28.6          | 4.4            | 78.8           | -27.5          | 3.7            | 79.9           |                |
| Frame 3                                                                       | -23.6 | 3.2  | 75.6 | -24.2 | 4.0  | 76.0 | -24.5 | 3.9  | 76.3 | -25.4 | 4.1  | 78.2 | -27.4     | 4.5            | 78.7           | -29.4          | 4.9            | 78.6           | -27.6          | 4.0            | 80.1           |                |
| Frame 4                                                                       | -23.4 | 3.0  | 75.4 | -24.4 | 3.8  | 76.0 | -23.9 | 4.3  | 76.3 | -27.1 | 4.5  | 77.7 | -27.2     | 3.9            | 78.7           | -29.9          | 4.8            | 78.7           | -27.7          | 3.8            | 80.0           |                |
| Frame 5                                                                       | -23.7 | 3.3  | 75.6 | -24.7 | 4.1  | 76.2 | -23.8 | 3.9  | 76.4 | -25.9 | 4.1  | 78.1 | -27.0     | 4.4            | 78.7           | -28.7          | 4.9            | 78.7           | -27.5          | 4.0            | 79.9           |                |
| Frame 6                                                                       | -23.4 | 3.3  | 75.4 | -24.8 | 3.9  | 76.5 | -24.3 | 4.2  | 76.5 | -25.5 | 4.1  | 78.1 | -28.0     | 4.2            | 78.7           | -29.4          | 4.6            | 78.7           | -27.9          | 3.8            | 79.9           |                |
| Frame 7                                                                       | -23.7 | 3.2  | 75.7 | -24.9 | 4.2  | 76.1 | -24.7 | 4.2  | 76.2 | -26.3 | 3.8  | 77.8 | -27.2     | 4.4            | 78.7           | -28.6          | 4.9            | 78.7           | -27.0          | 4.0            | 80.0           |                |
| Frame 8                                                                       | -23.9 | 3.3  | 75.5 | -24.0 | 3.8  | 76.1 | -24.3 | 4.1  | 76.4 | -24.9 | 3.7  | 78.3 | -28.0     | 4.3            | 78.7           | -28.9          | 4.6            | 78.8           | -27.3          | 3.6            | 79.6           |                |
| Frame 9                                                                       | -24.4 | 3.4  | 75.5 | -24.3 | 4.1  | 76.1 | -24.9 | 3.9  | 76.2 | -25.5 | 4.4  | 78.1 | -26.7     | 4.2            | 78.8           | -28.6          | 4.9            | 78.7           | -28.0          | 4.1            | 80.0           |                |
| Frame 10                                                                      | -23.8 | 3.2  | 75.5 | -24.1 | 3.8  | 76.0 | -24.3 | 4.1  | 76.3 | -24.9 | 3.6  | 78.2 | -27.3     | 4.0            | 78.7           | -29.0          | 4.5            | 78.7           | -27.6          | 3.7            | 79.8           |                |
| Average                                                                       | -23.8 | 3.3  | 75.5 | -24.3 | 3.9  | 76.1 | -24.4 | 4.1  | 76.3 | -25.6 | 4.1  | 78.1 | -27.3     | 4.2            | 78.7           | -29.1          | 4.8            | 78.7           | -27.5          | 3.9            | 79.9           |                |
| St. Deviation                                                                 | 0.27  | 0.12 | 0.11 | 0.41  | 0.19 | 0.11 | 0.33  | 0.15 | 0.12 | 0.65  | 0.30 | 0.19 | 0.41      | 0.18           | 0.08           | 0.49           | 0.18           | 0.07           | 0.37           | 0.16           | 0.09           |                |
| Raw Coordinates                                                               |       |      |      |       |      |      |       |      |      |       |      |      |           |                |                |                |                |                |                |                |                |                |
| St(degrees)                                                                   | 4.0   |      |      | 6.0   |      |      | 8.0   |      |      | 10.0  |      |      | (degrees) | θ <sub>1</sub> |                |                | θ <sub>2</sub> |                |                | θ <sub>3</sub> |                |                |
|                                                                               | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   | Xd    | Yd   | Zd   |           | θ <sub>1</sub> | θ <sub>2</sub> | θ <sub>3</sub> | θ <sub>1</sub> | θ <sub>2</sub> | θ <sub>3</sub> | θ <sub>1</sub> | θ <sub>2</sub> | θ <sub>3</sub> |
| Frame 1                                                                       | -28.2 | 3.9  | 80.1 | -30.0 | 3.5  | 79.4 | -29.9 | 2.5  | 80.4 | -34.1 | 2.8  | 81.3 | -8.0      | -4.8           | 1.1            | -1.3           | 0.60           | -0.14          | 0.17           |                |                |                |
| Frame 2                                                                       | -28.4 | 3.6  | 80.0 | -30.0 | 3.5  | 79.6 | -31.0 | 2.8  | 80.8 | -34.0 | 2.8  | 81.3 | -6.0      | -4.9           | 1.3            | -1.1           | 0.81           | -0.21          | 0.19           |                |                |                |
| Frame 3                                                                       | -28.1 | 3.8  | 79.9 | -30.1 | 3.6  | 79.3 | -30.7 | 2.6  | 80.4 | -32.2 | 2.1  | 81.2 | -4.0      | -6.1           | 1.3            | 0.7            | 1.53           | -0.32          | -0.16          |                |                |                |
| Frame 4                                                                       | -28.2 | 3.4  | 80.1 | -30.4 | 3.7  | 79.5 | -30.3 | 2.8  | 80.3 | -34.1 | 2.9  | 81.3 | -2.0      | -7.8           | 1.4            | 1.3            | 3.90           | -0.72          | -0.65          |                |                |                |
| Frame 5                                                                       | -27.7 | 3.3  | 80.2 | -30.2 | 3.6  | 79.3 | -31.4 | 2.8  | 80.5 | -33.1 | 2.2  | 81.2 | 0.0       | -6.6           | 2.0            | 1.3            |                |                |                |                |                |                |
| Frame 6                                                                       | -28.4 | 3.4  | 79.9 | -30.3 | 3.8  | 79.4 | -30.7 | 2.7  | 80.4 | -33.9 | 2.7  | 81.2 | 2.0       | -8.0           | 1.1            | 2.5            | -4.00          | 0.53           | 1.27           |                |                |                |
| Frame 7                                                                       | -27.5 | 3.8  | 80.2 | -30.4 | 3.6  | 79.4 | -31.0 | 2.7  | 80.5 | -32.5 | 2.8  | 81.2 | 4.0       | -8.6           | 0.7            | 2.6            | -2.15          | 0.17           | 0.66           |                |                |                |
| Frame 8                                                                       | -28.4 | 3.3  | 79.9 | -30.8 | 3.6  | 79.3 | -30.5 | 2.7  | 80.3 | -34.1 | 2.7  | 81.3 | 6.0       | -10.7          | 0.8            | 2.0            | -1.78          | 0.14           | 0.33           |                |                |                |
| Frame 9                                                                       | -28.3 | 3.2  | 80.0 | -30.3 | 3.8  | 79.4 | -30.1 | 2.6  | 80.3 | -33.8 | 2.8  | 81.3 | 8.0       | -11.2          | -0.1           | 3.0            | -1.39          | -0.01          | 0.38           |                |                |                |
| Frame 10                                                                      | -27.7 | 3.2  | 80.2 | -30.0 | 3.7  | 79.5 | -30.9 | 2.8  | 80.5 | -33.7 | 2.7  | 81.4 | 10.0      | -14.1          | -0.1           | 3.9            | -1.41          | -0.01          | 0.39           |                |                |                |
| Average                                                                       | -28.1 | 3.5  | 80.0 | -30.2 | 3.6  | 79.4 | -30.7 | 2.7  | 80.4 | -33.6 | 2.7  | 81.3 |           |                |                |                | -0.35          | -0.06          | 0.28           |                |                |                |
| St. Deviation                                                                 | 0.33  | 0.27 | 0.13 | 0.16  | 0.09 | 0.11 | 0.48  | 0.10 | 0.09 | 0.69  | 0.26 | 0.05 |           |                |                |                |                |                |                |                |                |                |

## Uncertainty

## Raw Coordinates



| $q_4$ control = 19.5 cm, $Y_4$ control = 2.8 cm, $Z_4$ control = 77.4 cm |       |       |       |       |       |       |       |       |       |       |       |       |       |
|--------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Raw Coordinates                                                          |       |       |       |       |       |       |       |       |       |       |       |       |       |
| $\theta_4$ (degrees)                                                     | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ |
| Frame 1                                                                  | -33.2 | 7.1   | 87.5  | -25.0 | 5.6   | 88.0  | -29.5 | 4.8   | 83.6  | -28.3 | 4.2   | 81.0  | -26.2 |
| Frame 2                                                                  | -33.7 | 6.8   | 87.3  | -25.0 | 6.0   | 88.0  | -29.8 | 4.9   | 83.7  | -28.3 | 3.9   | 81.1  | -26.4 |
| Frame 3                                                                  | -33.1 | 7.1   | 87.4  | -25.3 | 5.6   | 88.6  | -29.5 | 4.9   | 83.7  | -28.4 | 4.1   | 81.0  | -26.2 |
| Frame 4                                                                  | -33.4 | 6.9   | 87.5  | -25.3 | 5.9   | 88.6  | -29.7 | 4.8   | 83.6  | -28.5 | 4.1   | 81.0  | -26.2 |
| Frame 5                                                                  | -33.0 | 7.0   | 87.4  | -25.7 | 5.8   | 88.6  | -29.2 | 4.8   | 83.6  | -28.4 | 4.2   | 81.1  | -26.2 |
| Frame 6                                                                  | -33.3 | 7.0   | 87.4  | -25.8 | 5.9   | 88.6  | -29.4 | 4.8   | 83.6  | -28.4 | 3.9   | 81.1  | -26.6 |
| Frame 7                                                                  | -33.3 | 7.1   | 87.4  | -25.8 | 5.7   | 88.7  | -29.5 | 4.9   | 83.6  | -28.4 | 4.2   | 81.1  | -26.2 |
| Frame 8                                                                  | -33.5 | 6.8   | 87.3  | -25.4 | 5.9   | 88.6  | -29.8 | 4.9   | 83.6  | -28.3 | 3.9   | 81.1  | -26.3 |
| Frame 9                                                                  | -33.2 | 7.1   | 87.4  | -25.6 | 5.7   | 88.6  | -29.7 | 4.8   | 83.7  | -28.3 | 4.0   | 81.0  | -25.9 |
| Frame 10                                                                 | -33.1 | 6.8   | 87.3  | -25.9 | 6.0   | 88.6  | -30.0 | 5.0   | 83.6  | -28.2 | 3.9   | 81.1  | -26.4 |
| Average                                                                  | -33.3 | 7.0   | 87.4  | -25.5 | 5.8   | 88.6  | -29.6 | 4.9   | 83.7  | -28.4 | 4.0   | 81.1  | -26.3 |
| St. Deviation                                                            | 0.2   | 0.12  | 0.06  | 0.32  | 0.16  | 0.16  | 0.21  | 0.06  | 0.04  | 0.07  | 0.14  | 0.05  | 0.17  |
| Uncertainty                                                              |       |       |       |       |       |       |       |       |       |       |       |       |       |
| $\theta_4$ (degrees)                                                     | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ | $y_4$ | $z_4$ | $x_4$ |
| Frame 1                                                                  | -23.6 | 5.6   | 75.4  | -26.4 | 7.8   | 73.1  | -26.2 | 9.3   | 71.3  | -9.3  | -13.8 | 4.2   | 10.0  |
| Frame 2                                                                  | -24.0 | 5.7   | 75.4  | -26.2 | 7.7   | 73.2  | -26.6 | 9.3   | 71.2  | -3.9  | -10.1 | 2.1   | 9.3   |
| Frame 3                                                                  | -24.6 | 5.7   | 75.4  | -26.0 | 7.7   | 73.2  | -26.1 | 9.3   | 71.3  | -1.9  | -8.9  | 1.2   | 3.7   |
| Frame 4                                                                  | -24.0 | 5.7   | 75.5  | -25.8 | 7.8   | 73.3  | -26.2 | 9.2   | 71.5  | 0.0   | -6.8  | 0.5   | 1.3   |
| Frame 5                                                                  | -24.4 | 5.7   | 75.5  | -25.8 | 7.7   | 73.2  | -26.1 | 9.2   | 71.3  | 1.9   | -3.9  | 1.0   | 0.0   |
| Frame 6                                                                  | -24.1 | 5.9   | 75.5  | -26.3 | 7.8   | 73.2  | -26.0 | 9.1   | 71.3  | 3.9   | -4.8  | 3.0   | -2.0  |
| Frame 7                                                                  | -24.7 | 5.8   | 75.4  | -26.0 | 7.7   | 73.2  | -26.7 | 9.3   | 71.0  | 5.9   | -6.6  | 5.0   | 4.2   |
| Frame 8                                                                  | -24.6 | 5.9   | 75.5  | -26.2 | 7.8   | 73.3  | -25.9 | 9.2   | 71.4  | 9.3   | -6.8  | 6.5   | -8.1  |
| Frame 9                                                                  | -24.6 | 5.8   | 75.3  | -25.9 | 7.8   | 73.2  | -26.9 | 9.4   | 71.0  |       |       |       |       |
| Frame 10                                                                 | -24.0 | 5.8   | 75.5  | -26.6 | 7.9   | 73.3  | -26.2 | 9.3   | 71.4  |       |       |       |       |
| Average                                                                  | -24.3 | 5.8   | 75.4  | -26.1 | 7.8   | 73.2  | -26.3 | 9.3   | 71.3  |       |       |       |       |
| St. Deviation                                                            | 0.4   | 0.08  | 0.08  | 0.27  | 0.05  | 0.06  | 0.32  | 0.08  | 0.14  |       |       |       |       |

|                                                                                          |       |           |           |           |           |      |           |           |           |       |           |           |       |           |           |       |           |           |       |
|------------------------------------------------------------------------------------------|-------|-----------|-----------|-----------|-----------|------|-----------|-----------|-----------|-------|-----------|-----------|-------|-----------|-----------|-------|-----------|-----------|-------|
| $Q_1$ control: $X_1$ control = -19.5 cm, $Y_1$ control = 2.8 cm, $Z_1$ control = 77.4 cm |       |           |           |           |           |      |           |           |           |       |           |           |       |           |           |       |           |           |       |
| Raw Coordinates                                                                          |       |           |           |           |           |      |           |           |           |       |           |           |       |           |           |       |           |           |       |
| 2 $\gamma$ (degrees)                                                                     | -10.3 | $x_{y_1}$ | $x_{z_1}$ | $x_{y_2}$ | $x_{z_2}$ | -5.9 | $x_{y_3}$ | $x_{z_3}$ | $x_{y_4}$ | -3.2  | $x_{y_5}$ | $x_{z_5}$ | -3.0  | $x_{y_6}$ | $x_{z_6}$ | 0     | $x_{y_7}$ | $x_{z_7}$ |       |
| Frame 1                                                                                  | -53.9 | 11.4      | 76.6      | -48.9     | 8.3       | 76.9 | -48.9     | 8.3       | 76.9      | -39.9 | 6.3       | 76.0      | -38.1 | 6.3       | 77.2      | -27.9 | 4.4       | 76.2      |       |
| Frame 2                                                                                  | -44.1 | 11.4      | 76.6      | -40.4     | 8.8       | 76.8 | -40.4     | 8.8       | 76.8      | -40.0 | 6.8       | 76.0      | -38.1 | 6.1       | 77.2      | -27.1 | 4.4       | 76.5      |       |
| Frame 3                                                                                  | -53.6 | 11.3      | 76.6      | -46.8     | 8.2       | 76.8 | -46.8     | 8.2       | 76.8      | -35.1 | 9.8       | 80.1      | -37.9 | 6.2       | 77.5      | -27.4 | 4.3       | 76.4      |       |
| Frame 4                                                                                  | -53.9 | 11.4      | 76.6      | -46.5     | 8.7       | 76.8 | -46.5     | 8.7       | 76.8      | -35.6 | 7.1       | 80.0      | -38.3 | 6.3       | 77.1      | -28.0 | 4.7       | 76.2      |       |
| Frame 5                                                                                  | -49.8 | 11.3      | 76.6      | -49.7     | 8.6       | 76.5 | -49.7     | 8.6       | 76.5      | -35.1 | 8.9       | 80.0      | -37.9 | 6.2       | 77.4      | -27.2 | 4.0       | 76.3      |       |
| Frame 6                                                                                  | -53.9 | 11.4      | 76.6      | -49.3     | 8.7       | 76.9 | -49.3     | 8.7       | 76.9      | -35.0 | 7.1       | 80.1      | -38.0 | 6.1       | 77.2      | -28.0 | 4.5       | 76.4      |       |
| Frame 7                                                                                  | -53.9 | 11.3      | 76.6      | -49.0     | 8.4       | 76.8 | -49.0     | 8.4       | 76.8      | -35.3 | 6.9       | 80.1      | -37.4 | 6.3       | 77.2      | -27.1 | 4.0       | 76.2      |       |
| Frame 8                                                                                  | -44.1 | 11.4      | 76.7      | -49.5     | 8.8       | 76.8 | -49.5     | 8.8       | 76.8      | -35.2 | 7.0       | 80.3      | -33.8 | 6.7       | 76.2      | -28.1 | 4.6       | 76.2      |       |
| Frame 9                                                                                  | -53.9 | 11.3      | 76.6      | -46.8     | 8.1       | 76.9 | -46.8     | 8.1       | 76.9      | -35.0 | 6.9       | 80.2      | -33.2 | 6.5       | 76.3      | -27.7 | 4.3       | 76.4      |       |
| Frame 10                                                                                 | -44.0 | 11.4      | 76.6      | -49.3     | 8.7       | 76.9 | -49.3     | 8.7       | 76.9      | -34.9 | 7.1       | 80.2      | -33.2 | 6.7       | 76.5      | -27.7 | 4.4       | 76.5      |       |
| Average                                                                                  | -53.9 | 11.4      | 76.6      | -48.2     | 8.5       | 76.8 | -48.2     | 8.5       | 76.8      | -36.1 | 6.9       | 79.7      | -36.6 | 6.3       | 77.9      | -27.6 | 4.4       | 76.4      |       |
| St. Deviation                                                                            | 0.1   | 0.06      | 0.02      | 0.31      | 0.26      | 0.10 | 0.31      | 0.26      | 0.10      | 0.20  | 0.24      | 0.90      | 0.21  | 0.23      | 1.00      | 0.39  | 0.21      | 0.32      |       |
| Raw Coordinates                                                                          |       |           |           |           |           |      |           |           |           |       |           |           |       |           |           |       |           |           |       |
| 2 $\gamma$ (degrees)                                                                     |       | $x_{y_1}$ | $x_{z_1}$ | $x_{y_2}$ | $x_{z_2}$ | 3.2  | $x_{y_3}$ | $x_{z_3}$ | $x_{y_4}$ | 5.9   | $x_{y_5}$ | $x_{z_5}$ | 10.3  | $x_{y_6}$ | $x_{z_6}$ |       | $x_{y_7}$ | $x_{z_7}$ |       |
| Frame 1                                                                                  | -16.3 | 3.5       | 79.1      | -19.1     | 3.6       | 79.1 | -6.5      | 2.5       | 80.3      | 2.9   | 1.4       | 81.0      | 12.3  | 0.4       | 82.5      | -8.6  | -29.7     | 5.7       | -0.6  |
| Frame 2                                                                                  | -16.5 | 4.0       | 79.2      | -19.2     | 4.0       | 79.1 | -7.3      | 2.3       | 80.1      | 3.1   | 1.3       | 81.0      | 11.5  | 0.7       | 82.2      | -5.9  | -29.7     | 5.7       | -0.6  |
| Frame 3                                                                                  | -16.8 | 3.6       | 79.2      | -18.8     | 3.6       | 79.3 | -6.9      | 2.3       | 80.3      | 3.0   | 1.5       | 81.1      | 12.4  | 0.4       | 82.3      | -3.2  | -16.6     | 4.1       | 2.3   |
| Frame 4                                                                                  | -16.5 | 4.1       | 79.1      | -18.9     | 3.9       | 79.0 | -6.3      | 2.2       | 80.5      | 2.9   | 1.2       | 80.8      | 11.3  | 0.8       | 82.3      | -3.0  | -17.1     | 3.5       | 0.5   |
| Frame 5                                                                                  | -16.2 | 3.5       | 79.2      | -16.8     | 3.7       | 76.6 | -7.7      | 2.8       | 80.3      | 3.0   | 1.4       | 81.2      | 12.0  | 0.4       | 82.1      | 0.0   | -8.1      | 1.6       | 1.0   |
| Frame 6                                                                                  | -16.4 | 4.0       | 79.2      | -19.3     | 4.0       | 79.0 | -0.5      | 3.0       | 82.6      | 2.3   | 1.3       | 80.8      | 12.1  | 0.5       | 82.0      | 3.0   | 3.0       | 1.0       | 1.0   |
| Frame 7                                                                                  | -16.9 | 3.7       | 79.2      | -18.5     | 3.7       | 78.9 | -1.3      | 3.6       | 82.7      | 3.1   | 1.4       | 81.1      | 12.5  | 0.5       | 82.1      | 3.2   | 0.5       | 1.0       | 0.3   |
| Frame 8                                                                                  | -16.6 | 4.0       | 79.3      | -19.1     | 3.8       | 79.0 | -1.3      | 2.7       | 82.6      | 3.2   | 1.2       | 81.0      | 11.8  | 0.6       | 82.2      | 5.9   | 15.5      | 0.0       | 4.1   |
| Frame 9                                                                                  | -16.4 | 3.5       | 79.2      | -19.2     | 3.7       | 76.9 | -1.6      | 3.2       | 82.6      | 2.5   | 1.5       | 80.9      | 13.0  | 0.4       | 82.3      | 8.6   | 22.4      | -1.5      | 3.6   |
| Frame 10                                                                                 | -16.4 | 4.0       | 79.3      | -18.9     | 3.9       | 79.2 | -0.6      | 3.0       | 82.5      | 3.3   | 1.3       | 81.0      | 11.5  | 0.6       | 82.3      | 10.3  | 31.5      | -2.3      | 4.9   |
| Average                                                                                  | -16.5 | 3.8       | 79.2      | -18.0     | 3.8       | 79.0 | -4.0      | 2.8       | 81.5      | 2.9   | 1.3       | 81.0      | 12.0  | 0.5       | 82.3      |       |           |           |       |
| St. Deviation                                                                            | 0.2   | 0.24      | 0.06      | 0.24      | 0.15      | 0.15 | 0.304     | 0.45      | 1.22      | 0.31  | 0.11      | 0.13      | 0.53  | 0.17      | 0.15      |       | Ave       | 2.16      | -2.29 |

|                      |       |           |           |           |           |      |           |           |           |      |           |           |      |           |           |      |           |           |       |
|----------------------|-------|-----------|-----------|-----------|-----------|------|-----------|-----------|-----------|------|-----------|-----------|------|-----------|-----------|------|-----------|-----------|-------|
|                      |       |           |           |           |           |      |           |           |           |      |           |           |      |           |           |      |           |           |       |
| 2 $\gamma$ (degrees) |       | $x_{y_1}$ | $x_{z_1}$ | $x_{y_2}$ | $x_{z_2}$ | 3.2  | $x_{y_3}$ | $x_{z_3}$ | $x_{y_4}$ | 5.9  | $x_{y_5}$ | $x_{z_5}$ | 10.3 | $x_{y_6}$ | $x_{z_6}$ |      | $x_{y_7}$ | $x_{z_7}$ |       |
| Frame 1              | -16.3 | 3.5       | 79.1      | -19.1     | 3.6       | 79.1 | -6.5      | 2.5       | 80.3      | 2.9  | 1.4       | 81.0      | 12.3 | 0.4       | 82.5      | -8.6 | -29.7     | 5.7       | -0.6  |
| Frame 2              | -16.5 | 4.0       | 79.2      | -19.2     | 4.0       | 79.1 | -7.3      | 2.3       | 80.1      | 3.1  | 1.3       | 81.0      | 11.5 | 0.7       | 82.2      | -5.9 | -29.7     | 5.7       | -0.6  |
| Frame 3              | -16.8 | 3.6       | 79.2      | -18.8     | 3.6       | 79.3 | -6.9      | 2.3       | 80.3      | 3.0  | 1.5       | 81.1      | 12.4 | 0.4       | 82.3      | -3.2 | -16.6     | 4.1       | 2.3   |
| Frame 4              | -16.5 | 4.1       | 79.1      | -18.9     | 3.9       | 79.0 | -6.3      | 2.2       | 80.5      | 2.9  | 1.2       | 80.8      | 11.3 | 0.8       | 82.3      | -3.0 | -17.1     | 3.5       | 0.5   |
| Frame 5              | -16.2 | 3.5       | 79.2      | -16.8     | 3.7       | 76.6 | -7.7      | 2.8       | 80.3      | 3.0  | 1.4       | 81.2      | 12.0 | 0.4       | 82.1      | 0.0  | -8.1      | 1.6       | 1.0   |
| Frame 6              | -16.4 | 4.0       | 79.2      | -19.3     | 4.0       | 79.0 | -0.5      | 3.0       | 82.6      | 2.3  | 1.3       | 80.8      | 12.1 | 0.5       | 82.0      | 3.0  | 3.0       | 1.0       | 1.0   |
| Frame 7              | -16.9 | 3.7       | 79.2      | -18.5     | 3.7       | 78.9 | -1.3      | 3.6       | 82.7      | 3.1  | 1.4       | 81.1      | 12.5 | 0.5       | 82.1      | 3.2  | 0.5       | 1.0       | 0.3   |
| Frame 8              | -16.6 | 4.0       | 79.3      | -19.1     | 3.8       | 79.0 | -1.3      | 2.7       | 82.6      | 3.2  | 1.2       | 81.0      | 11.8 | 0.6       | 82.2      | 5.9  | 15.5      | 0.0       | 4.1   |
| Frame 9              | -16.4 | 3.5       | 79.2      | -19.2     | 3.7       | 76.9 | -1.6      | 3.2       | 82.6      | 2.5  | 1.5       | 80.9      | 13.0 | 0.4       | 82.3      | 8.6  | 22.4      | -1.5      | 3.6   |
| Frame 10             | -16.4 | 4.0       | 79.3      | -18.9     | 3.9       | 79.2 | -0.6      | 3.0       | 82.5      | 3.3  | 1.3       | 81.0      | 11.5 | 0.6       | 82.3      | 10.3 | 31.5      | -2.3      | 4.9   |
| Average              | -16.5 | 3.8       | 79.2      | -18.0     | 3.8       | 79.0 | -4.0      | 2.8       | 81.5      | 2.9  | 1.3       | 81.0      | 12.0 | 0.5       | 82.3      |      |           |           |       |
| St. Deviation        | 0.2   | 0.24      | 0.06      | 0.24      | 0.15      | 0.15 | 0.304     | 0.45      | 1.22      | 0.31 | 0.11      | 0.13      | 0.53 | 0.17      | 0.15      |      | Ave       | 2.16      | -2.29 |

## APPENDIX N

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point E

| Raw Coordinates                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
|--------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Q <sub>1</sub> control: x <sub>q control</sub> = -149.0 cm, y <sub>q control</sub> = 77.0 cm, z <sub>q control</sub> = 76.2 cm |                |                |                |                |                |                |                |                |                |                |                |                |
| ΔX (cm)                                                                                                                        | -18            |                |                | -14.4          |                |                | -10.8          |                |                | -7.2           |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -151.1         | 77.4           | 76.0           | -150.4         | 77.1           | 76.5           | -150.7         | 77.1           | 76.3           | -149.3         | 77.4           | 76.1           |
| Frame 2                                                                                                                        | -150.6         | 77.7           | 76.1           | -150.5         | 77.4           | 76.6           | -150.6         | 77.2           | 76.3           | -149.4         | 77.5           | 76.2           |
| Frame 3                                                                                                                        | -150.6         | 77.5           | 76.0           | -150.2         | 77.2           | 76.4           | -150.6         | 77.0           | 76.3           | -149.6         | 77.4           | 76.0           |
| Frame 4                                                                                                                        | -150.8         | 77.5           | 76.0           | -150.6         | 77.4           | 76.6           | -150.5         | 77.2           | 76.2           | -149.6         | 77.4           | 76.2           |
| Frame 5                                                                                                                        | -150.6         | 77.5           | 76.0           | -150.2         | 77.2           | 76.4           | -150.7         | 77.3           | 76.3           | -149.4         | 77.4           | 76.2           |
| Frame 6                                                                                                                        | -150.7         | 77.6           | 76.0           | -150.6         | 77.4           | 76.7           | -150.6         | 77.1           | 76.3           | -149.6         | 77.4           | 76.2           |
| Frame 7                                                                                                                        | -150.6         | 77.5           | 76.0           | -149.8         | 77.2           | 76.4           | -150.6         | 77.2           | 76.3           | -149.8         | 77.4           | 76.2           |
| Frame 8                                                                                                                        | -150.7         | 77.6           | 76.1           | -150.4         | 77.3           | 76.6           | -150.5         | 77.2           | 76.3           | -149.6         | 77.4           | 76.2           |
| Frame 9                                                                                                                        | -150.5         | 77.5           | 76.0           | -150.2         | 77.2           | 76.4           | -150.7         | 77.2           | 76.3           | -149.7         | 77.4           | 76.1           |
| Frame 10                                                                                                                       | -150.7         | 77.6           | 76.1           | -150.5         | 77.4           | 76.6           | -150.6         | 77.2           | 76.3           | -149.7         | 77.4           | 76.1           |
| Average                                                                                                                        | -150.7         | 77.5           | 76.0           | -150.3         | 77.3           | 76.5           | -150.6         | 77.2           | 76.3           | -149.6         | 77.4           | 76.2           |
| St. Deviation                                                                                                                  | 0.2            | 0.09           | 0.04           | 0.23           | 0.11           | 0.11           | 0.06           | 0.07           | 0.05           | 0.17           | 0.03           | 0.04           |
| Raw Coordinates                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
| ΔX (cm)                                                                                                                        | 7.2            |                |                | 10.8           |                |                | 14.4           |                |                | 18.0           |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -148.8         | 77.5           | 76.2           | -149.2         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.1         | 77.5           | 76.1           |
| Frame 2                                                                                                                        | -148.5         | 77.4           | 76.1           | -147.8         | 77.2           | 76.4           | -148.1         | 77.0           | 76.0           | -147.2         | 77.4           | 76.1           |
| Frame 3                                                                                                                        | -148.7         | 77.5           | 76.2           | -148.3         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.3         | 77.4           | 76.0           |
| Frame 4                                                                                                                        | -148.3         | 77.5           | 76.2           | -147.8         | 77.2           | 76.3           | -148.3         | 76.9           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 5                                                                                                                        | -148.9         | 77.4           | 76.2           | -147.9         | 77.1           | 76.3           | -148.6         | 77.1           | 76.2           | -147.1         | 77.4           | 76.1           |
| Frame 6                                                                                                                        | -148.4         | 77.4           | 76.2           | -147.8         | 77.2           | 76.4           | -148.4         | 77.0           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 7                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.8         | 77.1           | 76.3           | -148.5         | 77.1           | 76.2           | -147.4         | 77.4           | 76.0           |
| Frame 8                                                                                                                        | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.3         | 77.1           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 9                                                                                                                        | -148.8         | 77.5           | 76.2           | -148.1         | 77.2           | 76.3           | -148.6         | 77.1           | 76.2           | -147.0         | 77.4           | 76.1           |
| Frame 10                                                                                                                       | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.6         | 77.0           | 76.1           | -147.3         | 77.4           | 76.1           |
| Average                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.9         | 77.2           | 76.4           | -148.5         | 77.0           | 76.1           | -147.2         | 77.4           | 76.1           |
| St. Deviation                                                                                                                  | 0.2            | 0.03           | 0.05           | 0.20           | 0.06           | 0.06           | 0.17           | 0.05           | 0.06           | 0.13           | 0.04           | 0.05           |
| Raw Coordinates                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
| ΔX (cm)                                                                                                                        | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -148.8         | 77.5           | 76.2           | -149.2         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.1         | 77.5           | 76.1           |
| Frame 2                                                                                                                        | -148.5         | 77.4           | 76.1           | -147.8         | 77.2           | 76.4           | -148.1         | 77.0           | 76.0           | -147.2         | 77.4           | 76.1           |
| Frame 3                                                                                                                        | -148.7         | 77.5           | 76.2           | -148.3         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.3         | 77.4           | 76.0           |
| Frame 4                                                                                                                        | -148.3         | 77.5           | 76.2           | -147.8         | 77.2           | 76.3           | -148.3         | 76.9           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 5                                                                                                                        | -148.9         | 77.4           | 76.2           | -147.9         | 77.1           | 76.3           | -148.6         | 77.1           | 76.2           | -147.1         | 77.4           | 76.1           |
| Frame 6                                                                                                                        | -148.4         | 77.4           | 76.2           | -147.8         | 77.2           | 76.4           | -148.4         | 77.0           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 7                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.8         | 77.1           | 76.3           | -148.5         | 77.1           | 76.2           | -147.4         | 77.4           | 76.0           |
| Frame 8                                                                                                                        | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.3         | 77.1           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 9                                                                                                                        | -148.8         | 77.5           | 76.2           | -148.1         | 77.2           | 76.3           | -148.6         | 77.1           | 76.2           | -147.0         | 77.4           | 76.1           |
| Frame 10                                                                                                                       | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.6         | 77.0           | 76.1           | -147.3         | 77.4           | 76.1           |
| Average                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.9         | 77.2           | 76.4           | -148.5         | 77.0           | 76.1           | -147.2         | 77.4           | 76.1           |
| St. Deviation                                                                                                                  | 0.2            | 0.03           | 0.05           | 0.20           | 0.06           | 0.06           | 0.17           | 0.05           | 0.06           | 0.13           | 0.04           | 0.05           |
| Raw Coordinates                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
| ΔX (cm)                                                                                                                        | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -148.8         | 77.5           | 76.2           | -149.2         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.1         | 77.5           | 76.1           |
| Frame 2                                                                                                                        | -148.5         | 77.4           | 76.1           | -147.8         | 77.2           | 76.4           | -148.1         | 77.0           | 76.0           | -147.2         | 77.4           | 76.1           |
| Frame 3                                                                                                                        | -148.7         | 77.5           | 76.2           | -148.3         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.3         | 77.4           | 76.0           |
| Frame 4                                                                                                                        | -148.3         | 77.5           | 76.2           | -147.8         | 77.2           | 76.3           | -148.3         | 76.9           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 5                                                                                                                        | -148.9         | 77.4           | 76.2           | -147.9         | 77.1           | 76.3           | -148.6         | 77.1           | 76.2           | -147.1         | 77.4           | 76.1           |
| Frame 6                                                                                                                        | -148.4         | 77.4           | 76.2           | -147.8         | 77.2           | 76.4           | -148.4         | 77.0           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 7                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.8         | 77.1           | 76.3           | -148.5         | 77.1           | 76.2           | -147.4         | 77.4           | 76.0           |
| Frame 8                                                                                                                        | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.3         | 77.1           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 9                                                                                                                        | -148.8         | 77.5           | 76.2           | -148.1         | 77.2           | 76.3           | -148.6         | 77.1           | 76.2           | -147.0         | 77.4           | 76.1           |
| Frame 10                                                                                                                       | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.6         | 77.0           | 76.1           | -147.3         | 77.4           | 76.1           |
| Average                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.9         | 77.2           | 76.4           | -148.5         | 77.0           | 76.1           | -147.2         | 77.4           | 76.1           |
| St. Deviation                                                                                                                  | 0.2            | 0.03           | 0.05           | 0.20           | 0.06           | 0.06           | 0.17           | 0.05           | 0.06           | 0.13           | 0.04           | 0.05           |
| Raw Coordinates                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
| ΔX (cm)                                                                                                                        | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                | 18.0           |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -148.8         | 77.5           | 76.2           | -149.2         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.1         | 77.5           | 76.1           |
| Frame 2                                                                                                                        | -148.5         | 77.4           | 76.1           | -147.8         | 77.2           | 76.4           | -148.1         | 77.0           | 76.0           | -147.2         | 77.4           | 76.1           |
| Frame 3                                                                                                                        | -148.7         | 77.5           | 76.2           | -148.3         | 77.2           | 76.4           | -148.6         | 77.0           | 76.2           | -147.3         | 77.4           | 76.0           |
| Frame 4                                                                                                                        | -148.3         | 77.5           | 76.2           | -147.8         | 77.2           | 76.3           | -148.3         | 76.9           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 5                                                                                                                        | -148.9         | 77.4           | 76.2           | -147.9         | 77.1           | 76.3           | -148.6         | 77.1           | 76.2           | -147.1         | 77.4           | 76.1           |
| Frame 6                                                                                                                        | -148.4         | 77.4           | 76.2           | -147.8         | 77.2           | 76.4           | -148.4         | 77.0           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 7                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.8         | 77.1           | 76.3           | -148.5         | 77.1           | 76.2           | -147.4         | 77.4           | 76.0           |
| Frame 8                                                                                                                        | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.3         | 77.1           | 76.0           | -147.3         | 77.4           | 76.1           |
| Frame 9                                                                                                                        | -148.8         | 77.5           | 76.2           | -148.1         | 77.2           | 76.3           | -148.6         | 77.1           | 76.2           | -147.0         | 77.4           | 76.1           |
| Frame 10                                                                                                                       | -148.4         | 77.4           | 76.1           | -147.7         | 77.2           | 76.4           | -148.6         | 77.0           | 76.1           | -147.3         | 77.4           | 76.1           |
| Average                                                                                                                        | -148.6         | 77.5           | 76.2           | -147.9         | 77.2           | 76.4           | -148.5         | 77.0           | 76.1           | -147.2         | 77.4           | 76.1           |
| St. Deviation                                                                                                                  | 0.2            | 0.03           | 0.05           | 0.20           | 0.06           | 0.06           | 0.17           | 0.05           | 0.06           | 0.13           | 0.04           | 0.05           |

| 2Y (cm)        |  | Row Coordinates |       |       |        |       |       |        |       |       |        |       |       | Row Coordinates |       |       |        |       |       |        |       |       |        |       |       | Row Coordinates |       |       |        |       |       |        |      |      |  |  |  |
|----------------|--|-----------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|-----------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|-----------------|-------|-------|--------|-------|-------|--------|------|------|--|--|--|
|                |  | -10.0           |       |       |        | -8.0  |       |        |       | -6.0  |        |       |       | -4.0            |       |       |        | -2.0  |       |        |       | 0.0   |        |       |       | 2.0             |       |       |        |       |       |        |      |      |  |  |  |
|                |  | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$  | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$  | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ |        |      |      |  |  |  |
| Frame 1        |  | -148.7          | 76.7  | 78.3  | -146.5 | 76.5  | 78.1  | -148.8 | 77.0  | 78.4  | -148.9 | 77.2  | 78.8  | -149.0          | 77.6  | 78.5  | -149.1 | 77.7  | 78.4  | -149.2 | 77.2  | 78.3  | -148.8 | 77.6  | 78.1  | -148.9          | 77.6  | 78.5  | -149.0 | 77.4  | 78.3  | -148.6 | 77.6 | 78.1 |  |  |  |
| Frame 2        |  | -148.9          | 76.8  | 78.3  | -146.9 | 76.6  | 78.1  | -149.1 | 76.8  | 78.3  | -149.0 | 76.9  | 78.7  | -149.0          | 77.1  | 78.5  | -149.2 | 77.1  | 78.7  | -148.5 | 77.6  | 78.5  | -149.3 | 77.2  | 78.3  | -148.8          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0 | 77.4 | 78.1 |  |  |  |
| Frame 3        |  | -149.1          | 76.7  | 78.3  | -149.2 | 76.6  | 78.1  | -149.2 | 77.1  | 78.5  | -149.2 | 77.1  | 78.7  | -148.5          | 77.6  | 78.5  | -149.3 | 77.2  | 78.3  | -148.8 | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0          | 77.4  | 78.3  | -148.6 | 77.6  | 78.0  | -148.8 | 77.6 | 78.1 |  |  |  |
| Frame 4        |  | -149.0          | 76.8  | 78.4  | -150.0 | 76.6  | 78.1  | -149.9 | 76.9  | 78.4  | -149.6 | 77.0  | 78.7  | -148.7          | 77.6  | 78.4  | -149.2 | 77.1  | 78.7  | -148.7 | 77.6  | 78.4  | -149.2 | 77.1  | 78.3  | -148.4          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -148.6 | 77.6 | 78.1 |  |  |  |
| Frame 5        |  | -149.0          | 76.7  | 78.3  | -149.8 | 76.5  | 78.2  | -149.1 | 77.0  | 78.5  | -149.3 | 77.2  | 78.7  | -148.6          | 77.7  | 78.5  | -149.0 | 77.7  | 78.5  | -149.2 | 77.2  | 78.4  | -148.6 | 77.6  | 78.1  | -148.9          | 77.6  | 78.5  | -149.0 | 77.4  | 78.3  | -148.6 | 77.6 | 78.1 |  |  |  |
| Frame 6        |  | -149.1          | 76.9  | 78.3  | -149.9 | 76.8  | 78.1  | -149.1 | 76.9  | 78.4  | -149.6 | 76.9  | 78.5  | -148.6          | 77.7  | 78.5  | -149.0 | 77.7  | 78.5  | -149.1 | 77.4  | 78.4  | -148.5 | 77.6  | 78.0  | -148.9          | 77.6  | 78.5  | -149.0 | 77.4  | 78.3  | -148.6 | 77.6 | 78.1 |  |  |  |
| Frame 7        |  | -149.0          | 76.7  | 78.1  | -149.5 | 76.5  | 78.3  | -149.2 | 77.2  | 78.4  | -149.0 | 77.3  | 78.8  | -148.6          | 77.7  | 78.5  | -149.3 | 77.2  | 78.3  | -148.6 | 77.7  | 78.5  | -149.3 | 77.2  | 78.3  | -148.5          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0 | 77.4 | 78.1 |  |  |  |
| Frame 8        |  | -148.8          | 76.8  | 78.3  | -149.7 | 76.8  | 78.2  | -149.1 | 76.9  | 78.4  | -149.3 | 77.0  | 78.4  | -149.7          | 77.6  | 78.6  | -149.5 | 77.4  | 78.4  | -148.6 | 77.6  | 78.5  | -149.3 | 77.2  | 78.3  | -148.5          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0 | 77.4 | 78.1 |  |  |  |
| Frame 9        |  | -149.1          | 76.8  | 78.3  | -149.2 | 76.5  | 78.0  | -149.2 | 77.1  | 78.4  | -149.1 | 77.2  | 78.8  | -148.6          | 77.6  | 78.5  | -149.3 | 77.2  | 78.3  | -148.6 | 77.6  | 78.5  | -149.3 | 77.2  | 78.3  | -148.5          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0 | 77.4 | 78.1 |  |  |  |
| Frame 10       |  | -148.8          | 76.7  | 78.3  | -149.6 | 76.6  | 78.1  | -149.2 | 76.9  | 78.3  | -148.9 | 76.9  | 78.7  | -148.6          | 77.6  | 78.5  | -149.4 | 77.4  | 78.3  | -148.6 | 77.6  | 78.5  | -149.4 | 77.4  | 78.3  | -148.6          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -149.0 | 77.4 | 78.1 |  |  |  |
| Average        |  | -149.0          | 76.8  | 78.3  | -149.6 | 76.6  | 78.1  | -149.1 | 77.2  | 78.4  | -148.9 | 77.1  | 78.6  | -148.6          | 77.7  | 78.5  | -149.3 | 77.3  | 78.3  | -148.6 | 77.7  | 78.5  | -149.3 | 77.3  | 78.3  | -148.5          | 77.6  | 78.1  | -148.9 | 77.6  | 78.5  | -      | -    | -    |  |  |  |
| Std. Deviation |  | 0.1             | 0.06  | 0.07  | 0.29   | 0.08  | 0.06  | 0.1    | 0.12  | 0.07  | 0.21   | 0.15  | 0.08  | 0.17            | 0.05  | 0.05  | 0.10   | 0.11  | 0.04  | 0.13   | 0.04  | 0.13  | 0.04   | 0.13  | 0.04  | 0.13            | 0.04  | 0.13  | 0.04   | 0.13  | 0.04  | 0.13   | 0.04 |      |  |  |  |

| 2Y (cm)   |  | Row Coordinates |       |       |        |       |       |        |       |       |        |       |       | Row Coordinates |       |       |        |       |       |        |       |       |        |       |       | Row Coordinates |       |       |        |       |       |        |      |      |  |  |  |
|-----------|--|-----------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|-----------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|-----------------|-------|-------|--------|-------|-------|--------|------|------|--|--|--|
|           |  | -10.0           |       |       |        | -8.0  |       |        |       | -6.0  |        |       |       | -4.0            |       |       |        | -2.0  |       |        |       | 0.0   |        |       |       | 2.0             |       |       |        |       |       |        |      |      |  |  |  |
|           |  | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$  | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$  | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ | $x_s$           | $y_s$ | $z_s$ | $x_e$  | $y_e$ | $z_e$ |        |      |      |  |  |  |
| Frame 1   |  | -148.7          | 77.6  | 78.3  | -149.2 | 77.6  | 78.3  | -149.6 | 77.9  | 78.0  | -149.7 | 77.9  | 78.0  | -149.8          | 77.9  | 78.0  | -150.0 | 77.9  | 78.0  | -149.9 | 77.9  | 78.0  | -149.8 | 77.9  | 78.0  | -149.7          | 77.9  | 78.0  | -149.6 | 77.9  | 78.0  | -149.5 | 77.9 | 78.0 |  |  |  |
| Frame 2   |  | -150.2          | 77.4  | 78.1  | -149.3 | 77.4  | 78.2  | -149.7 | 77.7  | 78.2  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9 | 78.0 |  |  |  |
| Frame 3   |  | -149.8          | 77.6  | 78.2  | -149.2 | 77.6  | 78.1  | -149.6 | 77.9  | 78.1  | -149.9 | 77.9  | 78.0  | -149.1          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9 | 78.0 |  |  |  |
| Frame 4   |  | -149.5          | 77.4  | 78.1  | -149.2 | 77.4  | 78.3  | -149.6 | 77.7  | 78.3  | -149.0 | 78.0  | 78.0  | -149.0          | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0          | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0 | 78.0 |  |  |  |
| Frame 5   |  | -149.8          | 77.5  | 78.2  | -149.1 | 77.6  | 78.3  | -149.6 | 77.9  | 78.0  | -149.7 | 77.9  | 78.0  | -149.8          | 77.9  | 78.0  | -149.9 | 77.9  | 78.0  | -150.0 | 77.9  | 78.0  | -149.9 | 77.9  | 78.0  | -149.8          | 77.9  | 78.0  | -149.7 | 77.9  | 78.0  | -149.6 | 77.9 | 78.0 |  |  |  |
| Frame 6   |  | -149.7          | 77.4  | 78.0  | -149.2 | 77.4  | 78.2  | -149.6 | 77.7  | 78.2  | -149.0 | 78.0  | 78.0  | -149.0          | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0          | 78.0  | 78.0  | -149.0 | 78.0  | 78.0  | -149.0 | 78.0 | 78.0 |  |  |  |
| Frame 7   |  | -150.0          | 77.6  | 78.1  | -149.4 | 77.6  | 78.2  | -149.6 | 77.9  | 78.1  | -149.8 | 77.9  | 78.0  | -149.7          | 77.9  | 78.0  | -149.6 | 77.9  | 78.0  | -149.5 | 77.9  | 78.0  | -149.4 | 77.9  | 78.0  | -149.3          | 77.9  | 78.0  | -149.2 | 77.9  | 78.0  | -149.1 | 77.9 | 78.0 |  |  |  |
| Frame 8   |  | -149.9          | 77.4  | 78.2  | -149.1 | 77.4  | 78.2  | -149.5 | 77.7  | 78.1  | -149.9 | 77.9  | 78.0  | -149.1          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9 | 78.0 |  |  |  |
| Frame 9   |  | -150.0          | 77.6  | 78.3  | -149.2 | 77.6  | 78.1  | -149.6 | 77.9  | 78.1  | -149.7 | 77.9  | 78.0  | -149.8          | 77.9  | 78.0  | -149.9 | 77.9  | 78.0  | -150.0 | 77.9  | 78.0  | -149.9 | 77.9  | 78.0  | -149.8          | 77.9  | 78.0  | -149.7 | 77.9  | 78.0  | -149.6 | 77.9 | 78.0 |  |  |  |
| Frame 10  |  | -149.8          | 77.4  | 78.0  | -149.1 | 77.4  | 78.3  | -149.5 | 77.7  | 78.2  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0          | 77.9  | 78.0  | -149.0 | 77.9  | 78.0  | -149.0 | 77.9 | 78.0 |  |  |  |
| Average   |  | -149.9          | 77.5  | 78.2  | -149.2 | 77.5  | 78.2  | -149.6 | 77.8  | 78.1  | -149.8 | 77.9  | 78.0  | -149.7          | 77.9  | 78.0  | -149.6 | 77.9  | 78.0  | -149.5 | 77.9  | 78.0  | -149.4 | 77.9  | 78.0  | -149.3          | 77.9  | 78.0  | -149.2 | 77.9  | 78.0  | -149.1 | 77.9 | 78.0 |  |  |  |
| Deviation |  | 0.2             | 0.12  | 0.09  | 0.11   | 0.09  | 0.07  | 0.09   | 0.13  | 0.07  | 0.09   | 0.05  | 0.05  | 0.09            | 0.05  | 0.05  | 0.09   | 0.05  | 0.05  | 0.09   | 0.05  | 0.05  | 0.09   | 0.05  | 0.05  | 0.09            | 0.05  | 0.05  | 0.09   | 0.05  | 0.05  | 0.09   | 0.05 |      |  |  |  |

| Raw Coordinates                                                                            |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |  |  |  |
|--------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--|--|--|
| $q_0$ control: $x_0$ control = -149.0 cm, $y_0$ control = 77.0 cm, $z_0$ control = 78.2 cm |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |  |  |  |
| $z'$ (cm)                                                                                  | -16    |       |       | -14.4  |       |       | -10.6  |       |       | -7.2   |       |       | -3.6   |       |       | 0      |       |       | 3.6    |       |       |  |  |  |
|                                                                                            | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ |  |  |  |
| Frame 1                                                                                    | -149.1 | 77.4  | 77.3  | -150.3 | 77.2  | 77.5  | -149.7 | 77.3  | 78.0  | -150.4 | 77.3  | 77.9  | -149.5 | 77.5  | 78.2  | -150.1 | 77.2  | 78.4  | -149.3 | 77.5  | 78.3  |  |  |  |
| Frame 2                                                                                    | -149.2 | 77.5  | 77.4  | -150.2 | 77.4  | 77.5  | -149.8 | 77.0  | 78.1  | -150.6 | 77.5  | 77.9  | -149.7 | 77.7  | 78.1  | -149.6 | 77.3  | 78.5  | -149.4 | 77.5  | 78.2  |  |  |  |
| Frame 3                                                                                    | -149.1 | 77.5  | 77.4  | -150.3 | 77.3  | 77.5  | -149.5 | 77.2  | 78.2  | -150.0 | 77.3  | 77.9  | -149.7 | 77.4  | 78.2  | -149.8 | 77.2  | 78.4  | -149.4 | 77.5  | 78.1  |  |  |  |
| Frame 4                                                                                    | -148.9 | 77.5  | 77.4  | -150.0 | 77.3  | 77.5  | -149.5 | 77.1  | 78.1  | -150.8 | 77.4  | 77.8  | -149.9 | 77.6  | 78.1  | -149.9 | 77.2  | 78.5  | -149.6 | 77.5  | 78.2  |  |  |  |
| Frame 5                                                                                    | -149.3 | 77.5  | 77.4  | -150.3 | 77.3  | 77.6  | -149.7 | 77.3  | 78.2  | -150.4 | 77.3  | 77.7  | -149.7 | 77.4  | 78.1  | -149.9 | 77.2  | 78.6  | -149.5 | 77.5  | 78.1  |  |  |  |
| Frame 6                                                                                    | -148.9 | 77.5  | 77.3  | -150.2 | 77.3  | 77.3  | -149.6 | 77.1  | 78.1  | -150.9 | 77.5  | 77.8  | -149.9 | 77.6  | 78.1  | -149.8 | 77.3  | 78.5  | -149.6 | 77.4  | 78.2  |  |  |  |
| Frame 7                                                                                    | -149.3 | 77.5  | 77.4  | -150.2 | 77.3  | 77.5  | -149.4 | 77.3  | 78.2  | -150.3 | 77.3  | 77.9  | -149.4 | 77.3  | 78.2  | -149.9 | 77.2  | 78.4  | -149.5 | 77.5  | 78.1  |  |  |  |
| Frame 8                                                                                    | -149.1 | 77.3  | 77.3  | -150.1 | 77.6  | 77.5  | -149.3 | 77.1  | 78.2  | -150.8 | 77.6  | 77.9  | -149.5 | 77.7  | 78.2  | -149.6 | 77.3  | 78.5  | -149.3 | 77.5  | 78.2  |  |  |  |
| Frame 9                                                                                    | -151.4 | 77.0  | 75.9  | -150.8 | 77.2  | 77.5  | -149.4 | 77.3  | 78.2  | -150.6 | 77.3  | 77.8  | -149.6 | 77.4  | 78.1  | -150.1 | 77.2  | 78.4  | -149.3 | 77.5  | 78.2  |  |  |  |
| Frame 10                                                                                   | -148.9 | 77.5  | 77.3  | -150.2 | 77.5  | 77.5  | -149.8 | 77.0  | 78.1  | -150.7 | 77.5  | 78.0  | -149.8 | 77.7  | 78.1  | -149.5 | 77.3  | 78.5  | -149.4 | 77.5  | 78.2  |  |  |  |
| Average                                                                                    | -149.3 | 77.4  | 77.2  | -150.2 | 77.3  | 77.5  | -149.6 | 77.2  | 78.2  | -150.6 | 77.4  | 77.9  | -149.7 | 77.5  | 78.1  | -149.8 | 77.2  | 78.5  | -149.5 | 77.5  | 78.2  |  |  |  |
| St. Deviation                                                                              | 0.7    | 0.18  | 0.45  | 0.15   | 0.12  | 0.06  | 0.16   | 0.12  | 0.08  | 0.29   | 0.12  | 0.08  | 0.16   | 0.14  | 0.05  | 0.20   | 0.09  | 0.05  | 0.11   | 0.03  | 0.04  |  |  |  |

| Raw Coordinates |        |       |       |        |       |       |        |       |       |        |       |       |  |  |
|-----------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--|--|
| $z'$ (cm)       | 7.2    |       |       | 10.8   |       |       | 14.4   |       |       | 18.0   |       |       |  |  |
|                 | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ |  |  |
| Frame 1         | -149.5 | 77.2  | 78.3  | -149.8 | 77.1  | 78.9  | -149.7 | 77.2  | 79.2  | -149.1 | 77.0  | 79.2  |  |  |
| Frame 2         | -149.6 | 77.0  | 78.4  | -149.7 | 76.9  | 78.9  | -149.0 | 77.1  | 79.2  | -149.7 | 77.3  | 79.3  |  |  |
| Frame 3         | -149.6 | 77.2  | 78.5  | -149.7 | 77.1  | 78.7  | -148.5 | 77.3  | 79.3  | -149.5 | 77.0  | 79.3  |  |  |
| Frame 4         | -149.2 | 77.1  | 78.5  | -149.8 | 76.7  | 78.8  | -149.3 | 77.2  | 79.3  | -149.8 | 77.1  | 79.3  |  |  |
| Frame 5         | -149.5 | 77.2  | 78.5  | -149.8 | 77.1  | 78.8  | -148.5 | 77.1  | 79.1  | -149.8 | 77.0  | 79.2  |  |  |
| Frame 6         | -149.6 | 77.1  | 78.5  | -149.8 | 76.8  | 78.8  | -149.6 | 77.2  | 79.4  | -149.5 | 77.3  | 79.3  |  |  |
| Frame 7         | -149.7 | 77.2  | 78.4  | -149.7 | 77.1  | 78.6  | -149.3 | 77.2  | 78.4  | -149.8 | 77.0  | 79.3  |  |  |
| Frame 8         | -149.3 | 77.0  | 78.5  | -149.7 | 77.0  | 78.6  | -148.6 | 77.1  | 78.3  | -149.1 | 77.3  | 79.3  |  |  |
| Frame 9         | -149.6 | 77.2  | 78.4  | -149.6 | 77.0  | 78.8  | -149.7 | 77.2  | 79.1  | -149.7 | 77.0  | 79.2  |  |  |
| Frame 10        | -149.5 | 77.0  | 78.5  | -149.8 | 76.9  | 78.6  | -149.6 | 77.2  | 79.2  | -149.9 | 77.3  | 79.3  |  |  |
| Average         | -149.5 | 77.1  | 78.4  | -149.7 | 77.0  | 78.8  | -149.6 | 77.2  | 79.3  | -149.7 | 77.1  | 79.3  |  |  |
| St. Deviation   | 0.1    | 0.10  | 0.07  | 0.06   | 0.12  | 0.06  | 0.22   | 0.05  | 0.10  | 0.27   | 0.14  | 0.06  |  |  |

| Uncertainty   |            |       |       |            |       |       |            |       |       |            |       |       |            |        |       |
|---------------|------------|-------|-------|------------|-------|-------|------------|-------|-------|------------|-------|-------|------------|--------|-------|
| $z'$ (cm)     | $\Delta x$ |       |       | $\Delta y$ |       |       | $\Delta z$ |       |       | $\Delta x$ |       |       | $\Delta y$ |        |       |
|               | $x_0$      | $y_0$ | $z_0$ | $x_0$      | $y_0$ | $z_0$ | $x_0$      | $y_0$ | $z_0$ | $x_0$      | $y_0$ | $z_0$ | $x_0$      | $y_0$  | $z_0$ |
| Frame 1       | -149.5     | 77.2  | 78.3  | -149.8     | 77.1  | 78.9  | -149.7     | 77.2  | 79.2  | -18.0      | -0.3  | 0.4   | -1.0       | 0.0    | 0.1   |
| Frame 2       | -149.6     | 77.0  | 78.4  | -149.7     | 76.9  | 78.9  | -149.0     | 77.1  | 79.2  | -14.4      | -1.2  | 0.3   | -0.7       | 0.1    | 0.0   |
| Frame 3       | -149.6     | 77.2  | 78.5  | -149.7     | 77.1  | 78.7  | -148.5     | 77.3  | 79.3  | -10.8      | -0.6  | 0.2   | 0.0        | 0.1    | 0.0   |
| Frame 4       | -149.2     | 77.1  | 78.5  | -149.8     | 76.7  | 78.8  | -149.3     | 77.2  | 79.3  | -7.2       | -1.6  | 0.4   | -0.3       | 0.2    | -0.1  |
| Frame 5       | -149.5     | 77.2  | 78.5  | -149.8     | 77.1  | 78.8  | -148.5     | 77.1  | 79.1  | -3.6       | -0.7  | 0.5   | -0.1       | 0.2    | -0.1  |
| Frame 6       | -149.6     | 77.1  | 78.5  | -149.8     | 76.8  | 78.8  | -149.6     | 77.2  | 79.4  | 0.0        | -0.8  | 0.2   | 0.3        |        |       |
| Frame 7       | -149.7     | 77.2  | 78.4  | -149.7     | 77.1  | 78.6  | -149.3     | 77.2  | 78.4  | 3.6        | -0.5  | 0.5   | 0.0        | -0.1   | 0.1   |
| Frame 8       | -149.3     | 77.0  | 78.5  | -149.7     | 77.0  | 78.6  | -148.6     | 77.1  | 78.3  | 7.2        | -0.5  | 0.1   | 0.2        | -0.1   | 0.0   |
| Frame 9       | -149.6     | 77.2  | 78.4  | -149.6     | 77.0  | 78.8  | -149.7     | 77.2  | 79.1  | 10.8       | -0.7  | 0.0   | 0.6        | -0.1   | 0.1   |
| Frame 10      | -149.5     | 77.0  | 78.5  | -149.8     | 76.9  | 78.6  | -149.6     | 77.2  | 79.2  | 14.4       | 0.4   | 0.2   | 1.1        | 0.0    | 0.1   |
| Average       | -149.5     | 77.1  | 78.4  | -149.7     | 77.0  | 78.8  | -149.6     | 77.2  | 79.3  | 18.0       | 0.3   | 0.1   | 1.1        | 0.0    | 0.1   |
| St. Deviation | 0.1        | 0.10  | 0.07  | 0.06       | 0.12  | 0.06  | 0.22       | 0.05  | 0.10  | 0.27       | 0.14  | 0.06  | Ave.       | 0.0343 | -0.01 |

| RAW COORDINATES                                                                                                                |                |                |                |                |                |                |                |                |                |                |                |                |
|--------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| q <sub>z</sub> control: x <sub>q</sub> control = -149.0 cm, y <sub>q</sub> control = 77.0 cm, z <sub>q</sub> control = 78.2 cm |                |                |                |                |                |                |                |                |                |                |                |                |
| g(degrees)                                                                                                                     | -10.0          | -8.0           | -6.0           | -4.0           | -2.0           | 0.0            | 2.0            |                |                |                |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -148.1         | 77.4           | 77.7           | -148.0         | 77.5           | 78.1           | -148.1         | 77.7           | 78.2           | -148.6         | 77.4           | 78.8           |
| Frame 2                                                                                                                        | -148.0         | 77.5           | 77.6           | -148.1         | 77.5           | 77.9           | -148.3         | 77.4           | 78.3           | -150.2         | 77.0           | 78.8           |
| Frame 3                                                                                                                        | -148.9         | 77.3           | 77.7           | -148.4         | 77.4           | 77.9           | -149.1         | 77.4           | 78.2           | -148.5         | 77.6           | 78.2           |
| Frame 4                                                                                                                        | -148.1         | 77.5           | 77.8           | -148.4         | 77.5           | 78.0           | -148.4         | 77.3           | 78.0           | -148.5         | 77.6           | 78.2           |
| Frame 5                                                                                                                        | -148.9         | 77.3           | 77.7           | -148.3         | 77.4           | 78.1           | -149.1         | 77.4           | 78.1           | -148.2         | 77.6           | 78.4           |
| Frame 6                                                                                                                        | -148.8         | 77.5           | 77.7           | -148.4         | 77.5           | 78.0           | -149.1         | 77.3           | 78.1           | -148.3         | 77.5           | 78.3           |
| Frame 7                                                                                                                        | -148.6         | 77.3           | 77.8           | -148.5         | 77.5           | 77.9           | -149.1         | 77.4           | 78.0           | -148.7         | 77.7           | 78.1           |
| Frame 8                                                                                                                        | -149.2         | 77.5           | 77.7           | -149.2         | 77.5           | 78.0           | -149.0         | 77.3           | 78.1           | -148.5         | 77.5           | 78.3           |
| Frame 9                                                                                                                        | -148.9         | 77.4           | 77.8           | -149.1         | 77.4           | 78.0           | -149.1         | 77.4           | 78.0           | -148.1         | 77.6           | 78.4           |
| Frame 10                                                                                                                       | -149.0         | 77.4           | 77.8           | -149.3         | 77.4           | 78.0           | -149.0         | 77.4           | 78.0           | -148.2         | 77.6           | 78.4           |
| Average                                                                                                                        | -148.9         | 77.4           | 77.7           | -149.3         | 77.5           | 78.0           | -149.0         | 77.4           | 78.1           | -148.4         | 77.6           | 78.3           |
| St Deviation                                                                                                                   | 0.18           | 0.08           | 0.08           | 0.16           | 0.04           | 0.08           | 0.28           | 0.04           | 0.06           | 0.27           | 0.09           | 0.09           |
| Uncertainty                                                                                                                    |                |                |                |                |                |                |                |                |                |                |                |                |
|                                                                                                                                | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> | x <sub>q</sub> | y <sub>q</sub> | z <sub>q</sub> |
| Frame 1                                                                                                                        | -150.4         | 76.9           | 78.6           | -150.2         | 77.3           | 77.6           | -148.4         | 76.9           | 78.5           | -10.0          | 0.1            | 0.4            |
| Frame 2                                                                                                                        | -149.9         | 76.8           | 78.5           | -150.0         | 77.5           | 77.7           | -149.5         | 76.5           | 78.5           | -8.0           | 0.3            | 0.5            |
| Frame 3                                                                                                                        | -150.2         | 77.0           | 78.6           | -150.2         | 77.3           | 77.6           | -149.3         | 76.9           | 78.3           | -6.0           | 0.0            | 0.4            |
| Frame 4                                                                                                                        | -148.8         | 76.8           | 78.6           | -150.3         | 77.2           | 77.6           | -148.4         | 76.6           | 78.5           | -4.0           | 0.6            | 0.8            |
| Frame 5                                                                                                                        | -150.0         | 76.9           | 78.7           | -150.2         | 77.3           | 77.6           | -149.5         | 76.9           | 78.4           | -2.0           | -0.9           | 0.2            |
| Frame 6                                                                                                                        | -150.0         | 76.8           | 78.6           | -150.2         | 77.5           | 77.6           | -149.4         | 76.6           | 78.3           | 0.0            | -0.5           | 0.3            |
| Frame 7                                                                                                                        | -149.9         | 77.0           | 78.8           | -150.2         | 77.3           | 77.6           | -149.6         | 77.0           | 78.5           | 2.0            | 0.2            | 0.4            |
| Frame 8                                                                                                                        | -150.1         | 76.9           | 78.4           | -150.3         | 77.5           | 77.6           | -149.6         | 76.6           | 78.5           | 4.0            | -1.1           | -0.1           |
| Frame 9                                                                                                                        | -150.7         | 76.9           | 78.3           | -150.3         | 77.3           | 77.7           | -149.4         | 77.0           | 78.4           | 6.0            | -1.2           | 0.4            |
| Frame 10                                                                                                                       | -149.9         | 76.6           | 78.4           | -150.2         | 77.7           | 77.6           | -149.6         | 76.6           | 78.5           | 8.0            | -0.5           | -0.2           |
| Average                                                                                                                        | -150.1         | 76.9           | 78.6           | -150.2         | 77.4           | 77.6           | -149.5         | 76.8           | 78.4           | 10.0           | -0.6           | -0.2           |
| St Deviation                                                                                                                   | 0.27           | 0.11           | 0.14           | 0.09           | 0.15           | 0.05           | 0.11           | 0.19           | 0.07           | 0.24           | 0.11           | 0.09           |

## Uncertainty

## RAW COORDINATES

| $X_{\text{center}} = -149.0 \text{ cm}$ , $Y_{\text{center}} = 77.0 \text{ cm}$ , $Z_{\text{center}} = 76.2 \text{ cm}$ |        |       |       |        |       |       |        |       |       |        |       |       |        |       |      |
|-------------------------------------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|------|
| Raw Coordinates                                                                                                         |        |       |       |        |       |       |        |       |       |        |       |       |        |       |      |
| $\Delta\theta(\text{degrees})$                                                                                          | $x_s$  | $z_s$ | $y_s$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ |      |
|                                                                                                                         |        | -9.3  |       | -5.9   |       | -3.9  |        | -1.9  |       | 0      |       |       |        | 1.9   |      |
| Frame 1                                                                                                                 | -149.4 | 77.6  | 78.9  | -149.9 | 77.8  | 78.9  | -149.9 | 77.4  | 78.6  | -149.1 | 77.2  | 78.3  | -149.0 | 78.8  | 78.1 |
| Frame 2                                                                                                                 | -149.6 | 77.6  | 79.0  | -149.8 | 77.7  | 79.0  | -149.8 | 77.7  | 78.6  | -149.0 | 77.2  | 78.4  | -149.0 | 77.0  | 78.2 |
| Frame 3                                                                                                                 | -149.2 | 77.6  | 78.9  | -149.7 | 78.0  | 78.9  | -149.7 | 77.5  | 78.5  | -149.1 | 77.2  | 78.3  | -149.0 | 78.6  | 78.1 |
| Frame 4                                                                                                                 | -149.3 | 77.5  | 79.1  | -149.9 | 77.9  | 78.9  | -149.8 | 77.5  | 78.6  | -149.3 | 77.4  | 78.4  | -149.1 | 78.9  | 78.2 |
| Frame 5                                                                                                                 | -149.1 | 77.6  | 78.9  | -149.5 | 78.0  | 78.9  | -149.5 | 77.8  | 78.5  | -149.1 | 77.3  | 78.4  | -149.0 | 78.9  | 78.1 |
| Frame 6                                                                                                                 | -149.2 | 77.5  | 79.0  | -150.1 | 77.8  | 78.8  | -149.7 | 77.5  | 78.6  | -149.3 | 77.3  | 78.4  | -149.1 | 77.0  | 78.1 |
| Frame 7                                                                                                                 | -149.4 | 77.6  | 78.9  | -149.8 | 77.8  | 79.0  | -149.8 | 77.4  | 78.5  | -149.3 | 77.2  | 78.4  | -149.0 | 78.6  | 78.0 |
| Frame 8                                                                                                                 | -149.5 | 77.5  | 79.0  | -149.8 | 77.9  | 78.9  | -150.0 | 77.7  | 78.5  | -149.1 | 77.4  | 78.4  | -149.1 | 77.0  | 78.3 |
| Frame 9                                                                                                                 | -149.5 | 77.6  | 78.9  | -149.3 | 77.8  | 78.9  | -149.3 | 77.3  | 78.7  | -149.1 | 77.2  | 78.2  | -149.7 | 78.9  | 78.1 |
| Frame 10                                                                                                                | -149.3 | 77.6  | 78.9  | -149.7 | 77.9  | 78.8  | -149.6 | 77.6  | 78.6  | -149.1 | 77.5  | 78.4  | -149.2 | 77.0  | 78.1 |
| Average                                                                                                                 | -149.3 | 77.6  | 78.9  | -149.7 | 77.8  | 78.9  | -149.8 | 77.5  | 78.5  | -149.2 | 77.3  | 78.4  | -149.0 | 78.9  | 78.1 |
| ST Deviation                                                                                                            | 0.1    | 0.08  | 0.06  | 0.22   | 0.09  | 0.06  | 0.16   | 0.12  | 0.06  | 0.11   | 0.11  | 0.07  | 0.21   | 0.08  | 0.08 |
| Uncertainty                                                                                                             |        |       |       |        |       |       |        |       |       |        |       |       |        |       |      |
|                                                                                                                         |        |       |       |        |       |       |        |       |       |        |       |       |        |       |      |
| $\Delta\theta(\text{degrees})$                                                                                          | $x_s$  | $z_s$ | $y_s$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ | $y_r$ | $z_r$  | $x_r$ |      |
| Frame 1                                                                                                                 | -150.4 | 77.6  | 77.6  | -150.3 | 77.7  | 77.7  | -148.6 | 78.3  | 77.6  | -5.9   | -0.7  | 0.125 | -0.14  | -0.12 |      |
| Frame 2                                                                                                                 | -150.6 | 77.8  | 77.7  | -150.2 | 77.7  | 77.7  | -149.0 | 78.2  | 77.5  | -3.9   | -0.8  | 0.5   | 0.3    | 0.21  |      |
| Frame 3                                                                                                                 | -150.6 | 77.7  | 77.7  | -150.2 | 77.7  | 77.8  | -148.7 | 78.3  | 77.6  | -1.9   | -0.2  | 0.3   | 0.2    | 0.085 |      |
| Frame 4                                                                                                                 | -150.7 | 77.8  | 77.7  | -150.2 | 77.9  | 77.7  | -148.8 | 78.2  | 77.6  | 0.0    | 0.0   | -0.1  | -0.1   | -0.08 |      |
| Frame 5                                                                                                                 | -150.6 | 77.7  | 77.7  | -150.1 | 77.7  | 77.8  | -148.8 | 78.2  | 77.6  | 1.9    | 0.2   | 0.4   | -0.2   | 0.12  |      |
| Frame 6                                                                                                                 | -150.7 | 77.8  | 77.8  | -150.2 | 77.8  | 77.7  | -148.7 | 78.1  | 77.6  | 3.9    | -1.7  | 0.7   | -0.5   | -0.42 |      |
| Frame 7                                                                                                                 | -150.5 | 77.7  | 77.6  | -149.9 | 77.7  | 77.8  | -148.8 | 78.3  | 77.5  | 5.9    | -1.2  | 0.7   | -0.5   | -0.2  |      |
| Frame 8                                                                                                                 | -150.6 | 77.7  | 77.8  | -150.2 | 77.7  | 77.7  | -148.8 | 78.2  | 77.6  | 5.9    | -1.2  | 0.7   | -0.5   | -0.2  |      |
| Frame 9                                                                                                                 | -150.7 | 77.7  | 77.7  | -150.2 | 77.7  | 77.8  | -148.7 | 78.2  | 77.6  | 9.3    | 0.2   | 1.2   | -0.6   | 0.025 |      |
| Frame 10                                                                                                                | -150.7 | 77.8  | 77.8  | -150.2 | 77.7  | 77.7  | -148.7 | 78.2  | 77.6  |        |       |       |        |       |      |
| Average                                                                                                                 |        |       |       |        |       |       |        |       |       | Ave.   | 0.00  | 0.01  | -0.10  |       |      |
| ST Deviation                                                                                                            | 0.1    | 0.07  | 0.05  | 0.11   | 0.06  | 0.05  | 0.11   | 0.06  | 0.04  |        |       |       |        |       |      |



| $Q_{\text{a, control}} - x_{\text{a, control}} = -149.0 \text{ cm}$ , $Y_{\text{a, control}} = 77.0 \text{ cm}$ , $z_{\text{a, control}} = 76.2 \text{ cm}$ |                |                |                |                |                |                |                |                |                |                |                |                                               |                |                |                |                                     |                                     |      |      |      |     |      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------------------------------------|----------------|----------------|----------------|-------------------------------------|-------------------------------------|------|------|------|-----|------|
| Raw Coordinates                                                                                                                                             |                |                |                |                |                |                |                |                |                |                |                |                                               |                |                |                |                                     |                                     |      |      |      |     |      |
| 2Y (degrees)                                                                                                                                                |                | -10.3          |                | -5.9           |                | -3.2           |                | -3.0           |                | 0              |                |                                               |                |                |                |                                     |                                     |      |      |      |     |      |
| $x_{\text{a}}$                                                                                                                                              | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$ | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$ | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$                                | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$                      | $z_{\text{a}}$                      |      |      |      |     |      |
| Frame 1                                                                                                                                                     | -151.5         | 77.2           | 78.5           | -150.4         | 77.0           | 77.8           | -150.4         | 77.0           | 77.8           | -150.7         | 77.0           | 78.5                                          | -150.1         | 77.4           | 77.5           | -149.4                              | 77.2                                | 78.1 |      |      |     |      |
| Frame 2                                                                                                                                                     | -151.8         | 76.9           | 78.3           | -150.2         | 76.9           | 77.7           | -150.2         | 76.9           | 77.7           | -150.9         | 77.2           | 78.3                                          | -149.6         | 77.2           | 77.7           | -149.8                              | 77.2                                | 78.1 |      |      |     |      |
| Frame 3                                                                                                                                                     | -151.8         | 77.1           | 78.4           | -150.4         | 76.9           | 77.6           | -150.4         | 76.9           | 77.6           | -150.6         | 76.9           | 78.4                                          | -150.0         | 77.4           | 77.5           | -149.7                              | 77.2                                | 78.1 |      |      |     |      |
| Frame 4                                                                                                                                                     | -151.5         | 77.2           | 78.2           | -150.3         | 76.9           | 77.7           | -150.3         | 76.9           | 77.7           | -151.0         | 77.2           | 78.3                                          | -149.6         | 77.3           | 77.5           | -149.2                              | 77.2                                | 78.2 |      |      |     |      |
| Frame 5                                                                                                                                                     | -151.4         | 77.1           | 78.5           | -150.4         | 77.0           | 77.6           | -150.4         | 77.0           | 77.6           | -150.7         | 76.9           | 78.4                                          | -149.9         | 77.3           | 77.4           | -149.4                              | 77.2                                | 78.2 |      |      |     |      |
| Frame 6                                                                                                                                                     | -151.7         | 77.0           | 78.3           | -150.3         | 76.9           | 77.7           | -150.3         | 76.9           | 77.7           | -150.8         | 77.2           | 78.3                                          | -149.7         | 77.2           | 77.6           | -149.6                              | 77.2                                | 78.3 |      |      |     |      |
| Frame 7                                                                                                                                                     | -151.8         | 77.1           | 78.4           | -150.3         | 76.9           | 77.6           | -150.3         | 76.9           | 77.6           | -150.9         | 76.9           | 78.6                                          | -149.9         | 77.4           | 77.4           | -149.1                              | 77.3                                | 78.0 |      |      |     |      |
| Frame 8                                                                                                                                                     | -151.7         | 77.1           | 78.3           | -150.1         | 77.0           | 77.7           | -150.1         | 77.0           | 77.7           | -150.9         | 77.1           | 78.4                                          | -149.8         | 77.2           | 77.6           | -149.3                              | 77.2                                | 78.0 |      |      |     |      |
| Frame 9                                                                                                                                                     | -151.3         | 77.1           | 78.5           | -150.4         | 76.9           | 77.6           | -150.4         | 76.9           | 77.6           | -150.5         | 76.9           | 78.5                                          | -150.2         | 77.3           | 77.5           | -149.4                              | 77.2                                | 78.1 |      |      |     |      |
| Frame 10                                                                                                                                                    | -151.8         | 77.0           | 78.3           | -150.2         | 76.9           | 77.7           | -150.2         | 76.9           | 77.7           | -150.6         | 77.2           | 78.4                                          | -149.5         | 77.2           | 77.6           | -149.8                              | 77.2                                | 78.1 |      |      |     |      |
| Average                                                                                                                                                     | -151.6         | 77.1           | 78.4           | -150.3         | 76.9           | 77.7           | -150.3         | 76.9           | 77.7           | -150.8         | 77.0           | 78.4                                          | -149.6         | 77.3           | 77.5           | -149.2                              | 77.2                                | 78.1 |      |      |     |      |
| St. Deviation                                                                                                                                               | 0.2            | 0.08           | 0.10           | 0.09           | 0.05           | 0.07           | 0.09           | 0.05           | 0.07           | 0.15           | 0.14           | 0.10                                          | 0.23           | 0.07           | 0.09           | 0.29                                | 0.03                                | 0.09 |      |      |     |      |
| Raw Coordinates                                                                                                                                             |                |                |                |                |                |                |                |                |                |                |                |                                               |                |                |                |                                     |                                     |      |      |      |     |      |
| 2Y (degrees)                                                                                                                                                |                | 3.0            |                | 3.2            |                | 5.9            |                | 8.6            |                | 10.3           |                | $\frac{x_{\text{a}}}{z_{\text{a}}}$ (degrees) |                |                |                |                                     |                                     |      |      |      |     |      |
| $x_{\text{a}}$                                                                                                                                              | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$ | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$ | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $y_{\text{a}}$                                | $z_{\text{a}}$ | $x_{\text{a}}$ | $z_{\text{a}}$ | $\frac{x_{\text{a}}}{z_{\text{a}}}$ | $\frac{x_{\text{a}}}{z_{\text{a}}}$ |      |      |      |     |      |
| Frame 1                                                                                                                                                     | -148.6         | 77.4           | 77.9           | -148.5         | 77.2           | 78.2           | -147.7         | 77.8           | 78.2           | -148.9         | 77.4           | 78.3                                          | -149.6         | 78.0           | 79.2           | -8.6                                | -1.3                                | -0.5 | 0.2  | 0.0  | 0.1 |      |
| Frame 2                                                                                                                                                     | -148.7         | 77.6           | 77.9           | -148.7         | 77.3           | 78.2           | -147.5         | 77.8           | 78.1           | -147.1         | 77.8           | 78.4                                          | -148.4         | 77.7           | 79.2           | -5.9                                | -1.3                                | -0.1 | -0.5 | 0.2  | 0.0 | 0.1  |
| Frame 3                                                                                                                                                     | -148.5         | 77.5           | 77.9           | -148.5         | 77.5           | 78.2           | -147.8         | 77.5           | 78.1           | -147.1         | 77.4           | 78.3                                          | -148.7         | 78.0           | 79.1           | -3.2                                | -1.8                                | 0.0  | 0.2  | 0.5  | 0.0 | -0.1 |
| Frame 4                                                                                                                                                     | -148.6         | 77.7           | 77.8           | -148.6         | 77.3           | 78.2           | -147.5         | 77.7           | 78.3           | -146.9         | 77.8           | 78.5                                          | -148.7         | 77.8           | 79.0           | 3.0                                 | -0.8                                | 0.3  | -0.7 | -0.3 | 0.1 | -0.2 |
| Frame 5                                                                                                                                                     | -148.3         | 77.5           | 78.1           | -148.8         | 77.3           | 78.1           | -147.7         | 77.8           | 78.1           | -147.1         | 77.4           | 78.3                                          | -148.8         | 77.9           | 79.2           | 0.0                                 | -0.2                                | 0.2  | -0.1 |      |     |      |
| Frame 6                                                                                                                                                     | -148.3         | 77.7           | 77.9           | -148.9         | 77.3           | 78.2           | -147.4         | 77.9           | 78.3           | -147.2         | 77.7           | 78.5                                          | -146.5         | 77.9           | 78.9           | 3.0                                 | 0.6                                 | 0.6  | -0.3 | 0.2  | 0.2 | -0.1 |
| Frame 7                                                                                                                                                     | -148.5         | 77.7           | 77.8           | -148.5         | 77.2           | 78.1           | -148.0         | 77.7           | 78.3           | -146.8         | 77.4           | 78.3                                          | -146.4         | 78.0           | 79.1           | 3.2                                 | 0.4                                 | 0.0  | 0.1  | 0.1  | 0.0 | 0.0  |
| Frame 8                                                                                                                                                     | -148.3         | 77.6           | 78.0           | -148.6         | 77.2           | 78.1           | -147.8         | 77.7           | 78.2           | -147.0         | 77.6           | 78.4                                          | -148.4         | 77.8           | 79.0           | 5.9                                 | 1.3                                 | 0.7  | 0.0  | 0.2  | 0.1 | 0.0  |
| Frame 9                                                                                                                                                     | -148.1         | 77.5           | 77.9           | -148.5         | 77.3           | 78.2           | -148.2         | 77.5           | 78.2           | -146.9         | 77.4           | 78.3                                          | -146.6         | 78.0           | 79.2           | 8.6                                 | 2.0                                 | 0.5  | 0.2  | 0.2  | 0.1 | 0.1  |
| Frame 10                                                                                                                                                    | -148.5         | 77.6           | 77.8           | -148.7         | 77.4           | 78.2           | -147.4         | 77.7           | 78.1           | -147.1         | 77.7           | 78.5                                          | -146.4         | 77.9           | 79.2           | 10.3                                | 2.5                                 | 0.9  | 0.2  | 0.2  | 0.1 | 0.1  |
| Average                                                                                                                                                     | -148.4         | 77.6           | 77.9           | -148.6         | 77.3           | 78.2           | -147.7         | 77.7           | 78.2           | -147.0         | 77.5           | 78.4                                          | -146.5         | 77.9           | 79.1           |                                     |                                     |      |      |      |     |      |
| St. Deviation                                                                                                                                               | 0.2            | 0.09           | 0.08           | 0.13           | 0.05           | 0.04           | 0.24           | 0.11           | 0.07           | 0.12           | 0.12           | 0.11                                          | 0.14           | 0.12           | 0.10           |                                     |                                     |      |      |      |     |      |
|                                                                                                                                                             |                |                |                |                |                |                |                |                |                |                |                |                                               |                |                |                | Ave.                                | 0.19                                | 0.06 | 0.01 |      |     |      |

## APPENDIX O

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point F

| q control: $Y_{\text{control}} = -165.2 \text{ cm}$ , $Y_{\text{control}} = -3.7 \text{ cm}$ , $Z_{\text{control}} = 68.8 \text{ cm}$ |        |       |       |        |       |       |        |       |       |
|---------------------------------------------------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | -18    |       |       | -14.4  |       |       | -10.8  |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -167.1 | 8.2   | 68.6  | -166.3 | 7.2   | 68.8  | -166.0 | 6.4   | 69.4  |
| Frame 2                                                                                                                               | -169.9 | 8.3   | 69.6  | -166.3 | 7.2   | 70.0  | -168.0 | 6.5   | 69.3  |
| Frame 3                                                                                                                               | -168.9 | 8.2   | 69.5  | -166.3 | 7.4   | 69.9  | -168.2 | 6.3   | 69.3  |
| Frame 4                                                                                                                               | -168.9 | 8.3   | 69.5  | -166.4 | 7.2   | 69.9  | -168.2 | 6.6   | 69.2  |
| Frame 5                                                                                                                               | -168.9 | 8.2   | 69.5  | -166.2 | 7.3   | 69.9  | -168.0 | 6.4   | 69.4  |
| Frame 6                                                                                                                               | -168.9 | 8.3   | 69.5  | -166.5 | 7.3   | 69.9  | -168.2 | 6.5   | 69.3  |
| Frame 7                                                                                                                               | -167.0 | 8.2   | 69.5  | -166.1 | 7.3   | 69.6  | -168.1 | 6.4   | 69.4  |
| Frame 8                                                                                                                               | -168.9 | 8.3   | 69.6  | -166.4 | 7.2   | 69.8  | -168.0 | 6.6   | 69.4  |
| Frame 9                                                                                                                               | -168.7 | 8.1   | 69.6  | -166.2 | 7.2   | 69.8  | -168.1 | 6.3   | 69.3  |
| Frame 10                                                                                                                              | -168.8 | 8.3   | 69.6  | -166.3 | 7.2   | 70.0  | -168.2 | 6.5   | 69.3  |
| Average                                                                                                                               | -168.9 | 8.2   | 69.6  | -166.3 | 7.3   | 69.9  | -168.1 | 6.5   | 69.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.08  | 0.04  | 0.12   | 0.05  | 0.08  | 0.09   | 0.09  | 0.07  |
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | 7.2    |       |       | 10.8   |       |       | 14.4   |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -164.4 | 2.8   | 69.0  | -166.6 | 1.2   | 68.6  | -165.4 | 0.4   | 68.4  |
| Frame 2                                                                                                                               | -169.5 | 2.9   | 68.9  | -166.5 | 1.5   | 68.8  | -165.6 | 0.5   | 68.3  |
| Frame 3                                                                                                                               | -166.3 | 2.7   | 69.0  | -166.6 | 1.3   | 68.8  | -165.5 | 0.4   | 68.4  |
| Frame 4                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.9 | 1.5   | 68.7  | -165.6 | 0.4   | 68.3  |
| Frame 5                                                                                                                               | -166.3 | 2.7   | 68.9  | -166.8 | 1.3   | 68.7  | -165.4 | 0.3   | 68.3  |
| Frame 6                                                                                                                               | -166.3 | 2.9   | 68.9  | -166.7 | 1.4   | 68.8  | -165.7 | 0.4   | 68.3  |
| Frame 7                                                                                                                               | -169.5 | 2.9   | 69.0  | -166.7 | 1.3   | 68.6  | -165.4 | 0.3   | 68.3  |
| Frame 8                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.5   | 68.8  | -165.5 | 0.4   | 68.3  |
| Frame 9                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.3   | 68.8  | -165.4 | 0.5   | 68.4  |
| Frame 10                                                                                                                              | -166.3 | 2.9   | 69.0  | -166.6 | 1.5   | 68.8  | -165.7 | 0.5   | 68.3  |
| Average                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.7 | 1.4   | 68.8  | -165.5 | 0.4   | 68.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.07  | 0.03  | 0.11   | 0.11  | 0.07  | 0.12   | 0.08  | 0.05  |
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | 16.0   |       |       | 18.0   |       |       | 20.0   |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -164.4 | 2.8   | 69.0  | -166.6 | 1.2   | 68.6  | -165.4 | 0.4   | 68.4  |
| Frame 2                                                                                                                               | -169.5 | 2.9   | 68.9  | -166.5 | 1.5   | 68.8  | -165.6 | 0.5   | 68.3  |
| Frame 3                                                                                                                               | -166.3 | 2.7   | 69.0  | -166.6 | 1.3   | 68.8  | -165.5 | 0.4   | 68.4  |
| Frame 4                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.9 | 1.5   | 68.7  | -165.6 | 0.4   | 68.3  |
| Frame 5                                                                                                                               | -166.3 | 2.7   | 68.9  | -166.8 | 1.3   | 68.7  | -165.4 | 0.3   | 68.3  |
| Frame 6                                                                                                                               | -166.3 | 2.9   | 68.9  | -166.7 | 1.4   | 68.8  | -165.7 | 0.4   | 68.3  |
| Frame 7                                                                                                                               | -169.5 | 2.9   | 69.0  | -166.7 | 1.3   | 68.6  | -165.4 | 0.3   | 68.3  |
| Frame 8                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.5   | 68.8  | -165.5 | 0.4   | 68.3  |
| Frame 9                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.3   | 68.8  | -165.4 | 0.5   | 68.4  |
| Frame 10                                                                                                                              | -166.3 | 2.9   | 69.0  | -166.6 | 1.5   | 68.8  | -165.7 | 0.5   | 68.3  |
| Average                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.7 | 1.4   | 68.8  | -165.5 | 0.4   | 68.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.07  | 0.03  | 0.11   | 0.11  | 0.07  | 0.12   | 0.08  | 0.05  |
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | -3.6   |       |       | -7.2   |       |       | -10.8  |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -167.1 | 8.2   | 68.6  | -166.3 | 7.2   | 68.8  | -166.0 | 6.4   | 69.4  |
| Frame 2                                                                                                                               | -169.9 | 8.3   | 69.6  | -166.3 | 7.2   | 70.0  | -168.0 | 6.5   | 69.3  |
| Frame 3                                                                                                                               | -168.9 | 8.2   | 69.5  | -166.3 | 7.4   | 69.9  | -168.2 | 6.3   | 69.3  |
| Frame 4                                                                                                                               | -168.9 | 8.3   | 69.5  | -166.4 | 7.2   | 69.9  | -168.2 | 6.6   | 69.2  |
| Frame 5                                                                                                                               | -168.9 | 8.2   | 69.5  | -166.2 | 7.3   | 69.9  | -168.0 | 6.4   | 69.4  |
| Frame 6                                                                                                                               | -168.9 | 8.3   | 69.5  | -166.5 | 7.3   | 69.9  | -168.2 | 6.5   | 69.3  |
| Frame 7                                                                                                                               | -167.0 | 8.2   | 69.5  | -166.1 | 7.3   | 69.6  | -168.1 | 6.4   | 69.4  |
| Frame 8                                                                                                                               | -168.9 | 8.3   | 69.6  | -166.4 | 7.2   | 69.8  | -168.0 | 6.6   | 69.4  |
| Frame 9                                                                                                                               | -168.7 | 8.1   | 69.6  | -166.2 | 7.2   | 69.8  | -168.1 | 6.3   | 69.3  |
| Frame 10                                                                                                                              | -168.8 | 8.3   | 69.6  | -166.3 | 7.2   | 70.0  | -168.2 | 6.5   | 69.3  |
| Average                                                                                                                               | -168.9 | 8.2   | 69.6  | -166.3 | 7.3   | 69.9  | -168.1 | 6.5   | 69.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.08  | 0.04  | 0.12   | 0.05  | 0.08  | 0.09   | 0.09  | 0.07  |
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | -18.0  |       |       | -14.4  |       |       | -10.8  |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -164.4 | 2.8   | 69.0  | -166.6 | 1.2   | 68.6  | -165.4 | 0.4   | 68.4  |
| Frame 2                                                                                                                               | -169.5 | 2.9   | 68.9  | -166.5 | 1.5   | 68.8  | -165.6 | 0.5   | 68.3  |
| Frame 3                                                                                                                               | -166.3 | 2.7   | 69.0  | -166.6 | 1.3   | 68.8  | -165.5 | 0.4   | 68.4  |
| Frame 4                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.9 | 1.5   | 68.7  | -165.6 | 0.4   | 68.3  |
| Frame 5                                                                                                                               | -166.3 | 2.7   | 68.9  | -166.8 | 1.3   | 68.7  | -165.4 | 0.3   | 68.3  |
| Frame 6                                                                                                                               | -166.3 | 2.9   | 68.9  | -166.7 | 1.4   | 68.8  | -165.7 | 0.4   | 68.3  |
| Frame 7                                                                                                                               | -169.5 | 2.9   | 69.0  | -166.7 | 1.3   | 68.6  | -165.4 | 0.3   | 68.3  |
| Frame 8                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.5   | 68.8  | -165.5 | 0.4   | 68.3  |
| Frame 9                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.3   | 68.8  | -165.4 | 0.5   | 68.4  |
| Frame 10                                                                                                                              | -166.3 | 2.9   | 69.0  | -166.6 | 1.5   | 68.8  | -165.7 | 0.5   | 68.3  |
| Average                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.7 | 1.4   | 68.8  | -165.5 | 0.4   | 68.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.07  | 0.03  | 0.11   | 0.11  | 0.07  | 0.12   | 0.08  | 0.05  |
| Raw Coordinates                                                                                                                       |        |       |       |        |       |       |        |       |       |
| $\Delta X \text{ (cm)}$                                                                                                               | -18.0  |       |       | -14.4  |       |       | -10.8  |       |       |
|                                                                                                                                       | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ |
| Frame 1                                                                                                                               | -164.4 | 2.8   | 69.0  | -166.6 | 1.2   | 68.6  | -165.4 | 0.4   | 68.4  |
| Frame 2                                                                                                                               | -169.5 | 2.9   | 68.9  | -166.5 | 1.5   | 68.8  | -165.6 | 0.5   | 68.3  |
| Frame 3                                                                                                                               | -166.3 | 2.7   | 69.0  | -166.6 | 1.3   | 68.8  | -165.5 | 0.4   | 68.4  |
| Frame 4                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.9 | 1.5   | 68.7  | -165.6 | 0.4   | 68.3  |
| Frame 5                                                                                                                               | -166.3 | 2.7   | 68.9  | -166.8 | 1.3   | 68.7  | -165.4 | 0.3   | 68.3  |
| Frame 6                                                                                                                               | -166.3 | 2.9   | 68.9  | -166.7 | 1.4   | 68.8  | -165.7 | 0.4   | 68.3  |
| Frame 7                                                                                                                               | -169.5 | 2.9   | 69.0  | -166.7 | 1.3   | 68.6  | -165.4 | 0.3   | 68.3  |
| Frame 8                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.5   | 68.8  | -165.5 | 0.4   | 68.3  |
| Frame 9                                                                                                                               | -166.2 | 2.9   | 69.0  | -166.7 | 1.3   | 68.8  | -165.4 | 0.5   | 68.4  |
| Frame 10                                                                                                                              | -166.3 | 2.9   | 69.0  | -166.6 | 1.5   | 68.8  | -165.7 | 0.5   | 68.3  |
| Average                                                                                                                               | -166.3 | 2.9   | 69.0  | -166.7 | 1.4   | 68.8  | -165.5 | 0.4   | 68.3  |
| St. Deviation                                                                                                                         | 0.1    | 0.07  | 0.03  | 0.11   | 0.11  | 0.07  | 0.12   | 0.08  | 0.05  |

| q <sub>i</sub> control: X <sub>i</sub> control = -165.2 cm, Y <sub>i</sub> control = 3.7 cm, Z <sub>i</sub> control = 68.8 cm |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |       |
|-------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|------|-------|
| Raw Coordinates                                                                                                               |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |       |
| ΔY (cm)                                                                                                                       | -10.0          |                |                | -8.0           |                |                | -6.0           |                |                | -4.0           |                |                | -2.0           |                |                | 0.0            |                |                | 2.0            |                |                |      |       |
|                                                                                                                               | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> |      |       |
| Frame 1                                                                                                                       | -167.0         | 3.9            | 69.1           | -167.2         | 3.5            | 69.2           | -165.5         | 3.5            | 69.3           | -166.8         | 4.3            | 69.3           | -166.2         | 3.9            | 69.0           | -166.3         | 4.1            | 69.1           |                |                |                |      |       |
| Frame 2                                                                                                                       | -167.0         | 3.9            | 69.0           | -166.8         | 3.5            | 69.2           | -166.1         | 3.6            | 69.2           | -166.6         | 4.0            | 69.7           | -166.9         | 4.5            | 69.3           | -166.2         | 3.9            | 69.1           | -166.5         | 4.4            | 69.1           |      |       |
| Frame 3                                                                                                                       | -167.0         | 3.9            | 69.1           | -166.6         | 3.4            | 69.2           | -165.9         | 3.7            | 69.3           | -166.4         | 3.9            | 69.6           | -166.7         | 4.3            | 69.3           | -166.4         | 4.0            | 69.1           | -166.1         | 4.2            | 69.1           |      |       |
| Frame 4                                                                                                                       | -166.7         | 3.7            | 69.3           | -167.2         | 3.6            | 69.1           | -165.8         | 3.6            | 69.3           | -166.3         | 3.9            | 69.7           | -166.9         | 4.5            | 69.3           | -166.1         | 3.9            | 69.0           | -166.1         | 4.3            | 69.1           |      |       |
| Frame 5                                                                                                                       | -166.9         | 3.8            | 69.2           | -166.8         | 3.5            | 69.2           | -165.9         | 3.7            | 69.4           | -166.3         | 4.0            | 69.6           | -166.7         | 4.3            | 69.4           | -166.2         | 4.0            | 69.1           | -166.1         | 4.2            | 69.1           |      |       |
| Frame 6                                                                                                                       | -167.1         | 3.8            | 69.2           | -166.9         | 3.6            | 69.2           | -166.1         | 3.5            | 69.2           | -166.6         | 4.1            | 69.6           | -167.0         | 4.5            | 69.3           | -166.0         | 4.0            | 69.1           | -166.1         | 4.3            | 69.1           |      |       |
| Frame 7                                                                                                                       | -167.1         | 4.0            | 69.1           | -166.9         | 3.5            | 69.3           | -165.8         | 3.6            | 69.2           | -166.6         | 4.2            | 69.7           | -166.9         | 4.4            | 69.3           | -166.5         | 4.0            | 69.1           | -166.2         | 4.2            | 69.0           |      |       |
| Frame 8                                                                                                                       | -166.8         | 3.9            | 69.1           | -166.9         | 3.6            | 69.3           | -165.8         | 3.5            | 69.2           | -166.4         | 4.0            | 69.6           | -167.0         | 4.4            | 69.3           | -166.2         | 4.0            | 69.1           | -166.2         | 4.3            | 69.0           |      |       |
| Frame 9                                                                                                                       | -167.1         | 3.8            | 69.1           | -166.8         | 3.4            | 69.1           | -165.8         | 3.7            | 69.3           | -166.4         | 3.9            | 69.6           | -166.9         | 4.4            | 69.3           | -166.3         | 4.0            | 69.1           | -166.1         | 4.2            | 69.0           |      |       |
| Frame 10                                                                                                                      | -166.7         | 3.7            | 69.1           | -167.0         | 3.5            | 69.1           | -165.9         | 3.5            | 69.2           | -166.5         | 3.9            | 69.6           | -166.8         | 4.4            | 69.3           | -166.3         | 4.1            | 69.0           | -166.2         | 4.3            | 69.1           |      |       |
| Average                                                                                                                       | -166.9         | 3.8            | 69.1           | -166.8         | 3.5            | 69.2           | -165.9         | 3.6            | 69.3           | -166.5         | 4.0            | 69.6           | -166.9         | 4.4            | 69.3           | -166.3         | 4.0            | 69.1           | -166.2         | 4.2            | 69.1           |      |       |
| St. Deviation                                                                                                                 | 0.1            | 0.09           | 0.07           | 0.20           | 0.06           | 0.07           | 0.18           | 0.10           | 0.06           | 0.11           | 0.07           | 0.04           | 0.11           | 0.05           | 0.02           | 0.14           | 0.05           | 0.04           | 0.11           | 0.08           | 0.04           |      |       |
| Raw Coordinates                                                                                                               |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |      |       |
| ΔY (cm)                                                                                                                       | 4.0            |                |                | 6.0            |                |                | 8.0            |                |                | 10.0           |                |                | ΔY (cm)        | ΔX (cm)        | ΔZ (cm)        | ΔX / ΔY        | ΔZ / ΔY        |                |                |                |                |      |       |
|                                                                                                                               | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> | X <sub>i</sub> | Y <sub>i</sub> | Z <sub>i</sub> |                |                |                |                |                |                |                |                |                |      |       |
| Frame 1                                                                                                                       | -167.2         | 4.4            | 69.2           | -166.3         | 4.0            | 69.1           | -166.0         | 4.3            | 69.1           | -164.7         | 4.1            | 69.1           | -8.0           | -1.7           | 0.1            | 0.3            | 0.2            | 0.0            | 0.0            |                |                |      |       |
| Frame 2                                                                                                                       | -167.4         | 4.4            | 69.2           | -166.5         | 4.0            | 69.1           | -166.4         | 4.3            | 69.1           | -164.9         | 4.2            | 69.1           | -5.0           | -0.7           | -0.1           | 0.5            | 0.1            | 0.0            | -0.1           |                |                |      |       |
| Frame 3                                                                                                                       | -167.2         | 4.4            | 69.2           | -166.4         | 4.0            | 69.1           | -166.3         | 4.4            | 69.2           | -164.8         | 4.1            | 69.1           | -4.0           | -1.3           | 0.3            | 0.8            | 0.3            | -0.1           | -0.2           |                |                |      |       |
| Frame 4                                                                                                                       | -167.5         | 4.3            | 69.1           | -166.2         | 4.1            | 69.2           | -166.1         | 4.3            | 69.1           | -164.8         | 4.0            | 69.1           | -2.0           | -1.7           | 0.7            | 0.5            | 0.8            | -0.4           | -0.3           |                |                |      |       |
| Frame 5                                                                                                                       | -167.2         | 4.3            | 69.2           | -166.2         | 4.0            | 69.2           | -166.2         | 4.4            | 69.1           | -164.7         | 4.0            | 69.2           | 0.0            | -1.1           | 0.3            | 0.3            |                |                |                |                |                |      |       |
| Frame 6                                                                                                                       | -167.3         | 4.3            | 69.1           | -166.4         | 4.1            | 69.1           | -166.1         | 4.3            | 69.1           | -164.7         | 4.1            | 69.2           | 2.0            | -1.0           | 0.5            | 0.3            | -0.5           | 0.3            | 0.1            |                |                |      |       |
| Frame 7                                                                                                                       | -167.4         | 4.5            | 69.1           | -166.5         | 4.0            | 69.1           | -166.1         | 4.3            | 69.1           | -164.6         | 4.1            | 69.1           | 4.0            | -2.1           | 0.7            | 0.4            | -0.5           | 0.2            | 0.1            |                |                |      |       |
| Frame 8                                                                                                                       | -167.3         | 4.4            | 69.2           | -166.5         | 4.2            | 69.1           | -166.1         | 4.3            | 69.1           | -164.5         | 4.1            | 69.1           | 6.0            | -1.2           | 0.4            | 0.3            | -0.2           | 0.1            | 0.1            |                |                |      |       |
| Frame 9                                                                                                                       | -167.4         | 4.4            | 69.2           | -166.3         | 4.0            | 69.1           | -166.3         | 4.4            | 69.1           | -164.8         | 4.2            | 69.2           | 8.0            | -1.0           | 0.6            | 0.3            | -0.1           | 0.1            | 0.0            |                |                |      |       |
| Frame 10                                                                                                                      | -167.3         | 4.4            | 69.2           | -166.5         | 4.1            | 69.1           | -166.1         | 4.2            | 69.1           | -165.0         | 4.2            | 69.1           | 10.0           | 0.5            | 0.4            | 0.3            | 0.0            | 0.0            | 0.0            |                |                |      |       |
| Average                                                                                                                       | -167.3         | 4.4            | 69.2           | -166.4         | 4.1            | 69.1           | -166.2         | 4.3            | 69.1           | -164.7         | 4.1            | 69.1           |                |                |                |                |                |                |                |                |                |      |       |
| St. Deviation                                                                                                                 | 0.1            | 0.09           | 0.05           | 0.13           | 0.06           | 0.05           | 0.12           | 0.06           | 0.04           | 0.14           | 0.08           | 0.04           |                |                |                |                |                |                |                | Ave.           | 0.03           | 0.02 | -0.03 |

| $Q_0$ control: $X_0$ control = -149.0 cm, $Y_0$ control = 77.0 cm, $Z_0$ control = 78.2 cm |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |               |       |       |               |       |       |               |       |       |
|--------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|---------------|-------|-------|---------------|-------|-------|---------------|-------|-------|
| Raw Coordinates                                                                            |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |               |       |       |               |       |       |               |       |       |
| $\Delta Z$ (cm)                                                                            | -16    |       |       | -14.4  |       |       | -10.8  |       |       | -7.2   |       |       | -3.6   |       |       | 0             |       |       | 3.6           |       |       |               |       |       |
|                                                                                            | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$         | $y_i$ | $z_i$ | $x_i$         | $y_i$ | $z_i$ |               |       |       |
| Frame 1                                                                                    | -168.1 | 4.0   | 68.5  | -168.9 | 3.6   | 68.5  | -168.8 | 4.0   | 69.0  | -167.7 | 4.1   | 68.8  | -168.7 | 4.4   | 69.0  | -165.9        | 4.2   | 69.2  | -167.2        | 4.2   | 69.0  |               |       |       |
| Frame 2                                                                                    | -166.7 | 4.0   | 68.5  | -166.9 | 3.7   | 68.5  | -167.2 | 3.6   | 69.0  | -166.0 | 4.2   | 68.7  | -167.1 | 4.3   | 68.9  | -165.8        | 4.1   | 69.1  | -166.7        | 4.1   | 68.9  |               |       |       |
| Frame 3                                                                                    | -166.6 | 4.0   | 68.6  | -168.9 | 3.7   | 68.4  | -168.8 | 3.9   | 69.0  | -167.2 | 4.1   | 68.7  | -167.0 | 4.3   | 69.0  | -166.0        | 4.0   | 69.2  | -167.1        | 4.2   | 68.8  |               |       |       |
| Frame 4                                                                                    | -166.3 | 4.0   | 68.6  | -168.8 | 3.6   | 68.5  | -167.1 | 3.8   | 69.0  | -166.3 | 4.2   | 68.9  | -166.9 | 4.3   | 68.8  | -165.7        | 4.0   | 69.2  | -167.0        | 4.2   | 69.0  |               |       |       |
| Frame 5                                                                                    | -166.2 | 3.9   | 68.4  | -167.0 | 3.7   | 68.6  | -166.8 | 3.9   | 69.1  | -167.6 | 4.1   | 68.8  | -166.9 | 4.2   | 68.9  | -165.7        | 4.0   | 69.3  | -167.1        | 4.2   | 68.8  |               |       |       |
| Frame 6                                                                                    | -166.3 | 3.9   | 68.6  | -166.9 | 3.7   | 68.4  | -167.1 | 3.7   | 69.0  | -166.2 | 4.2   | 68.8  | -166.8 | 4.3   | 68.9  | -165.8        | 4.1   | 69.2  | -167.0        | 4.2   | 69.3  |               |       |       |
| Frame 7                                                                                    | -166.1 | 3.9   | 68.5  | -166.9 | 3.6   | 68.4  | -166.7 | 3.9   | 69.0  | -166.1 | 4.2   | 68.9  | -166.9 | 4.2   | 69.0  | -165.9        | 3.9   | 69.2  | -167.0        | 4.3   | 68.8  |               |       |       |
| Frame 8                                                                                    | -166.3 | 3.9   | 68.6  | -166.7 | 3.7   | 68.4  | -167.1 | 3.7   | 69.1  | -167.9 | 4.2   | 66.7  | -167.1 | 4.3   | 69.0  | -165.7        | 4.1   | 69.2  | -166.6        | 4.1   | 68.9  |               |       |       |
| Frame 9                                                                                    | -166.7 | 4.0   | 68.5  | -167.0 | 3.6   | 68.5  | -166.7 | 3.6   | 69.0  | -166.0 | 4.1   | 66.8  | -166.6 | 4.3   | 66.9  | -166.1        | 4.0   | 69.2  | -167.0        | 4.3   | 69.0  |               |       |       |
| Frame 10                                                                                   | -166.6 | 4.0   | 68.6  | -166.9 | 3.6   | 68.4  | -167.2 | 3.6   | 68.9  | -167.9 | 4.2   | 66.8  | -167.1 | 4.3   | 69.0  | -165.8        | 4.1   | 69.1  | -167.2        | 4.1   | 69.0  |               |       |       |
| Average                                                                                    | -166.4 | 4.0   | 68.5  | -166.9 | 3.7   | 68.5  | -166.9 | 3.8   | 69.0  | -167.9 | 4.2   | 66.8  | -166.9 | 4.3   | 68.9  | -165.8        | 4.0   | 69.2  | -167.0        | 4.2   | 68.9  |               |       |       |
| St. Deviation                                                                              | 0.2    | 0.06  | 0.07  | 0.09   | 0.05  | 0.05  | 0.21   | 0.12  | 0.07  | 0.30   | 0.06  | 0.06  | 0.14   | 0.05  | 0.06  | 0.15          | 0.06  | 0.08  | 0.15          | 0.06  | 0.07  |               |       |       |
| Raw Coordinates                                                                            |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |               |       |       |               |       |       |               |       |       |
| $\Delta Z$ (cm)                                                                            | 7.2    |       |       | 10.8   |       |       | 14.4   |       |       | 18.0   |       |       | (u)    |       |       | $\frac{u}{Z}$ |       |       | $\frac{u}{Z}$ |       |       | $\frac{u}{Z}$ |       |       |
|                                                                                            | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$  | $y_i$ | $z_i$ | $x_i$         | $y_i$ | $z_i$ | $x_i$         | $y_i$ | $z_i$ | $x_i$         | $y_i$ | $z_i$ |
| Frame 1                                                                                    | -167.3 | 4.0   | 69.1  | -166.3 | 3.6   | 69.5  | -164.3 | 3.6   | 69.8  | -164.6 | 3.6   | 69.6  | -18.0  | -1.2  | 0.3   | -0.3          | 0.1   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 2                                                                                    | -167.3 | 4.1   | 69.2  | -166.4 | 3.7   | 69.6  | -164.6 | 3.4   | 69.6  | -164.2 | 3.4   | 69.6  | -10.8  | -1.7  | 0.1   | 0.2           | 0.2   | 0.0   | 0.0           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 3                                                                                    | -167.0 | 3.9   | 69.3  | -166.3 | 3.7   | 69.4  | -164.4 | 3.6   | 69.8  | -164.1 | 3.2   | 69.6  | -7.2   | -2.7  | 0.5   | 0.0           | 0.4   | -0.1  | 0.0           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 4                                                                                    | -167.2 | 4.0   | 69.2  | -166.2 | 3.6   | 69.4  | -164.2 | 3.3   | 69.8  | -164.0 | 3.4   | 69.6  | -3.6   | -1.7  | 0.6   | 0.1           | 0.5   | -0.2  | 0.0           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 5                                                                                    | -166.7 | 4.0   | 69.4  | -166.3 | 3.7   | 69.5  | -164.8 | 3.5   | 69.7  | -164.5 | 3.5   | 69.6  | 0.0    | -0.6  | 0.3   | 0.4           |       |       |               |       |       |               |       |       |
| Frame 6                                                                                    | -167.0 | 3.9   | 69.4  | -166.1 | 3.6   | 69.4  | -164.1 | 3.3   | 70.0  | -164.0 | 3.4   | 69.7  | 3.6    | -1.8  | 0.5   | 0.1           | -0.5  | 0.1   | 0.0           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 7                                                                                    | -167.1 | 3.9   | 69.2  | -166.4 | 3.5   | 69.4  | -164.3 | 3.5   | 69.6  | -164.5 | 3.6   | 69.7  | 7.2    | -1.8  | 0.3   | 0.5           | -0.3  | 0.0   | 0.1           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 8                                                                                    | -167.1 | 3.9   | 69.3  | -165.9 | 3.7   | 69.5  | -164.2 | 3.3   | 69.8  | -164.0 | 3.4   | 69.7  | 10.8   | -1.0  | -0.1  | 0.7           | -0.1  | 0.0   | 0.1           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 9                                                                                    | -167.0 | 3.9   | 69.2  | -166.3 | 3.6   | 69.5  | -164.7 | 3.7   | 69.6  | -164.2 | 3.5   | 69.6  | 14.4   | 0.8   | -0.2  | 0.9           | 0.1   | 0.0   | 0.1           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Frame 10                                                                                   | -166.8 | 3.9   | 69.1  | -166.1 | 3.7   | 69.3  | -164.7 | 3.4   | 69.6  | -164.2 | 3.4   | 69.6  | 18.0   | 1.0   | -0.3  | 0.6           | 0.1   | 0.0   | 0.1           | 0.0   | 0.0   | 0.0           | 0.0   | 0.0   |
| Average                                                                                    | -167.0 | 4.0   | 69.3  | -166.2 | 3.6   | 69.5  | -164.4 | 3.5   | 69.7  | -164.2 | 3.4   | 69.6  |        |       |       |               |       |       |               |       |       |               |       |       |
| St. Deviation                                                                              | 0.2    | 0.06  | 0.09  | 0.15   | 0.05  | 0.07  | 0.24   | 0.15  | 0.14  | 0.21   | 0.10  | 0.06  |        |       |       |               |       |       |               |       |       |               |       |       |
|                                                                                            |        |       |       |        |       |       |        |       |       |        |       |       | Ave    |       |       | 0.0048        |       |       | -0.01         |       |       | 0.0245        |       |       |

| q control = -165.2 cm, Y control = 3.7 cm, z control = 68.8 cm |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |     |  |
|----------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--|--|-----|--|
| Raw Coordinates                                                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |     |  |
| St(degrees)                                                    | -10.0          |                |                |                |                |                | -6.0           |                |                |                |                |                | -4.0           |                |                |                |                |                | -2.0           |                |                |  |  | 2.0 |  |
|                                                                | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> |  |  |     |  |
| Frame 1                                                        | -165.0         | 3.7            | 70.2           | -165.0         | 4.2            | 70.0           | -165.4         | 4.0            | 69.4           | -166.2         | 4.4            | 68.9           | -166.1         | 4.5            | 69.8           | -166.3         | 4.5            | 69.0           | -166.3         | 3.6            | 69.0           |  |  |     |  |
| Frame 2                                                        | -165.1         | 3.5            | 70.2           | -165.4         | 4.3            | 68.9           | -165.8         | 4.2            | 69.4           | -166.4         | 4.3            | 68.9           | -166.6         | 4.3            | 69.5           | -166.3         | 4.3            | 69.1           | -166.2         | 3.7            | 69.0           |  |  |     |  |
| Frame 3                                                        | -165.0         | 3.7            | 70.4           | -165.6         | 4.4            | 69.9           | -165.3         | 4.0            | 69.5           | -166.2         | 4.4            | 70.1           | -166.5         | 4.6            | 69.6           | -166.4         | 4.6            | 68.8           | -166.0         | 3.6            | 69.1           |  |  |     |  |
| Frame 4                                                        | -164.8         | 3.4            | 70.2           | -165.6         | 4.4            | 70.0           | -165.3         | 4.0            | 69.5           | -166.7         | 4.3            | 69.8           | -166.4         | 4.3            | 69.6           | -166.6         | 4.3            | 68.9           | -166.4         | 3.7            | 68.9           |  |  |     |  |
| Frame 5                                                        | -165.1         | 3.7            | 70.3           | -165.6         | 4.3            | 70.0           | -165.2         | 4.1            | 69.5           | -166.1         | 4.5            | 70.0           | -166.4         | 4.6            | 69.7           | -166.4         | 4.5            | 68.9           | -166.2         | 3.7            | 68.9           |  |  |     |  |
| Frame 6                                                        | -164.7         | 3.4            | 70.2           | -165.6         | 4.3            | 69.9           | -165.4         | 4.0            | 69.7           | -166.1         | 4.1            | 69.8           | -166.5         | 4.4            | 69.6           | -166.5         | 4.3            | 69.0           | -166.5         | 3.7            | 69.0           |  |  |     |  |
| Frame 7                                                        | -165.1         | 3.6            | 70.4           | -165.7         | 4.3            | 68.9           | -165.2         | 4.1            | 69.4           | -166.2         | 4.5            | 69.8           | -166.1         | 4.5            | 69.7           | -166.3         | 4.5            | 68.8           | -166.1         | 3.6            | 69.0           |  |  |     |  |
| Frame 8                                                        | -165.1         | 3.5            | 70.3           | -165.6         | 4.4            | 70.1           | -165.3         | 4.0            | 69.6           | -166.5         | 4.2            | 69.9           | -166.4         | 4.4            | 69.7           | -166.5         | 4.4            | 68.9           | -166.2         | 3.7            | 68.9           |  |  |     |  |
| Frame 9                                                        | -165.2         | 3.8            | 70.3           | -165.6         | 4.3            | 70.0           | -165.5         | 4.1            | 69.5           | -166.2         | 4.4            | 69.9           | -166.4         | 4.5            | 69.7           | -166.3         | 4.5            | 68.9           | -166.3         | 3.7            | 69.1           |  |  |     |  |
| Frame 10                                                       | -165.2         | 3.5            | 70.2           | -165.4         | 4.2            | 68.9           | -165.5         | 4.1            | 69.5           | -166.0         | 4.3            | 69.8           | -166.3         | 4.4            | 69.7           | -166.3         | 4.4            | 68.9           | -166.2         | 3.7            | 69.0           |  |  |     |  |
| Average                                                        | -165.0         | 3.6            | 70.3           | -165.5         | 4.3            | 70.0           | -165.4         | 4.1            | 69.5           | -166.3         | 4.3            | 69.9           | -166.4         | 4.5            | 69.7           | -166.4         | 4.4            | 68.9           | -166.2         | 3.7            | 69.0           |  |  |     |  |
| St. Deviation                                                  | 0.16           | 0.12           | 0.07           | 0.22           | 0.06           | 0.06           | 0.16           | 0.07           | 0.09           | 0.22           | 0.13           | 0.08           | 0.16           | 0.11           | 0.08           | 0.11           | 0.10           | 0.07           | 0.14           | 0.05           | 0.06           |  |  |     |  |

| Raw Coordinates |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |                |  |  |
|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|--|--|
| St(degrees)     | 4.0            |                |                |                |                |                | 6.0            |                |                |                |                |                | 8.0            |                |                |                |                |                | 10.0           |                |                |  |  |
|                 | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> | x <sub>i</sub> | y <sub>i</sub> | z <sub>i</sub> |  |  |
| Frame 1         | -166.8         | 4.8            | 68.5           | -167.6         | 5.6            | 67.3           | -167.7         | 2.4            | 67.5           | -166.5         | 2.4            | 67.5           | -166.0         | 0.2            | -0.1           | 1.5            | -0.02          | 0.01           | -0.15          |                |                |  |  |
| Frame 2         | -166.7         | 4.6            | 68.6           | -167.4         | 5.3            | 67.3           | -167.8         | 2.5            | 67.7           | -166.5         | 2.5            | 67.5           | -166.0         | -0.3           | 0.6            | 1.2            | 0.04           | -0.07          | -0.14          |                |                |  |  |
| Frame 3         | -166.8         | 4.8            | 68.6           | -167.8         | 5.6            | 67.2           | -167.7         | 2.4            | 67.6           | -166.3         | 2.4            | 67.4           | -166.0         | -0.2           | 0.4            | 0.7            | 0.03           | -0.06          | -0.12          |                |                |  |  |
| Frame 4         | -166.8         | 4.7            | 68.8           | -167.2         | 5.5            | 67.4           | -167.6         | 2.5            | 67.5           | -166.6         | 2.7            | 67.4           | -166.0         | -1.1           | 0.6            | 1.1            | 0.27           | -0.16          | -0.27          |                |                |  |  |
| Frame 5         | -166.7         | 4.8            | 68.7           | -167.6         | 5.6            | 67.3           | -167.9         | 2.5            | 67.6           | -166.8         | 2.4            | 67.5           | -166.0         | -1.2           | 0.7            | 0.1            |                |                |                |                |                |  |  |
| Frame 6         | -167.2         | 4.4            | 68.3           | -167.3         | 5.6            | 67.4           | -167.6         | 2.5            | 67.5           | -166.7         | 2.7            | 67.3           | -166.0         | -1.0           | 0.0            | 0.2            | -0.52          | -0.01          | 0.09           |                |                |  |  |
| Frame 7         | -166.3         | 4.6            | 68.8           | -167.3         | 5.5            | 67.3           | -167.7         | 2.4            | 67.7           | -166.4         | 2.5            | 67.4           | -166.0         | -1.5           | 0.9            | -0.2           | -0.37          | 0.23           | -0.04          |                |                |  |  |
| Frame 8         | -166.5         | 4.4            | 68.7           | -167.6         | 5.5            | 67.3           | -167.7         | 2.5            | 67.6           | -166.9         | 2.6            | 67.4           | -166.0         | -2.3           | 1.8            | -1.5           | -0.36          | 0.30           | -0.26          |                |                |  |  |
| Frame 9         | -166.9         | 4.5            | 68.6           | -167.4         | 5.5            | 67.3           | -167.6         | 2.4            | 67.6           | -166.4         | 2.3            | 67.5           | -166.0         | -2.5           | -1.3           | -1.2           | -0.31          | -0.16          | -0.15          |                |                |  |  |
| Frame 10        | -166.8         | 4.1            | 68.6           | -167.5         | 5.5            | 67.3           | -167.7         | 2.5            | 67.6           | -166.5         | 2.7            | 67.4           | -166.0         | -4.3           | -1.2           | -1.4           | -0.43          | -0.12          | -0.14          |                |                |  |  |
| Average         | -166.7         | 4.6            | 68.6           | -167.5         | 5.5            | 67.3           | -167.7         | 2.4            | 67.6           | -166.5         | 2.5            | 67.4           | -166.0         |                |                |                |                |                |                |                |                |  |  |
| St. Deviation   | 0.24           | 0.24           | 0.15           | 0.17           | 0.07           | 0.07           | 0.06           | 0.05           | 0.07           | 0.28           | 0.14           | 0.06           |                |                |                |                | -0.11          | -0.04          | -0.16          |                |                |  |  |







## APPENDIX P

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point G

| $X_0 \text{ control} = -167.4 \text{ cm}, Y_0 \text{ control} = 76.7 \text{ cm}, Z_0 \text{ control} = 23.3 \text{ cm}$ |        |       |       |        |       |       |         |         |        |                    |       |       |        |        |        |
|-------------------------------------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|---------|---------|--------|--------------------|-------|-------|--------|--------|--------|
| Raw Coordinates                                                                                                         |        |       |       |        |       |       |         |         |        |                    |       |       |        |        |        |
| $sX \text{ (cm)}$                                                                                                       | $X_0$  | $Y_0$ | $Z_0$ | $s_x$  | $s_y$ | $s_z$ | $-14.4$ | $-10.8$ | $-7.2$ | $-3.6$             | $0$   | $3.6$ | $7.2$  | $10.8$ | $14.4$ |
| Frame 1                                                                                                                 | -165.5 | 77.2  | 25.5  | -165.4 | 77.0  | 25.2  | -166.2  | 76.6    | 24.8   | -166.0             | 76.9  | 23.8  | -166.2 | 77.0   | 23.4   |
| Frame 2                                                                                                                 | -165.4 | 77.3  | 25.6  | -165.4 | 76.9  | 25.3  | -166.3  | 76.7    | 24.7   | -166.1             | 76.8  | 23.8  | -165.9 | 77.0   | 23.3   |
| Frame 3                                                                                                                 | -165.5 | 77.1  | 25.4  | -165.3 | 76.9  | 25.1  | -166.2  | 76.6    | 24.7   | -166.3             | 76.8  | 23.8  | -166.1 | 77.0   | 23.4   |
| Frame 4                                                                                                                 | -165.5 | 77.2  | 25.4  | -165.4 | 76.9  | 25.3  | -166.4  | 76.6    | 24.8   | -166.2             | 76.8  | 23.9  | -165.9 | 77.0   | 23.3   |
| Frame 5                                                                                                                 | -165.5 | 77.2  | 25.4  | -165.3 | 76.9  | 25.2  | -166.1  | 76.6    | 24.8   | -166.1             | 76.8  | 23.9  | -166.0 | 77.0   | 23.3   |
| Frame 6                                                                                                                 | -165.4 | 77.2  | 25.4  | -165.7 | 76.9  | 25.2  | -166.3  | 76.6    | 24.7   | -166.2             | 76.8  | 23.9  | -166.0 | 77.0   | 23.3   |
| Frame 7                                                                                                                 | -165.3 | 77.1  | 25.4  | -165.3 | 77.0  | 25.1  | -166.1  | 76.6    | 24.8   | -166.2             | 76.9  | 23.9  | -166.1 | 77.0   | 23.4   |
| Frame 8                                                                                                                 | -165.4 | 77.2  | 25.5  | -165.5 | 76.9  | 25.2  | -166.2  | 76.6    | 24.8   | -166.2             | 76.8  | 23.9  | -166.2 | 77.0   | 23.2   |
| Frame 9                                                                                                                 | -165.3 | 77.1  | 25.4  | -165.4 | 77.0  | 25.1  | -166.2  | 76.6    | 24.7   | -166.3             | 76.9  | 23.8  | -166.2 | 77.0   | 23.4   |
| Frame 10                                                                                                                | -165.3 | 77.2  | 25.5  | -165.1 | 76.9  | 25.3  | -166.3  | 76.6    | 24.7   | -166.3             | 76.8  | 23.8  | -165.9 | 77.0   | 23.3   |
| Average                                                                                                                 | -165.4 | 77.2  | 25.4  | -165.4 | 76.9  | 25.2  | -166.2  | 76.6    | 24.7   | -166.2             | 76.8  | 23.9  | -166.1 | 77.0   | 23.3   |
| St. Deviation                                                                                                           | 0.1    | 0.05  | 0.06  | 0.15   | 0.03  | 0.09  | 0.10    | 0.04    | 0.05   | 0.10               | 0.03  | 0.05  | 0.11   | 0.02   | 0.08   |
| Raw Coordinates                                                                                                         |        |       |       |        |       |       |         |         |        |                    |       |       |        |        |        |
| $sX \text{ (cm)}$                                                                                                       | $X_0$  | $Y_0$ | $Z_0$ | $s_x$  | $s_y$ | $s_z$ | 10.8    | 14.4    | 18.0   | $s_x \text{ (cm)}$ | $s_y$ | $s_z$ | $X_0$  | $Y_0$  | $Z_0$  |
| Frame 1                                                                                                                 | -166.9 | 76.9  | 22.1  | -166.4 | 76.5  | 21.5  | -167.2  | 77.0    | 21.0   | -167.1             | 76.8  | 20.1  | -18.0  | 20     | 0.5    |
| Frame 2                                                                                                                 | -166.9 | 77.1  | 22.0  | -166.3 | 76.8  | 21.5  | -167.3  | 77.0    | 20.9   | -167.3             | 76.7  | 20.2  | -18.0  | 20     | 0.2    |
| Frame 3                                                                                                                 | -167.0 | 76.8  | 22.0  | -166.5 | 76.5  | 21.5  | -167.3  | 77.0    | 21.0   | -167.2             | 76.8  | 20.1  | -18.0  | 20     | 0.2    |
| Frame 4                                                                                                                 | -167.0 | 77.1  | 22.0  | -166.6 | 76.7  | 21.3  | -167.3  | 77.0    | 21.0   | -167.3             | 76.7  | 20.2  | -18.0  | 20     | 0.2    |
| Frame 5                                                                                                                 | -167.1 | 76.8  | 22.0  | -166.8 | 76.5  | 21.4  | -167.3  | 77.1    | 21.0   | -167.1             | 76.8  | 20.1  | 0.0    | 10     | 0.0    |
| Frame 6                                                                                                                 | -166.8 | 77.1  | 22.0  | -166.6 | 76.8  | 21.4  | -167.4  | 77.0    | 21.0   | -167.4             | 76.8  | 20.1  | 3.6    | 0.6    | 0.0    |
| Frame 7                                                                                                                 | -167.0 | 76.9  | 22.1  | -166.8 | 76.8  | 21.4  | -167.3  | 77.0    | 20.9   | -167.2             | 76.8  | 20.1  | 7.2    | 0.4    | 0.2    |
| Frame 8                                                                                                                 | -167.0 | 77.0  | 22.0  | -166.4 | 76.7  | 21.5  | -167.3  | 77.1    | 20.9   | -167.2             | 76.7  | 20.2  | 10.8   | 0.9    | -0.1   |
| Frame 9                                                                                                                 | -167.0 | 76.9  | 22.1  | -166.3 | 76.5  | 21.5  | -167.3  | 77.0    | 21.0   | -167.1             | 76.8  | 20.1  | 14.4   | 0.1    | 0.0    |
| Frame 10                                                                                                                | -166.9 | 77.1  | 22.0  | -166.3 | 76.7  | 21.5  | -167.4  | 77.0    | 21.0   | -167.3             | 76.7  | 20.2  | 18.0   | 0.2    | 0.1    |
| Average                                                                                                                 | -167.0 | 76.9  | 22.0  | -166.5 | 76.6  | 21.4  | -167.3  | 77.0    | 21.0   | -167.2             | 76.8  | 20.1  |        |        |        |
| St. Deviation                                                                                                           | 0.1    | 0.12  | 0.04  | 0.14   | 0.11  | 0.07  | 0.07    | 0.02    | 0.02   | 0.08               | 0.04  | 0.04  | Ave.   | -0.06  | -0.01  |

| $q_0$ control - $x_0$ control = -167.4 cm, $y_0$ control = 76.7 cm, $z_0$ control = 23.3 cm |        |       |       |        |       |       |        |       |       |        |       |         |        |       |               |        |       |         |        |       |               |  |  |
|---------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|---------|--------|-------|---------------|--------|-------|---------|--------|-------|---------------|--|--|
| Raw Coordinates                                                                             |        |       |       |        |       |       |        |       |       |        |       |         |        |       |               |        |       |         |        |       |               |  |  |
| $3Y(\text{cm})$                                                                             | -10.0  |       |       | -8.0   |       |       | -6.0   |       |       | -4.0   |       |         | -2.0   |       |               | 0.0    |       |         | 2.0    |       |               |  |  |
|                                                                                             | $x_0$  | $x_1$ | $z_0$ | $x_2$  | $y_0$ | $z_1$ | $x_3$  | $y_1$ | $z_2$ | $x_4$  | $y_2$ | $z_3$   | $x_5$  | $y_3$ | $z_4$         | $x_6$  | $y_4$ | $z_5$   | $x_7$  | $y_5$ | $z_6$         |  |  |
| Frame 1                                                                                     | -168.3 | 76.7  | 22.8  | -166.9 | 76.5  | 22.8  | -165.8 | 76.8  | 22.8  | -168.1 | 76.9  | 23.2    | -166.5 | 77.1  | 23.2          | -166.4 | 76.9  | 22.8    | -165.7 | 77.0  | 23.0          |  |  |
| Frame 2                                                                                     | -166.4 | 76.7  | 22.8  | -167.0 | 76.6  | 22.9  | -166.4 | 76.6  | 22.9  | -166.1 | 76.8  | 23.2    | -166.7 | 77.1  | 23.2          | -166.4 | 76.9  | 22.9    | -165.8 | 77.0  | 23.0          |  |  |
| Frame 3                                                                                     | -168.3 | 76.8  | 22.9  | -168.8 | 76.6  | 22.9  | -168.2 | 76.7  | 23.1  | -168.3 | 76.9  | 23.3    | -166.5 | 77.2  | 23.2          | -166.5 | 76.8  | 23.0    | -165.8 | 77.0  | 23.1          |  |  |
| Frame 4                                                                                     | -166.2 | 76.7  | 22.9  | -167.0 | 76.7  | 22.8  | -166.2 | 76.7  | 23.0  | -166.2 | 76.7  | 23.3    | -166.5 | 77.1  | 23.3          | -166.3 | 76.9  | 22.9    | -165.8 | 76.9  | 23.1          |  |  |
| Frame 5                                                                                     | -168.2 | 76.8  | 22.9  | -168.7 | 76.6  | 23.0  | -168.2 | 76.7  | 23.1  | -169.2 | 76.9  | 23.3    | -166.4 | 77.2  | 23.2          | -166.5 | 76.8  | 23.0    | -165.8 | 77.0  | 23.1          |  |  |
| Frame 6                                                                                     | -168.2 | 76.8  | 22.9  | -168.7 | 76.6  | 23.0  | -168.3 | 76.7  | 22.9  | -168.3 | 76.7  | 23.4    | -166.6 | 77.1  | 23.3          | -166.3 | 76.9  | 22.9    | -165.7 | 77.0  | 23.1          |  |  |
| Frame 7                                                                                     | -168.3 | 76.8  | 22.9  | -168.7 | 76.5  | 23.1  | -168.5 | 76.8  | 23.0  | -168.3 | 76.9  | 23.4    | -166.5 | 77.2  | 23.2          | -166.5 | 76.9  | 23.0    | -165.8 | 77.0  | 23.1          |  |  |
| Frame 8                                                                                     | -168.3 | 76.8  | 22.9  | -168.7 | 76.6  | 23.0  | -168.3 | 76.7  | 22.9  | -168.4 | 76.7  | 23.3    | -168.6 | 77.1  | 23.3          | -168.4 | 76.9  | 23.0    | -165.8 | 76.9  | 23.1          |  |  |
| Frame 9                                                                                     | -168.4 | 76.8  | 22.8  | -168.4 | 76.8  | 22.9  | -168.5 | 76.8  | 23.0  | -168.3 | 76.9  | 23.3    | -168.6 | 77.1  | 23.2          | -166.5 | 76.9  | 22.9    | -165.9 | 77.0  | 23.1          |  |  |
| Frame 10                                                                                    | -168.3 | 76.7  | 22.9  | -167.0 | 76.6  | 22.9  | -168.4 | 76.7  | 23.0  | -168.4 | 76.7  | 23.3    | -168.5 | 77.1  | 23.3          | -168.5 | 76.9  | 22.9    | -165.9 | 76.9  | 23.1          |  |  |
| Average                                                                                     | -168.3 | 76.8  | 22.9  | -166.8 | 76.6  | 22.9  | -166.3 | 76.7  | 23.0  | -166.2 | 76.8  | 23.3    | -166.5 | 77.1  | 23.2          | -166.4 | 76.9  | 22.9    | -165.8 | 77.0  | 23.1          |  |  |
| St. Deviation                                                                               | 0.1    | 0.04  | 0.04  | 0.14   | 0.06  | 0.09  | 0.18   | 0.06  | 0.10  | 0.10   | 0.11  | 0.06    | 0.08   | 0.05  | 0.04          | 0.09   | 0.03  | 0.06    | 0.06   | 0.04  | 0.05          |  |  |
| Raw Coordinates                                                                             |        |       |       |        |       |       |        |       |       |        |       |         |        |       |               |        |       |         |        |       |               |  |  |
| $3Y(\text{cm})$                                                                             | 4.0    |       |       | 6.0    |       |       | 8.0    |       |       | 10.0   |       |         | 12.0   |       |               | 14.0   |       |         | 16.0   |       |               |  |  |
|                                                                                             | $x_0$  | $y_0$ | $z_0$ | $x_1$  | $y_1$ | $z_1$ | $x_2$  | $y_2$ | $z_2$ | $x_3$  | $y_3$ | $z_3$   | $x_4$  | $y_4$ | $z_4$         | $x_5$  | $y_5$ | $z_5$   | $x_6$  | $y_6$ | $z_6$         |  |  |
| Frame 1                                                                                     | -167.2 | 76.5  | 23.2  | -166.4 | 76.6  | 23.2  | -166.2 | 76.9  | 23.3  | -165.9 | 76.9  | 23.1    | -16.0  | 1.1   | 0.1           | -0.4   | -0.1  | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Frame 2                                                                                     | -167.1 | 76.6  | 23.4  | -166.2 | 76.7  | 23.2  | -166.5 | 76.7  | 23.4  | -166.1 | 76.8  | 23.0    | -6.0   | 1.1   | 0.0           | -0.3   | -0.2  | 0.0     | 0.1    | 0.0   | 0.1           |  |  |
| Frame 3                                                                                     | -167.0 | 76.6  | 23.2  | -166.3 | 76.6  | 23.2  | -168.4 | 76.9  | 23.4  | -165.9 | 76.9  | 23.1    | -4.0   | 1.2   | 0.1           | 0.0    | -0.3  | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Frame 4                                                                                     | -167.4 | 76.5  | 23.2  | -166.0 | 76.7  | 23.3  | -168.3 | 76.7  | 23.4  | -165.9 | 76.8  | 23.0    | -2.0   | 0.9   | 0.4           | -0.1   | -0.4  | -0.2    | 0.0    | 0.0   | 0.0           |  |  |
| Frame 5                                                                                     | -167.2 | 76.6  | 23.2  | -166.2 | 76.6  | 23.3  | -166.4 | 76.9  | 23.4  | -165.9 | 76.9  | 23.1    | 0.0    | 1.0   | 0.2           | -0.4   | -0.4  | -0.2    | 0.0    | 0.0   | 0.0           |  |  |
| Frame 6                                                                                     | -167.2 | 76.8  | 23.2  | -166.3 | 76.7  | 23.2  | -168.4 | 76.7  | 23.4  | -165.6 | 76.8  | 23.1    | 2.0    | 1.6   | 0.3           | -0.2   | 0.8   | 0.1     | -0.1   | -0.1  | -0.1          |  |  |
| Frame 7                                                                                     | -167.1 | 76.6  | 23.1  | -166.3 | 76.6  | 23.3  | -166.4 | 76.9  | 23.3  | -165.7 | 76.9  | 23.1    | 4.0    | 0.2   | -0.1          | -0.1   | 0.1   | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Frame 8                                                                                     | -167.2 | 76.5  | 23.3  | -166.4 | 76.7  | 23.2  | -168.4 | 76.7  | 23.4  | -165.9 | 76.8  | 23.1    | 6.0    | 1.1   | -0.1          | -0.1   | 0.2   | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Frame 9                                                                                     | -167.2 | 76.6  | 23.3  | -166.2 | 76.8  | 23.2  | -166.4 | 76.9  | 23.4  | -165.9 | 76.9  | 23.1    | 8.0    | 1.0   | 0.1           | 0.1    | 0.1   | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Frame 10                                                                                    | -167.2 | 76.5  | 23.3  | -166.2 | 76.7  | 23.3  | -166.4 | 76.6  | 23.4  | -166.0 | 76.7  | 23.1    | 10.0   | 1.5   | 0.1           | -0.2   | 0.2   | 0.0     | 0.0    | 0.0   | 0.0           |  |  |
| Average                                                                                     | -167.2 | 76.6  | 23.2  | -166.3 | 76.6  | 23.2  | -168.4 | 76.8  | 23.4  | -165.9 | 76.8  | 23.1    |        |       |               |        |       |         |        |       |               |  |  |
| St. Deviation                                                                               | 0.1    | 0.03  | 0.06  | 0.10   | 0.04  | 0.05  | 0.08   | 0.12  | 0.04  | 0.13   | 0.07  | 0.04    |        |       |               |        |       |         |        |       |               |  |  |
|                                                                                             |        |       |       |        |       |       |        |       |       |        |       | Average |        |       | St. Deviation |        |       | Average |        |       | St. Deviation |  |  |
|                                                                                             |        |       |       |        |       |       |        |       |       |        |       | 0.02    |        |       | 0.01          |        |       | 0.02    |        |       | 0.01          |  |  |

| $\Delta Z$ (cm) |        | Raw Coordinates |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        | Uncertainty |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
|-----------------|--------|-----------------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|--------|------|------|
|                 |        | -18             |       |        |       |       |        | -14.4 |       |        |       |       |        | -10.6 |       |        |       |       |        | -7.2        |       |        |       |       |        | -3.6  |       |        |       |       |        | 0     |       |        |       |       |        | 3.6   |       |        |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
|                 |        | $x_3$           | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$       | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  |       |       |        |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 1         | -171.2 | 76.6            | 22.7  | -171.6 | 76.6  | 22.6  | -171.5 | 76.3  | 22.2  | -170.7 | 76.4  | 22.3  | -168.4 | 76.9  | 22.5  | -167.9 | 76.7  | 23.1  | -166.4 | 77.0        | 22.7  | -171.2 | 76.6  | 22.7  | -171.6 | 76.6  | 22.6  | -171.5 | 76.3  | 22.2  | -170.7 | 76.4  | 22.3  | -168.4 | 76.9  | 22.5  | -167.9 | 76.7  | 23.1  | -166.4 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 2         | -171.3 | 76.8            | 22.6  | -171.6 | 76.7  | 22.6  | -171.6 | 76.0  | 22.1  | -170.7 | 76.5  | 22.2  | -168.1 | 76.8  | 22.5  | -167.4 | 76.8  | 23.0  | -166.4 | 77.0        | 22.7  | -171.3 | 76.8  | 22.6  | -171.6 | 76.7  | 22.6  | -171.6 | 76.0  | 22.1  | -170.7 | 76.5  | 22.2  | -168.1 | 76.8  | 22.5  | -167.4 | 76.8  | 23.0  | -166.4 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 3         | -171.4 | 76.6            | 22.8  | -171.6 | 76.7  | 22.6  | -171.4 | 76.3  | 22.2  | -170.7 | 76.4  | 22.2  | -168.3 | 76.8  | 22.5  | -167.6 | 76.8  | 23.0  | -166.6 | 77.0        | 22.6  | -171.4 | 76.6  | 22.8  | -171.6 | 76.7  | 22.6  | -171.4 | 76.3  | 22.2  | -170.7 | 76.4  | 22.2  | -168.3 | 76.8  | 22.5  | -167.6 | 76.8  | 23.0  | -166.6 | 77.0  | 22.6  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 4         | -171.3 | 76.9            | 22.7  | -171.6 | 76.7  | 22.8  | -171.5 | 76.1  | 22.3  | -170.9 | 76.4  | 22.4  | -169.3 | 76.8  | 22.5  | -167.2 | 76.7  | 23.0  | -166.6 | 77.0        | 22.7  | -171.3 | 76.9  | 22.7  | -171.6 | 76.7  | 22.8  | -171.5 | 76.1  | 22.3  | -170.9 | 76.4  | 22.4  | -169.3 | 76.8  | 22.5  | -167.2 | 76.7  | 23.0  | -166.6 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 5         | -171.4 | 76.8            | 22.8  | -171.6 | 76.7  | 22.7  | -171.1 | 76.3  | 22.4  | -170.8 | 76.4  | 22.2  | -168.3 | 76.9  | 22.4  | -167.7 | 76.8  | 23.1  | -166.8 | 77.1        | 22.7  | -171.4 | 76.8  | 22.8  | -171.6 | 76.7  | 22.7  | -171.1 | 76.3  | 22.4  | -170.8 | 76.4  | 22.2  | -168.3 | 76.9  | 22.4  | -167.7 | 76.8  | 23.1  | -166.8 | 77.1  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 6         | -171.5 | 76.6            | 22.7  | -171.6 | 76.5  | 22.7  | -171.4 | 76.1  | 22.3  | -170.9 | 76.4  | 22.3  | -168.1 | 76.8  | 22.5  | -167.4 | 76.8  | 23.0  | -166.6 | 77.0        | 22.7  | -171.5 | 76.6  | 22.7  | -171.6 | 76.5  | 22.7  | -171.4 | 76.1  | 22.3  | -170.9 | 76.4  | 22.3  | -168.1 | 76.8  | 22.5  | -167.4 | 76.8  | 23.0  | -166.6 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 7         | -171.3 | 76.6            | 22.7  | -171.7 | 76.7  | 22.7  | -171.1 | 76.4  | 22.3  | -170.9 | 76.4  | 22.4  | -168.4 | 76.8  | 22.5  | -167.6 | 76.8  | 23.0  | -166.7 | 76.9        | 22.6  | -171.3 | 76.6  | 22.7  | -171.7 | 76.7  | 22.7  | -171.1 | 76.4  | 22.3  | -170.9 | 76.4  | 22.4  | -168.4 | 76.8  | 22.5  | -167.6 | 76.8  | 23.0  | -166.7 | 76.9  | 22.6  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 8         | -171.3 | 76.8            | 22.7  | -171.6 | 76.8  | 22.7  | -171.2 | 76.5  | 22.3  | -170.8 | 76.5  | 22.2  | -168.0 | 76.9  | 22.5  | -167.4 | 76.7  | 23.0  | -166.6 | 77.0        | 22.7  | -171.3 | 76.8  | 22.7  | -171.6 | 76.8  | 22.7  | -171.2 | 76.5  | 22.3  | -170.8 | 76.5  | 22.2  | -168.0 | 76.9  | 22.5  | -167.4 | 76.7  | 23.0  | -166.6 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 9         | -171.3 | 76.8            | 22.6  | -171.6 | 76.7  | 22.7  | -171.7 | 76.1  | 22.2  | -170.8 | 76.4  | 22.3  | -167.9 | 76.8  | 22.5  | -167.3 | 76.9  | 22.9  | -166.5 | 77.0        | 22.7  | -171.3 | 76.8  | 22.6  | -171.6 | 76.7  | 22.7  | -171.7 | 76.1  | 22.2  | -170.8 | 76.4  | 22.3  | -167.9 | 76.8  | 22.5  | -167.3 | 76.9  | 22.9  | -166.5 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 10        | -171.4 | 76.8            | 22.6  | -171.6 | 76.7  | 22.7  | -171.8 | 76.1  | 22.2  | -170.8 | 76.4  | 22.3  | -167.9 | 76.8  | 22.5  | -167.3 | 76.9  | 22.9  | -166.5 | 77.0        | 22.7  | -171.4 | 76.8  | 22.6  | -171.6 | 76.7  | 22.7  | -171.8 | 76.1  | 22.2  | -170.8 | 76.4  | 22.3  | -167.9 | 76.8  | 22.5  | -167.3 | 76.9  | 22.9  | -166.5 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Average         | -171.3 | 76.7            | 22.7  | -171.6 | 76.7  | 22.7  | -171.4 | 76.2  | 22.3  | -170.8 | 76.4  | 22.3  | -168.2 | 76.9  | 22.5  | -167.6 | 76.7  | 23.0  | -166.6 | 77.0        | 22.7  | -171.3 | 76.7  | 22.7  | -171.6 | 76.7  | 22.7  | -171.4 | 76.2  | 22.3  | -170.8 | 76.4  | 22.3  | -168.2 | 76.9  | 22.5  | -167.6 | 76.7  | 23.0  | -166.6 | 77.0  | 22.7  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| St. Deviation   | 0.1    | 0.13            | 0.05  | 0.05   | 0.07  | 0.05  | 0.20   | 0.13  | 0.09  | 0.09   | 0.04  | 0.07  | 0.16   | 0.04  | 0.04  | 0.26   | 0.04  | 0.06  | 0.13   | 0.04        | 0.05  | 0.1    | 0.13  | 0.05  | 0.05   | 0.07  | 0.05  | 0.20   | 0.13  | 0.09  | 0.09   | 0.04  | 0.07  | 0.16   | 0.04  | 0.04  | 0.26   | 0.04  | 0.06  | 0.13   | 0.04  | 0.05  |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| $\Delta Z$ (cm) |        | Raw Coordinates |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        | Uncertainty |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
|                 |        | 7.2             |       |        |       |       |        | 10.8  |       |        |       |       |        | 14.4  |       |        |       |       |        | 18.0        |       |        |       |       |        | 21.6  |       |        |       |       |        | 25.2  |       |        |       |       |        | 28.8  |       |        |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
|                 |        | $x_3$           | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$       | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  | $x_3$ | $x_2$ | $x_1$  | $z_3$ | $z_2$ | $z_1$  |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |
| Frame 1         | -164.6 | 76.7            | 22.9  | -163.3 | 76.6  | 23.1  | -161.8 | 76.9  | 23.1  | -160.5 | 76.7  | 23.0  | -158.5 | 76.7  | 23.0  | -157.4 | 76.8  | 23.0  | -156.4 | 77.0        | 22.7  | -164.6 | 76.7  | 22.9  | -163.3 | 76.6  | 23.1  | -161.8 | 76.9  | 23.1  | -160.5 | 76.7  | 23.0  | -158.5 | 76.7  | 23.0  | -157.4 | 76.8  | 23.0  | -156.4 | 77.0  | 22.7  | -164.6 | 76.7 | 22.9 | -163.3 | 76.6 | 23.1 | -161.8 | 76.9 | 23.1 | -160.5 | 76.7 | 23.0 | -158.5 | 76.7 | 23.0 | -157.4 | 76.8 | 23.0 | -156.4 | 77.0 | 22.7 |
| Frame 2         | -164.3 | 76.6            | 22.9  | -163.3 | 76.6  | 23.2  | -162.0 | 76.7  | 23.1  | -160.4 | 76.8  | 23.0  | -158.4 | 76.8  | 23.0  | -157.3 | 76.9  | 23.0  | -156.3 | 77.0        | 22.6  | -164.3 | 76.6  | 22.9  | -163.3 | 76.6  | 23.2  | -162.0 | 76.7  | 23.1  | -160.4 | 76.8  | 23.0  | -158.4 | 76.8  | 23.0  | -157.3 | 76.9  | 23.0  | -156.3 | 77.0  | 22.6  | -164.3 | 76.6 | 22.9 | -163.3 | 76.6 | 23.2 | -162.0 | 76.7 | 23.1 | -160.4 | 76.8 | 23.0 | -158.4 | 76.8 | 23.0 | -157.3 | 76.9 | 23.0 | -156.3 | 77.0 | 22.6 |
| Frame 3         | -164.5 | 76.7            | 22.9  | -163.4 | 76.6  | 23.0  | -162.0 | 76.9  | 23.0  | -160.1 | 76.8  | 22.9  | -158.2 | 76.8  | 22.9  | -157.1 | 76.9  | 22.9  | -156.1 | 77.0        | 22.5  | -164.5 | 76.7  | 22.9  | -163.4 | 76.6  | 23.0  | -162.0 | 76.9  | 23.0  | -160.1 | 76.8  | 22.9  | -158.2 | 76.8  | 22.9  | -157.1 | 76.9  | 22.9  | -156.1 | 77.0  | 22.5  | -164.5 | 76.7 | 22.9 | -163.4 | 76.6 | 23.0 | -162.0 | 76.9 | 23.0 | -160.1 | 76.8 | 22.9 | -158.2 | 76.8 | 22.9 | -157.1 | 76.9 | 22.9 | -156.1 | 77.0 | 22.5 |
| Frame 4         | -164.4 | 76.6            | 23.0  | -163.6 | 76.5  | 23.1  | -161.7 | 76.8  | 23.2  | -160.3 | 76.8  | 23.2  | -158.3 | 76.8  | 23.2  | -157.2 | 76.9  | 23.2  | -156.2 | 77.0        | 22.4  | -164.4 | 76.6  | 23.0  | -163.6 | 76.5  | 23.1  | -161.7 | 76.8  | 23.2  | -160.3 | 76.8  | 23.2  | -158.3 | 76.8  | 23.2  | -157.2 | 76.9  | 23.2  | -156.2 | 77.0  | 22.4  | -164.4 | 76.6 | 23.0 | -163.6 | 76.5 | 23.1 | -161.7 | 76.8 | 23.2 | -160.3 | 76.8 | 23.2 | -158.3 | 76.8 | 23.2 | -157.2 | 76.9 | 23.2 | -156.2 | 77.0 | 22.4 |
| Frame 5         | -164.5 | 76.7            | 22.9  | -163.5 | 76.6  | 23.1  | -162.1 | 76.8  | 23.1  | -160.2 | 76.8  | 23.1  | -158.2 | 76.8  | 23.1  | -157.1 | 76.9  | 23.1  | -156.1 | 77.0        | 22.5  | -164.5 | 76.7  | 22.9  | -163.5 | 76.6  | 23.1  | -162.1 | 76.8  | 23.1  | -160.2 | 76.8  | 23.1  | -158.2 | 76.8  | 23.1  | -157.1 | 76.9  | 23.1  | -156.1 | 77.0  | 22.5  | -164.5 | 76.7 | 22.9 | -163.5 | 76.6 | 23.1 | -162.1 | 76.8 | 23.1 | -160.2 | 76.8 | 23.1 | -158.2 | 76.8 | 23.1 | -157.1 | 76.9 | 23.1 | -156.1 | 77.0 | 22.5 |
| Frame 6         | -164.4 | 76.6            | 23.0  | -163.5 | 76.6  | 23.1  | -161.8 | 76.8  | 23.3  | -160.3 | 76.8  | 23.1  | -158.3 | 76.8  | 23.1  | -157.2 | 76.9  | 23.2  | -156.2 | 77.0        | 22.4  | -164.4 | 76.6  | 23.0  | -163.5 | 76.6  | 23.1  | -161.8 | 76.8  | 23.3  | -160.3 | 76.8  | 23.1  | -158.3 | 76.8  | 23.1  | -157.2 | 76.9  | 23.2  | -156.2 | 77.0  | 22.4  | -164.4 | 76.6 | 23.0 | -163.5 | 76.6 | 23.1 | -161.8 | 76.8 | 23.3 | -160.3 | 76.8 | 23.1 | -158.3 | 76.8 | 23.1 | -157.2 | 76.9 | 23.2 | -156.2 | 77.0 | 22.4 |
| Frame 7         | -164.5 | 76.7            | 22.9  | -163.4 | 76.5  | 23.1  | -161.8 | 76.7  | 23.3  | -160.2 | 76.7  | 23.2  | -158.2 | 76.7  | 23.2  | -157.1 | 76.8  | 23.2  | -156.1 | 77.0        | 22.5  | -164.5 | 76.7  | 22.9  | -163.4 | 76.5  | 23.1  | -161.8 | 76.7  | 23.3  | -160.2 | 76.7  | 23.2  | -158.2 | 76.7  | 23.2  | -157.1 | 76.8  | 23.2  | -156.1 | 77.0  | 22.5  | -164.5 | 76.7 | 22.9 | -163.4 | 76.5 | 23.1 | -161.8 | 76.7 | 23.3 | -160.2 | 76.7 | 23.2 | -158.2 | 76.7 | 23.2 | -157.1 | 76.8 | 23.2 | -156.1 | 77.0 | 22.5 |
| Frame 8         | -164.3 | 76.6            | 22.9  | -163.3 | 76.6  | 23.1  | -161.8 | 76.7  | 23.2  | -160.3 | 76.7  | 23.1  | -158.3 | 76.7  | 23.1  | -157.2 | 76.8  | 23.1  | -156.2 | 77.0        | 22.4  | -164.3 | 76.6  | 22.9  | -163.3 | 76.6  | 23.1  | -161.8 | 76.7  | 23.2  | -160.3 | 76.7  | 23.1  | -158.3 | 76.7  | 23.1  | -157.2 | 76.8  | 23.1  | -156.2 | 77.0  | 22.4  | -164.3 | 76.6 | 22.9 | -163.3 | 76.6 | 23.1 | -161.8 | 76.7 | 23.2 | -160.3 | 76.7 | 23.1 | -158.3 | 76.7 | 23.1 | -157.2 | 76.8 | 23.1 | -156.2 | 77.0 | 22.4 |
| Frame 9         | -164.6 | 76.7            | 22.8  | -163.3 | 76.6  | 23.0  | -162.1 | 76.8  | 23.0  | -160.1 | 76.8  | 22.9  | -158.1 | 76.8  | 22.9  | -157.0 | 76.9  | 22.9  | -156.0 | 77.0        | 22.3  | -164.6 | 76.7  | 22.8  | -163.3 | 76.6  | 23.0  | -162.1 | 76.8  | 23.0  | -160.1 | 76.8  | 22.9  | -158.1 | 76.8  | 22.9  | -157.0 | 76.9  | 22.9  | -156.0 | 77.0  | 22.3  | -164.6 | 76.7 | 22.8 | -163.3 | 76.6 | 23.0 | -162.1 | 76.8 | 23.0 | -160.1 | 76.8 | 22.9 | -158.1 | 76.8 | 22.9 | -157.0 | 76.9 | 22.9 | -156.0 | 77.0 | 22.3 |
| Frame 10        | -164.5 | 76.7            | 22.8  | -163.6 | 76.6  | 23.0  | -162.1 | 76.8  | 23.1  | -160.2 | 76.8  | 23.2  | -158.2 | 76.8  | 23.2  | -157.1 | 76.9  | 23.2  | -156.1 | 77.0        | 22.4  | -164.5 | 76.7  | 22.8  | -163.6 | 76.6  | 23.0  | -162.1 | 76.8  | 23.1  | -160.2 | 76.8  | 23.2  | -158.2 | 76.8  | 23.2  | -157.1 | 76.9  | 23.2  | -156.1 | 77.0  | 22.4  | -164.5 | 76.7 | 22.8 | -163.6 | 76.6 | 23.0 | -162.1 | 76.8 | 23.1 | -160.2 | 76.8 | 23.2 | -158.2 | 76.8 | 23.2 | -157.1 | 76.9 | 23.2 | -156.1 | 77.0 | 22.4 |
| Average         | -164.5 | 76.7            | 22.9  | -163.4 | 76.6  | 23.1  | -161.8 | 76.8  | 23.2  | -160.3 | 76.8  | 23.2  | -158.3 | 76.8  | 23.2  | -157.2 | 76.9  | 23.2  | -156.2 | 77.0        | 22.4  | -164.5 | 76.7  | 22.9  | -163.4 | 76.6  | 23.1  | -161.8 | 76.7  | 23.2  | -160.3 | 76.8  | 23.2  | -158.3 | 76.8  | 23.2  | -157.2 | 76.9  | 23.2  | -156.  |       |       |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |        |      |      |

| $q_0$ control- $x_0$ control = -167.4 cm, $y_0$ control = 76.7 cm, $z_0$ control = 23.3 cm |        |       |       |        |       |       |        |       |       |        |       |
|--------------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|
| RAW COORDINATES                                                                            |        |       |       |        |       |       |        |       |       |        |       |
| sl(degrees)                                                                                | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ |
| Frame 1                                                                                    | -160.0 | 77.5  | 22.5  | -161.6 | 77.5  | 23.2  | -163.4 | 76.8  | 22.9  | -163.6 | 77.1  |
| Frame 2                                                                                    | -158.8 | 77.1  | 22.5  | -161.6 | 77.2  | 23.0  | -163.2 | 76.9  | 23.0  | -163.4 | 77.1  |
| Frame 3                                                                                    | -159.7 | 77.2  | 22.6  | -162.2 | 77.5  | 23.1  | -163.3 | 76.8  | 23.1  | -163.6 | 77.1  |
| Frame 4                                                                                    | -159.8 | 77.1  | 22.5  | -161.7 | 77.2  | 23.1  | -162.9 | 76.8  | 23.0  | -163.7 | 77.1  |
| Frame 5                                                                                    | -159.7 | 77.3  | 22.6  | -161.7 | 77.5  | 23.1  | -163.1 | 76.8  | 23.0  | -163.4 | 77.2  |
| Frame 6                                                                                    | -159.8 | 77.1  | 22.5  | -161.7 | 77.2  | 23.1  | -163.0 | 76.8  | 23.1  | -163.5 | 76.9  |
| Frame 7                                                                                    | -159.8 | 77.3  | 22.7  | -162.1 | 77.5  | 23.0  | -163.7 | 76.8  | 22.8  | -164.2 | 77.1  |
| Frame 8                                                                                    | -160.1 | 77.1  | 22.5  | -161.5 | 77.2  | 23.0  | -163.1 | 76.8  | 23.0  | -163.6 | 77.0  |
| Frame 9                                                                                    | -159.9 | 77.4  | 22.6  | -161.7 | 77.5  | 23.1  | -163.7 | 76.8  | 22.9  | -163.3 | 77.1  |
| Frame 10                                                                                   | -159.8 | 77.1  | 22.5  | -161.5 | 77.2  | 23.1  | -163.1 | 76.8  | 23.0  | -163.2 | 77.2  |
| Average                                                                                    | -159.8 | 77.2  | 22.6  | -161.7 | 77.3  | 23.1  | -163.2 | 76.8  | 23.0  | -163.5 | 77.1  |
| St. Deviation                                                                              | 0.12   | 0.13  | 0.08  | 0.23   | 0.15  | 0.07  | 0.26   | 0.04  | 0.08  | 0.27   | 0.07  |
| RAW COORDINATES                                                                            |        |       |       |        |       |       |        |       |       |        |       |
| sl(degrees)                                                                                | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ |
| Frame 1                                                                                    | -160.6 | 76.5  | 22.6  | -171.5 | 76.6  | 21.0  | -172.2 | 76.1  | 21.1  | -174.6 | 76.2  |
| Frame 2                                                                                    | -169.7 | 76.5  | 22.6  | -171.4 | 76.8  | 21.0  | -172.3 | 76.2  | 21.3  | -174.5 | 76.3  |
| Frame 3                                                                                    | -169.6 | 76.3  | 22.6  | -171.6 | 76.5  | 21.0  | -172.2 | 76.1  | 21.1  | -174.3 | 76.2  |
| Frame 4                                                                                    | -169.8 | 76.5  | 22.7  | -171.3 | 76.9  | 21.0  | -172.1 | 76.2  | 21.1  | -174.7 | 76.3  |
| Frame 5                                                                                    | -170.2 | 76.3  | 22.5  | -171.4 | 76.5  | 21.0  | -172.2 | 76.2  | 21.1  | -174.2 | 76.2  |
| Frame 6                                                                                    | -170.4 | 76.7  | 22.4  | -171.2 | 76.9  | 21.1  | -172.2 | 76.2  | 21.1  | -174.6 | 76.3  |
| Frame 7                                                                                    | -169.5 | 76.3  | 22.8  | -171.4 | 76.6  | 21.0  | -172.2 | 76.2  | 21.2  | -174.7 | 76.2  |
| Frame 8                                                                                    | -170.2 | 76.6  | 22.4  | -171.4 | 76.8  | 21.0  | -172.2 | 76.2  | 21.2  | -174.7 | 76.4  |
| Frame 9                                                                                    | -170.9 | 76.5  | 22.2  | -171.5 | 76.6  | 21.0  | -172.0 | 76.1  | 21.1  | -174.5 | 76.2  |
| Frame 10                                                                                   | -170.6 | 76.7  | 22.3  | -171.4 | 76.9  | 21.1  | -172.2 | 76.2  | 21.2  | -174.3 | 76.3  |
| Average                                                                                    | -170.1 | 76.5  | 22.5  | -171.4 | 76.7  | 21.0  | -172.2 | 76.2  | 21.2  | -174.5 | 76.3  |
| St. Deviation                                                                              | 0.47   | 0.13  | 0.19  | 0.12   | 0.15  | 0.04  | 0.08   | 0.03  | 0.06  | 0.16   | 0.07  |
| UNCERTAINTY                                                                                |        |       |       |        |       |       |        |       |       |        |       |
| sl(degrees)                                                                                | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ | $z_0$ | $x_0$  | $y_0$ |
| Frame 1                                                                                    | -10.0  | 7.6   | 0.5   | -0.7   | -0.76 | -0.05 | 0.07   |       |       |        |       |
| Frame 2                                                                                    | -8.0   | 5.7   | 0.6   | -0.2   | -0.71 | -0.08 | 0.03   |       |       |        |       |
| Frame 3                                                                                    | -4.0   | 4.2   | 0.1   | -0.3   | -0.69 | -0.02 | 0.05   |       |       |        |       |
| Frame 4                                                                                    | -2.0   | 3.4   | 0.3   | 0.7    | -1.21 | -0.15 | -0.33  |       |       |        |       |
| Frame 5                                                                                    | -0.4   | 0.1   | -0.5  |        |       |       |        |       |       |        |       |
| Frame 6                                                                                    | 2.0    | 0.2   | -0.1  | -0.8   | 0.12  | -0.07 | -0.28  |       |       |        |       |
| Frame 7                                                                                    | -0.2   | -0.2  | -0.2  | -0.67  | -0.05 | -0.19 |        |       |       |        |       |
| Frame 8                                                                                    | 6.0    | -4.0  | 0.0   | -2.3   | -0.67 | 0.00  | -0.38  |       |       |        |       |
| Frame 9                                                                                    | 8.0    | -4.8  | -0.5  | -2.1   | -0.69 | -0.07 | -0.27  |       |       |        |       |
| Frame 10                                                                                   | 10.0   | -7.1  | -0.4  | -2.7   | -0.71 | -0.04 | -0.27  |       |       |        |       |
| Average                                                                                    |        |       |       | -0.69  | -0.06 | -0.16 |        |       |       |        |       |

| $q_0$ control: $x_0$ control = -167.4 cm, $y_0$ control = 76.7 cm, $z_0$ control = 23.3 cm |                 |       |       |        |       |       |        |       |       |        |       |       |        |       |
|--------------------------------------------------------------------------------------------|-----------------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|
| $\theta$ (degrees)                                                                         | Raw Coordinates |       |       |        |       |       |        |       |       |        |       |       |        |       |
|                                                                                            | -9.3            |       |       |        | -5.9  |       |        |       | -3.9  |        |       |       | -1.9   |       |
|                                                                                            | $x_0$           | $y_0$ | $z_0$ | $x_1$  | $y_1$ | $z_1$ | $x_2$  | $y_2$ | $z_2$ | $x_3$  | $y_3$ | $z_3$ | $x_4$  | $y_4$ |
| Frame 1                                                                                    | -165.6          | 72.5  | 24.0  | -166.0 | 72.7  | 23.7  | -166.5 | 74.1  | 23.2  | -168.3 | 75.5  | 23.1  | -166.1 | 76.4  |
| Frame 2                                                                                    | -168.0          | 72.4  | 24.0  | -166.0 | 72.7  | 23.8  | -166.6 | 74.2  | 23.3  | -168.3 | 75.6  | 23.1  | -166.4 | 76.3  |
| Frame 3                                                                                    | -165.7          | 72.5  | 24.0  | -166.0 | 72.8  | 23.8  | -166.6 | 74.1  | 23.2  | -168.4 | 75.6  | 23.1  | -166.2 | 76.4  |
| Frame 4                                                                                    | -165.6          | 72.4  | 24.2  | -166.1 | 72.7  | 23.7  | -166.6 | 74.2  | 23.2  | -168.3 | 75.6  | 23.1  | -166.4 | 76.3  |
| Frame 5                                                                                    | -165.7          | 72.5  | 24.1  | -165.9 | 72.8  | 23.8  | -166.6 | 74.2  | 23.2  | -168.2 | 75.6  | 23.1  | -166.2 | 76.3  |
| Frame 6                                                                                    | -165.6          | 72.4  | 24.1  | -166.1 | 72.7  | 23.7  | -166.5 | 74.1  | 23.3  | -168.3 | 75.5  | 23.1  | -166.4 | 76.2  |
| Frame 7                                                                                    | -165.9          | 72.5  | 24.0  | -166.0 | 72.7  | 23.7  | -166.5 | 74.1  | 23.2  | -168.3 | 75.6  | 23.2  | -166.0 | 76.3  |
| Frame 8                                                                                    | -165.9          | 72.4  | 24.0  | -165.9 | 72.7  | 23.8  | -166.4 | 74.2  | 23.2  | -168.2 | 75.6  | 23.1  | -166.2 | 76.3  |
| Frame 9                                                                                    | -165.8          | 72.4  | 24.0  | -165.9 | 72.7  | 23.7  | -166.6 | 74.0  | 23.3  | -168.3 | 75.6  | 23.0  | -166.0 | 76.4  |
| Frame 10                                                                                   | -165.8          | 72.4  | 24.0  | -166.1 | 72.6  | 23.7  | -166.4 | 74.2  | 23.2  | -168.2 | 75.6  | 23.1  | -166.3 | 76.3  |
| Average                                                                                    | -165.6          | 72.4  | 24.0  | -166.0 | 72.7  | 23.7  | -166.5 | 74.1  | 23.2  | -168.3 | 75.6  | 23.1  | -166.2 | 76.3  |
| St. Deviation                                                                              | 0.1             | 0.04  | 0.06  | 0.07   | 0.04  | 0.03  | 0.09   | 0.06  | 0.04  | 0.05   | 0.03  | 0.04  | 0.14   | 0.06  |
| Uncertainty                                                                                |                 |       |       |        |       |       |        |       |       |        |       |       |        |       |
| $\theta$ (degrees)                                                                         | Raw Coordinates |       |       |        |       |       |        |       |       |        |       |       |        |       |
|                                                                                            | -9.3            |       |       |        | -5.9  |       |        |       | -3.9  |        |       |       | -1.9   |       |
|                                                                                            | $x_0$           | $y_0$ | $z_0$ | $x_1$  | $y_1$ | $z_1$ | $x_2$  | $y_2$ | $z_2$ | $x_3$  | $y_3$ | $z_3$ | $x_4$  | $y_4$ |
| Frame 1                                                                                    | -168.6          | 78.3  | 22.1  | -168.7 | 79.5  | 22.0  | -168.3 | 80.6  | 22.5  | -5.9   | 1.4   | -4.0  | 0.4    | -0.24 |
| Frame 2                                                                                    | -168.8          | 78.3  | 22.0  | -168.7 | 79.6  | 22.6  | -168.6 | 80.5  | 22.4  | -3.9   | 0.6   | -2.6  | -0.1   | -0.22 |
| Frame 3                                                                                    | -168.9          | 78.3  | 22.1  | -168.6 | 79.5  | 22.7  | -168.2 | 80.6  | 22.6  | -1.9   | 1.1   | -1.1  | -0.2   | -0.59 |
| Frame 4                                                                                    | -168.9          | 78.2  | 22.1  | -168.5 | 79.6  | 22.6  | -168.3 | 80.6  | 22.5  | 0.0    | 1.2   | -0.4  | -0.5   | -0.59 |
| Frame 5                                                                                    | -168.9          | 78.3  | 22.1  | -168.7 | 79.6  | 22.6  | -168.3 | 80.6  | 22.5  | 1.9    | 0.3   | 0.7   | -1.4   | 0.179 |
| Frame 6                                                                                    | -168.7          | 78.3  | 22.1  | -168.8 | 79.6  | 22.5  | -168.4 | 80.6  | 22.5  | 3.9    | -1.4  | 1.6   | -1.2   | -0.36 |
| Frame 7                                                                                    | -168.8          | 78.3  | 22.2  | -168.6 | 79.5  | 22.6  | -168.4 | 80.6  | 22.5  | 5.9    | -1.3  | 2.8   | -0.7   | -0.22 |
| Frame 8                                                                                    | -168.9          | 78.2  | 22.1  | -168.7 | 79.6  | 22.6  | -168.3 | 80.6  | 22.5  | 9.3    | -1.0  | 3.9   | -0.8   | -0.1  |
| Frame 9                                                                                    | -168.7          | 78.4  | 22.1  | -168.6 | 79.5  | 22.7  | -168.3 | 80.6  | 22.6  |        |       |       |        |       |
| Frame 10                                                                                   | -168.9          | 78.3  | 22.2  | -168.6 | 79.6  | 22.7  | -168.3 | 80.6  | 22.4  |        |       |       |        |       |
| Average                                                                                    | -168.8          | 78.3  | 22.1  | -168.7 | 79.5  | 22.6  | -168.4 | 80.6  | 22.5  |        |       |       |        |       |
| St. Deviation                                                                              | 0.1             | 0.04  | 0.04  | 0.06   | 0.05  | 0.05  | 0.10   | 0.04  | 0.04  |        |       |       |        |       |



## APPENDIX Q

Digitized Coordinates,  $dn_i$  and  $dn_i / dQ$  calculations of Point H



|                 |          | Raw Coordinates |       |        |        |       |        |        |       |        |        |       |        | Raw Coordinates |       |        |        |                 |        |        |       |                        |       |       |       | Raw Coordinates                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|-----------------|----------|-----------------|-------|--------|--------|-------|--------|--------|-------|--------|--------|-------|--------|-----------------|-------|--------|--------|-----------------|--------|--------|-------|------------------------|-------|-------|-------|----------------------------------------------|-------|-------|-------|----------------------------------------------|-------|--|--|----------------------------------------------|--|--|--|
|                 |          | -18             |       |        |        | -14.4 |        |        |       | -10.8  |        |       |        | -7.2            |       |        |        | -3.6            |        |        |       | 0                      |       |       |       | 3.6                                          |       |       |       |                                              |       |  |  |                                              |  |  |  |
| 3X (cm)         |          | $x_0$           | $y_0$ | $z_0$  | $x_1$  | $y_1$ | $z_1$  | $x_0$  | $y_0$ | $z_0$  | $x_1$  | $y_1$ | $z_1$  | $x_0$           | $y_0$ | $z_0$  | $x_1$  | $y_1$           | $z_1$  | $x_0$  | $y_0$ | $z_0$                  | $x_1$ | $y_1$ | $z_1$ | $x_0$                                        | $y_0$ | $z_0$ | $x_1$ | $y_1$                                        | $z_1$ |  |  |                                              |  |  |  |
| 3X (cm)         | Frame 1  | -147.3          | 8.1   | 6.4    | -146.5 | 7.3   | 5.8    | -147.7 | 6.5   | 5.0    | -148.1 | 5.6   | 4.2    | -145.9          | 5.3   | 3.3    | -146.2 | 4.3             | 2.8    | -144.5 | 3.6   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 2  | -147.1          | 8.4   | 6.3    | -146.4 | 7.2   | 6.0    | -147.5 | 6.5   | 5.0    | -148.3 | 5.7   | 4.1    | -145.9          | 5.2   | 3.1    | -144.9 | 4.3             | 2.5    | -144.7 | 3.4   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 3  | -147.1          | 8.1   | 8.2    | -146.2 | 7.4   | 5.9    | -147.6 | 6.5   | 5.0    | -148.4 | 5.6   | 4.1    | -145.8          | 5.2   | 3.2    | -146.3 | 4.4             | 2.5    | -144.8 | 3.5   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 4  | -147.1          | 8.2   | 6.4    | -146.3 | 7.4   | 6.1    | -147.7 | 6.5   | 4.9    | -148.4 | 5.8   | 4.2    | -146.0          | 5.2   | 3.0    | -145.9 | 4.1             | 2.6    | -145.0 | 3.4   | 1.9                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 5  | -147.1          | 8.2   | 6.3    | -146.3 | 7.4   | 5.9    | -147.5 | 6.6   | 5.1    | -148.1 | 5.7   | 4.3    | -145.9          | 5.2   | 3.2    | -146.3 | 4.3             | 2.5    | -146.1 | 3.5   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 6  | -147.2          | 8.3   | 6.3    | -146.9 | 7.4   | 6.0    | -147.6 | 6.5   | 5.0    | -148.2 | 5.7   | 4.3    | -146.1          | 5.2   | 3.1    | -146.0 | 4.1             | 2.4    | -144.9 | 3.3   | 2.0                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 7  | -147.3          | 8.1   | 6.4    | -146.4 | 7.4   | 5.7    | -147.5 | 6.5   | 5.2    | -148.2 | 5.7   | 4.2    | -145.7          | 5.2   | 3.3    | -145.4 | 4.3             | 2.5    | -144.7 | 3.4   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 8  | -147.0          | 8.3   | 8.4    | -146.6 | 7.2   | 5.9    | -147.6 | 6.4   | 5.0    | -148.4 | 5.7   | 4.2    | -146.1          | 5.3   | 3.0    | -146.1 | 4.2             | 2.5    | -144.5 | 3.4   | 2.0                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 9  | -147.0          | 8.1   | 6.4    | -146.4 | 7.4   | 5.6    | -147.5 | 6.5   | 5.0    | -148.4 | 5.7   | 4.2    | -146.0          | 5.3   | 3.2    | -146.3 | 4.3             | 2.6    | -144.4 | 3.5   | 2.1                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 10 | -147.0          | 8.3   | 6.4    | -146.5 | 7.3   | 6.0    | -147.6 | 6.5   | 5.0    | -148.5 | 5.8   | 4.2    | -145.7          | 5.2   | 3.2    | -145.3 | 4.3             | 2.6    | -145.5 | 3.4   | 1.7                    |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
| Average         | -147.1   | 8.2             | 6.3   | -146.5 | 7.3    | 5.9   | -147.6 | 6.5    | 5.0   | -148.3 | 5.7    | 4.2   | -145.9 | 5.2             | 3.2   | -146.2 | 4.3    | 2.5             | -144.8 | 3.4    | 2.0   |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
| St. Deviation   | 0.1      | 0.09            | 0.04  | 0.20   | 0.07   | 0.12  | 0.11   | 0.04   | 0.08  | 0.13   | 0.05   | 0.08  | 0.14   | 0.04            | 0.11  | 0.19   | 0.08   | 0.05            | 0.33   | 0.08   | 0.14  |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
| Raw Coordinates |          |                 |       |        |        |       |        |        |       |        |        |       |        |                 |       |        |        |                 |        |        |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 |          | Raw Coordinates |       |        |        |       |        |        |       |        |        |       |        | Raw Coordinates |       |        |        |                 |        |        |       |                        |       |       |       | Raw Coordinates                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 |          | 7.2             |       |        |        | 10.8  |        |        |       | 14.4   |        |       |        | 18.0            |       |        |        | $\Delta X$ (cm) |        |        |       | $\frac{\Delta X}{X_0}$ |       |       |       | $\frac{\Delta X}{X_0} \cdot \frac{X_0}{X_0}$ |       |       |       | $\frac{\Delta X}{X_0} \cdot \frac{X_0}{X_0}$ |       |  |  | $\frac{\Delta X}{X_0} \cdot \frac{X_0}{X_0}$ |  |  |  |
| 3X (cm)         |          | $x_0$           | $y_0$ | $z_0$  | $x_1$  | $y_1$ | $z_1$  | $x_0$  | $y_0$ | $z_0$  | $x_1$  | $y_1$ | $z_1$  | $x_0$           | $y_0$ | $z_0$  | $x_1$  | $y_1$           | $z_1$  | $x_0$  | $y_0$ | $z_0$                  | $x_1$ | $y_1$ | $z_1$ | $x_0$                                        | $y_0$ | $z_0$ | $x_1$ | $y_1$                                        | $z_1$ |  |  |                                              |  |  |  |
| 3X (cm)         | Frame 1  | -145.1          | 29    | 16     | -146.4 | 13    | 0.5    | -145.6 | 0.7   | 0.0    | -144.4 | 0.1   | -1.3   | -14.4           | -1.1  | 3.9    | 3.9    | 0.1             | -0.3   | -0.3   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 2  | -146.4          | 29    | 15     | -146.4 | 15    | 0.3    | -145.3 | 0.7   | 0.0    | -144.5 | 0.0   | -1.3   | -10.8           | -2.2  | 3.0    | 3.0    | 0.2             | -0.3   | -0.3   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 3  | -145.1          | 27    | 16     | -145.7 | 15    | 0.4    | -145.6 | 0.7   | 0.0    | -144.4 | 0.1   | -1.3   | -7.2            | -0.9  | 2.2    | 2.2    | 0.1             | -0.3   | -0.3   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 4  | -145.3          | 29    | 16     | -145.6 | 16    | 0.4    | -145.8 | 0.6   | -0.1   | -144.3 | -0.1  | -1.4   | -3.6            | -0.5  | 1.7    | 1.7    | 0.1             | -0.5   | -0.3   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 5  | -145.2          | 29    | 16     | -145.6 | 13    | 0.4    | -145.4 | 0.7   | -0.1   | -144.5 | 0.0   | -1.4   | 0.0             | 0.2   | 0.8    | 0.5    |                 |        |        |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 6  | -145.2          | 29    | 15     | -145.6 | 16    | 0.4    | -145.9 | 0.7   | -0.1   | -144.6 | 0.0   | -1.3   | 3.6             | 0.6   | -0.1   | 0.0    | 0.2             | 0.0    | 0.0    |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 7  | -145.2          | 30    | 16     | -145.8 | 15    | 0.3    | -145.4 | 0.6   | -0.1   | -144.6 | 0.1   | -1.3   | 7.2             | 0.2   | -0.6   | -0.4   | 0.0             | -0.1   | -0.1   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 8  | -145.2          | 29    | 16     | -146.4 | 15    | 0.4    | -145.8 | 0.7   | -0.1   | -144.5 | 0.0   | -1.3   | 10.8            | -0.1  | -2.0   | -1.6   | 0.0             | -0.2   | -0.1   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 9  | -145.0          | 29    | 17     | -145.5 | 1.4   | 0.5    | -145.4 | 0.7   | 0.0    | -144.4 | 0.0   | -1.2   | 14.4            | -0.2  | -2.8   | -2.1   | 0.0             | -0.2   | -0.1   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
|                 | Frame 10 | -145.2          | 29    | 16     | -145.5 | 1.6   | 0.4    | -145.8 | 0.7   | -0.1   | -144.7 | 0.0   | -1.2   | 18.0            | 0.9   | 3.5    | -3.3   | 0.1             | -0.2   | -0.2   |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
| Average         | -145.2   | 29              | 16    | -145.5 | 1.5    | 0.4   | -145.6 | 0.7    | -0.1  | -144.5 | 0.0    | -1.3  |        |                 |       |        |        |                 |        |        |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |
| Deviation       | 0.1      | 0.07            | 0.04  | 0.14   | 0.10   | 0.06  | 0.20   | 0.02   | 0.04  | 0.05   | 0.11   | 0.05  |        |                 |       |        |        |                 |        |        |       |                        |       |       |       |                                              |       |       |       |                                              |       |  |  |                                              |  |  |  |

| Q1 central: $x_0$ central = -145.4 cm, $y_0$ central = 3.5 cm, $z_0$ central = 2.0 cm |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |      |      |        |      |      |
|---------------------------------------------------------------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|------|------|--------|------|------|
| Raw Coordinates                                                                       |        |       |       |        |       |       |        |       |       |        |       |       |        |       |       |        |      |      |        |      |      |
| $zY$ (cm)                                                                             |        | -10.0 |       | -8.0   |       | -6.0  |        | -4.0  |       | -2.0   |       | 0.0   |        | 2.0   |       |        |      |      |        |      |      |
| $x_0$                                                                                 | $y_0$  | $x_0$ | $y_0$ | $x_0$  | $y_0$ | $x_0$ | $y_0$  | $x_0$ | $y_0$ | $x_0$  | $y_0$ | $x_0$ | $y_0$  | $x_0$ | $y_0$ |        |      |      |        |      |      |
| Frame 1                                                                               | -145.9 | 3.1   | 3.0   | -147.1 | 3.2   | 3.0   | -144.8 | 3.4   | 3.1   | -144.4 | 3.2   | 2.7   | -146.0 | 4.3   | 3.2   | -145.4 | 4.1  | 2.5  | -145.1 | 4.2  | 3.1  |
| Frame 2                                                                               | -145.8 | 3.2   | 2.9   | -147.0 | 3.3   | 3.0   | -144.8 | 3.5   | 3.0   | -144.8 | 3.1   | 2.9   | -145.6 | 4.4   | 3.2   | -145.5 | 4.2  | 2.6  | -145.3 | 4.5  | 3.2  |
| Frame 3                                                                               | -145.8 | 3.1   | 3.0   | -146.9 | 3.2   | 3.0   | -144.7 | 3.4   | 3.0   | -144.9 | 3.3   | 3.1   | -145.7 | 4.4   | 3.1   | -145.6 | 4.1  | 2.8  | -145.2 | 4.3  | 3.1  |
| Frame 4                                                                               | -145.7 | 3.2   | 3.0   | -147.1 | 3.3   | 2.9   | -144.9 | 3.6   | 3.0   | -144.5 | 3.1   | 3.1   | -145.6 | 4.4   | 3.3   | -145.2 | 4.2  | 2.6  | -144.9 | 4.4  | 3.2  |
| Frame 5                                                                               | -145.8 | 3.1   | 2.9   | -146.7 | 3.2   | 3.0   | -144.8 | 3.5   | 3.2   | -144.8 | 3.3   | 3.2   | -145.4 | 4.4   | 3.2   | -145.5 | 4.1  | 2.8  | -145.1 | 4.3  | 3.1  |
| Frame 6                                                                               | -145.9 | 3.3   | 3.1   | -146.8 | 3.4   | 3.1   | -144.8 | 3.6   | 3.3   | -145.1 | 3.2   | 2.9   | -145.7 | 4.4   | 3.3   | -145.4 | 4.1  | 2.7  | -145.0 | 4.5  | 3.3  |
| Frame 7                                                                               | -145.8 | 3.1   | 3.0   | -146.8 | 3.2   | 3.1   | -144.9 | 3.5   | 3.2   | -144.7 | 3.3   | 3.0   | -146.0 | 4.5   | 3.2   | -145.6 | 4.1  | 2.7  | -145.2 | 4.3  | 3.2  |
| Frame 8                                                                               | -145.8 | 3.3   | 3.0   | -146.8 | 3.2   | 3.1   | -144.9 | 3.6   | 3.2   | -144.9 | 3.1   | 2.8   | -146.0 | 4.3   | 3.2   | -145.4 | 4.1  | 2.7  | -145.1 | 4.5  | 3.2  |
| Frame 9                                                                               | -145.9 | 3.1   | 3.0   | -146.8 | 3.2   | 2.9   | -144.7 | 3.4   | 3.1   | -144.9 | 3.2   | 2.9   | -145.9 | 4.3   | 3.2   | -145.7 | 4.2  | 2.7  | -145.2 | 4.3  | 3.1  |
| Frame 10                                                                              | -145.7 | 3.2   | 3.0   | -147.0 | 3.2   | 3.0   | -144.8 | 3.5   | 3.1   | -144.8 | 3.1   | 3.0   | -145.4 | 4.3   | 3.3   | -145.7 | 4.2  | 2.7  | -145.2 | 4.5  | 3.3  |
| Average                                                                               | -145.8 | 3.2   | 3.0   | -146.9 | 3.2   | 3.0   | -144.8 | 3.5   | 3.1   | -144.8 | 3.5   | 3.1   | -145.7 | 4.4   | 3.2   | -145.5 | 4.2  | 2.7  | -145.1 | 4.4  | 3.2  |
| St. Deviation                                                                         | 0.1    | 0.08  | 0.08  | 0.17   | 0.08  | 0.08  | 0.09   | 0.06  | 0.09  | 0.09   | 0.06  | 0.09  | 0.22   | 0.05  | 0.05  | 0.18   | 0.02 | 0.08 | 0.12   | 0.11 | 0.09 |

| Raw Coordinates |        |       |       |        |       |       |        |           |       |        |      |      |      |      |      |     |      |      |      |
|-----------------|--------|-------|-------|--------|-------|-------|--------|-----------|-------|--------|------|------|------|------|------|-----|------|------|------|
| $zY$ (cm)       |        |       |       |        |       |       |        |           |       |        |      |      |      |      |      |     |      |      |      |
| 4.0             |        | 6.0   |       | 8.0    |       | 10.0  |        | $zY$ (cm) |       |        |      |      |      |      |      |     |      |      |      |
| $x_0$           | $y_0$  | $x_0$ | $y_0$ | $x_0$  | $y_0$ | $x_0$ | $y_0$  | $x_0$     | $y_0$ |        |      |      |      |      |      |     |      |      |      |
| Frame 1         | -145.7 | 4.4   | 3.3   | -145.5 | 4.4   | 3.0   | -145.2 | 4.8       | 2.6   | -144.8 | 4.7  | 2.6  | -8.0 | -1.5 | -0.3 | 1.0 | 0.2  | 0.0  | -0.1 |
| Frame 2         | -145.8 | 4.3   | 3.1   | -145.8 | 4.5   | 3.0   | -145.6 | 4.6       | 3.0   | -144.9 | 4.7  | 2.6  | -6.0 | 0.6  | 0.0  | 1.1 | -0.1 | 0.0  | -0.2 |
| Frame 3         | -145.8 | 4.4   | 3.1   | -145.4 | 4.4   | 3.0   | -145.5 | 4.9       | 3.0   | -144.8 | 4.7  | 2.6  | -4.0 | 0.6  | 0.0  | 1.1 | -0.2 | 0.0  | -0.3 |
| Frame 4         | -146.2 | 4.2   | 3.2   | -145.4 | 4.4   | 3.0   | -145.3 | 4.6       | 2.9   | -145.1 | 4.7  | 2.6  | -2.0 | -0.3 | 0.8  | 1.2 | 0.2  | -0.4 | -0.6 |
| Frame 5         | -145.7 | 4.3   | 3.1   | -145.4 | 4.5   | 3.1   | -145.5 | 4.8       | 3.0   | -144.9 | 4.7  | 2.6  | 0.0  | -0.1 | 0.7  | 0.7 |      |      |      |
| Frame 6         | -146.2 | 4.2   | 3.1   | -145.6 | 4.6   | 3.0   | -145.5 | 4.7       | 3.0   | -145.0 | 4.8  | 2.6  | 2.0  | 0.3  | 0.9  | 1.2 | 0.1  | 0.4  | 0.8  |
| Frame 7         | -146.1 | 4.5   | 3.1   | -145.7 | 4.5   | 3.0   | -145.5 | 4.8       | 3.0   | -144.8 | 4.8  | 2.6  | 4.0  | -0.5 | 0.8  | 1.2 | -0.1 | 0.2  | 0.3  |
| Frame 8         | -145.9 | 4.3   | 3.2   | -145.8 | 4.6   | 3.0   | -145.5 | 4.7       | 3.1   | -144.6 | 4.7  | 2.5  | 6.0  | -0.1 | 1.0  | 1.0 | 0.0  | 0.2  | 0.2  |
| Frame 9         | -145.9 | 4.4   | 3.3   | -145.6 | 4.4   | 2.9   | -145.7 | 4.8       | 3.0   | -144.9 | 4.8  | 2.6  | 8.0  | 0.0  | 1.2  | 1.0 | 0.0  | 0.2  | 0.1  |
| Frame 10        | -146.0 | 4.4   | 3.1   | -145.4 | 4.4   | 3.0   | -145.2 | 4.6       | 3.1   | -145.3 | 4.8  | 2.7  | 10.0 | 0.5  | 1.2  | 0.8 | 0.0  | 0.1  | 0.1  |
| Average         | -145.9 | 4.3   | 3.2   | -145.5 | 4.5   | 3.0   | -145.4 | 4.7       | 3.0   | -144.9 | 4.7  | 2.6  |      |      |      |     |      |      |      |
| St. Deviation   | 0.2    | 0.11  | 0.07  | 0.11   | 0.07  | 0.05  | 0.18   | 0.10      | 0.09  | 0.20   | 0.04 | 0.05 |      |      |      |     |      |      |      |



| Q <sub>1</sub> control: X <sub>5</sub> control = -145.4 cm, Y <sub>5</sub> control = 3.5 cm, Z <sub>5</sub> control = 2.0 cm |                |                |                |                |                |                |                |                |                |
|------------------------------------------------------------------------------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Raw Coordinates                                                                                                              |                |                |                |                |                |                |                |                |                |
| St. (degrees)                                                                                                                | -10.0          |                |                | -8.0           |                |                | -6.0           |                |                |
|                                                                                                                              | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> |
| Frame 1                                                                                                                      | -135.8         | 0.3            | 1.7            | -137.9         | 1.4            | 2.2            | -138.6         | 1.8            | 2.1            |
| Frame 2                                                                                                                      | -135.8         | 0.1            | 1.7            | -137.7         | 1.4            | 2.0            | -139.2         | 1.9            | 2.0            |
| Frame 3                                                                                                                      | -135.7         | 0.2            | 1.8            | -138.1         | 1.4            | 2.2            | -138.6         | 1.8            | 2.1            |
| Frame 4                                                                                                                      | -135.8         | 0.4            | 1.8            | -138.1         | 1.5            | 2.1            | -138.1         | 1.5            | 2.0            |
| Frame 5                                                                                                                      | -135.6         | 0.2            | 1.9            | -138.2         | 1.4            | 2.3            | -138.3         | 1.7            | 2.0            |
| Frame 6                                                                                                                      | -135.7         | 0.2            | 1.7            | -138.5         | 1.6            | 2.2            | -138.6         | 1.8            | 2.1            |
| Frame 7                                                                                                                      | -136.0         | 0.3            | 1.8            | -138.7         | 1.5            | 2.0            | -138.7         | 1.7            | 1.8            |
| Frame 8                                                                                                                      | -135.9         | 0.2            | 1.8            | -137.9         | 1.6            | 2.3            | -138.4         | 1.8            | 2.1            |
| Frame 9                                                                                                                      | -136.1         | 0.4            | 1.8            | -137.9         | 1.4            | 2.4            | -138.7         | 1.8            | 2.1            |
| Frame 10                                                                                                                     | -135.8         | 0.1            | 1.7            | -138.0         | 1.4            | 2.1            | -138.5         | 1.7            | 2.0            |
| Average                                                                                                                      | -135.8         | 0.3            | 1.6            | -138.1         | 1.5            | 2.2            | -138.6         | 1.7            | 2.0            |
| St. Deviation                                                                                                                | 0.16           | 0.11           | 0.08           | 0.30           | 0.09           | 0.13           | 0.28           | 0.09           | 0.09           |
| Raw Coordinates                                                                                                              |                |                |                |                |                |                |                |                |                |
| St. (degrees)                                                                                                                | 4.0            |                |                | 6.0            |                |                | 8.0            |                |                |
|                                                                                                                              | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> |
| Frame 1                                                                                                                      | -148.7         | 5.1            | 2.8            | -152.4         | 5.9            | 1.6            | -154.2         | 5.5            | 1.8            |
| Frame 2                                                                                                                      | -150.0         | 5.1            | 2.7            | -152.4         | 5.7            | 1.7            | -154.5         | 5.2            | 1.7            |
| Frame 3                                                                                                                      | -148.7         | 5.1            | 2.8            | -152.6         | 5.9            | 1.6            | -154.0         | 5.5            | 1.6            |
| Frame 4                                                                                                                      | -148.7         | 5.1            | 2.9            | -152.1         | 5.9            | 1.8            | -154.2         | 5.1            | 1.7            |
| Frame 5                                                                                                                      | -148.7         | 5.1            | 3.0            | -152.5         | 5.9            | 1.8            | -154.2         | 5.5            | 1.8            |
| Frame 6                                                                                                                      | -148.9         | 4.8            | 2.4            | -152.4         | 6.0            | 1.8            | -154.1         | 5.1            | 1.7            |
| Frame 7                                                                                                                      | -150.4         | 5.2            | 2.4            | -152.4         | 6.0            | 1.7            | -154.0         | 5.4            | 1.6            |
| Frame 8                                                                                                                      | -150.2         | 4.8            | 2.4            | -152.6         | 5.8            | 1.5            | -154.3         | 5.2            | 1.8            |
| Frame 9                                                                                                                      | -150.0         | 4.8            | 2.6            | -152.3         | 5.9            | 1.6            | -154.2         | 5.5            | 1.7            |
| Frame 10                                                                                                                     | -148.8         | 4.8            | 2.6            | -152.5         | 5.9            | 1.6            | -154.3         | 5.2            | 1.8            |
| Average                                                                                                                      | -148.9         | 5.0            | 2.7            | -152.4         | 5.9            | 1.7            | -154.2         | 5.3            | 1.7            |
| St. Deviation                                                                                                                | 0.24           | 0.17           | 0.21           | 0.14           | 0.07           | 0.11           | 0.15           | 0.18           | 0.07           |
| Uncertainty                                                                                                                  |                |                |                |                |                |                |                |                |                |
| St. (degrees)                                                                                                                | (degrees)      |                |                | 10.0           |                |                | -10.0          |                |                |
|                                                                                                                              | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> | X <sub>5</sub> | Y <sub>5</sub> | Z <sub>5</sub> |
| Frame 1                                                                                                                      | -148.7         | 5.1            | 2.8            | -157.1         | 6.0            | 1.4            | -8.0           | 7.4            | -2.0           |
| Frame 2                                                                                                                      | -150.0         | 5.1            | 2.7            | -157.2         | 5.9            | 1.3            | -6.0           | 6.9            | -1.8           |
| Frame 3                                                                                                                      | -148.7         | 5.1            | 2.8            | -158.7         | 5.9            | 1.2            | -4.0           | 4.6            | -0.8           |
| Frame 4                                                                                                                      | -148.7         | 5.1            | 2.9            | -157.1         | 5.8            | 1.4            | -2.0           | 2.0            | 0.0            |
| Frame 5                                                                                                                      | -148.7         | 5.1            | 3.0            | -159.7         | 5.9            | 1.3            | 0.0            | -0.6           | 1.0            |
| Frame 6                                                                                                                      | -148.9         | 4.8            | 2.4            | -157.2         | 5.8            | 1.4            | 2.0            | -1.4           | 1.0            |
| Frame 7                                                                                                                      | -150.4         | 5.2            | 2.4            | -156.8         | 6.0            | 1.2            | 4.0            | -4.4           | 1.5            |
| Frame 8                                                                                                                      | -150.2         | 4.8            | 2.4            | -157.1         | 5.8            | 1.4            | 6.0            | -6.9           | 2.4            |
| Frame 9                                                                                                                      | -150.0         | 4.8            | 2.6            | -157.0         | 6.0            | 1.4            | 8.0            | -8.7           | 1.8            |
| Frame 10                                                                                                                     | -148.8         | 4.8            | 2.6            | -157.1         | 5.8            | 1.4            | 10.0           | -11.5          | 2.4            |
| Average                                                                                                                      | -148.9         | 5.0            | 2.7            | -157.0         | 5.9            | 1.3            |                |                |                |
| St. Deviation                                                                                                                | 0.24           | 0.17           | 0.21           | 0.22           | 0.09           | 0.07           |                |                |                |





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