ABSTRACT

AN EVENT-ORIENTED CORN PRODUCTION SIMULATION MODEL

By

Samuel Dale Parsons

A computer simulation model was developed for evaluating the physical performance of the corn production, harvesting and marketing system of an individual firm. The model was structured to provide the capability of evaluating numerous user-specific variations in land base, equipment inventory, labor force, and management policy. The model developed utilizes: 1) a daily simulation technique for environmental and management factors associated with the system -- soil and crop attributes as well as operating procedures and labor availability may change from day to day; and 2) an event-oriented simulation technique for the performance of functional activities associated with the system -- tillage, planting, harvesting, crop or supply transport, and other activities. The development of this latter aspect of the model was based on a conceptualization of the corn production system as a set of mobile discrete objects (men, tractors, combines, trucks, etc.) that interact with a set of immobile discrete objects (fields, farmstead facilities, off-farm markets, etc.) based on a set

of policy and procedure rules (some of which are specified by the model-user) to accomplish the desired production, harvesting and marketing activities.

The model consists of a very small main program and 130 subroutines that are called as needed. Of these, about 45 could be classified as input-output routines or those involved with the daily simulation aspect of the model. The remaining subroutines were required for the detailed activity-simulation, which utilized the filing system and event control features of the GASP II simulation language.

Certain unique features of the model appear to be adequate, and necessary, for realistic performance results with complex multi-man, multi-machine corn production, harvesting and marketing systems. These include: 1) the definition of activity periods based on weather, soil, crop and/or management factors which permits the specification, and determination of field operations and other activities that are feasible at any point in simulated time; and 2) the definition of a field-operations-status array, or similar accounting device, to facilitate scheduling and to maintain the current work/no-work status of fields that are to receive various field operations.

Another unique feature of the model, the provisions made for declaring an activity-simulation day on days when field work cannot be done, is also an important concept for realistic simulation results. In the real world non-field activities <u>do</u> occur on days when field work cannot be done (equipment refueling and maintenance, corn handling, off-farm marketing, etc.) which permits a more efficient utilization of available field time on those days when it can be done.

The model was developed sufficiently to demonstrate its use for a one-man system in which the corn shelled at harvest-time (with a self-propelled combine) is moved to on-farm high-moisture storage and/or to off-farm markets. To do so an example farm with four alternative equipment-management systems was devised. The daily simulation portion of the model and the event-oriented portion of the model performed in a reasonable and realistic manner for the single crop-year simulations.

Certain features of the model developed are unique in comparison to other simulation models that have been developed for crop production systems. For example, the capability of simulating a series of several field operations (and their necessary support functions) rather than just the so-called key operations (planting and/or harvesting). The capability of realistically evaluating the interaction of field equipment and/or transport subsystems and/or grain receiving facilities under specific operating policies and with specific physical constraints (field shapes, field arrangements, road networks, etc.) is another example.

These capabilities, however, were not without certain "costs": complexity in specifying input information, complexity in programming, especially for the activity-simulation, and relatively high computer storage and execution time requirements. Because of these factors, the potential use of the model is probably not, as was initially hoped, as a management tool for practicing farm managers.

Rather, its most important future role may be in developing realistic performance coefficients for other simulation or optimization models -- particularly field efficiency values for equipment operating in specific situations. Another important use may be for sensitivity analysis, to determine what policies, procedures, characteristics or other factors significantly affect the performance of complex crop production systems. Such information could be used to establish criteria for developing simpler models for research and/or practical management purposes.

Approved J B Holtman
Major Professor

Approved B A Stout
Department Chairman

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CORN PRODUCTION SIMULATION MODEL

by

Samuel Dale Parsons

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INTRODUCTION

The operation of a commercial corn farm requires management skills and abilities unmatched in most other businesses. The corn producer must be a purchasing agent for production supplies, a salesman for the crop produced, and a host of other things. One of his key roles is to assemble and manage the system of men and machines needed to actually produce the crop (a biological product) in an environment that is usually unpredictable and sometimes hostile (the weather).

Performing these functions has become increasingly difficult as new technologies have continued to develop in all phases of corn production. Simply understanding the cause-effect relationships at work within a complex corn production system is not an easy task. The farm manager must be continually alert that some anticipated change in equipment, operating procedure or policy does not optimize or improve some component of the system at the expense of overall system performance.

Computer simulation models have proven to be an effective means of analyzing and understanding many complex systems. A carefully designed simulation model of the corn production system could be a practical management tool for the farm manager, as well as a powerful research tool for the agricultural scientist. How practical and how powerful this tool would be, though, depends on how well real world phenomena and processes can be modeled to produce realistic results.

The development of such a model, in the author's judgement, should be done with two basic requirements in mind:

1) It should be highly user-specific, i.e., it should have the capability of dealing with a variety of real-world situations regarding the availability and use of land, equipment and labor.
2) It should employ event-oriented simulation techniques in order to produce the most realistic quantitative predictions of system performance possible.

The justification for these two requirements will be discussed in some detail.

Each corn farm in existence today is unique in many ways. These include its location and physical makeup, and the farm manager's ability and biases regarding the adoption of new technology, the operation of equipment, the use of part-time help, and so forth.

The farm's very location defines certain factors which will affect the management and performance of a corn production system. The prevailing temperature and rainfall patterns in the area will influence such things as actual and potential yields, and the number of operating days possible in a given time period. The type, cost and availability of part-time labor and custom services (for fertilizer and chemical application, harvesting, hauling, drying, etc.) will influence labor-equipment size relationships. The general farming pattern in the area (corn surplus vs. corn deficit areas), the type and distribution of roads in the area, and the number, size, type and distance to off-farm marketing outlets will influence such things as transport times for production supplies and marketed corn, the length of waiting lines at elevators during harvest, corn price levels and moisture discount schedules.

The physical makeup of the farm also affects system management and performance. The natural fertility and drainage of the soils will influence yield potential and equipment tractability. The soils' susceptibility to water and wind erosion will influence the advisability of fall tillage operations and may dictate row direction. The size and shape of fields will influence the field efficiency of equipment, and may dictate unload patterns for harvesting, and refill patterns for planting and other material application jobs. The geographic distribution of fields, or of contiguous tracts of fields in the operation will influence travel and transport times, policies for the overnight storage of equipment (in-field versus at the farmstead), and the sequence in which fields receive a given field operation.

The farm's total acreage, the size of the permanent labor force, the farm manager's use of part-time help in critical periods, and the complement of equipment in-place at any given time will all affect the management and performance of the over-all system. Equipment size is one characteristic that distinguishes the complement of machinery on one farm from that on another. The type of equipment, based on the particular practices the farm manager has selected to produce, harvest, and market the corn crop, is another distinguishing characteristic. The farm manager may also decide that certain practices should be done with custom-hired equipment, while others are performed with farm-controlled equipment.

The corn production techniques of modern agriculture usually require equipment to perform all or most of the following field operations: residue management, tillage, planting, fertilizer application, special pest control practices (for weeds, insects, or corn diseases), harvesting, and transport of the harvested crop from the field. In addition, many corn producers also dry and/or store all or part of the crop on the farm where it is produced. This corn is then marketed off-farm, or through a complementary livestock enterprise on the farm. With each of these practices there is a multitude of alternative technologies which the farm manager may adopt. A few examples of alternative technologies and their possible affect on system performance will be cited.

In the area of tillage and planting systems, conventional tillage is still the most prevalent method of seedbed preparation used in most areas of the cornbelt. This method involves the use of a primary tillage tool (a moldboard or chisel plow used in the fall or spring), followed by one, two or more secondary tillage operations (with a disk, field cultivator, spring-tooth harrow, or similar implement in the spring) prior to planting. The primary tillage operation may or may not be preceded with a residue management operation (disking or shredding of last year's cornstalks).

It is now possible, however, to "prepare" the land and plant in as few as one or two trips over the field using so-called reduced tillage or no-till methods. Obviously the number and type of tillage operations to be performed, coupled with the total acreage to be planted and other factors, will influence the farm manager's equipment sizing, selection and scheduling policies. He may also have built-in constraints or biases (his own or imposed by the owner of rented land) which affect scheduling. For instance, he may want to perform a given field operation in various fields in a particular sequence, or certain fields will be fall plowed (weather and time permitting) while others will not because of the wind or water erosion hazard.

Alternative technologies are also available for supplying the nutrient requirements (N, P and K) of the crop. The farm manager's choice of fertilizer materials and methods of application, as well as the required rates of application, can have an important influence on equipment sizing, selection and scheduling, and on system performance. Phosphorus (P) and potassium (K) may be bulk spread in a dry form prior to primary tillage or afterwards. This is usually done, however, before the last secondary tillage operation preceding planting. They may also be applied, in either the liquid or dry form, and with nitrogen (N), as a sideband application of complete-mix starter fertilizer during planting.

Bulk nitrogen is readily available in several forms. These include high-pressure gas (anhydrous ammonia), low-pressure liquids and non-pressure liquids. Application may be made in a variety of ways. The non-pressure materials can be surface applied with special spraying equipment. Mixing a chemical herbicide with non-pressure liquid nitrogen and applying it preplant, postplant or postemerge is popular in many areas (the so-called feed-n-weed technique). High-pressure gas and low-pressure liquid forms of nitrogen must be injected or incorporated into the soil to minimize losses. They can be applied during a primary tillage operation by fitting the moldboard or chisel plow with distribution hoses to release the material below ground (a supply tank is usually mounted on the tractor or plow, or a nurse tank is pulled behind the plow). These materials may also be applied with a special knife-down applicator, either in the spring (usually preplant on plowed ground) or after the corn has emerged (this method is called sidedressing).

Harvesting and marketing is yet another phase of the corn production system in which alternative technologies abound. Each one has special implications regarding equipment sizing, selection and scheduling, and overall system performance. The farm manager may chose to harvest all or part of the crop in a number of different forms: as whole-plant corn silage, as ground ear-corn silage, as standard ear corn, or as field-shelled corn. In each case a transport system of some type is usually maintained, under control of the farm manager, to move the harvested material from the field.

In the case of shelled corn, the transport system usually consists of farm trucks, wagons pulled by tractors, or a combination of these two. The specific makeup of the transport system may depend on where the corn is going (to a farmstead or direct to an off-farm market). But other factors also influence the number and type of transport vehicles employed. These include such things as harvesting capacity, grain tank size, combine unload points in a particular field (affected by yield, moisture content and row length), method of transfer from the combine (stop unloading versus on-the-go unloading), and the "turn-around" time at, and travel times to and from the delivery point.

If corn is to be dried at the farm and then marketed off-farm, either at harvest or at a later date, then the farm manager must arrange for it to be moved by custom haulers, or provide the necessary transport capability himself.

On-farm drying of shelled corn may also be done in various ways. These include in-bin layer drying, batch-in-bin drying, portable batch drying and continuous flow drying. Another alternative includes the use of dryeration with batch and continuous flow driers.* Each method has certain capacity limitations and each has special handling facility requirements (dump pit, conveyors, wet holding, dry holding, etc.) for a good "match" with a particular harvesting and hauling system.

The alternative technologies and modes of operation just cited, plus a host of others, are all being used in varying combinations on farms throughout the corn belt. Usually no two farm managers employ or utilize <u>precisely</u> the same set of technologies or operating policies. Similarly, no two farms are identical in terms of labor and other resources, or in terms of physical makeup and location (with the implicit effects on system performance which these factors carry with them).

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* The corn is only partially dried in the drier, then transferred "hot" to a separate "steeping" and (slow) cooling bin.

If a computer simulation model of the corn production system is to be of practical significance as a management tool to all but a few select farm managers, then it must be highly user-specific. That is, it should have the capability of dealing with various resource and land base configurations, a variety of land, equipment and labor policy options, and at least the major technological variations in production, harvesting and marketing practices.

The development of such a model, to "deal with" these various factors, can be done in a number of different ways. The purpose of this study was to explore a particular way of doing it, namely that of using event-oriented simulation techniques.* The corn production system is conceptualized as a set of mobile discrete objects (men, tractors, combines, trucks, etc.) that interact with a set of immobile discrete objects (fields, drying equipment, off-farm markets, etc.) based on a set of policy and procedure rules (some of which would be specified by the model-user) to accomplish the desired production, harvesting and marketing activities.

Such a scheme would, of necessity, involve a rather detailed analysis (and knowledge) of the real-world activities to be simulated. It was envisioned, for instance, that a

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* The term event-oriented simulation will be used and understood to be synonymous with discrete-event or variable-time increment simulation, i.e., simulated time is sequentially advanced to the time of occurence of the next imminent event, as opposed to continuous time or fixed-time increment simulation techniques.

typical sequence of activities at the beginning of a simulated day, for a particular piece of field equipment and its operator, might be: prepare the equipment, move to the field, begin "on-row" operation, stop for adjustment, continue operation, turn at the end of the field, continue operation, etc. Concurrent with these activities, a second operator in the system might be doing the following things: prepare a transport vehicle, move to a production supply point or corn delivery point, load production supplies or unload corn left on the vehicle overnight, move to the field and position the vehicle for the next materials handling job (outflow of production supplies or inflow of harvested corn), wait at this position if materials handling is not immediately required, etc.

For one-man systems, a single operator would perform both sets of activities; being assigned first to the transport vehicle, and then to the field equipment. For multi-man systems, two or more operators might be assigned to perform the same or different field operations with different sets of equipment, while simultaneously other men might be assigned to perform transport activities, on-farm drying or grain handling activities, and so forth.

The following model requirements were identified:

1) It should provide the capability of realistically accounting for certain "non-productive" time requirements that occur in the real world on a deterministic or stochastic basis.

2) It should permit realistic (simulated) scheduling of two or more activites that compete for the same men and/or machines.

3) It should allow the model-user to realistically evaluate various equipment combinations and management policies with a minimum of a priori knowledge.

The first requirement implies modeling such things as the time required for out-of-field equipment movement (deterministic), and the time required for equipment repairs and/or adjustment, plus their actual time of occurrence (stochastic).

The second requirement implies modeling:

1) the allocation of resources among the various functions needed to accomplish a given field activity on a given day, e.g., the field operation itself (corn combining, for instance) vs. supporting transport activities (hauling corn, for instance) vs. supporting farmstead activities (dryer operation or grain handling, for instance), and

2) the allocation of resources among two or more field activities (and their support functions) that might be performed on a given day, e.g., land preparation vs. planting vs. crop-tending field operations in late May, or harvesting vs. fall tillage activities during the harvest season.

The third requirement noted above implies a particular format for input specifications for field operations and other activities to be simulated. With continuous time simulation techniques, for instance, modeling is usually based on average rates of accomplishment or performance, e.g., field capacities in acres per hour or harvesting rates in bushels per hour must be given. If the model-user, then, is to determine the overall impact of using a larger combine, of using on-the-go combine unloading instead of stop-unloading, of using a different corn transport system, or using a new drying facility, etc., then he must assume that his labor and equipment will be able to perform in a particular way in order to specify the average performance rates needed as input.

With the proposed approach in this study, using event-oriented simulation, however, the model-user must provide only the more basic operating specifications such as preferred (or attainable) on-row equipment speeds, travel and transport speeds, handling rates, etc., plus the desired mode of operation. The simulation model, then, not the model-user, determines "how well" the labor and equipment is able to perform, i.e., it computes the average performance rates on specific days, when operating in specific fields, or for the farm as a whole over a specific season.

This could be an important distinction between the two modeling approaches, especially for the following: 1) For large operations that are composed of a number of non-contiguous land bases (where a good deal of road travel is involved in moving equipment, supplies and harvested corn), and 2) For those aspects of all systems that depend on a meshing of two or more distinct equipment and labor subsystems, e.g., a corn harvesting subsystem, a corn transport subsystem and an on-farm drying and handling subsystem (where the corn-flow output from one subsystem is the corn-flow input to the next).

It has been suggested that event-oriented simulation, and the amount of detail it requires is necessary only to evaluate equipment and policy decisions that could at best have a minor impact on the overall performance and profitability of a corn production, harvesting and marketing system. This may well be true. Until the present time, however, a simulation model had not been developed with the capability of <u>realistically</u> evaluating these "minor" equipment and policy decisions -- ones which farm managers <u>are</u> making decisions on, without the help of such a management tool.

REVIEW OF LITERATURE

Machinery Performance Measures

The _theoretical_ field capacity of a machine (TFC), in acres per hour, is SW/8.25 where S is the forward travel speed (in miles per hour) and W is the rated width of coverage (in feet). The _effective_ field capacity (EFC), in acres per hour, is the actual (or demonstrated) average rate of coverage or accomplishment by the machine based upon total field time. Field efficiency (E) is defined as the ratio of the effective and theoretical field capacity, expressed as percent, i.e., E = 100 EFC/TFC.

Effective field capacity is a commonly used measure of field machine performance in farm machinery management studies (selection, scheduling and replacement problems) to predict machine and labor time requirements. To do so the investigator normally uses the generally accepted equation EFC = SWE/8.25 (McKibben, 1930, Kepner _et al._, 1972, _Agricultural Engineers Yearbook_, 1974), where E is assigned a value based on the type or category of machine, or the conditions under which it will be operating. Out-of-field time requirements are sometimes brought into the study by simply adding some percentage of the field time for the particular operation (Stapleton and Hinz, 1974).

The effective field capacity of a machine will always be less than its theoretical capacity -- field efficiency will always be less than 100% -- due to time lost in the field and failure to utilize the full width of the machine.* Because of its importance to farm machinery management, considerable research has been conducted to determine field efficiencies for agricultural machines. Data available prior to 1971 have been summarized and reported in the Agricultural Engineers Yearbook (1974), where a typical range in values is given for most types of machines.

Time loss in the field is due to turning and idle travel, materials handling activities, cleaning, unclogging and adjusting machines, lubrication and refueling (over daily service), and waiting on other machines. Field efficiency is not a constant for a particular machine, but varies with operator capability and habits, operating policy, and field or crop conditions. For instance, a greater proportion of total field time will be needed for turning in a field with short

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* A common assumption is that row-crop machines utilize 100% of their rated width, whereas open-field implements with spaced functional units are subject to losses from overlapping (Kepner et al., 1972). The first part of this assumption is true only if the rated width of the planter and postplant row-crop machines are computed as Nw, where N is the number of rows covered or processed, and w is the average row width. The average row width may be slightly less (more) than the measured center-to-center distance between adjacent rows of a cultivator or combine cornhead (or between units on the planter), due to "mis-setting" of the planter marker device or driving "errors", or both, whether planned or unintentional. Some farmers consistently "crowd" the marker, especially with wide-row planters, to produce an average row width that is one or two inches less than the planter setting.

rows than in one with longer rows, all other factors being the same.

Renoll (1969) found that rough or narrow turn areas can increase turning time as much as 50%. Barnes et al. (1959) found a similar increase in average turning time for 6-row cultivators and planters compared to 4-row units.

Stapleton and Hinz (1974) suggest that realistic times for semicircular turns can be computed as (W/88s) + (W/40), where s is the speed of travel of the outer end of the machine (mph). The w/40 term is a "lag time" allowed to lift the machine before the turn and lower it again after the turn.

Materials handling activities can produce significant amounts of lost time in field operations. Handling bagged materials can easily occupy 25% of total field time in planting-fertilizing operations (Kepner et al., 1972). Renoll (1970) found a nearly 15% increase in planting capacity when the method of transferring water to the planter tanks for chemical application was improved. Stapleton and Hinz (1974) illustrate how cotton picker capacity might be increased about 3 % by eliminating the extra time required to "overfill" cotton trailers.

Research studies on field machine and transport system interrelationships, and their affect on field capacity and efficiency are quite limited. Von Bargen (1970) used simulation to evaluate corn planting systems, including supply transport and handling activites, for 14 Indiana farms. The simulated field efficiencies were all within the range of typical values reported in the Agricultural Engineers Yearbook (1974).

Determining Machine Performance

Time studies have been made by a number of investigators to determine field efficiencies and provide information for operations analysis. If only the field efficiency is desired, one can observe the total field time for one or more days, the average speed for performing the operation, the total acres covered, and the rated width of the machine (Kepner et al., 1972). The actual average rate of coverage can then be related to the theoretical field capacity to determine the field efficiency. Such a study yields but a single field efficiency value for the particular set of circumstances for which it was obtained: a particular machine and operator, field size and shape, operating procedure, field or crop condition, etc.

A more useful technique is to carry out detailed time studies of the various activities involved in the field operations (and/or related out-of-field activities). The type of activities timed would depend on the type of field operation under study. Planting, filling boxes, turning and delay time for adjusting, cleaning and checking the planter were used by Barnes et al. (1959) to compare 4-row and 6-row corn planters. Renoll (1966) used activities of adding seed, fertilizer and water, adjustment and downtime, turning and planting to study factor's affecting the performance of cotton planters. In a later study, Renoll (1970) obtained activity times for a cotton picker in the categories of picking, turning, dumping basket, cleaning machine, idle travel, travel to and from wagon, packing basket and other downtime. Geyer (1963) defined nearly 100 different activities related to corn harvesting and handling operations. Von Bargen (1968) proposed the five basic activities of operate, delay, travel, service and idle for describing the performance of a field machine for any scheduled period.

Using the results of such studies, models can be developed to synthesize the machine (and system) performance and field efficiencies for the almost limitless combinations of conditions and circumstances under which farm machinery is (and is likely to be) used. Renoll (1972) proposed a simple model for predicting machine performance in a particular field based on a minutes-per-acre concept for operate, turning and "support" functions. Von Bargen (1970) developed a stochastic simulation model for evaluating the performance of planting, materials transport and handling systems.

The use of models for analyzing agricultural machinery systems is presently limited by the lack of data characterizing primary and support activities for field operations, and for other facets of the system as well. Energy consumption, functional performance, capacity, costs of all kinds and interactions among system components are the kinds of data needed (Stapleton and Barnes, 1967).

Simulation Languages

There are at least two broad classes of computer simulations (Manetsch, 1969):

> "One class, called " discrete" simulations, takes a microscopic view of the world and models individual system entities or events, whatever they might be -- individual carriers or arrivals in a transportation system, individual units in a production process, etc. A second important class, called " continuous flow" simulation, essentially takes a macroscopic view of the world and models a system in terms of flows or aggregates of basic system entities or events -- flows of physical output, streams of income, and so forth."

A number of so-called "simulation languages" have been developed to simplify the task of writing simulation programs for a variety of different types of models and systems (Naylor *et al.*, 1966).* These include DYNAMO and CSMP for continuous flow simulations, and GPSS, SIMSCRIPT and GASP for discrete simulations.** The simulation languages GPSS and SIMSCRIPT are used more frequently than

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* Sammett (1969) states that programming languages have become the major means of communication between the person with a problem and the digital computer used to help solve it. The most well known language (FORTRAN) is merely one of approximately 120 languages he describes. Of these, about 20 are completely dead or on obsolete computers, 35 are receiving very little usage, 50 are for specialized application areas, and 15 are widely used and/or implemented (circa the fall of 1967).

** Several versions of many programming languages have been developed with special features and/or for use on particular computers, e.g. CSMP/360, CSMP/1130, SIMSCRIPT, SIMSCRIPT 1.5, SIMSCRIPT II, GPSS, GPSSII, GPSS/360, GASP, GASP II, GASP IIa and GASP IV. Some programming languages developed initially for discrete simulations, may have, with subsequent versions, the capability of handling continuous flow simulations.

GASP, FORTRAN and other languages for simulation programming in the United States, while SIMULA and CSL are more popular in Europe and Great Britain (Pritsker and Kiviat, 1969). The simulation language best suited for a particular study depends upon the nature of the system and upon the programming skill of the individual conducting the study (Naylor et al., 1969). For example, GPSS II is best suited to certain types of scheduling and waiting line problems, while DYNAMO is best suited to simulations of large-scale economic systems that are described by models involving complex feed back mechanisms.

Pritsker and Kiviat (1969) present the following discussion of the GASP II, SIMSCRIPT and GPSS/360 programming languages used for discrete simulations. Concerning static modeling concepts they state:

> "GASP II views the world as composed of entities that are described by attributes and related through files. A system state can be changed only if entities are created or destroyed; attribute values changed; or file contents altered. Existing in a FORTRAN framework, GASP II treats the creation and destruction of new entities logically, rather than physically, by keeping track of available columns in arrays. Arrays are used for storing attributes of entities as well as files of entities.
>
> SIMSCRIPT also deals with entities and attributes but substitutes a more general device called a set for the file. Entities are divided into two categories, temporary and permanent. Temporary entities are physically created and destroyed through special statements. Permanent entities have their attributes stored as arrays. Both temporary and permanent entities can belong to sets and own sets. SIMSCRIPT, like GASP, uses pointers to chain together entities that are members of sets; i.e., that are contained in files.

GPSS/360 deals with objects called transactions, facilities, and storages. Transactions have parameters that describe them and are generated and terminated dynamically. Facilities and storages represent permanent entities and have capacity-limited properties. Transactions may be grouped together into user chains, which can be manipulated like files and sets.

Any system modeled in SIMSCRIPT or GPSS/360, therefore, bears a strong relationship to a GASP II model as far as its static state model is concerned. It is not difficult to translate such a GASP model into SIMSCRIPT or GPSS/360 or vice versa. However, difficulties exist in modifying other features. For example, in GASP several attributes cannot be packed into one computer word. Translation may even be impossible, although usually something can be worked out except in the largest or more complex simulation."

Concerning dynamic modeling concepts they state:

"GASP II is concerned with events that occur at points in time at which system state changes take place. Events are represented by computer programs that make state changes, query the system about its past and present, and perhaps forecast its future state. The programs also schedule future state changes to take place through other events.

SIMSCRIPT has a concept similar to that of GASP. A SIMSCRIPT program contains an events program and event subroutines. But, in addition, SIMSCRIPT contains a mechanism for automatically scheduling exogenous events (externally caused events) by special exogenous event data cards.

GPSS/360 takes a different view of system dynamics. A GPSS programmer does not write a program in the same sense as a GASP or SIMSCRIPT programmer does. Instead, he constructs a block diagram made up of 45 different types of blocks, each of which performs a special simulation-oriented function. A GPSS programmer prepares a block diagram by visualizing how a typical transaction will flow through a system. Some blocks, such as ADVANCE, represent time delays. The GPSS system generates a calendar of events to make them happen. Other blocks, such as SIEZE, represent logical operations and are executed without delay. All GPSS programming takes place in the context of these 45 blocks, just as GASP II programming takes place within the context of FORTRAN and the standard GASP II subroutines and functions.

> Translations between GASP II and SIMSCRIPT, therefore, are quite direct. Translations between either GASP II or SIMSCRIPT and GPSS/360 are more difficult. Although GASP II and GPSS/360 models may have the same static structures, their dynamic models are completely different."

Naylor et al. (1966) make the following observations about discrete simulation languages: GASP represents a completely different concept in simulation languages than that offered by GPSS II and SIMSCRIPT because it is written in FORTRAN and can therefore be recompiled using any FORTRAN compiling system available to a particular analyst. Most simulation languages have been written exclusively for large-scale computers (of the magnitude of the IBM 7090/94). The fact that GASP is written in FORTRAN, a universal scientific programming language, the programmer is not likely to find it necessary to learn a new language or obtain a compiler which is not readily available for his particular computer. Programs written in GASP consist of a FORTRAN "main program" associated with an elaborate set of FORTRAN subroutines which when combined yield a very powerful simulation programming package. The advantage of this modular approach is that each person can design his own simulation language in a manner that is best suited to his particular simulation requirements.

OBJECTIVES

1. To develop a user-specific, event-oriented simulation model for corn production systems.
2. To demonstrate the use of event-oriented simulation for corn harvesting, handling and marketing.

SYSTEM BOUNDARIES AND DESIRED MODEL CHARACTERISTICS

The purpose of this study was to explore a particular model-development scheme: The use of event-oriented simulation with the discrete objects that comprise corn production systems. A number of system constraints and desirable model characteristics were established at the onset:

1) The model should be developed for an individual farming operation (an individual firm) that exists solely for the production of corn. There should be no competition for men, machines or field time from other crop enterprises.
2) The corn that is produced should be field-shelled using self-propelled combines. The use of ear-corn harvesting and handling equipment, and the use of tractor-mounted picker-shellers would not be considered.
3) The model should permit detailed simulation of <u>all</u> activities required to produce, harvest and market the corn crop, excluding the use of custom services, i.e., those activities normally performed by the men and equipment under the direct control of the farm manager. This should include, in addition to normal field operations and related on-farm activities, such

things as the transport of production supplies (mainly fertilizer) to the farm from local off-farm supply points, if not done during the "off-season", and the transport of corn from the farm to local off-farm market points.*

4) The model should be sensitive to weather-related factors that affect the performance of field activities and the development and maturity of the crop.

5) The model should permit simulation of a single crop-year or several sequential crop-years of activities. A single crop-year, it was recognized, might encompass up to three distinct calendar-years, e.g., fall tillage in 1972, planting and harvesting in 1973, and harvesting and/or off-farm marketing in 1974.

6) The model should be compatible with and complementary to the basic modeling concepts and structural considerations previously developed by Holtman et al. (1970). This should include the use of daily weather data as input, the use of special-purpose subroutines to perform often-repeated accounting functions, and

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* The movement of production supplies (seed, fertilizer, herbicide, etc.) to the farm, and their placement into an on-farm storage structure should be assumed to occur if it is done at a time when it is not in direct competition with critical field activities. Similarly, the disappearance of farm-stored corn that is marketed through an on-farm livestock enterprise should be assumed to occur, i.e., the feeding activities related to the livestock enterprise should not be simulated.

the use of "field sections" as the basic accounting unit for weather-related factors such as soil moisture, soil tractability, and various crop development items.

MODEL INPUT CONSIDERATIONS

The initial phase of the study was concerned primarily with the identification of user (farm manager) policy options and peculiarities that exist in the real world, and the selection of the most desirable ones to be included in the model development. A method of specifying these to minimize the burden for farm managers was then considered. In developing the input form (see Appendix A) an attempt was made to ask for information in a way and in terms that are commonly used or easily understood by corn producers. Much of the information needed to physically describe the farm and certain field-related policy factors, for instance, is contained on, or can easily be added to, a scale map drawing of the farm under study. Most farm managers maintain up-to-date field maps of their farms. It was understood that an intermediary would be needed to transform the information given on the input form into actual input data for the simulation model.

Operating specifications for the farm are asked for in an approximate chronological order -- production, then harvesting, then handling and marketing. In general, four types of information are requested for each broad category of operating specifications: 1) What activities are to be done, 2) What equipment is available to do them, 3) How are they to be done (special instructions or restrictions), and finally 4) How much labor is available to do them.

Not all of the special policy options shown on the input form have been developed for the present model. Four basic handling and marketing options, for instance, are shown: 1) on-farm storage of high-moisture corn, 2) in-bin layer drying, 3) batch or continuous flow drying, and 4) direct marketing from the field. Only the first and last options are possible with the present model. Information storage and model structuring, however, have been done in such a way that these other options can be developed and incorporated into the model at a later date.

MODEL FORMULATION CONCEPTS AND MANAGEMENT POLICY OPTIONS

Concurrent with the development of the input form came the formulation of certain basic modeling concepts needed to adequately deal with the desired user-options to be incorporated into the model.

Activity Period Concept

The calendar year was conceptualized as consisting of six basic activity periods in which farm managers may want to perform certain types of field operations. These are: 1) the fall land preparation period, 2) the winter land preparation period, 3) the preplant or spring land preparation period, 4) the planting period, 5) the postplant (crop tending) period, and 6) the harvest period. If desired, the model-user can specify field operations to be performed in each period. It is not necessary, however, to use all six activity periods. Some farm managers, for instance, plan no fall tillage work.

Upon completion of the field operation(s) specified for a given period the current activity period number is automatically updated by the model to the next one in which field operations are possible. Field operations for the new activity period may not be permitted, however, until certain other criterion are met. The planting and harvesting operations are always carried to completion, regardless of the calendar date or other factors. Field operations for activity periods No. 1,2,3 and 5 may or may not be carried to completion depending on the following:

1) Fall land preparation period -- This activity period terminates on the day the soil freezes in the fall if it is in effect on that day. Residue management, fertilizer application, and tillage operations are the primary activities to be carried-out during this period. Note that this activity period (1) for a given year, sequentially follows the harvest period (6) for the previous year. If harvesting extends beyond the soil-freeze date, then activity period No. 1 will not occur that particular year. The termination of activity period No. 1 marks the beginning of activity period No. 2, 3 or 4, depending on the next scheduled field operations. Activity period No. 1 (2, 3 or 4) begins the moment that the harvest operation is completed.

2) Winter land preparation period -- This activity period automatically terminates on the day the soil thaws in the spring if it is in effect on that day. Shredding stalks and spreading fertilizer (surface application) are the primary activities to be carried-out during this period. If the soil fails to freeze naturally during a mild winter,

then it is assumed to be frozen (and saturated with ground water) on March 1. The termination of activity period No. 2 marks the beginning of activity period No. 3 or 4.

3) Preplant or spring land preparation period -- This activity period is automatically terminated, if in effect, based on the preferred and mandatory start-planting dates (D_p and D_m) specified by the model-user, and the date on which the soil temperature reaches 50 degrees (D_{50}). Activity period No. 3 may terminate on --

D_m, if $D_p = D_m$

or on D_p, if $D_p < D_m$ and $D_{50} \leq D_p$

or on D_{50}, if $D_p < D_m$ and $D_p < D_{50} \leq D_m$

Field operations that are not tied to planting, i.e., that do not have to be done immediately in front of planting, are the primary activities to be carried-out during this period. These include primary and certain secondary tillage operations, and fertilizer and chemical applications. The termination of activity period No. 3 always marks the beginning of the planting period (4).

5) Postplant (crop tending) period -- This activity period automatically terminates on the day the shortest corn on the farm attains a height of 40 inches if it is in effect on that day. This plant-height criteria may be altered in subroutine PLTHT. The termination of activity period No. 5 always marks the beginning of the harvest period (6). Activity period No. 5 (or 6) begins the moment that the planting operation is completed.

The completion of all possible field operations in a given activity period marks the termination of that period, and causes the current activity period number to be set to the next one in which field operations are possible. Because of the method used to define the beginning and end of activity periods, their actual calendar dates will change from year to year in multi-year simulations. Activity period No. 1 (fall land preparation) will not occur in certain years even though the model-user has specified field operations for, if the soil freezes before harvesting is completed.

Field-Op-Status Array Concept

The model-user may specify up to five different field operations that might be performed for each of activity periods 1 through 5. In activity period No. 4, one of those operations specified must be planting.

To each different field operation (fld op) he assigns a 2-digit fld op code number, and specifies a DO BEFORE - DO AFTER fld op code number, i.e., do this fld op before the DO BEFORE fld op, but after the DO AFTER fld op in those fields that receive all three. (See Appendix A). Note that certain fld ops may be specified as possible in two or more different activity periods, e.g., plowing might be specified in periods No. 1 and 3, bulk spreading P and K in periods No. 1, 2 or 3, knife-down N in periods No. 3 and 5, and so forth.

The model-user may also impose restrictions on the performance of fld ops, on a whole-field basis, as follows (see Appendix A):

1) Fld op I may only be performed in certain fields (maximum of five) during activity periods No. 1 and 2. Example: all other fields in the farm may have too much erosion or runoff potential to permit fall plowing or the surface application of fertilizers in the fall or winter.

2) Fld op I may not be performed in certain fields (maximum of five) during activity periods No. 1 and 2. This is the inverse of the previous restriction.

3) Fld op I should be performed on only a portion of the total acreage each year in a rotational manner: Example: bulk spread P and K on only a third of the total acreage each year, and do it in such a way that the whole acreage is covered in each three-year period.

4) Fld op I should be performed on the whole acreage every n years ($n \geq 2$). Example: bulk spread P and K on the whole acreage every two years, do no spreading of P and K every other year.

5) Fld op I is to be performed on only a portion of the total acreage each year in a random manner. Example: rotary hoeing or cultivation may be needed somewhere on the farm each year, but never on the whole acreage and not necessarily in the same fields. The portion to be covered each year (%) is specified. Optionally, up to five "problem" fields may be specified.

6) Fld op I (I = 30, harvesting) may be eliminated in certain fields (maximum of five) that are to be harvested as whole-plant corn silage.

7) Fld op I and fld op J should not be performed in the same field in any given crop year (up to ten pairs of complementary fld ops may be specified). Example: A farm manager may knifedown N, either preplant on plowed ground or postplant as a sidedress operation, only in those fields that were not fall plowed _if_ he applies N _with_ the plowing operation in the fall.

8) Fld ops I, J, K ..... should be done "sequentially" or "concurrently" during a particular activity period. Example: If discing stalks and plowing are the only two fld ops possible during the fall land preparation period, then one farm manager may prefer to do as much discing as possible and then switch to plowing, while another may prefer to disc a field, then plow it, disc another field, then plow it, etc.

In addition to these types of restrictions, there are certain weather-related factors which will affect the adviseability of performing a particular fld op in a particular field on a particular day. The corn in fields that were planted on different days, for instance, will reach "lay by" height on different days (precluding the completion of certain postplant fld ops). Similarly, the corn in different fields will reach maturity (in the absence of an "early freeze") on different days, and a "harvestable" moisture content may be reached in different fields on different days.

To assist with the accounting needed to implement these types of restrictions and policies, a fld-op-status array was established to indicate the work-status of fld ops in all fields during the activity periods. The fld-op-status array may be conveniently thought of as 12 columns of information, each with 33 rows (or lines or entries). During simulation each non-empty column represents:

1) a complementary fld op completed in an earlier activity period (note -- if fld op I and J are complementary, then fields that receive I should not receive J this year),
2) a fld op for the current or a later activity period which has already been completed, which is now being done, or which has not yet been started.

The first n rows in each column (n = number of fields ≤ 30) contain numbers corresponding to the current work-status of the fld op in each field. The remaining rows in each column contain:

row 31 = the fld op code number

row 32 = the activity period (1-6) in which the fld op is to be done

row 33 = the fld op completion indicator, e.g., 1 means this fld op has not yet been started, 2 means it has been started, but is not yet complete, and 3 means it has been completed.

Work-status values (S) which a field may have were defined as follows:

$0 \leq S \leq 4$	This field is not to receive this fld op this year.
$5 \leq S \leq 9$	This field is not yet ready to receive this fld op. Status is to be reset to the next level as soon as certain climatic or plant height conditions are met.
$10 \leq S \leq 14$	This field is not yet ready to receive this fld op. Status is to be reset to the next level as soon as all required "prior" fld ops are completed in the field.
$15 \leq S \leq 19$	This field is now ready to receive this fld op.
$20 \leq S \leq 24$	This field is now "in-process", i.e., this fld op has been started in this field but it has not been completed.
$S \geq 25$	This field is finished, i.e., this fld op has been completed in this field. S is set to the completion date.
$S < 0$	Certain conditions were encountered which precluded the starting and/or completion of this field op in this field. S is set to - mmddaaaa.aa, where mm, dd is the month, day on which this happened, and aaa.aa is the number of acres in this field that did not receive the fld op.

Two programs were developed to perform the primary accounting functions associated with the fld-op-status array. These were subroutine STATUS, a general purpose routine, and subroutine CORNMS, a special corn-moisture-status routine.*

During simulation subroutine STATUS may be called in three different types of situations:

* Three other subroutines were also developed to assist with the mechanics of information storage and retrieval, and with the testing of subprograms that use the fld-op-status array: FINDEM -- to find a column in the array with a particular value in one of its 33 rows; RMOVEM -- to remove an entire column of information from the array; and PRTFOP -- to print the entire contents of the array (a table 12 columns wide by n+3 rows deep, where n = the number of fields).

1) At the beginning of each new activity period. With this type of call STATUS examines the fld ops in the fld-ops-status array, removes those that are not complementary fld ops and that cannot be done in the new activity period or a later one, and then loads-in new fld ops for the new activity period. Before fld ops are removed from the fld-op-status array (and the information lost), STATUS calls a special print routine (subroutine COLPRT). At the beginning of the harvest period (6), fld ops are also loaded for activity periods No. 1 and 2, and at the beginning of the planting period (4), fld ops are also loaded for activity No. 5. This insures that men and equipment will be active (in multi-men, multi-tractor situations) when work could be done, if needed, on fld ops planned later.

2) Daily, after planting has begun, when postplant fld ops are possible. With this type of call STATUS sets a "ready" work-status for those fields in which at least one field section meets the "ready" requirements for postplant operations, and a "no-completion" work-status for those fields in which the corn in all field sections has grown too tall to complete the postplant operations. The "ready/no-completion" criterion being used is:

fld ops	set "ready" work-status when --	set "no-completion" work-status when --
rotary hoeing	elapsed time since planting ≥ 8 days, or a 1" rainfall has occurred since planting	corn ht. ≥ 5"
cultivation	corn ht. ≥ 5"	corn ht. ≥ 40"
field spraying	corn ht. ≥ 15"	corn ht. ≥ 40"
sidedressing N	corn ht. ≥ 15"	corn ht. ≥ 40"

STATUS recognizes these fld ops due to special implement codes (see input form, Appendix A). The "ready/no-completion" criterion to be used may be altered in subroutine STATUS.

3) On the day the soil freezes prior to the completion of harvesting when fld ops are possible in the fall land preparation period. This special call to STATUS will set a "not-yet-ready" work-status in those fields that have not yet received a fld op if it cannot be done in activity period No.2 (winter land preparation).

Subroutine CORNMS is called each day during the harvest period to update the work-status of unharvested fields based on the kernel moisture content of the corn. A total of three kernel moisture specifications may be supplied by the model-user. These are MC_{max} and MC_{min}, the preferred moisture content range when corn is being harvested for on-farm high-moisture storage; and MC, the maximum moisture content allowed when corn is being harvested for all other handling and marketing options(in-bin layer drying, batch and continuous flow drying, or direct from the field marketing). The model-user also specifies a mandatory start-harvest date, beyond which harvesting is allowed regardless of kernel moistures. With the present model, an attempt is made to satisfy the on-farm high-moisture storage option, if it is selected by the model-user, before harvesting for the other options is permitted. To "satisfy" this option, the entire storage capacity so designated must be filled with high-moisture corn.

Assuming that the mandatory start-harvest date has not been reached, and designating the high-moisture storage option as "A" and all other options as "B", subroutine CORNMS establishes the following work policy for fields in which harvesting has not yet begun:

1) "A" has been satisfied -- set a "ready" work-status for the field if at least one field section has a kernel moisture $\leq$ MC. Note -- If "A" has been satisfied and harvesting is still not complete, then the model-user must have selected at least one of the "B" options, otherwise he must insure that enough high-moisture storage capacity is available to hold

the largest quantity of corn that will <u>ever</u> be produced.

2) "A" has not been satisfied -- set a "ready" work-status for the field if at least one field section has a kernel moisture in the desired range ($MC_{max} \geq$ kernel moisture $\geq MC_{min}$). If the kernel moisture drops below MC_{min} in all field sections, then set a temporary "no-completion" work-status for the field. If there are no partially-harvested fields remaining, and if all other fields have a temporary "no-completion" work-status, then a) set a "ready" work-status for all other fields if "B" options have not been specified, or b) switch to "B" option harvesting and set a "ready" work-status for fields in which at least one field section has a kernel moisture $\leq$ MC.

The fld-op-status array is used, among other things, as a quick-scanning device at the start of each day (in subroutine GOFLDS) to determine if field work can be done anywhere on the farm that day. At the completion of a fld op in a particular field, a "completed" work-status is set by the routines controlling the simulation of the fld op activity. At the same time, these routines examine the other fld ops in the fld-op-status array, if any, and may update the work-status of the field for another fld op, e.g., if the fld op just completed in a field was harvesting, then discing stalks or fall plowing may now be permitted in this particular field.

Activity Class Concept

Primary emphasis in the model is on the simulation of field activities, i.e., plowing, planting, harvesting, hauling corn away from the combine, and so forth. There are in the real world, however, certain non-field activities that are necessary or essential to the conduct of field operations and to the overall success or profitability of the farm business.

Tractors, combines and other engine-powered equipment must be refueled and receive daily or extended-period maintenance if they are to perform the field and non-field activities required of them. Daily maintenance is the checking of fluid levels in engines, the lubrication of chains, sprockets and bearings, etc., which may require 5 - 30 minutes of operator time. Extended-period maintenance is the replacement of engine or transmission oils, the replacement or servicing of filters, etc., which may require an hour or two (up to a half-day) of operator time.

Daily and extended-period maintenance may appear insignificant in the total picture, but they <u>do</u> reduce available field time for the men and machines involved, if they must be performed on a day when field activities are possible, as it often happens in the real world. In most cases, the performance of these activities on rainy days, especially extended-period maintenance, in preparation for the next good work day, will improve the performance of man-machine combinations.

The same thing can be said of the harvesting-hauling equipment subsystems if the simulation model would allow on-farm drying and handling (an essential non-field activity on certain farms), to be done on days when the harvester could not be operated, i.e., on a non-harvest day following a harvest day. This _is_ allowed, and done routinely in the real world, especially with the two systems: 1) _batch-in-bin drying_, where the batch of corn that was dried and cooled out overnight must be transferred out of the bin, either directly into storage or into transport vehicles, before more wet corn can be placed in the bin, and 2) _portable batch or continuous flow drying_, where transport vehicles are used to "accumulate" wet corn on the input side of the drier, or to receive dry corn on the output side of the drier.

Another non-field activity which many farm managers must deal with is the marketing function associated with farm-stored corn. Corn that is stored on the farm at harvest-time, but which will not be utilized on the farm (through a live-stock enterprise), must be marketed, usually before the start of the next harvest period. Some farm managers do this by arranging to have a custom hauler pick up the corn at the farm, usually in semi-truck-laod lots. Others perform this function themselves, hauling the corn in farm owned transport vehicles to local elevators.

In both cases, the following is usually true:

1) This activity will involve a certain amount of farm-personnel time, and equipment time. Equipment time in the first case may be only for farmstead equipment (augers, bucket elevators, electric motors, etc.). In the latter case it may be for farmstead equipment plus the transport vehicles (trucks or wagons pulled by tractors).

2) This activity will be carried-out within the framework of an overall marketing strategy, which the farm manager can verbalize, though not necessarily in explicit terms. The marketing strategy may be flexible enough to take advantage of, or may be based on, favorable market price changes or trends.

3) This activity will not take precedence over the performance of field work, if both types of activities can be done on the same day and if both require the same personnel and/or equipment. If marketing corn and field work are both feasible

activities on a given day in mid-May, for instance, then the field work will normally have top priority -- the marketing activity being delayed until field operations are suspended.

Thus the capability of simulating a different type of non-field activity is desireable, with certain kinds of systems, on days when field activities cannot be done.

To account for these types of real-world situations in the model developed, the following activity classes were defined:

Activity Class 1 -- Field work, i.e., all field operations and the transport functions (supplies, corn) needed to support them.

Activity Class 2 -- General farmstead work, i.e., the refueling, maintenance and servicing of equipment, plus the drying and handling of corn during the harvest period.

Activity Class 3 -- Corn marketing work, i.e., the transport functions and/or farmstead operations needed to market farm-stored corn at an off-farm location.

At the beginning of each day, class 1 activities have top priority. If field work is not possible, then class 2 activities have the next highest priority. If general farmstead work is not needed, then class 3 activities have the next highest priority. If corn marketing work is not needed, then no activities, either field or non-field, will be simulated that day.*

Activity class indicators were established within the model, and may assume the following values to indicate that the particular class of activities:

0.0 - is not planned and will never be needed during this simulation run

1.0 - is feasible, but is not needed or possible at this time

2.0 - is feasible, and should be done at the earliest opportunity in simulated-time

A total of six activity class 1 indicators were established -- one for each activity period. These are used in the present model to control activity period sequencing, i.e., updating the current activity period number when needed, managing the fld-op-status array, etc. The other activity class indicators are checked as needed at the start of each day, as indicated earlier, on days when field work cannot be done.

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* Actually this is not quite true with the present model. A special activity class 4 was defined to allow on-farm drying, handling and storage activities to be performed on Sunday, even though the model-user had specified that labor was not available for Sunday work. This seems reasonable in terms of the real world: many farmers will not haul corn to market or do field work on Sundays, or perform messy maintenance jobs, but they may be willing to check on the drier occasionally, or push a few buttons to move corn around, especially if it appears that Monday will be a good harvest day, or if climatic conditions are such that excessive mold activity may develop in the wet corn on hand.

All activity class indicators are managed internally. The class 1 indicators are set initially to 1.0 if fld ops are planned for the activity period (for initial loading of the fld-op-status array), then reset to 2.0 at the beginning of the activity period. The routines controlling the actual simulation of field activities reset a 1.0 value at the completion of the last fld op to be done in the activity period.

Daily Simulation Concept

The overall model structure developed is shown in Figure 1. After initialization, control is transferred to a daily loop until all activities for the simulation run are complete. Final summaries are then printed and the run ends.

At the beginning of the daily loop a new date is generated, and a check is made to see if all field activities have been completed. If they have been, all that remains is the simulation of drying and handling, or off-farm marketing activities, so a check is immediately made to determine if these activities may be simulated on this day. Otherwise, today's weather is read, and selected state variables of the system are updated. If today marks the beginning of a new activity period (soil will become frozen or un-frozen, start-planting or start-harvest dates have been reached, corn will become too tall to complete postplant fld ops, etc.), then the fld-op-status array and attributes

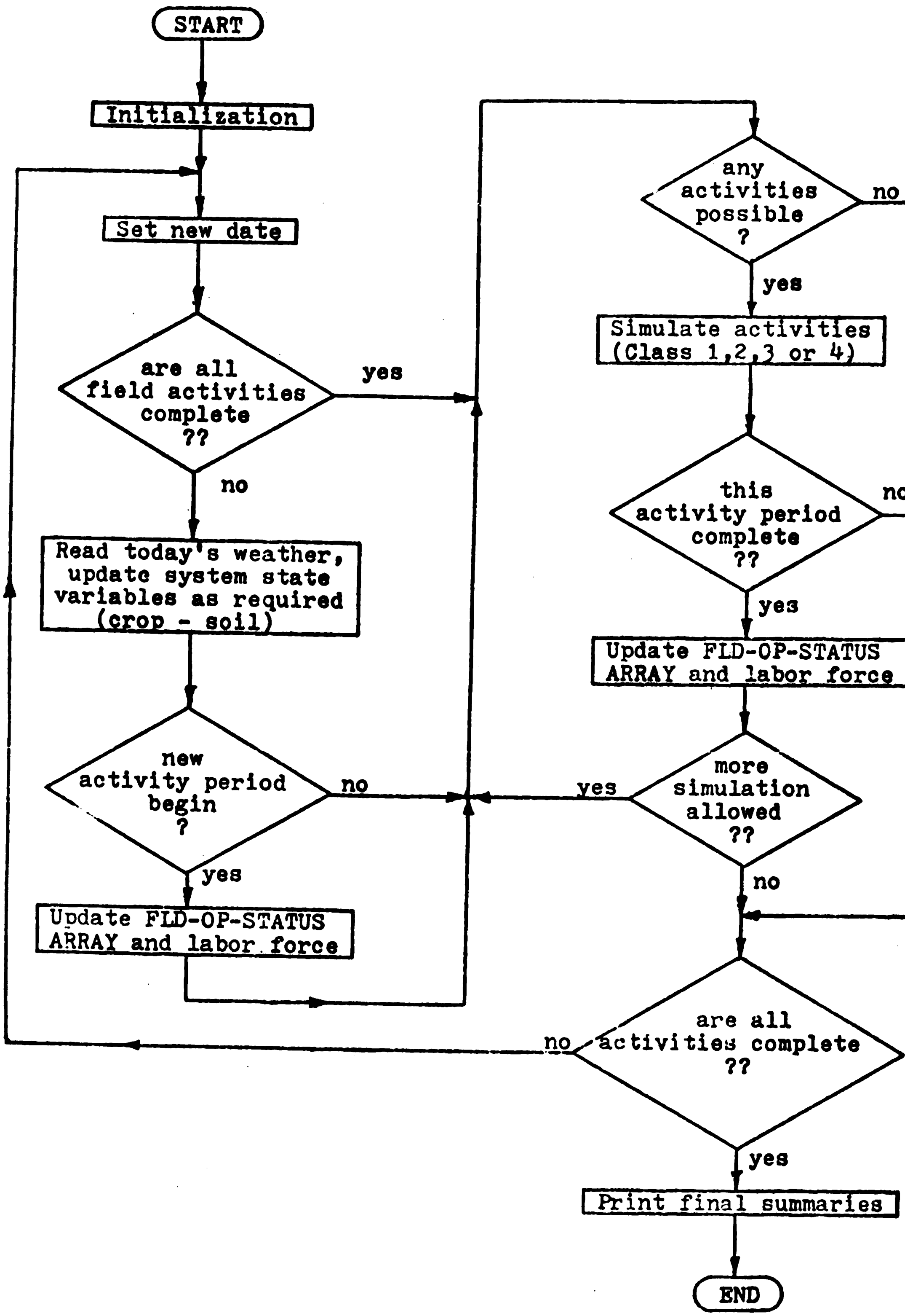

Figure 1. Overall Model Structure.

of the labor force are updated before checking to determine if activities of any kind may be simulated today.

If activities are possible, then control remains with the routines that perform actual activity-simulation until all available labor or field time for the day has been used, or until additional activity-simulation is no longer possible: 1) the field, farmstead or marketing activities are completed, 2) non-tractable soil conditions are encountered, or 3) kernel moistures too high for harvesting are encountered. If the completion of this activity-simulation marks the end of the current activity period (all possible fld ops for it are finished), then there may still be some labor and field time left for today which could be used to simulate activities in the next activity period. The fld-op-status array and attributes of the labor force are updated. Then a decision is made as to whether or not more activity-simulation will be allowed today. If it will, control transfers back to determine if activities of any kind (in the new activity period) may be simulated today.

The current activity period and date of initial entry into the daily loop at the beginning of a simulation run depends on the feasibility of field operations in activity periods No. 1 and 2 (fall and winter land preparation), and on the soil state (frozen - unfrozen) on November 15 preceeding the initial planting period as follows:

fld ops possible in activity period		soil frozen on November 15	date (activity period) of initial entry into daily loop
No. 1	No. 2		
yes	yes	no	Nov. 15 (1)
yes	yes	yes	Nov. 15 (2)
yes	no	no	Nov. 15 (1)
yes	no	yes	Mar. 1 (3 or 4)
no	yes	---	Nov. 15 (2)
no	no	---	Mar. 1 (3 or 4)

This is automatically determined by initialization subroutine SETDAT. (Note -- It is the model-user's responsibility, however, to provide adequate weather data for making this determination -- see Daily Weather Records below.)

Master time variable IDATE

The first thing computed at the beginning of each day is the master time variable IDATE, a composite 6-digit integer number mmddyy, where mm = the month (01-12), dd = the day (01-31), and yy = the last two digits of the year, e.g., 74 for 1974. This is done by subroutine DATE2, a modified version of subroutine DATE (Holtman et al., 1970).

DATE2 computes today's date based on yesterday's date, taking into consideration that February has 29 days (Leap year) when yy is an even multiple of four. Note that IDATE for the start of the simulation run must be read as input. DATE2 also computes or resets the following indicator variables:

a) The day-of-the week (1 = Monday, 2 = Tuesday,..... 7 = Sunday), which must also be initially read as input.

b) The day count from March 1, where March 1 = 1, February 28 = 365 and February 29 = 366.

c) The last day of the current month, number of days from March 1, which might be used (at some future time) as a signal for the collection of cash flow data, the resetting of variables for marketing farm-stored corn, etc.

Daily weather records

Values for six different weather variables must be provided as input for each day of the simulation. These are maximum, minimum and wet bulb air temperatures (all in degrees F), and precipitation, open pan evaporation and snow depth for the day (all in inches).

Subroutine CLMAT2, a modified version of subroutine CLIMAT (Holtman et al., 1970), reads matched sets of date/weather records until the records for the current day, IDATE, are found. If a value for open pan evaporation has not been provided, then subroutine NOPAN (Holtman et al., 1970) estimates a value for the particular day.

If fall land preparation is feasible with a particular simulation run, then the weather records provided must begin with the October 1 data preceding the first planting period, so that the soil state on November 15 can be determined. Otherwise the weather records may begin with March 1 data. The last set of weather records required is the February 28 (or 29) data following the last calendar year in which planting is to be simulated.

Updating system state variables

Certain state variables* of the system are updated at the start of each day before any activity-simulation takes place. These are state variables related to soil factors and crop development that are affected by weather conditions. The updated values are retained throughout the day.

Special-purpose subroutines are used for this daily state variable updating:

FREEZ -- This subroutine, developed by Fridley (1971), is called on consecutive days in the spring and fall to determine when the soil thaws and freezes. It computes and maintains an accumulated heat unit total (base 32 degrees F) for the soil as a whole using average air temperatures.**The heat units accumulated on a given day is divided by six if the ground is covered by snow on that day. To declare the soil unfrozen, (spring thaw date), +25 heat units must be accumulated. To declare the soil frozen (fall freeze date), -110 heat units must be accumulated.

*A state variable is an attribute of some component of the system whose value does not remain constant. The collective value of the variable attributes of the system at any point in time defines the state of the system at that time. The size (attribute) and soil type (attribute) of a particular field are constants. The soil moisture (attribute) of the field and its crop height (attribute) are examples of attribute values that usually change with time (and weather).

**The heat unit for a given day is the number which results when the degree-base is subtracted from the average of the maximum and minimum air temperatures for the day.

STEMP -- When required (preferred ≠ mandatory start-planting dates), this subroutine, also developed by Fridley (1971), is called on consecutive days in the spring to compute soil temperature. The routine is a first-order delay with average air temperature as input, and is based on the FORDYN subroutine DELDT.

(Note -- The remaining subroutines discussed here update the state of individual field sections, of which there are 100 in each farm being simulated. This division of the farm into 100 field sections is done by initialization subroutine FARM1 using the field or (large) field section information supplied by the model-user.)

SOILMC -- This subroutine, developed by Holtman *et al.* (1970), called each day on which the soil is in an unfrozen state to update the moisture content of the soil. Moisture information is maintained for three soil layers in each section, to a depth of six inches: the first soil layer is 1.2 inches thick, the second is 1.8 inches thick and the third is 3.0 inches thick.

Moisture adjustments are based on precipitation, runoff and potential evapotranspiration for each day. Runoff is assumed to occur if a half-inch or more of precipitation is received on any given day. The amount of runoff, and thus the quantity of water to be absorbed by the soil is a function of the precipitation received that day and during the last nine days. The computation of evapotranspiration is based on open pan evaporation for the day and the ratio of the actual and maximum available moisture in the soil layers.

The maximum available moisture of the soil is user-dependent. A total of twelve soil types, each with different moisture holding capacities were defined. The model-user may specify a total of two different soil types for each field in the farm, and the percentage of the field to which each applies. Initialization subroutine SETH20 then sets the moisture holding capacity for each section of the field using pre-set values for the three soil layers of each soil type. The percentage figure provided is applied on a whole-section basis, e.g, if the model-user indicates that a particular field is 40% soil type 7, the rest being soil type 8, and if this field is composed of 12 field sections, then 5 of the sections will be set for soil type 7, the rest for soil type 8.

HUP -- This subroutine, developed by Holtman *et al.* (1970), is called on consecutive days during the growing season. It computes and maintains an accumulated heat unit total (base 50 degrees F) for each field section that has been planted, but has not yet matured.

PLTHT -- When required (postplant fld ops are planned), this subroutine is called on consecutive days during the growing season. It computes and maintains the plant height for each field section that has been planted.

The computation of plant height for a given field section is based on the ratio $R = HU_{rec}/HU_{req}$, where HU_{rec} is the number of heat units received since planting (as maintained by subroutine HUP), and HU_{req} is the number of heat units required to (naturally) mature the corn hybrid planted in the field section.* Emergence of the corn is assumed to occur at R = 0.06. A straight-line relationship for plant height is assumed between R = 0.06 (plant emergence) and R = 0.26 (a 40-inch plant height).

When the corn in all field sections reaches a height of 40 inches (too tall for postplant fld ops to be done), PLTHT sets an indicator to show this, then zeros the plant height in all field sections. Daily calls to PLTHT are suspended from this day forward, until the start of planting in the following year.

MAT2 -- This subroutine, a modified version of subroutine MAT (Holtman et al., 1970), is called on consecutive days during the latter part of the growing season.

* The routines that control activity-simulation, namely the planting routine, must record the particular hybrid type planted in each field section. Only three hybrid types are allowed with the present model: 1) a short-season hybrid, 2)a medium-season hybrid, and 3) a full-season hybrid. When the model-user specifies the planting policy to be used (based on hybrid types 1, 2 or 3), he must also specify a latitude code for the farm. Initialization subroutine SETHYB uses this latitude code to set values for several hybrid type characteristics, including the number of heat units required for maturity. As an example, latitude code 6 (for farms in the northern third of Indiana or on an equivalent latitude in other states) would cause the number of heat units required for maturity to be set at 2400 for hybrid type 1, 2500 for hybrid type 2 and 2600 for hybrid type 3.

It compares the heat units received since planting (HU_{rec}) in each field section with the heat units required (HU_{req}) to mature the corn hybrid planted there. On the day that $HU_{rec} \geq HU_{req}$ in a particular field section, the corn in that section is declared mature, i.e., MAT2 sets the maturity date to IDATE and the kernel moisture to 30 percent, wet basis (w.b.).

Should a killing freeze occur, i.e., minimum air temperature of 28 degrees F or lower, MAT2 immediately declares maturity for all field sections not previously declared mature. In so doing it sets the kernel moisture in these sections to 30% plus 0.05% times (HU_{req} - HU_{rec}), e.g., a 100 heat unit deficit would result in the kernel moisture being set to 35%. If the model-user specified a start-harvest kernel moisture that is greater than 30%, then MAT2 routinely uses this same relationship and computes (daily) the kernel moisture of all field sections not previously declared mature.

YIELD2 -- This subroutine, a modified version of subroutine YIELD (Holtman *et al.*, 1970), is also called on consecutive days during the latter part of the growing season. It examines the maturity date of each field section, and computes the potential harvestable yield (Y) on the day that each section is declared mature using the relationship

$$Y = Y_p \times F_h \times F_d \times F_f$$

where Y is in bushels per acre.

The term Y_p is the maximum harvestable yield (bu/acre) that might be expected in this field section if the best hybrid type available were planted here at the optimum time during the planting period. This value is user-specified (on a field basis).

Factor F_h is the decimal fraction (≤ 1.0) of the maximum yield possible if the hybrid type actually planted in this field section had been planted at the optimum time. This value is set by initialization subroutine SETHYB to 0.85 for short-season hybrids, 0.90 for medium-season hybrids, and 1.00 for full-season hybrids.

Factor F_d is based on the stochastic yield model developed by Tulu _et_ _al_. (1973), and depends on the actual date of planting in the field section and the normalized yield curve generated for the particular year.

Factor F_f is a decimal fraction ($0.6 \leq F_f \leq 1.0$) corresponding to a yield penalty if the corn in this field section matured abnormally, i.e., due to a killing freeze. The percent yield reduction (maximum of 40% allowed) is computed as $2R^2$, where $R = (HU_{req} - HU_{rec})/100$, HU_{req} being the heat units required for maturity, HU_{rec} the heat units received since planting.

CORNMC -- This subroutine, developed by Holtman et al. (1970), called on consecutive days during the latter part of the growing season and throughout the harvest period. For each field section that is mature, but not yet harvested, CORNMC updates the kernel moisture based on field drying conditions for the day, which is a function of the maximum, minimum and wet bulb air temperatures of that particular day.

Since all of these subroutines are not needed to update state variables on every simulation day, special indicators are automatically maintained to control the calls.* Each subroutine is called on consecutive days through the daily loop according to the following:

	First Day Called	Last Day Called
Soil Related		
Sub. FREEZ	March 1 for spring thaw	Day of spring thaw
	Sept. 1 for fall freeze	Day of fall freeze
Sub. STEMP	Day of spring thaw	Day soil temp ≥ 50°
Sub. SOILMC	Day of spring thaw	Day of fall freeze
Crop Related		
Sub. HUP	Day after planting starts	Day last corn matures
Sub. PLTHT	Day after planting starts	Day last corn ≥ 40"
Sub. MAT2	August 1	Day last corn matures
Sub. YIELD2	Day first corn matures	Day last corn matures
Sub. CORMC	Day first corn matures	Day harvest ends

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* Certain of these special indicators are reset, and a number of other "initialization" functions performed, by a call to subroutine SETMAR on the first day of March each year of the simulation.

Declaration of an activity-simulation day

An activity-simulation day is declared whenever possible for the highest-priority type of activities possible. Figure 2 illustrates the procedure used to set MCLASS, the highest priority class of activites that may be simulated on a given day. MCLASS = 1 (field operations possible) is the highest priority setting -- see discussion under Activity Class Concept.

After setting MCLASS to a tentative value of 1, subroutine RESET1 checks the activity period criterion that must be met in order for fld ops to be possible today. Two example situations are considered here for illustration:

1) Activity period 3 (preplant or spring land preparation) is in effect today. Setting of the activity period to 3 may have occurred at the conclusion of harvest (6) last fall, or at the conclusion of fld ops in activity periods No. 1 or 2. But activity period 3 fld ops are not permitted until after March 1, and then only after the spring thaw of the soil has occurred. Set MCLASS = 2 if these criterion have not been met.

2) Activity period 4 (planting) is in effect today. Again, setting of the activity period to 4 may have occurred at the conclusion of harvest (6) last fall, or at the conclusion of fld ops in activity periods No. 1, 2 or 3. But planting period fld ops are not permitted until the preferred start-planting date has been reached (and then only if the soil temperature is 50° or greater), or until the mandatory start-planting date has been reached. If these criterion have not been met, then set MCLASS = 2.

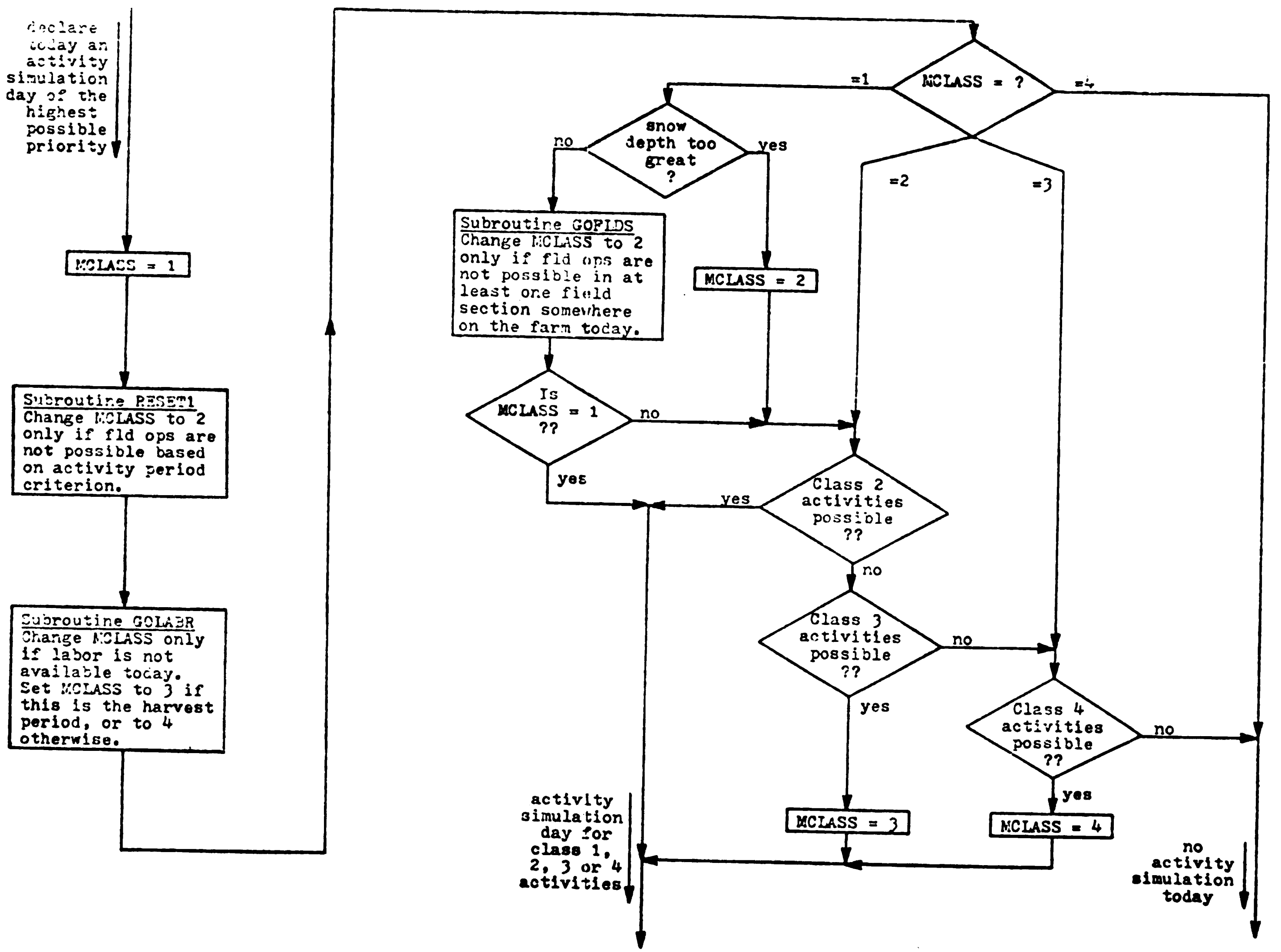

Figure 2. Declaring An Activity-Simulation Day.

Note that setting MCLASS = 2 only rules out the simulation of class 1 activities (fld ops) for the day, while class 2 or 3 activities may still be possible.

Subroutine GOLABR next considers labor availability factors for the day. If labor is available, then MCLASS is unchanged (from its current setting of 1 or 2), and GOLABR sets MDAY = 1, 3 or 5 if today is a weekday, a Saturday or a Sunday. This MDAY-value will be used later to set the overall time limits for simulation if today is declared an activity-simulation day.

In determining if labor is available, GOLABR may check up to three different labor schedules if activity period No. 4 (planting) is currently in effect. The model-user may specify different (or identical) labor schedules for the before May 3 time period, the May 3 - May 23 time period, and the after May 23 time period.

If labor is not available, then today must be Saturday, or Sunday, since weekday labor is always available, and GOLABR will take the following action:

1) Set MCLASS = 3, MDAY = 1 if the harvest period (6) is currently in effect.

2) Set MCLASS = 4, otherwise.

The MCLASS = 3 setting will allow class 4 activities (on-farm drying and handling only) to be simulated today, if they are needed, using the harvest-time, weekday labor schedule. The MCLASS = 4 setting is a special signal that no activity-simulation of any kind will be allowed today since labor is not available.

If MCLASS is still set at 1 (fld ops still possible) after considering labor, then the snow depth for the day is checked. The snow-depth criteria (currently set at 3 inches) is defined in subroutine SETCON. Its purpose is to prevent harvesting and other activity period No. 1 and 2 fld ops if the actual snow cover for the day is too great.

If MCLASS is still set at 1 (fld ops still possible), then subroutine GOFLDS is called to determine if there is at least one field section somewhere on the farm in which a field operation of some type could be performed. If one cannot be found, then MCLASS is changed to 2.

GOFLDS considers individual fld ops one at a time. During the planting period (4) and harvest period (6), it examines the planting fld op and harvesting fld op first, respectively, then considers other non-plant, non-harvest fld ops that might be possible, in the sequence they were loaded in the fld-op-status array.

In order to exit subroutine GOFLDS with MCLASS = 1, a field section must be found which:

1) is ready, but has not yet received the fld op

and, 2) is tractable, i.e., the soil is able to support field equipment.

Note that "ready" implies a soil temperature of 50°F or greater prior to the mandatory start-planting date, for the planting field operation itself. Soil temperature is maintained for the farm as a whole, and is assumed to be the same in all field sections. "Ready" also implies a kernel moisture in the desired range prior to the mandatory start-harvest date when the fld op being considered is harvesting. Recall that subroutine CORNMS set a "ready" work-status for the field as a whole if at least one field section was in the desired kernel moisture range. The kernel moisture in individual sections must be examined if some harvesting has already been done in the field being considered.

All field sections are considered tractable if the soil is in the frozen state. If it is not, then subroutine TRCBL2, a modified version of Holtman's subroutine TRACBL, is called by GOFLDS. A single call to TRCBL2 sets the tractability state of all field sections in the farm. To declare a section tractable, the ratio of the actual available soil moisture to the maximum available soil moisture must be 0.95 or less in the top 2 soil layers. For those soils classified as "medium" or "heavy", this ratio must be 0.985 or less in the third soil layer also. The tractability criterion to be used in each field section, i.e., assignment of a light, medium or heavy classification, is automatically done in initialization subroutine SETH2O at the same time that the moisture holding capacity of the individual soil layers is set.

For a given field operation, subroutine GOFLDS initially checks the first and last field section for each field in which the fld op has not yet been started. It then considers fields that are "in-process", checking only the first field section, the last field section and/or those field sections that bound the "unworked" areas in the field. The sections that are actually checked will depend on the particular field pattern being used with the field operation. The information needed to do this is contained in GASP files 9 (current field operations possible) and 10 (fields currently in-process) discussed later.

Subroutine GOFLDS is exited as soon as a field section which meets the GO-criterion is found (with MCLASS = 1), or only after exploring all possibilities for field work and finding none (set MCLASS = 2). If the field section which meets the GO-criterion was found while considering the harvest operation, then GOFLDS calls subroutine LODGE. This routine computes and records the amount of stalk lodging that has occured to-date in all mature and unharvested field sections. It is based on a lodging function developed by Holtman et al. (1970), and depends solely on the number of days since physiological death of the corn in the section and a varietal constant multiplier. This multiplier is set, for the currently-used short-, medium- and full-season hybrids, by initialization subroutine SETHYB.

On exit from subroutine GOFLDS, the MCLASS setting is immediately checked. If field operations are still possible, an activity-simulation day for class 1 activities is declared. Otherwise, the need for class 2, 3 or 4 activities is determined (by testing the activity class indicators discussed earlier) in sequence. The declaration of an activity-simulation day may or may not occur.

<u>Whole-day vs. partial-day activity-simulation</u>

To initiate activity-simulation, subroutine MYSET is called to set overall time limits: TNOW is set to the earliest starting time of all the men in today's labor force, and TFIN is set to the latest quitting time of all the men, i.e., a target time which will signal the end of activity-simulation for the day.

Activity-simulation may terminate prior to TFIN, however, for several reasons. If non-field activities were being simulated, for instance, they may have been completed prior to TFIN because there simply wasn't that much to do. If field activities were being simulated, then the reasons for an "early" termination include:

1) A non-tractable field section was encountered in the field being worked, and another suitable field could not be found.

2) A field section with kernel moisture outside the desired range for harvest was encountered in the field being harvested, and another suitable field could not be found.

3) The fld op being done was completed in one field, and another suitable field could not be found.

4) The fld op being done was completed in the final field that was to receive it, and this completed all fld ops possible in the current activity period. In this case the routines controlling the activity-simulation should reset the activity class 1 indicator for the current activity period from a value of 2 (fld ops for this period not completed) to a value of 1 (fld ops completed).

The means used to test for "early" termination (partial-day activity-simulation), and to decide what to do about it is illustrated in Figure 3, where TNOW is the current simulation clock time.

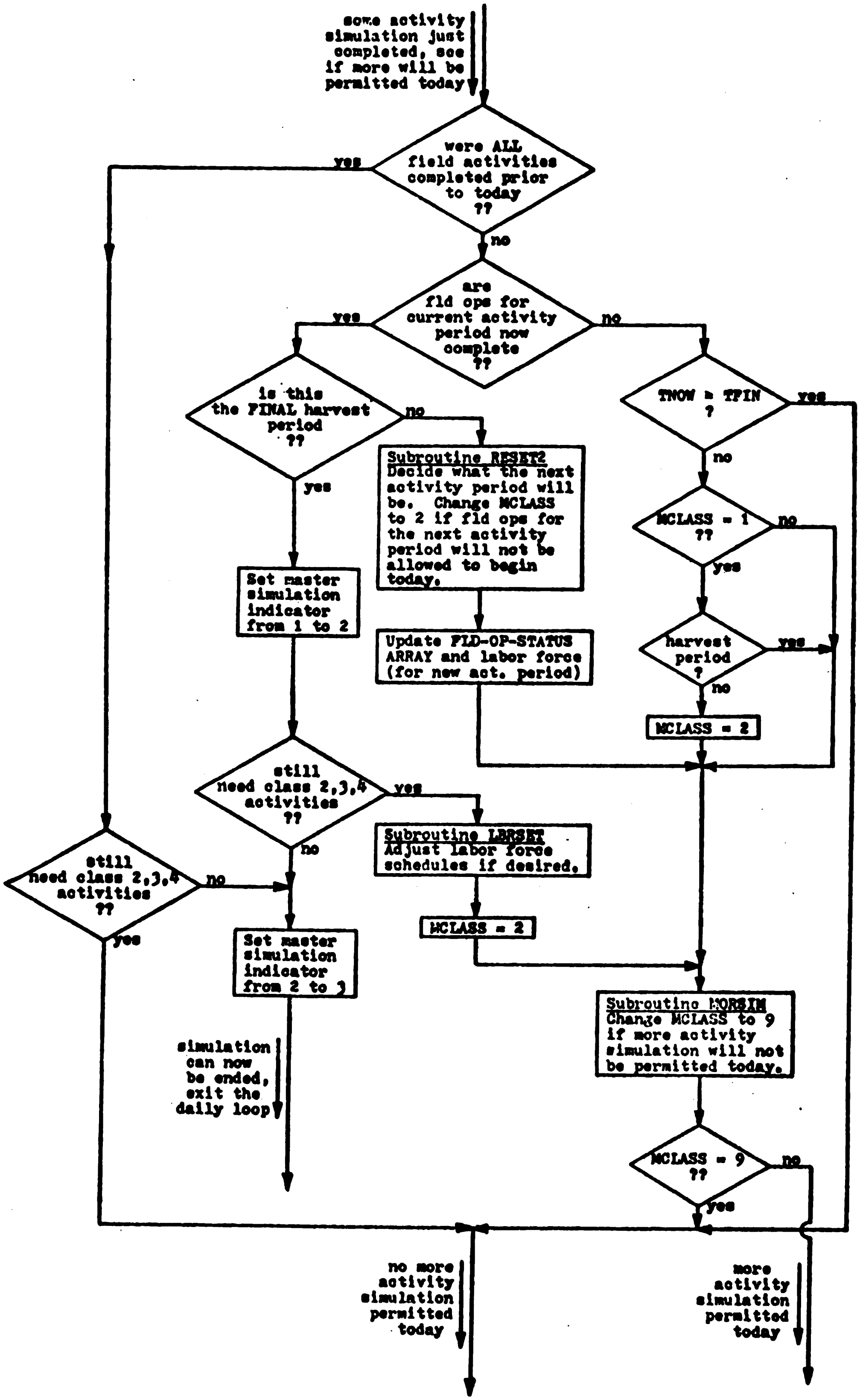

Figure 3. Concluding An Activity-Simulation Day.

Two general situations exist in which additional activity-simulation on a given day would be permitted (if needed and possible):

1) If the activity-simulation just completed did not signal the end of the current activity period, then additional activity-simulation would be permitted a) for non-field activities (MCLASS = 2, 3 or 4), regardless of the activity period, and b) for field activities (MCLASS = 1), during the harvest period only.

2) If the activity-simulation just completed did signal the end of the current activity period, then additional activity-simulation would be permitted prior to the completion of the final harvest period of the overall simulation run, i.e., for field or non-field activities in the next activity period, or after the completion of the final harvest period, only if non-field activities are needed. In the former case, subroutine RESET2 leaves the MCLASS = 1 setting unchanged at the end of the harvest period (6) if fld ops are possible in activity period No. 1 or 2, at the end of the fall land preparation period (1)

if fld ops are possible in activity period No. 2, and at the end of the planting period (4) if fld ops are possible in activity period No. 5. In the latter case, subroutine LBRSET may be used to make adjustments in the labor force for the remainder of the simulation run, e.g., part-time men might be eliminated, Sunday work-hours for full-time men might be eliminated, etc. LBRSET is not being utilized with the current model, i.e., the subroutine now in place is a dummy-routine.

In all cases, the final check on allowing more simulation of activities on a given day rests with subroutine MORSIM.

In its present form, subroutine MORSIM tests two criteria only. It sets MCLASS = 9 as a signal that more simulation will not be permitted:

1) If the day in question is a Sunday, or
2) If (TFIN - TNOW) < T, where T is currently set, in MORSIM, at 2 hours.

Otherwise, MCLASS is unchanged, and control transfers back to test the criterion for declaring an activity-simulation day. If another activity-simulation "day" is declared (for this day), then subroutine MYSET receives a special signal that prevents TNOW from being altered, though TFIN may be if a new activity period (and labor force) is now in effect.

Subroutine RESET2 performs other functions, in addition to those noted above, that are important to the present model. At the conclusion of the planting period, RESET2 resets the activity class 1 indicators for activity periods No. 1, 2, 3 and 4 from a value of 1 (fld ops for this period have been completed) to a value of 2 (they have not been completed), in preparation for the simulation of another crop-year of activities -- this is done by RESET2 for activity period No. 5 at the conclusion of activity period No. 5. If there will not be another crop-year of simulation, i.e., this is the final year of this simulation run, then RESET2, at the conclusion of activity period No. 4 or 5, resets a master simulation indicator from a value of 0 to a value of 1. The values which the master simulation indicator may assume, and their interpretation are:

0 - the <u>final</u> harvest period for this simulation run has not yet begun

1 - the <u>final</u> harvest period is now in effect

2 - the <u>final</u> harvest activity is now complete, but certain non-field activities may be needed before the simulation can be ended

3 - the overall simulation of activities, both field and non-field is now complete, exit the daily loop and print final summaries.

The values 2 and 3 are set in Figure 3 as indicated.

ACTIVITY-SIMULATION MODELING

As noted earlier, the actual simulation of activities to produce, harvest, and market corn can be done with fixed increment timekeeping methods, i.e., simulated clock time is advanced by fixed increments. The model structure described thus far is independent of the timekeeping method used for activity-simulation.* In the box labeled "SIMULATE ACTIVITIES" in the flow chart of Figure 1, a master control routine or series of activity-simulation routines which use fixed increment timekeeping methods could be inserted. The special indicators discussed and all information supplied by the model-user as input would be stored and available for use, and the operation of the daily-loop would be unchanged from that described.

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* Of the 26 subroutines already mentioned or described, only STATUS, GOFLDS and MYSET reference the particular activity-simulation method being used with the present model, and would require minor modifications if another method were to be used. Of the 15 subroutines used for initialization before entering the daily-loop of Figure 1, only 5 are specific to the particular activity-simulation method being used (SETGAS, MACHRY, TRSET1, GOFRM1 and LBRFIL), and would have to be omitted, slightly revised or completely reworked if another method were to be used.

Event-oriented simulation is carried out by programs that interact with each other at discrete points in time, rather than continuously -- much the same way as entities in a corn production system (men, combines, transport units, driers, off-farm markets, etc.) interact with each other at discrete points in time, rather than continuously. With this method of simulation, which was used for activity-simulation in the model developed, system behavior is traced by the pattern of state changes that occur due to the occurrence of system events.

Simulation With GASP

GASP, a General Activity Simulation Program, is an event-oriented simulation "language", consisting of a series of special-purpose, FORTRAN-based subroutines. Its primary purpose is to assist "the analyst by providing a modeling frame-work and a set of programming language statements that both expedite and improve his task" (Pritsker and Kiviat, 1969).*

In the GASP view, the real world consists of entities of different types and with different characteristics that interact with one another, and engage in different types of activities. Events indicate the start and completion of activities.

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* Much of the material presented in this section was taken from this reference.

Entities and events both possess attributes. Attributes associated with a man in a corn production system, for instance, might include the total time he is available for daily assignment, the type of activities he would prefer to do, his current assignment, his type attribute (part-time vs. full-time), etc. Every event must have an attribute that defines the time it is to occur. Other attributes normally associated with events describe the event type and attributes of entities affected by the event.

When an event occurs, it can change the system state in three ways: by altering the value of one or more attributes of the entities, by altering relationships that exist among entities, and/or by changing the number of entities present in the system. Entities, attributes and relationships make up the static structure of the simulation model. They describe the state of the system, but not how the system operates -- which is the role of events.

The key to discrete-event simulation is one's ability to organize system events so that the order in which they are executed within the computer corresponds to the order in which they would occur in the real system. Ordinary programming languages are unsuited to this task because they operate in a strictly sequential manner. Usually considerable time and effort must be expended in designing programs that organize and schedule events in a model so that a simulated system moves through time in a realistic manner.

It was for this reason that the event control features of GASP, and its associated information storage and retrieval techniques were selected for use with the model developed.*

<u>The GASP filing system</u>

The GASP filing system consists of two single-dimension arrays: QSET for floating-point attribute values, and NSET for fixed-point attribute values.** These two arrays may be visualized as if they existed in the configuration shown in Figure 4. That is, the entire filing system is ID columns wide and (IMM + MXX) elements deep. ID, IMM and MXX are GASP variables that are programmer-defined, so the overall size of the filing system may be varied to meet the needs of the particular simulation problem. The programmer must dimension QSET and NSET to ID * IMM and ID * MXX, respectively.

Each column of the GASP filing array may be used to store the attribute values of a single event or entity. When an entry (an event or entity) is to be stored (its attribute values placed in an unoccupied column of the filing array),

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* GASP is organized to provide seven specific functional capabilities required by every simulation: 1) event control, 2) information storage and retrieval, 3) system state initialization, 4) system performance data collection, 5) program monitoring and event reporting, 6) statistical computations and report generation, and 7) random variable generation. As noted, only the first 2 were incorporated into the model developed.

** The filing system described here is actually for GASP IIA, which is an extended version of GASP II, which was developed from the original version of GASP (see Pritsker and Kiviat, 1969).

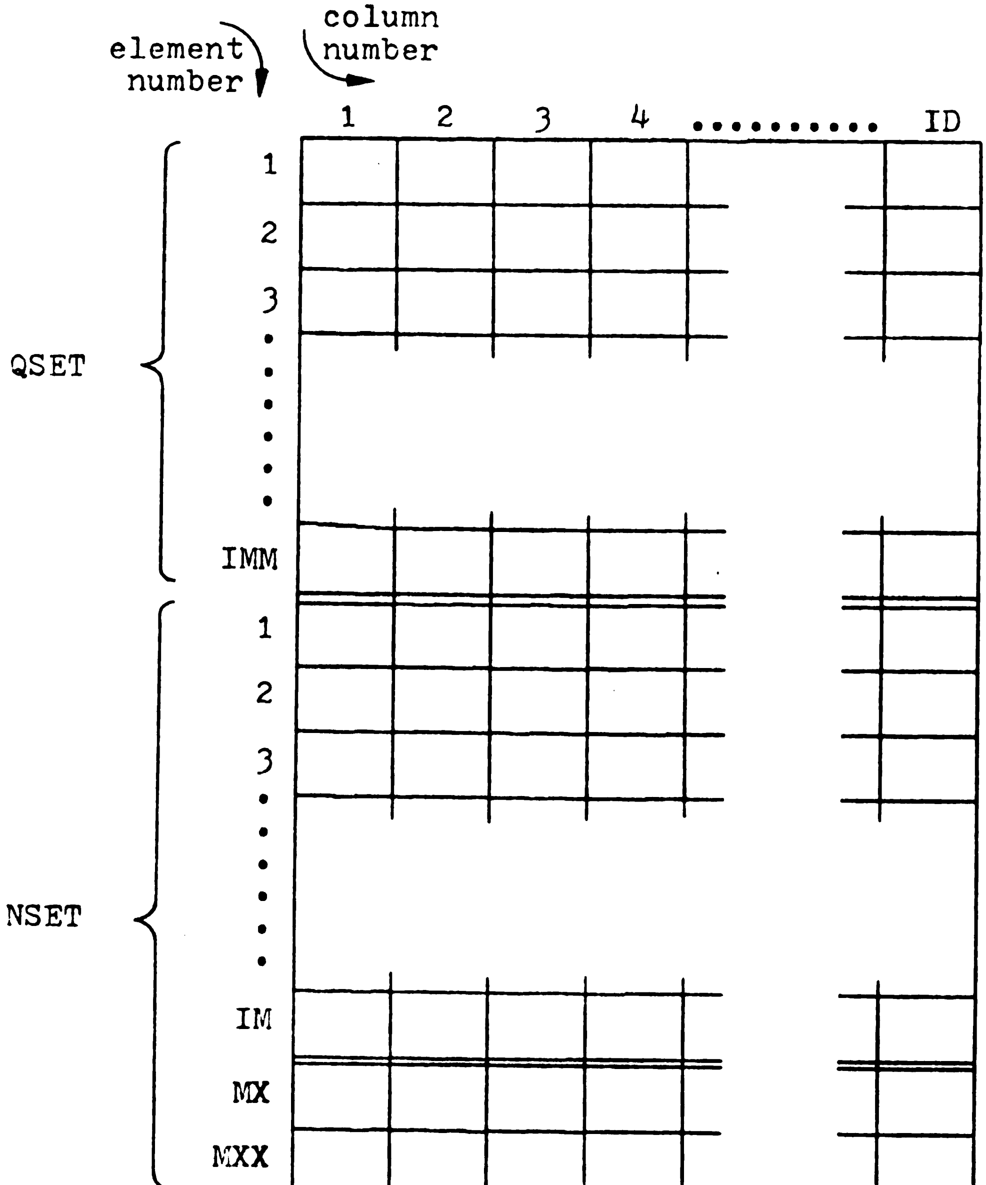

Figure 4. The GASP Filing Array.

the programmer may wish to have it associated with other similar entries that are currently in the filing system, or will be placed there later. An association or grouping of entries is called a file.

The programmer may define as many different files as is needed for the particular simulation problem. NOQ is a GASP variable which is programmer-defined to indicate the total number of files being used. In the computer, files are referred to by number, e.g., file 1, 2, ..., NOQ, which may correspond to particular file names, envisioned by the programmer, e.g., file 1 is the events file, file 2 is the labor file, file 3 is the unassigned tractor file, etc. In GASP simulations, file 1 is always designated the events file, with the first QSET-attribute value (see Figure 4) of each event representing its time of occurence, and the first NSET-attribute value representing the event code number.

Each entry in each file may have up to IMM QSET-attribute values, but only IM NSET-attribute values, where IM = MXX-2. The last two rows of the GASP filing system (the last two elements in each column) are reserved for a special pointer system used to associate the entries belonging to each file.*

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*The pointer system operates this way: the MX element of each entry points to (contains the column number of) the <u>next</u> entry in the file, where a pointer value of 7777 indicates there is no <u>next</u> entry, i.e., this is the "last" entry in this file. The MXX element of each entry points to (contains the column number of) the <u>preceding</u> entry in the file, where a pointer value of 9999 indicates there is no <u>preceding</u> entry, i.e., this is the "first" entry in this file. In multi-entry files, which entry is "first" and which is "last" depends on the ordering method desired for that particular file.

This pointer system and other file information is automatically maintained by the GASP subroutines, and is based on a programmer-defined ordering, or ranking procedure for the entries in each file.

The GASP variable KRANK defines the row or element number of the attribute used for ranking.* The variable INN defines the ranking procedure to be used with each file. KRANK and INN are dimensioned to NOQ.

INN (JQ) = 1 gives priority to entries in file JQ with low KRANK (JQ) attribute values, while INN (JQ) = 2 gives priority to entries with high KRANK (JQ) attribute values. With the events file (file 1), for example, the time of occurence of the event is stored in the first QSET element of the entry. Setting KRANK(1) = 1 and INN(1) = 1 gives priority to entries in file 1 with low values in QSET attribute No. i (time of occurence), i.e., the event with the lowest event-time, the <u>next</u> event to occur, will always be the "first" entry, or at the <u>front</u> of file 1, as indicated by the pointer system.

<u>Information storage and retrieval</u>

Three GASP subroutines are used to store information in, to retrieve information from, and to do the accounting for the GASP filing system: subroutines FILEM, RMOVE and SET.

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*A KRANK value of 1,2,...., indicates the first, second, ... attribute of QSET, a value of 101,102,.... indicates the first, second, ... attribute of NSET is to be used for ranking entries within the file.

When an entry is to be stored (placed into one of the columns of the filing system), the attribute values of the entry are first placed in special buffer arrays ATRIB and JTRIB. These GASP arrays are dimensioned to IMM and IM, respectively. A call is then made to subroutine FILEM (JQ, NSET, QSET), where JQ is the file number with which this entry is to be associated. FILEM transfers the ATRIB-JTRIB values into the corresponding QSET-NSET elements of the next unoccupied column of the filing system. It then calls subroutine SET(JQ,NSET,QSET), which assigns the appropriate file JQ pointer information to the last two elements (MX and MXX, see Figure 4) of the column. SET will also update the pointer values of elements MX and MXX for other entries in file JQ.

To retrieve an entry (remove a column of information from the filing system), a call is made to subroutine RMOVE (KCOL, JQ, NSET, QSET), where JQ is the file number and KCOL is the column number to be removed. RMOVE first transfers the QSET-NSET values of column KCOL into the corresponding elements of the ATRIB-JTRIB arrays. It then calls subroutine SET (JQ, NSET, QSET), which updates the pointer information in all remaining entries of file JQ. SET then initializes the QSET-NSET elements of column KCOL, including the MX and MXX elements, to a value of 0.0 in QSET and 0 in NSET, and updates other file statistics.

These three subroutines were used without alteration in the model developed, except for the following:

1) The call (in each one) to GASP subroutine ERROR (J, NSET, QSET), where J = an error type code number, was replaced with a call to subroutine MYERR (KERR, NSET, QSET), where KERR = an error type-location-cause code number.

2) A few statements were added to define the error type-location-cause code numbers (KERR) for each.

Subroutine MYERR was also used for error-reporting in several other GASP and non-GASP subprograms.

General use of the GASP filing system*

While certain GASP variables and arrays must be programmer defined, namely ID, IMM, MXX, NOQ, KRANK and INN, others are maintained automatically by subroutine SET, and are available for use by the programmer. These include variable MFA, the column number of the first un-used (unoccupied) column in the filing array, and the arrays MFE, MLE and NQ, all dimensioned to NOQ, which contain the column number of the first entry (MFE), the column number of the last entry (MLE), and the total number of entries (NQ) in each file at any given point in simulated time.

There are occasions when the programmer wishes to know the column number of a particular entry in a particular file so that the column can be removed or certain attribute values changed. GASP subroutines FINDN and FINDQ provide this capability. The list variables are:

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*Certain GASP subroutines must be initialized before the GASP filing system is used. With the present model this is done with a call to subroutine SETGAS.

FINDN (NVAL, MCODE, JQ, JATT, KCOL, NSET, QSET)

FINDQ (QVAL, MCODE, JQ, JATT, TOL, KCOL, NSET, QSET)

FINDN searches file JQ looking for a particular relationship (MCODE) between NVAL and attribute JATT in NSET. The column number returned (KCOL) is for the entry whose attribute value is --

the maximum value > NVAL for MCODE = 1

the minimum value > NVAL for MCODE = 2

the maximum value < NVAL for MCODE = 3

the minimum value < NVAL for MCODE = 4

the first value = NVAL for MCODE = 5

If a file JQ entry which satisfies the relationship is not found, KCOL = 0 is returned. FINDQ does the same thing, but for attributes in QSET, where TOL is a tolerance for the QVAL - attribute value relationship.

A sixth MCODE-relationship was added to both of these subroutines so that an entry with two particular attribute values in NSET or QSET could be located. This was done without altering the variable list by using composite numbers for NVAL and JATT. For example, to use FINDN with MCODE = 6, NVAL is set to MMNN, and JATT to JMJN. The search carried out then is for an entry in which the JM attribute value is MN <u>and</u> the JN attribute value is NN.

Two other additions were made to facilitate the handling of information to be stored or retrieved from the GASP filing array: A second set of buffer arrays, BTRIB and KTRIB, corresponding to ATRIB and JTRIB, were defined, and a management program, subroutine TRIBS (MCODE), was developed. TRIBS performs the following functions based on the value of the list variable MCODE at execution:

MCODE	ACTION TAKEN
1	Initialize ATRIB and JTRIB to 0.0 and 0
2	Initialize BTRIB and KTRIB to 0.0 and 0
3	Initialize ATRIB, BTRIB, JTRIB and KTRIB
4	Set ATRIB = BTRIB and JTRIB = KTRIB
5	Set BTRIB = ATRIB and KTRIB = JTRIB

This permits the definition, examination or manipulation of attribute values for two file entries at the same time.

Another subroutine was also developed as an aid to testing subprograms that use the GASP filing array. Subroutine PRTFIL (JQ, NSET, QSET) prints the contents of file JQ in the configuration illustrated in Figure 4, placing the entries (columns) in their proper sequence per the ordering procedure defined for file JQ.

Event control with the GASP filing system

With the GASP filing technique, and the unique method of ordering the entries in each file, the execution of events in their proper time sequence is a simple matter. Assuming that KRANK (1) = 1 (the event time attribute) and INN (1) = 1 (low values have priority) for file 1, the events file, as indicated earlier, Figure 5 illustrates a very simplified version of the event control procedure.

An initial event must be filed before entering the event-control loop. The first thing done in the event control-loop

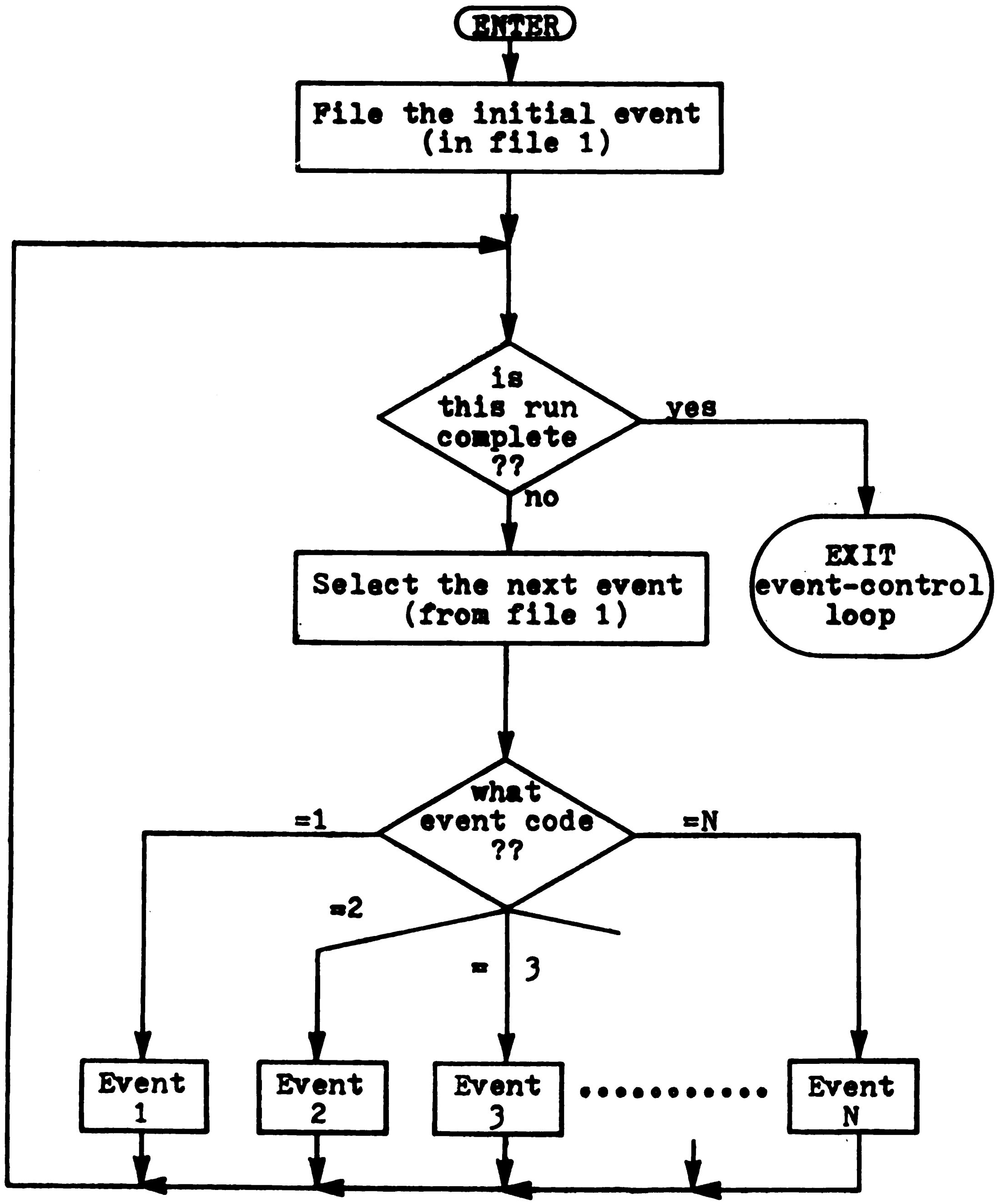

Figure 5. Event Control with GASP.

is to determine if the end of the current run has been reached. If it has, then the event-control loop is exited. Otherwise, the next event is selected from file 1. This is done with the FORTRAN statements:

```
CALL RMOVE (MFE(1), 1, NSET, QSET)
TNOW = ATRIB (1)
JEVNT = JTRIB (1)
```

RMOVE removes the first entry (MFE) in file 1 from the GASP filing array, which is automatically the entry with the smallest (earliest) event time, and places its QSET-NSET attribute values in the buffer arrays ATRIB-JTRIB. Simulated clock time (TNOW) is updated to the time of occurence of this event, and the event code JEVNT is set. Note that ATRIB-JTRIB may (still) contain other information needed to handle this event.

A branch is then taken, based on JEVNT, to a particular subroutine designed (by the programmer) for this event. In Figure 5, the boxes labeled "Event 1", "Event 2", etc. stand for programmer-developed subroutines for the various events. Each event subroutine will 1) alter the value of one or more attributes of the system entities, 2) alter relationships that exist among the system entities, 3) change the number of entities present in the system, and/or 4) schedule one or more future events, i.e., place entries in file 1 with event times greater than TNOW. With GASP the JEVNT-branch is usually done with the FORTRAN subroutine EVNTS (JEVNT, NSET, QSET).

Upon return from subroutine EVNTS, a GO TO is executed back to the start of the event-control loop. If the end of the run has not been reached, the next event is selected from the "front" of file 1, which is (again) the entry with the smallest (earliest) event time, i.e., the next event to occur.

File Organization for GASP Simulation

Except for the structural considerations already discussed, GASP imposes no restrictions on the number, type or attribute content of the non-event files to be used. The files defined for the present model are listed in Table 1.

The unassigned equipment files (2-5), along with the farmstead and off-farm market file (11), contain all the equipment and facility entities that will be available for assignment to activities or for use during a particular simulation run. They are created before entering the daily simulation loop of Figure 1 by initialization subroutine MACHRY. One column of the GASP filing array is required for each tractor, implement, combine and transport vehicle specified; each farmstead designated for high-moisture corn storage and/or dry corn storage; and each grain conveyor designated for use at the drier-site (if on-farm drying is used). In addition, one column is required for the drier itself, one for the dump pit, and, if used, one each for a wet corn holding bin, a dryeration bin, or a dry corn holding bin. The size of files 2-5 and 11 (number of entries in each) remains relatively constant throughout an entire simulation run, as will be noted later.

The labor file (6) contains entries for men available for assignment during the current activity period. This file is dissolved and recreated (using subroutine LBRFIL) at the beginning of each new activity period. Its size (one column for each man) will depend on the size of the labor force specified by the model-user for each activity period in which field operations are to be performed.

The assembled equipment and transport set files (7 and 8) are created from the entities in the unassigned equipment files (2-5) to perform field operations and transport activities. The following definitions apply:

equipment set -- a self-powered equipment unit or combination of equipment units placed in file 7 in a special way for use in the performance of a particular field operation. Two types are possible with the present model: 1) harvest equipment sets (self-propelled combines with cornheads) and 2) production equipment sets (a tractor with one or two field implements)

Table 1. GASP Files Defined for Corn Production, Harvesting, and Marketing Systems.

File Number	File Name	No. of Entries* Maximum	Usual
1	Events file	--	6 -10
2	Unassigned tractors	90	2 - 6
3	Unassigned (non-powered) implements	80	8 -12
4	Unassigned self-propelled combines	5	1 - 2
5	Unassigned transport vehicles	50	2 - 4
6	Current labor force	10	2 - 4
7	Currently assembled equipment sets	--	2 - 3
8	Currently assembled transport sets	--	1 - 2
9	Field operations currently feasible	--	2 - 4
10	Fields currently in process	30	3 - 5
11	Farmstead equipment and structures, and off-farm markets	28	2 -10

* Maximum is based on total number of specifications permitted on the user input form. Usual is an estimate of the range that might be expected from a small, one-man system up to a large, multi-man system.

transport set -- a self-powered transport vehicle or combination of transport vehicles placed in file 8 in a special way for use in the performance of a particular transport function. Two types are possible with the present model: 1) a farm truck, with or without trailing wagons, and 2) a tractor plus one or two wagons.

These files may be altered, entries added or removed, at the beginning of or during a particular activity-simulation day, using subroutines LOADCB for combines, LOADIM for production equipment sets, or LOADTR for both types of transport sets.* The size of the files will depend on the specific activities to be simulated and the number of men available for assignment at any given moment in simulated time, e.g., part-time help may arrive (leave) at 4:00 p.m. each afternoon, signaling a need to create or activate (dissolve or de-activate) a reserve equipment set.**

With the file manipulation required to assemble or disassemble entities for files 7 and 8, the GASP filing array requirements (number of columns required) may increase, decrease or remain the same, depending on the particular action

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* The filing requirements for production equipment sets have been determined, but subroutine LOADIM has not actually been developed as yet.

** This capability is not available with the model in its present stage of development, i.e., the model as currently developed will perform activity-simulation for harvesting activities only, and then only for a one-man labor force situation.

taken. Table 2 illustrates this. In general, certain information about the individual entities that makeup a file 7 or 8 entity is retained in the power-source entity column of file 2, 4 or 5.*

The field operations file (9) contains all fld ops that are feasible at any given moment in simulated time. The file is updated at the beginning of each new activity period by subroutine STATUS. The actual filing procedure is done by subroutine FOPFIL (when called from STATUS). Each fld op requires one column of the GASP filing array. When a fld op is completed in all fields scheduled to receive it, the event-routines remove it from file 9.

The fields "in process" file (10) contains all fields in which a fld op has been started, but is not yet complete. Fields are added to the file (one GASP column per field) by the field-selection routines, and by calling subroutine FLDFIL to carry out the actual filing procedure. Fields are removed

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*This is not true when certain farmstead activities, specified by the model-user, require the services of a tractor, e.g., pto-driven drier, pto-driven inclined auger, pto-driven blower for high-moisture silos, etc. In these cases, and when needed, all information for a tractor from the unassigned tractor file (2) is transferred to the farmstead equipment file (11) using subroutine LOADTS. This removes an entry from file 2 and adds one to file 11, so the number of columns being used in the GASP filing array is unchanged.

TABLE 2. Changes in GASP Filing Array Requirements with the Assembly of Equipment and Transport Sets in Files 7 and 8.*

Assembly Action To Be Taken **	GASP Columns Occupied BEFORE	GASP Columns Occupied AFTERWARDS
Create harvest equipment set with combine CB1	1, for CB1 in file 4	2, for CB1 in file 4 and CB1 in file 7
Create production equipment set with tractor TR1 and implement IM1	2, for TR1 in file 2 and IM1 in file 3	2, for TR1 in file 2 and TR1 + IM1 in file 7
Create production equipment set with tractor TR1 and impls. IM1, IM2	3, for TR1 in file 2 and IM1 in file 3 and IM2 in file 3	2, for TR1 in file 2 and TR1 + IM1 + IM2 in file 7
Create transport set with truck TK1	1, for TK1 in file 5	2, for TK1 in file 5 and TK1 in file 8
Create transport set with truck TK1 and wagon WG1	2, for TK1 in file 5 and WG1 in file 5	2, for TK1 in file 5 and TK1 + WG1 in file 8
Create transport set with truck TK1 and wagons WG1,WG2	3, for TK1 in file 5 and WG1 in file 5 and WG2 in file 5	2, for TK1 in file 5 and TK1 + WG1 + WG2 in file 8
Create transport set with tractor TR1 and wagon WG1	2, for TR1 in file 2 and WG1 in file 5	2, for TR1 in file 2 and TR1 + WG1 in file 8
Create transport set with tractor TR1 and wagons WG1,WG2	3, for TR1 in file 2 and WG1 in file 5 and WG2 in file 5	2, for TR1 in file 2 and TR1 + WG1 + WG2 in file 8

* The reverse is true when equipment and transport sets are dis-assembled.

** The assembly (or dis-assembly) action is performed by subroutine LOADCB for combines, LOADIM for production equipment sets, and LOADTR for transport sets. NOTE -- Subroutine LOADIM has not been developed for the present model though the filing requirements have been determined.

from file 10 by the event-routines when the fld op is completed in a particular field. File 10 may contain two entries for the <u>same</u> field in certain situations, e.g., planting might begin in a field before a "prior" land preparation fld op is entirely complete in the field, or disking stalks might begin before a field is completely harvested.

The individual attributes defined for the various types of entries in each non-event file (files 2 through 11), and the specific QSET-NSET cell locations being used are presented in Appendix B. Proposed attribute requirements for non-harvest equipment sets, and for the entities needed for on-farm drying and storage are also identified, though event-routines to utilize these entities have not been developed for the present model.

Each entry illustrated in Appendix B occupies the same amount of "space" in the GASP filing array. This is because the maximum number of attribute values required for <u>any</u> entry in <u>any</u> file dictates the entry "size" for <u>all</u> GASP files. This was determined to be fifteen floating-point attribute values (IMM = 15 for QSET), and eight fixed-point attribute values (IM = 8 for NSET, MXX = 10, see Figure 4).

The overall size requirements of the GASP filing array depends on the number of entries required for a given simulation run. Applying the "usual" estimates in Table 1, an average-sized corn production system might require about 45 GASP columns (ID = 45). For that particular simulation run, then, QSET would have to be dimensioned to no less than 675 (IMM * ID), while NSET would have to be dimensioned to no less than 450 (MXX * ID). If these values are not set high enough for a particular run, an error message will be printed by (and an EXIT taken from) subroutine FILEM.* All file descriptor variables (KRANK, INN, MFE, etc.) must be dimensioned to no less than 11, the number of files being used (NOQ = 11), which is fixed for the present model.

Attribute Organization and Management of the Non-Event Files

Basically three different types of attributes are defined for non-event file entries:

1) identification attributes (code numbers, code types, etc.)

2) static or fixed attributes (physical size, capacity, etc.)

3) dynamic or state attributes (location, material levels, etc.)

The state attributes, those that change with activity-simulation, are created and maintained internally by the model.

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* In which case a re-run must be made with ID set to a higher value, and with QSET-NSET dimensioned appropriately higher if necessary. QSET and NSET are dimensioned in the main program, then passed to the subroutines that use them through the subroutine variable list.

Identification and static attribute values are supplied by, or computed from model-user input.*

Location attributes

To describe a particular corn production system, the model-user may specify up to 30 different fields, up to 6 different farmsteads, and up to 6 different off-farm locations. During activity-simulation the unassigned men and the unassigned tractors, implements, combines and transport vehicles are "stored" at the base farmstead designated by the model-user. The equipment and transport sets of file 7 and 8, however, may be in a field, at a farmstead, at an off-farm location, or on a road traveling between any two of these at any moment in simulated time, with the following exceptions:

1) Combines, and production equipment sets that do not apply materials are not permitted to travel to an off-farm location, since there is no need for them to do so.

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* All information supplied by the model-user is read and stored in the system state vector (the X-array) by initialization subroutines FARM1, FARM2 and FARM3. Because of the large quantity of information involved a composite number system was used to conserve storage space with this initial storage of information. A particular cell in the X-array, for instance, may contain values of four variables stored as AABCCCDD.D or as ABBBCDD.DD, etc., where each letter or group of common letters designates different variable values with implied decimal-points for floating-point values. The subroutines used to load the non-event GASP files (MACHRY for files 2 thru 5, and 11, LBRFIL for file 6, FOPFIL for file 9, and FLDFIL for file 10) are designed to decipher the composite-number system of the X-array, and place attribute values appropriately in the files for easy use during GASP simulation. Certain information, then, is available in two places -- in the X-array and in the GASP files. In general, information that was needed only infrequently was not placed in the GASP files.

2) Production equipment sets that apply materials are permitted to travel to an off-farm location, but only to refill supply tanks or hoppers at the beginning of the day or when needed throughout the day. This mode of operation is intended primarily for the bulk application of nitrogen, where the field operation tractor (and operator) returns to the fertilizer dealer's place of business to refill or exchange a trail-type applicator, or a nurse tank that is used with a tractor-mounted toolbar applicator.

Transport set travel is restricted only by the supply source and corn marketing policies specified by the model-user.

If a file 7 or 8 entity is in a field, then x-y coordinates are maintained to pinpoint its location within the field. The field coordinate system being used is presented in Appendix C. During activity-simulation, the location attributes are used to define the current location and/or the most recent in-field location of file 7 and 8 entities.

Activity state attributes

During activity-simulation the system, and entities within the system, change from one state to another at the event times, i.e., at the simulated clock times when events occur. This is illustrated in Figure 6.

For a particular entity, a change in state may mean a change in its location, a change in the material levels associated with it, and/or a change in the type of activity it is doing, e.g., a combine may be harvesting, stopped for repairs, traveling from one point to another, etc. The types of activities, or activity states defined for harvesting corn

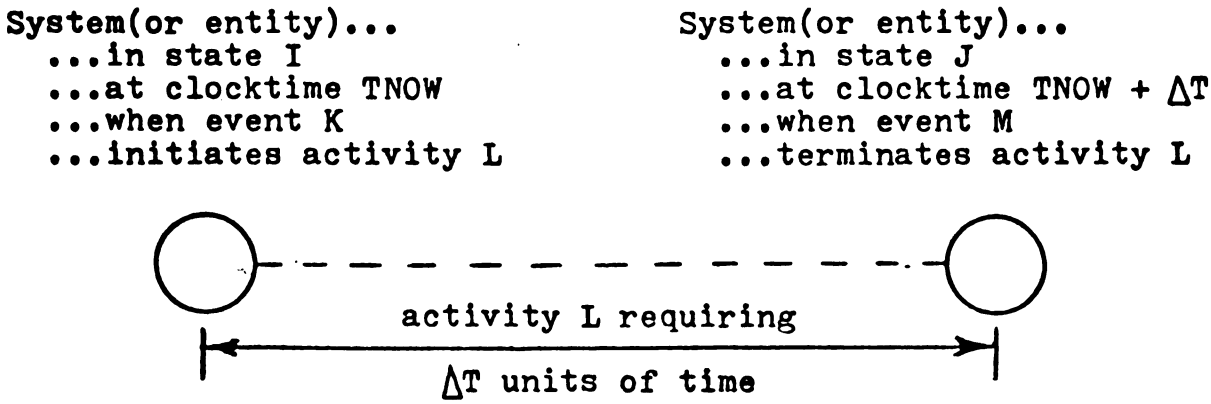

Figure 6. State Changes in Simulated Time.

intended for on-farm high moisture storage, and for direct from the field off-farm marketing are listed in Table 3.*

During activity-simulation, entities are advanced from state-to-state by the event routines. At the occurrence of each event, subroutine STATE1 is called to record (store) the state-time information for each entity associated with the particular event. The amount of time that each entity has existed in each activity state is accumulated on an annual basis and on a field basis. For combines, for production equipment sets that apply no materials, and for those that apply materials but utilize an in-field supply vehicle,

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* The file 7 activity states are equally applicable to production and harvest equipment sets, and the file 8 activity states are equally applicable to transport sets involved in handling production supplies or in transporting corn. The activity states proposed for the file 11 entities associated with on-farm drying are presented in Appendix D.

Table 3. Activity States Defined for Equipment and Facility Entities.*

File	Type of Entity	Activity State No.**	Type of Activity
7	Equipment Sets	1	All out-of-field travel.
		2	Non-operate in-field travel necessary for the field pattern being used (turning at the ends, etc.).
		3	Extra non-operate in-field travel, above normal field pattern requirements, needed to obtain production supplies being applied or to unload harvested corn.
		4	On-row operation.
		5	Delay for refueling and/or maintenance.
		6	Delay for repairs and/or machine adjustments.
		7	Delay for materials handling -- taking on production supplies, or transferring harvested corn to a transport vehicle.
		8	All other delays with or without an assigned operator present.
8	Transport Sets	1	All out-of-field travel.
		2	All in-field travel.
		3	Out-of-field materials handling -- taking on production supplies or farm-stored corn, or unloading corn.
		4	In-field materials handling -- transferring supplies to a production equipment set, or receiving corn from a combine.
		5	Delay for refueling and/or maintenance.
		6	Delay for repairs.
		7	All other delays with an assigned driver present.
		8	All delays with no assigned driver present.
11	Drier and Silo-Fill Tractors	1	Non-operate or idle.
		2	Operate or non-idle.
11	High MC Storage Sites	1	In-active (empty, partially filled,full).
		2	Operate or non-idle.

* Activity states are not maintained for file 11 off-farm market entities. See Appendix D for the activity states proposed for file 11 entities associated with on-farm drying.

** These values may be assumed by the NST-attributes (see Appendix B)--NST1 for file 7 entities, NST2 for file 8 entities, and NST3 for the file 11 entities indicated.

Table 4. Activity States Defined for Labor Entities.

Labor State No.	Equipment or Activity Assignment
1	Assigned to a non-harvest equipment set.
2	Assigned to a harvest equipment set (corn combine).
3	Assigned to a production supply transport set.
4	Assigned to a corn transport set.
5	All other assignments -- operating the drying and handling equipment at an on-farm drier site, moving the filling equipment from one silo to another at a high-moisture storage site, or refuel and maintenance activities for field equipment on non-field-work days.*

* Labor time is accumulated in states 1 through 4 for refuel and maintenance activities on field-work days.

the traditional measure of field efficiency (%) is 100 x (time in state 4) ÷ (sum of the times in states 2 thru 8).

Activity time for labor, the file 6 entities, is maintained separately from equipment time. The labor states, and time records maintained, are listed in Table 4.

<u>Materials handling attributes</u>

A total of eight different non-fuel materials were identified as being potentially important for event-oriented activity-simulation. These are the Q1..,Q2.., etc. attributes defined in Appendix B, where the single-digit numbers indicate the material "type" code numbers used (see the input form also, Appendix A).

In general, corn attribute values (material code 1) are important for combines (files 4 and 7), transport vehicles used to haul corn (files 5 and 8), and for all of the non-tractor entities in file 11 -- dump pits, conveyors, holding, cooling and drying bins, driers, and storage facilities, both on-farm and off-farm. Production material attribute values (material codes 2 through 8), however, are necessary only for production equipment sets that apply materials (file 7), and for the transport vehicles that supply them (files 5 and 8).

The attribute values maintained for corn are on the basis of equivalent bushels of No. 2 corn, i.e., bushels of corn at 15.5% kernel moisture (wet basis). These include the holding capacity and flow-rate specifications supplied by the model-user, and the "current level" attributes generated and maintained by the model.

Where the current corn level is an important factor in determining activity and event times, a moisture content and actual volume attribute value is also maintained, since the space occupied by a given quantity of corn depends on its moisture content. An equation developed by Herum (1962) was used to approximate this volume-moisture relationship:

$$V = \frac{0.889}{(1-M)^2}$$

where V is the volume (in cubic feet) that would be occupied by one bushel of No. 2 corn (15.5% moisture) if it were at a moisture content of M (decimal, wet basis).

The significance of this relationship with event-oriented simulation is illustrated in the following two examples:

1) A 6-row, 30-inch corn combine with a "100-bushel" grain tank is to harvest a field that will yield 125 bushels of No. 2 corn per acre. If harvesting is done at a kernel moisture of 20%, then the combine must travel 126 rods to "fill" the grain tank. If kernel moisture is 25% at harvest, all other factors being the same, then the combine must only travel 111 rods to "fill" the grain tank. This could mean the difference between being able to make a complete round in the field, and thereby needing transport vehicles only at one end of the field, and not being able to make a complete round, and thereby needing a transport vehicle at both ends of the field or a single unit positioned midway through the field. So it has implication for such things as the number of transport units required, the frequency of combine unloading activities, the feasibility of using certain field patterns, etc.

2) The corn harvested in this same field is to be hauled away from the combine in a "350-bushel" truck. If the size of the field is 20 acres, then 9 "truck-loads" must be hauled away at the 25% moisture level, while only 8 "loads" must be hauled at the 20% moisture level.

Production material attribute values are defined somewhat differently for equipment sets than for supply vehicles.* This difference is based partly on the following assumptions and model-user restrictions:**

1) Non-planting production equipment sets may apply a maximum of one material.

2) Planting equipment sets may apply a maximum of four materials, and must apply a minimum of one -- seed corn (material code 6).

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* Proposed to be defined differently, since non-harvest activity-simulation was not developed for the present model.

** And partly on the desire to minimize computer storage space requirements, both in the X-array and in the GASP files.

3) The carrying capacity (tank or hopper size), the application rate, and the supply source used for a particular material is closely associated with the field operation involved, and with the particular way in which field equipment is assembled to perform the field operation (and apply the material).

4) The depletion of any material carried on and applied by an equipment set can signal the need for a "refill" activity for the equipment set.

5) Only the depletion of "high-volume-use" materials carried on an in-field supply vehicle can signal the need for a "refill" activity for the supply vehicle. The high-volume-use materials were identified as water (material code 2) used as a carrier for pesticides, and fertilizers (either bagged -- material code 4, or bulk -- material codes 3 or 5).* If a transport vehicle is used to supply the planting operation where seed, dry herbicide and fertilizer are being applied, for instance, then only the depletion of the fertilizer supply on the vehicle can signal the need for a vehicle refill activity, i.e., it is assumed that the vehicle can carry enough seed corn and dry herbicide to last until the next fertilizer refill is needed, at which time the seed and dry herbicide supply carried on the vehicle would also be replenished.

6) Material transfer rates, and thus the refill time requirements, vary widely in practice only for bulk materials (water and bulk fertilizer), and depend on the particular materials handling techniques and equipment employed by the farm manager. The material transfer rates for bagged fertilizer, seed corn, dry herbicide, etc., which require manual handling, will be approximately the same for all corn production systems.

Based on these factors, the model-user is required to specify the material type, the carrying capacity and application rate (in consistent units), and the supply source for all production equipment sets that apply materials (see input form, Appendix A). These attribute values, plus current

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* It was assumed that farm managers would not require a single in-field, planter-supply vehicle to carry two different types of bulk fertilizers.

material levels, should be entered and maintained in the GASP files <u>only</u> when the particular production equipment is assembled in file 7 for the performance of the field operation. Excessively high values (999999.0) should be entered in the material-level attribute cells that are not required, since current material level can be used to indicate the need for a refill activity.

If an in-field supply vehicle (not maintained by a dealer) is indicated as a supply source for any material to be applied, then the model-user must also provide information about it. This includes, if applicable, the on-off material transfer rates and/or carrying capacities of high-volume-use materials (in units consistent with those specified for the equipment set). These values become permanent attributes of the transport vehicle (file 5).

Material transfer rates must be assumed (and incorporated into the event-routines) for all materials other than the high-volume-use materials supplied by a farm-operated, in-field supply vehicle. Transfer rates must also be assumed for the high-volume-use materials, <u>if</u> an equipment set must leave the field for refills.

<u>Fuel attributes</u>

Two fuel-related attributes are associated with all self-propelled equipment units (tractors, combines and trucks): 1) fuel tank capacity (supplied by the model-user), and 2) current fuel level (generated and maintained by the model). For tractors and combines the model-user must also indicate the fuel type, whether gasoline, diesel or LP-gas. All trucks are assumed to have gasoline engines.

During activity-simulation the current fuel-level attribute of a file 7 or 8 entity, or of a tractor doing farmstead work (file 11) is adjusted at the event times based on the entity's activity state (see activity states in Table 3). Equipment sets were assumed to consume fuel when in activity states 1 through 4, transport sets in activity states 1 and 2, and farmstead tractors in activity state 2 only. The fuel used for materials handling operations with equipment sets (state 7) and with transport sets (states 3 and 4), if any, was neglected.

Subroutine FUEL was developed to compute fuel-use rates (in gallons per hour) for the various types of entities when engaged in various activities.* For instance, estimates of tractor fuel consumption when using the different types of field implements (on-row operation, state 4 only) were stored in subroutine FUEL as the gallons of gasoline per hour per foot of implement width (assuming typical speeds). If the tractor is pulling two implements, then total fuel use was assumed to be the sum of the individual implement requirements. A conversion factor of 0.72 for diesel fuel and 1.20 for LP-gas is applied when the tractor is not gasoline powered.

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* The adjustment (reduction) in current fuel level for the entity at the occurrence of a given event is (G x T) gallons, where G is the fuel-use rate computed by subroutine FUEL in gallons per hour, and T is the total elapsed time in hours since the entity last changed activity states, i.e., the total time in hours since the last event involving this entity occurred.

Except for corn combine harvesting, which was estimated at 0.055 gallons of gasoline per hour per rated engine horsepower (on-row operation, state 4 only), all other fuel consumption values were estimated on a straight gallons (of gasoline)-per-hour basis. These included estimates for corn combine transport (non-operate travel), truck transport (corn or production supplies), and tractors engaged in 1) implement transport (non-operate travel), 2) hauling corn or production supplies, 3) PTO crop drier and forage blower operation, and 4) PTO grain conveyor operation.

Fuel consumption for corn and production supply transport activities was assumed to range from 80 to 100 percent of the base fuel-use rate stored in subroutine FUEL, depending on the amount of actual loading at the time, i.e., depending on the ratio QHAUL/QMAX, where QHAUL is the actual bushels of corn or pounds of production supplies being hauled, and QMAX is the maximum bushels of corn or pounds of production supplies that could be hauled. Values specified by the model-user were used for QMAX, except for the case of a transport set composed of a tractor and one or two wagons engaged in hauling corn. In this case, it was assumed that QMAX was a function of the tractor size: QMAX (bushels) = 2 * HP + 50, where HP is the rated PTO horsepower of the tractor.

EPM attributes

An EPM attribute (extended-period-maintenance attribute) is generated and maintained by the model for each self propelled equipment unit (each tractor, combine and truck).* The EPM attribute value of a given entity indicates the accumulated hours of use that remain for that entity before an EPM activity will be needed.

During activity-simulation the EPM attribute value of an entity is reduced each time it is engaged in a fuel-consuming activity, e.g., activity states 1 through 4 for equipment sets (file 7), states 1 and 2 for transport sets (file 8), and state 2 for tractors performing farmstead work (file 11). This is done at the event times, by an amount equal to the total elapsed time since the entity last changed activity states, i.e., the elapsed time since the last event involving this entity occurred. When the EPM attribute value becomes zero or negative, the need for an EPM activity is indicated. With the present model, this is checked only at the start of each activity-simulation day.

Initial EPM attribute values are assigned to each unit when the unassigned equipment files (files 2, 4 and 5) are created by initialization subroutine MACHRY. The actual value used is obtained from subroutine MAINT.

During this initialization, subroutine MAINT also generates and stores an EPM schedule for each tractor, combine and truck. With the present version of MAINT, the EPM schedule generated for tractors in the 100+ PTOHP category, for example, is:

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* See page 41 for a general discussion of daily vs. extended-period maintenance.

H_1= 50 hours T_1 = 0.50 hours

H_2=100 hours T_2 = 0.75 hours

H_3=200 hours T_3 = 1.25 hours

H_4=800 hours T_4 = 2.25 hours

where H_i indicates the service interval and T_i the corresponding expected value of man-time required to perform the EPM activity. This particular EPM schedule can be interpreted as follows: each 50 hours of operation a type 1 EPM activity requiring 0.50 hours of man-time will be needed; each 100 hours of operation a type 2 EPM activity requiring 0.75 hours of man-time will be needed; etc.

Subroutine MAINT is designed so that different EPM schedules could be generated and maintained for each of the 9 tractor sizes with each of the 3 fuel types available, for each of the fuel types available with combines, and for each of the 4 different types of gasoline-powered trucks, i.e., a total of 34 different EPM schedules can be handled by subroutine MAINT. At the moment, only five different EPM schedules are being used. These apply to 1) tractors with less than 50 hp, 2) tractors with 50 - 99 hp, 3) tractors with 100 hp or more, 4) combines, and 5) trucks.

During activity-simulation, subroutine MAINT is called only when an EPM activity for a particular tractor, combine or truck is to be scheduled, i.e., at the start of the next activity-simulation day following the activity-simulation day on which the EPM attribute value for the entity became zero or negative. MAINT updates the EPM schedule for the particular entity, it determines the reset value for the

EPM attribute, and it determines how much man-time will be required for the EPM activity to be scheduled.

The man-time required, and thus the duration of the EPM activity will depend on the type of EPM jobs needed. For instance, with the EPM schedule given above, a type 1, 2 and 3 EPM job will be needed at the end of 200 hours of operation. Subroutine MAINT sums the expected values of the man-time required for each (T_{sum}), and sets T_{sum} = maximum ($0.5*T_{sum}$, T_i), where i = 1, k (k ≥ 2). T_{sum} is unaltered if k = 1, i.e., if only one EPM job is needed (which is possible with the EPM schedule given above at 50 hours, 150 hours, 250 hours, etc.). This model assumes that certain EPM jobs can be done concurrently, e.g., while one is waiting for the old transmission fluid to drain completely, he might be performing another needed EPM job.

It is then assumed that the <u>actual</u> man-time required for the EPM activity to be scheduled (T_{epm}) may range from 80 to 120 percent of the computed T_{sum}. Subroutine MAINT then computes the actual duration of the EPM activity to be scheduled as $T_{epm} = T_{sum} (0.8 + 0.4 * R)$, where R is a 0-1 uniformly distributed random number.

<u>Repair attributes</u>

Two types of repair attributes are generated and maintained by the model for each self-propelled equipment unit (each tractor, combine and truck), for each implement available for performing field operations, and for the farmstead equipment that, with use, is normally subject to mechanical failure or malfunction. These are the RMAJ and RMIN attributes listed in Appendix B, corresponding to the hours of use until the next major repair and minor repair, respectively. Repair attributes are not maintained for non-powered transport vehicles (trailers and wagons). Separate repair attributes are maintained for combines (the base units) and for combine cornheads (attachments to the base units).

The distinction between major and minor repairs was made as follows:

major repair -- An operating interruption that may require special skills, repair tools and/or parts not readily available on the farm for its correction. The operating interruption (which may be 1, 2 or more hours in length) will be of sufficient duration that it may bring other equipment units to a standstill, e.g., a major combine repair might eventually cause the transport subsystem and the on-farm drying and handling subsystem to cease operations due to a lack of corn.

minor repair -- An operating interruption that can readily be corrected with the skills, repair tools and/or spare parts normally available or maintained on the farm. The operating interruption (which may be only a few minutes up to 40 or or 50 minutes in length) may be due to an actual mechanical failure or to the need for a simple adjustment of the unit.

The operating time between repairs was assumed to be (negative) exponentially distributed with the expected values shown in Table 5. The duration of a repair activity was assumed to have both a deterministic and random component, the random component being (negative) exponentially distributed also. The deterministic components and expected values of the random components of repair time now being used for the various categories of equipment are also shown in Table 5.

Table 5. Repair Attribute Factors.

Equipment Category	Major Repairs* RNEXT (hrs)	Major Repairs* RTIME (hrs)	Major Repairs* CMAJOR (hrs)	Minor Repairs* RNEXT (hrs)	Minor Repairs* RTIME (min)	Minor Repairs* CMINOR (min)
Tractor, gasoline	500	5	2	100	15	1
Tractor, diesel	700	5	2	100	15	1
Tractor, LP-gas	600	5	2	100	15	1
Rotary stalk chopper	100	3	2	50	10	4
Flail stalk shredder	100	3	2	50	10	4
Moldboard plow	100	3	2	5	10	4
Chisel plow	200	3	2	50	10	4
Powered rotary tiller	100	3	2	50	10	4
Hvy. tandem disc	200	3	2	200	10	4
Std. tandem disc	200	3	2	200	10	4
Field cultivator	500	3	2	100	10	4
Spring-tooth harrow	1000	3	2	100	10	4
Row-crop planter	200	3	2	2	10	4
Rotary hoe	1000	3	2	500	10	4
Row-crop cultivator	500	3	2	2	10	4
Field sprayer	50	3	2	1	10	4
Bulk fert. spreader	500	3	2	500	10	4
Knifedown N appl.	200	3	2	5	10	4
Nitrogen nurse tank	1000	3	2	1000	10	4
Combine, gasoline	400	5	2	20	10	3
Combine, diesel	450	5	2	20	10	3
Combine, LP-gas	425	5	2	20	10	3
Combine cornhead	300	5	2	2	10	3
Trucks (all types)	2000	5	2	500	30	30
Dump pit, gravity**	C6	0	0	C6	0	0
Dump pit, mechanical	100	1	1	50	15	10
Bucket elevator	500	3	2	250	15	10
Auger conveyor	100	2	1	50	15	10
Belt conveyor	200	2	1	100	15	10
Other mech. conveyors	300	2	1	150	15	10
Gravity flow**	C6	0	0	C6	0	0
Bin sweep conveyor	100	1	1	50	15	10
Burner and/or fan + controls Low †	200	1	1	200	15	10
Burner and/or fan + controls High †	200	1	1	200	15	10
Int. Handling Equip. ††	200	2	1	200	15	10

* RNEXT = expected value of time between repairs; RTIME = expected value of random component of repair time; CMAJOR/CMINOR = deterministic component of repair time.

** C6 = 1,000,000 hours.

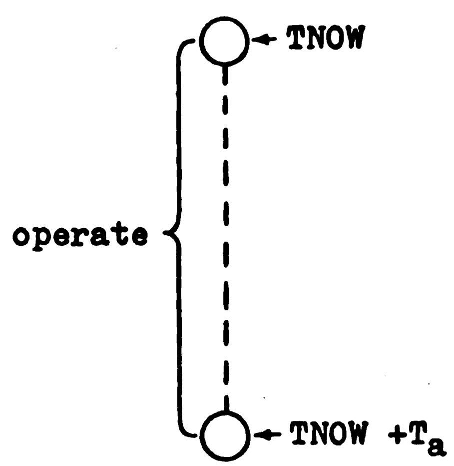
† Low = for dryeration bin, for batch-in-bin and for layer-drying bin; High = for portable batch or continuous flow driers.

†† Integral handling equipment (augers, pressure switches, etc.) of portable batch and continuous flow driers.

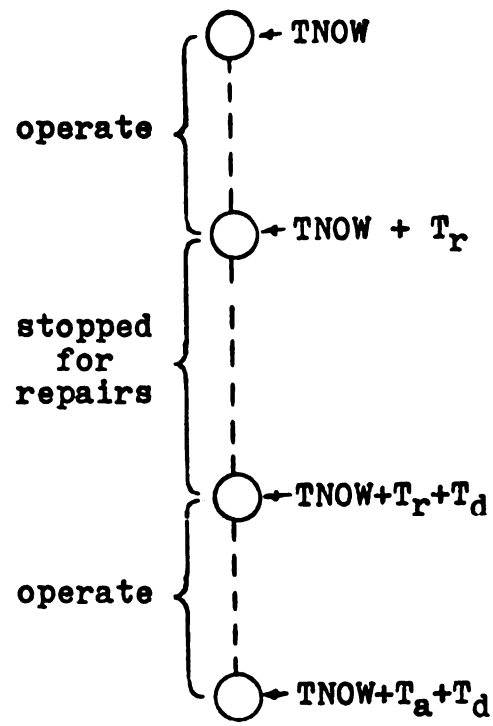
Management of the repair attribute values during activity-simulation is similar to that of the EPM attribute values in some respects, but different in others. Both types of attribute values indicate the "accumulated hours of use" until the next EPM or repair activity will be needed. Both types are reduced at the event times by an amount equal to the just-concluded activity time for certain types of activities. With the EPM attribute this is done for all fuel-consuming activities. This is generally true also for the repair attributes, except for equipment sets in file 7. Here it was assumed that only on-row operation (activity state 4) contributed to reducing the time remaining until the next repair activity, i.e., non-operate travel of equipment sets (activity states 1 through 3) does nothing to hasten the time of occurrence of the next repair activity.

While the EPM attribute values are checked only at the beginning of each activity-simulation day, the repair attribute values must be checked throughout the day, at the beginning of each relevant activity, to see if the activity can be concluded without a repair interruption. The procedure is illustrated in Figure 7, and proceeds as follows: A particular event routine is ready to schedule an event that will signal the termination of an activity of duration T_a hours. The event routine has placed appropriate values in the ATRIB and JTRIB arrays in preparation for filing the event in events file 1. The

Case 1 -- $T_a < T_r$
(a repair activity
will not be needed)



Case 2 -- $T_a \geq T_r$
(a repair activity
will be needed)



TNOW = current clock time

T_a = duration of an activity about to be scheduled

T_r = smallest repair attribute value of the entity(s)

T_d = time required to complete the repair

Figure 7. Scheduling of a Repair Activity

event routine, however, is designed to recognize that this activity is one which is relevant to the repair attributes of the entity (or entities) involved, i.e., it is a relevant operate-activity. Before calling subroutine FILEM, then, the event routine calls subroutine RPRCHK, which examines the appropriate repair attribute values and sets T_r, the smallest repair attribute value found. RPRCHK then compares T_r with T_a. In case 1, $T_a < T_r$, a repair activity will not be needed, so RPRCHK returns control to the event routine which files the event with an event time equal to TNOW + T_a. In case 2, $T_a \geq T_r$, a repair activity will be needed, so RPRCHK calls subroutine REPAIR which generates T_d and a new repair attribute value (to replace T_r at the conclusion of the repair activity). It then schedules the event which initiates the repair activity (at TNOW + T_r), it schedules the event which terminates the repair activity (at TNOW + T_r + T_d), and it updates the ATRIB and JTRIB arrays so that, upon return to the event routine, the conclusion of the operate-activity can be scheduled with an event time equal to TNOW + T_a + T_d.*

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*Actually this is not quite true. Before returning to the event routine, RPRCHK computes $T_a' = T_a - T_r$ (the amount of operate-time remaining <u>after</u> the scheduled repair activity). It then re-examines the appropriate repair attribute values, using the accumulated hours of use value generated by subroutine REPAIR to replace T_r at the conclusion of the scheduled repair activity, to see if <u>another</u> repair interruption will occur before the operate-activity can be concluded. If so, it files events to initiate and terminate the second repair activity, and repeats the re-examination procedure until all required repair activities have been scheduled before returning control to the event routine from which it was called.

The deterministic components of repair times (see Table 5) are set by assignment statements in subroutine REPAIR. The random components of repair times (expected values) and the expected values of the time between repairs are stored in the X-array by initialization subroutine SETRPR.

Event Control and Other Simulation Concepts

When an activity-simulation day is declared in the daily simulation loop of Figure 1, subroutine MYSET is called to set the overall time limits for the day (TNOW and TFIN).* MYSET also schedules the first event of the day by placing an entry in the events file (file 1). The events file is "empty" prior to this filing action.

A call is then made to subroutine MYGASP, the master event-control routine for activity-simulation. Control remains with MYGASP until clock-time exceeds TFIN, or until one of the "early" termination factors cited previously is encountered. This is recognized in MYGASP (see Figure 8) by the events file again being empty, i.e., no more events to process.

When the events file is non-empty, MYGASP removes column MFE(1), the first entry in file 1, sets TLAST to the clock-time at which the last event occurred (TNOW before the clock-time is updated), then takes a branch based

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* TNOW, the master clock-time variable (current clock-time), is set to the earliest starting time for the current labor force, and TFIN, the "target" completion time (clock-time) for the day, is set to the latest quitting time for the current labor force.

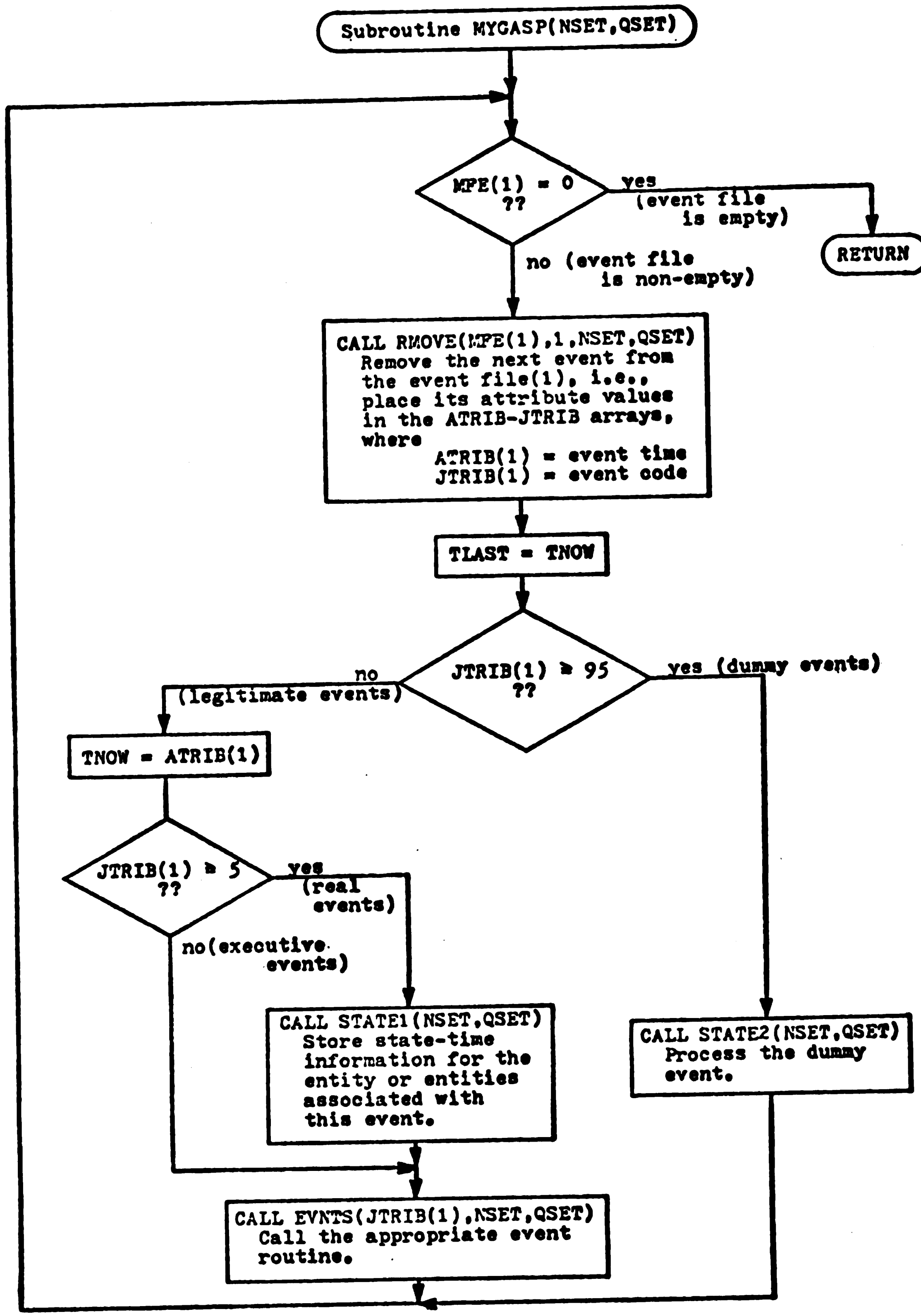

Figure 8. Event Control with Subroutine MYGASP.

on the event code JTRIB(1). If the event is a "dummy" event (discussed below), subroutine STATE2 processes it. If it is a "legitimate" event, then the current clock-time TNOW is updated, state-time information is stored (by subroutine STATE1) for "real" events, and subroutine EVNTS is called, which in turn calls the appropriate event-routine.

Event types and attributes

Three types of events (or event code designations) were defined for activity-simulation. These are:

Event codes 01-04 = Executive events

Event codes 05-94 = Real events

Event codes 95-99 = Dummy events

Subroutine MYGASP is designed to recognize these event types, and to process them accordingly.

Executive events are initially filed at the start of an activity-simulation day by subroutine MYSET. These initial executive events have but two attributes: ATRIB(1) = TNOW and JTRIB(1) = MCLASS, where MCLASS is the highest priority class of activities that may be simulated on a given day.* Subroutine MYGASP removes this initial executive event from file 1 (file 1 is now empty), defines TLAST and (redefines) TNOW, then calls subroutine EVNTS which in turn calls subroutine EXEC1, EXEC2, EXEC3 or EXEC4.** These EXEC

* Recall that MCLASS may be set to 1 -- field work, 2 -- general farmstead work, 3 -- corn marketing work, or 4 -- on-farm drying, handling and storage work on Sunday during the harvest season (the model-user did not permit Sunday work).

** Only EXEC1 is operational with the current development.

routines initialize certain variables and arrays, assemble equipment and transport sets that will be needed today (files 7 and 8), assign men to various jobs, and file the first real events (file 1 is no longer empty) to start the activity-simulation.

Real events are filed as needed by the EXEC routines and by the various event routines developed. Real events designate the actual termination of one activity and the beginning of another for the entities involved. Real-event entries in file 1 utilize the attributes defined and the specific cell locations presented in Figure 9.

At the event times, attribute value TNEW minus attribute TOLD is the total amount of time that the entities associated with the event have existed in their current state. Subroutine STATE1 uses this time difference, plus the activity state values filed with the various entities to record (store) state-time information.

Floating-point attribute locations 3 through 15 are utilized as needed for specific events. Examples are: the new x-y field coordinates for a combine or transport set when <ins>this</ins> event occurs, the amount of corn to be added to the combine's grain tank when <ins>this</ins> event occurs, the amount of corn to be transferred from the combine to a transport set when <ins>this</ins> event occurs, etc.

The entity-ID information being filed, when needed, for corn harvesting events is generally positioned as follows:

$NTITY_2$ - an operator (man) in file 6

Location	Attribute	Definitions:
QSET(1)	TNEW	TNEW = Time of occurrence of this event.
2	TOLD	TOLD = Time at which the entity(s) associated with this event last changed state.
3	ATT_3	ATT_i = Attribute values needed for specific events.
.	.	JVENT = Event code number.
.	.	$NTITY_i$ = Entity-ID information for the entity(s) associated with this event. Stored as AABB, where AA is the GASP column number, and BB is the GASP file number.
.	.	NACT = Current mode of operation indicator.
.	.	
15	ATT_{15}	
NSET(1)	JVENT	
2	$NTITY_2$	
.	.	
.	.	
.	.	
.	.	
7	$NTITY_7$	
8	NACT	

Figure 9. Attributes of the Events File.

$NTITY_3$ - a corn delivery point in file 11

$NTITY_4$ - the harvest field in file 10

$NTITY_5$ - a tractor doing farmstead work in file 11

$NTITY_6$ - the combine in file 7

$NTITY_7$ - a transport set in file 8

This information-storage technique provides a convenient method of locating entity attributes during activity-simulation.* The combine's EPM attribute (fifth floating-point attribute value in file 7), for instance, is QSET (I+5), where

*A few event-routines developed utilize a slightly different positioning scheme for the entity-ID information, e.g., an event involving two transport sets requires two entity-ID positions for the transport sets (one may be spotted in the field and the driver transfers to another to move it to a delivery point).

I = ($NTITY_6$/100-1)*IMM, the current activity state of the transport set (eighth fixed-point attribute value in file 8) is NSET (J+8), where J = ($NTITY_7$/100-1)*MXX, etc.

The indicator (NACT) representing the current mode of operation may assume several values for corn harvesting events. These are:

NACT = ABCDE A special start-of-the-day indicator that will be discussed later.

NACT = 1 Harvesting to "open-up" a field, i.e., harvesting turn rows prior to the start of "normal pattern" harvesting in a particular field.

NACT = 2 Normal pattern harvest is proceeding away from the field-origin side of the field.

NACT = 3 Normal pattern harvest is proceeding toward the field-origin side of the field.

NACT = 4 End of the day. All activities now aimed at moving equipment units to their overnight storage locations.

NACT = 5 End of the season. All activities now aimed at moving equipment units to their long-term storage locations.

The concept of dummy events was developed so that inactive or idle (waiting) times associated with entities would be accountable. Equipment and transport sets, for instance, may be inactive at various times throughout the day: a combine may have to wait (activity state 8, file 7) for a transport set to return to the field; a transport set may have to wait (activity state 7 or 8, file 8) for the combine to complete an on-row harvest pass; a tractor that operates unloading equipment at the farmstead may have to wait (activity state 1, file 11) for a transport set to arrive; etc. When an entity is placed into an inactive state, the clock-time at which it will be activated again may not be known. Since there is no clock-time attribute associated with any of the non-event files (files 2 through 11), the dummy event technique provides the accounting capability needed.

Dummy events utilize all of the fixed-point attributes shown in Figure 9, where JVENT designates the type of (inactive) entity:

95 = an unassigned man in today's labor force

96 = a farmstead equipment unit (and its assigned tractor)*

97 = a combine with or without an operator present

98 = a transport set with a driver present

99 = a transport set without a driver

Only the first two floating-point attributes are used with dummy events. The program filing the dummy event sets TOLD = TNOW and TNEW = TNOW + 10^6. This gives the dummy event an event time (TNEW) that is artificially large compared to event times for real events. Thus, dummy events are filed at the "end" of the events file, "behind" any real events that are in file 1 at the time, or that are placed there later.

Dummy events are routinely used during three specific phases of an activity-simulation day:

1) At the start of the day. The controling EXEC-routine for the day files a dummy event for <u>all</u> entities that are available for use or assignment at that time (after this determination has been made, of course). When the EXEC-routine

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* A grain conveyor, a drier, a high moisture storage facility, or a dry corn storage facility not at the drier-site.

files the first real event(s) to get the activity-simulation started, it removes the dummy event(s) from file 1 for the entity(s) that will not be inactive when it returns control to subroutine EVNTS, then MYGASP.

2) Throughout the day. Specific event-routines are designated to file and/or retrieve dummy events as needed as the activity-simulation proceeds. When a dummy event is removed from file 1, attribute TOLD always designates the clock-time at which the entity(s) became inactive, and TNOW minus TOLD is the total amount of inactive time. The event-routines are designed to call subroutine STATE1 after removing a dummy event from file 1, which uses the time difference TNOW - TOLD to record state-time information for the entity(s) involved.

3) At the end of the day. The "end-of-the-day" event-routines file dummy events for entities as they are deactivated. For instance, the event-routine that handles the event signalling the completion of combine travel to its over-night storage location will file a 95 dummy event for the combine operator (if he is no longer needed) and/or a 97 dummy event for the combine. When all real events have been processed by subroutine MYGASP, all that will remain in file 1 is a series of dummy events, representing <u>all</u> entities that were available for use or assignment at the conclusion of activity-simulation. As these dummy events are removed from file 1 by MYGASP, subroutine STATE2 will call subroutine STATE1 to record the final state-time information for the day. After the last dummy event has been removed, MYGASP finds that file 1 is empty, and control transfers back into the daily simulation loop of Figure 1.

Under normal circumstances, MYGASP should never remove a dummy event from file 1 except at the end of the day. If for some reason it does, subroutine STATE2 re-files the dummy event, setting attribute TNEW = TNOW + 10^6, but leaving attribute TOLD as previously set, i.e., TOLD is <u>always</u> the clock-time at which the entity(s) became inactive. STATE2 recognizes this situation by examining attribute NACT, e.g., if NACT ≤ 3, re-file the dummy event; if NACT ≥ 4, do not re-file it.

Executive subroutine EXEC1

Of the executive routines proposed for the four basic classes of activity-simulation days (field work, general farmstead work, corn marketing work, and on-farm drying, handling and storage work), only subroutine EXEC1, for field work, is presently operational, and only for corn harvesting and its associated support functions.* In addition, event-routines capable of carrying-out the event-oriented activity-simulation initiated by EXEC1 have presently been developed only for corn harvesting systems with the following characteristics:

1) The harvest-period labor force must consist of a single man only, i.e., multi-man, multi-combine systems are not allowed. This single man is, by necessity, responsible for operating the combine, driving the transport sets, and performing all other activities required.**

2) The harvest-time handling of corn must be done with option #1 (on-farm high-moisture storage), with option #4 (direct-from-the-field off-farm

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* EXEC1 is presently capable of handling planting operations, as will be discussed later. It cannot handle (and event-routines have not been developed for) non-planting, non-harvesting field operations.

** Event codes have been defined, and flow charts for the corresponding event-routines have been completed for a multi-man, single-combine harvest situation. The development, testing and declaration of an operational status for these routines, however, will have to await the future energies of the author or another investigator. Several of the routines presently operational, including EXEC1 and a number of specific event-routines, are now capable of handling, or will be applicable to, the multi-man, single-combine harvest situation. With EXEC1, though, the multi-man work force must have a common work schedule, i.e., all men must have the same starting and quitting times.

marketing), or with a combination of these two options, i.e., in-bin layer drying (option #2) and high-temperature drying (option #3), with batch-in-bin, portable batch or continuous flow drying equipment, is not allowed.

The procedure used by EXEC1 to initiate activity-simulation is illustrated in Figure 10.

When EXEC1 was being developed, it was assumed that <u>all</u> user options available with the model input form would in fact be developed and operational at some point in time. The first two tests in EXEC1 are required for one of these user options that is not presently operational: a multi-man work force in which at least one of the men is scheduled to start and/or quit at a different clock-time then the others, i.e., the <u>active</u> labor force will change at least once between clock-time TNOW and TFIN.

With the initial call to EXEC1 each day TLAST will be less than 999999.0 (set to TNOW in subroutine MYGASP) and file 1 will be empty (number of entries in file 1, NQ(1), will be zero). EXEC1 then calls subroutine SCHEXC which will schedule (file in events file 1) an EXEC1-event to occur each time the active labor force changes. At <u>these</u> event times, EXEC1 will again be called to activate or deactivate one or more men. This portion of the model has not yet been developed, though SCHEXC has been.

If on-farm high-moisture storage (option #1) is a corn handling option at harvest-time, as specified by the model-user, then the model as presently developed will attempt to satisfy this option first, before harvesting any

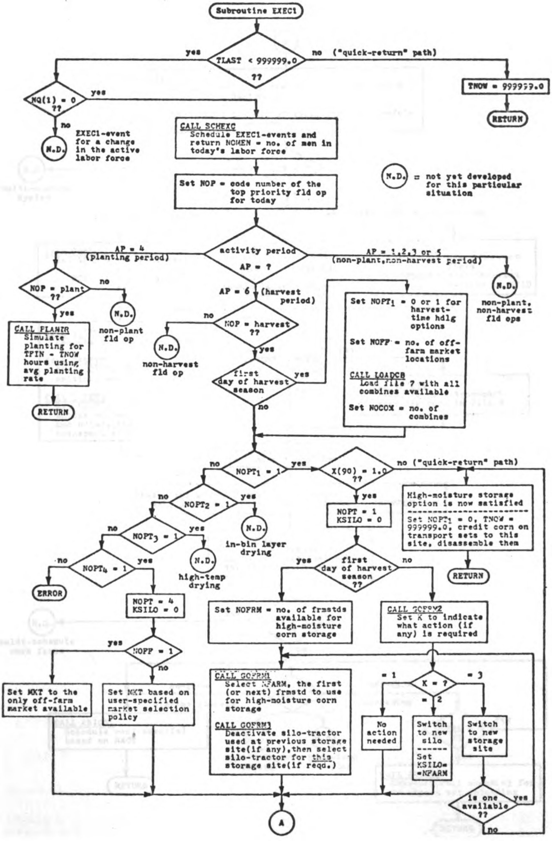

Figure 10. Executive Subroutine EXEC1.

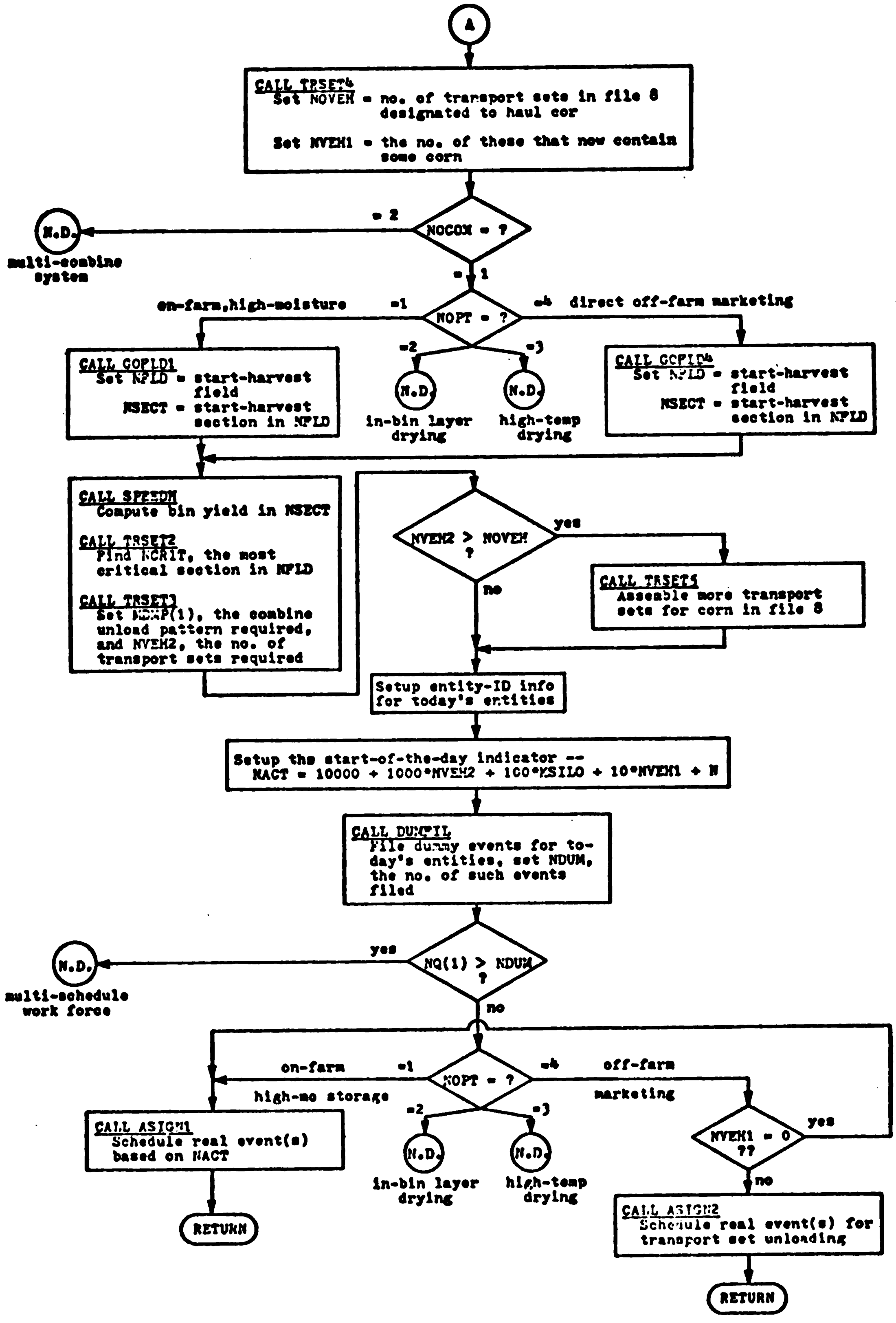

Figure 10 (cont'd.)

corn to be handled with the other three options. To "satisfy" this option, all available high-moisture storage specified by the user must be filled, or the kernel moisture of all corn that remains to be harvested must have dropped below the minimum moisture desireable for high-moisture storage. In either case, the fact that this option has been "satisfied" will not be detected until the next initial call to EXEC1, i.e., at the start of a new activity-simulation day.*

At that time, as will be discussed later, EXEC1 will set TNOW = 999999.0, as a flag, and a return (to subroutine EVNTS) will be executed without filing any real events. EVNTS returns control to subroutine MYGASP, which examines file 1, and returns control to the daily simulation loop of Figure 1 if file 1 is empty. If it is not empty (subroutine SCHEXC may have filed one or more EXEC1-events), then EXEC1 will again be called, but will detect the flag TLAST (set to TNOW = 999999.0) and take the "quick return" path. The daily simulation loop of Figure 1 is also designed to recognize this "quick return" procedure, and branches back to see if an activity-simulation day can be declared for the new harvest-time handling option then in effect (option 2, 3 or 4).

After calling SCHEXC, EXEC1 sets NOP to the top priority field operation code number for the day (this was originally

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*The model is designed so that the particular handling option in effect at the start of a new activity-simulation day remains in effect throughout that day.

determined by subroutine GOFLDS), then branches to the appropriate section based on the value of the current activity period (AP). For activity periods 4 and 6, NOP is compared with the fld-op code number for planting and harvesting, respectively. If the comparison is not true, a branch is taken to the section reserved for initiating activity-simulation for non-plant, non-harvest field operations, which has not yet been developed.

If the top priority job for the day is planting, then subroutine PLANTR is called. PLANTR is a simple continuous-time planting routine that relinquishes control back to EXEC1 only after clock-time TFIN is reached, i.e., only after a full day of planting has been done.*

If the top priority job for the day is harvesting, then EXEC1 proceeds through the next section of instructions, which are applicable to both single-combine and multi-combine harvest systems. On the first day of the harvest season the $NOPT_i$ variables are set (to 0 or 1) to indicate the feasibility, or

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* To facilitate the event-oriented activity-simulation techniques developed for harvesting, the corn crop had to be planted and brought to "maturity". This simple planting routine was the technique selected for doing this. So even though activity-simulation of non-harvest field operations is not possible with the present model, the model-user is required to specify one (only) non-harvest field operation (planting), and to provide the necessary planting equipment and planting policy specifications requested by the model input form. The field pattern to be used for the planting operation in each field (this is input as part of the field description specifications) must be input as field pattern 2 -- continuous alternating field pattern, i.e., circular-planted fields (field pattern 1) are not allowed with the present model.

lack thereof, of the four basic harvest-time handling options. NOFF, the number of off-farm markets available, is also set if $NOPT_4$ is non-zero, and file 7 is loaded (using subroutine LOADCB) with all the combines available for use. NOCOM is set to the number of different combines. The $NOPT_i$ variables are then checked, in sequence, to determine the appropriate setting for NOPT, the basic handling option to use in initiating today's activity-simulation.*

Corn delivery point determinations with EXEC1

For the two harvest-time handling options developed (options 1 and 4), EXEC1 first considers where the corn that is harvested today should be delivered. For the high-moisture storage option, all corn harvested on a given day is delivered to the same farmstead (storage site) and is placed in the same silo (storage unit) at that farmstead. For the direct-from-the-field off-farm marketing option, the delivery point for each (or all) load of corn will depend on the particular market selection policy specified by the model-user.

If high-moisture storage is feasible ($NOPT_1 = 1$), and if

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* The $NOPT_i$ variables are set to zero as the handling options are satisfied. They are re-set (to one), if they are viable options, at the start of each new harvest season.

this option has not been satisfied ($X(90) = 1.0$), then, on the first day of the harvest season, EXEC1 sets NOFRM to the number of farmsteads at which high-moisture corn can be stored. From these (NOFRM) farmsteads, NFARM is selected (by subroutine GOFRM1) as the first one to be used. * If NFARM requires the services of a tractor (to operate the silo-filling equipment), then one is selected from the unassigned tractor file (2) by subroutine GOFRM3 and placed in the farmstead equipment file (11), using subroutine LOADTS.

On all subsequent days, subroutine GOFRM2 is called to determine what action, if any, is required concerning the high-moisture storage site. If K = 1 is returned, no action is required. If K = 2 is returned, the silo-filling equipment should be moved from one silo to another, at the present storage site (NFARM), before harvest begins, but after any corn left on transport sets overnight has been unloaded.**

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* The "selection" portion of subroutine GOFRM1 is not presently developed -- an error message will be printed (and an EXIT taken) if NOFRM $\geq$ 2 when called. It is anticipated that this selection criteria might involve the total storage capacity at each farmstead, the actual or desired planting sequence of the fields to be stored at each, and/or other factors.

** The model-user must specify the number of silos to be filled at each farmstead and the amount of man-time involved in moving the silo-filling equipment. Subroutine GOFRM2 assumes that all silos at a given storage site are of equal size.

If K = 3 is returned, all silos at the present storage site (NFARM) have been filled (or will be once the corn then on transport sets has been unloaded), i.e., all high-moisture storage at this farmstead is (will be) full. If another farmstead is available for storing high-moisture corn, then the corn harvested today should be delivered to it -- select a new NFARM, assign a tractor if required, etc. If another one is not available, then the high-moisture storage option has been satisfied, and a "quick return" from EXEC1 is to be taken -- after crediting any corn then on transport sets to the high-moisture storage site, after disassembling the transport sets then assembled, and after returning any farmstead tractors then assigned (in file 11) to the unassigned tractor file (2).* A branch is taken to this point also if $NOPT_1 = 1$, but X(90) = 0.0 at the start of the day, i.e., the high-moisture storage option is assumed to be "satisfied" (without

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* The man-time (and farmstead-tractor-time) required to unload transport sets in this situation is assumed to be negligible, i.e., state-time information for the man, transport sets, and farmstead tractor, if used, is not recorded, and the repair and fuel level attributes of the farmstead tractor are unchanged. The corn transport sets are disassembled at this time since the next handling option to be used (it will be in effect with the next legitimate call to EXEC1) may require a different complement of transport vehicles.

storing the desired quantity of high-moisture corn) due to the kernel moisture in all unharvested corn now being below that required for safe high-moisture corn storage.

If direct-from-the-field off-farm marketing is the handling option for the day ($NOPT_1 = NOPT_2 = NOPT_3 = 0$, $NOPT_4 = 1$), then variable MKT is set (or temporarily set) to the off-farm market to be used throughout the day (or for determining the transport system requirements for the day). If there is but one off-farm market location, then it will be used, of course. If NOFF is greater than one, however, then the market selection policy specified by the model - user will be used to set MKT. Of the seven market selection policies proposed in the input form, only the first 3 are currently operational:

Policy 1 -- Random selection for each load of corn.

Policy 2 -- Random selection for each harvest day.

Policy 3 -- Shortest round-trip time for each load.

With policy 1 and 3, MKT is temporarily set to the off-farm market location whose attribute information is stored in the last column of file 11 (all off-farm markets are stored at the back of file 11).

Start-harvest point determinations with EXEC1

Subroutine GOFLDS determined earlier that field work (in this case harvesting) could be done somewhere on the farm today. It is now necessary to determine specifically where harvest should begin -- so that the combine can be moved there, so that transport sets can be spotted appropriately, etc.

Before doing this, however, EXEC1 sets the current value of NOVEH and NVEH1 (see Figure 10) by calling subroutine TRSET4. These values will be needed later regardless of the number of combines in use today. A branch is then taken to the appropriate section for the multi-combine situation (not developed) or for the single-combine situation, to carry-out its next function -- selection of the specific field (NFLD) and field section (NSECT) in which harvest will begin today.*

This selection procedure is done by subroutine GOFLD1 when handling option (NOPT =) 1 is in effect, or by subroutine GOFLD4 when NOPT = 4. GOFLD1 makes the selection of NFLD and NSECT by considering fields (and their field sections) in the following sequence: 1) It first considers the last field

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* For the multi-combine situation, subroutines must be developed to select $NFLD_i$ and $NSECT_i$ for i = 1, NOCOM.

in which the combine worked, if any; 2) It considers next the "preferred fields" for NFARM, as specified by the model-user, if any -- looking first at those fields currently in-process (in file 10), then at those not currently in-process; 3) It then considers other fields that may be currently in-process (but are not "preferred fields"); and 4) Finally it considers each field in its "preferred planting sequence", as specified by the model-user. GOFLD4 considers fields in essentially the same sequence, except that a "preferred fields" list is not provided by the model-user for off-farm markets.* Both routines select the first NFLD-NSECT combination that satisfies the harvest criteria (an unharvested section, kernel moisture in the desired range, and tractable soil conditions).

Transport system determinations with EXEC1

Given the combine, the field and field section in which to begin harvesting, and the corn delivery point, the final determination to be made by EXEC1 is the composition of the corn transport system to be used for the day. Subroutine SPEEDH (to be discussed later) is called to compute the (combine) "bin yield" in section NSECT, i.e., the potential harvestable yield in the section minus machine losses (see Figure 10). Subroutine TRSET2 is then called to

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* With proposed market selection policy #6 a "preferred fields" list will be available. When this option is developed, GOFLD4 should be modified to consider these first before considering the other fields in-process.

determine NCRIT, the most critical field section from the standpoint of combine unloading requirements that is likely to be encountered. Assuming all other field sections in NFLD have the same bin yield as field section NSECT, field section NCRIT is the one with the longest effective row length (section length minus headlands, if any) that the combine is likely to encounter today. Subroutine TRSET3 is then called to determine the combine unloading pattern (variable MDMP) that will be needed in section NCRIT, and the number of different transport sets (NVEH2) required to accomodate it.

The basic combine unload patterns defined for STOP-unloading (as opposed to ON-THE-GO unloading) are illustrated in Figure 11. The setting of MDMP(1)* is based on the ratio D = QTNK/QRND, where QTNK is the capacity of the combine's grain tank in cubic feet, and QRND is the (estimated) cubic feet of corn that would be harvested on each round in section NCRIT:

If $D \geq 1.00$, MDMP(1) = 1 is set.

> The combine can make at least one full round (2 harvest passes through the field), so unloading is needed only at one end of the field.

If $1.0 > D \geq 0.50$, MDMP(1) = 2 is set.

> The combine can make one full pass, but not a full round, so unloading is needed at both ends of the field (requiring 2 transport vehicles), or mid-way through the field (requiring only 1 transport vehicle).

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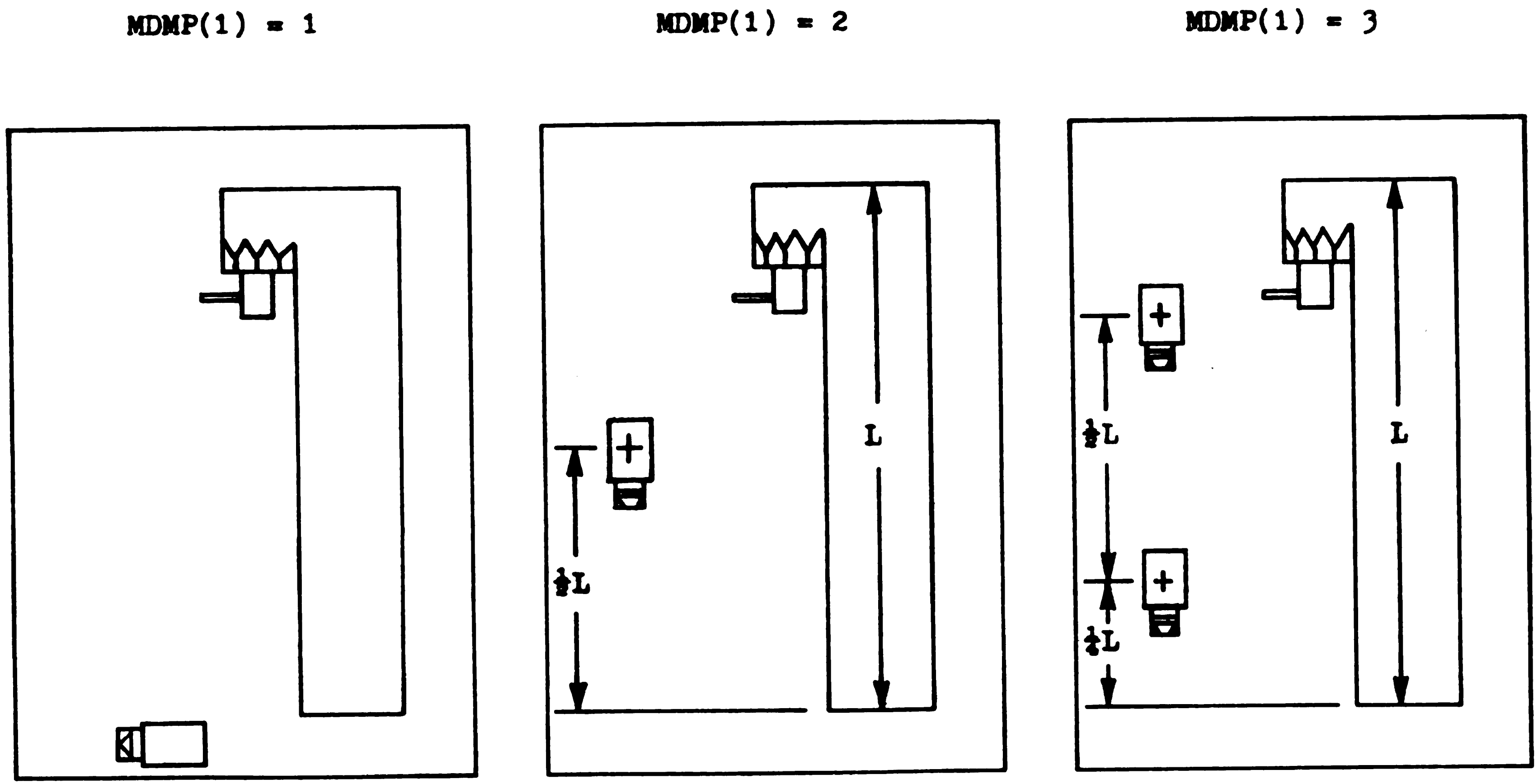
* Variable MDMP is dimensioned to 5 to accomodate the multi-combine situation, i.e., up to 5 different combines.



a) Transport vehicle(s) spotted at one end of the field only.

b) Transport vehicle(s) spotted midway through the field.

c) Transport vehicles spotted at the 1/4 and 3/4 points through the field.

Figure 11. Combine Unloading Patterns for STOP-Unloading.

If $0.5 > D \geq 0.25$, MDMP(1) = 3 is set.

The combine can make half a pass, but not a full pass, so unloading is needed at both ends of the field and in the middle (requiring 3 transport vehicles), or at the 1/4 and 3/4 points through the field (requiring only 2 transport vehicles).

If $D < 0.25$, then the run is aborted.

The combine cannot harvest at least halfway through the field before the grain tank is full.

For a one-man system, TRSET3 returns NVEH2 = 1 for MDMP(1) ≤ 2, or NVEH2 = 2 for MDMP(1) = 3.* This dictates that the transport sets be positioned for unloading as indicated in Figure 11, and that a continuous alternating harvest pattern be used

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* Setting NVEH2 is somewhat more complicated for the multi-man, single-combine case. Subroutine TRSET3 is currently operational for this situation. With a multi-man work force it is assumed that one man will operate the combine, and at least one man will always be available to drive transport sets. With this assumption, the <u>absolute</u> <u>minimum</u> number of transport sets required is:

1 -- when on-the-go unloading is to be practiced, regardless of the MDMP(1) setting, or when stop-unloading is used with MDMP(1) ≤ 2.

2 -- when stop unloading is used with MDMP(1) = 3.

Consider THARV = the time required for the combine to move from one unload point to the next (on-row harvesting plus turning at the ends), and THAUL = the transport set unload-cycle-time (travel to the delivery point plus unloading plus travel back to the field). If THARV ≥ THAUL, then the combine will not have to wait for a transport set to return to the field (barring the need for transport set repairs), even if the <u>minimum</u> number of transport sets is used. However, if THARV < THAUL, then combine delays can be expected (consistently) each time a transport set must leave the field to unload, <u>if an extra transport set</u> (the minimum number plus one) <u>is not provided</u>, i.e., one to remain at the combine unload point (with or without a driver) while another leaves the field to unload at the day's corn delivery point. Subroutine TRSET3 is designed to compute THARV and THAUL, and then set NVEH2 to the <u>minimum</u> number required (above) if THARV ≥ THAUL, or to the <u>minimum</u> plus one otherwise.

by the combine when MDMP(1) $\geq$ 2.*

Once the transport system requirements for the day are determined (NVEH2), EXEC1 creates additional transport sets (loads them into file 8) if needed. This is done by subroutine TRSET5, which utilizes subroutine LOADTR for the actual filing procedure. TRSET5 selects <u>particular</u> transport sets for assembly (trucks or tractors plus one or two trailed vehicles) from predetermined lists of feasible transport set combinations for the four types of harvest-time hauling activities possible:

1) Wet corn, hauling from a field to an off-farm location.

2) Wet corn, hauling from a field to an on-farm location (farmstead).

3) Dry corn, hauling from the drier site to an off-farm location.

4) Dry corn, hauling from the drier site to a different on-farm location (farmstead).

* A continuous alternating field pattern is an absolute necessity when MDMP(1) = 3, regardless of the number of transport sets or the positioning technique used with the one-man system and the multi-man system (with STOP-unloading) situations. When MDMP(1) = 2, however, the choice (or lack of choice) of a field pattern depends on the number of transport sets and their positioning. Using two transport sets, positioned at the ends of the field, leaves the choice of field pattern unrestricted, e.g., a continuous alternating pattern can be used, a land pattern of some type can be used, or a continuous overlap pattern of some type can be used; using a single transport set, positioned midway through the field as illustrated in Figure 11, dictates the use of a continuous alternating pattern. When MDMP(1) = 1, the choice of field pattern is unrestricted. Because of these considerations, the simulation of combine activities with the present model (the event routines that are currently operational) is done with a continuous alternating field pattern regardless of the choice specified by the model-user.

These lists are created by initialization subroutine TRSET1, which utilizes the use-restrictions, if any, specified by the model-user. Larger transport sets are placed at the front of the lists, smaller ones at the back. A transport set consisting of a truck plus 0, 1 or 2 trailed vehicles is given higher priority (placed closer to the front of the list) than one of equal size which consists of a tractor plus 1 or 2 trailed vehicles.

To assemble K transport sets (K = NVEH2 - NOVEH), TRSET5 begins at the front of the appropriate list and considers each transport set combination in sequence. If a particular transport set combination has already been assembled, or if one of the components of a particular combination is not available in the unassigned files (trucks and trailed vehicles in file 5, a tractor of minimum size or larger in file 2), then TRSET5 proceeds to the next one on the list until the required number of units (K) have been assembled, or until the end of the list is reached (which aborts the run). Once transport sets have been assembled in file 8 they remain assembled there until the basic harvest-time handling option changes, as was noted earlier in the discussion about "satisfying" the high-moisture storage option.

Initiating activity-simulation with EXEC1

Having determined the labor and equipment availability and requirements for the day's harvest activities, EXEC1 performs three additional duties that are necessary to initiate activity-simulation with the present model (see Figure 10):

1) It generates the entity-ID attributes for the day (the $NTITY_i$ attributes in Figure 9), and places them in the KTRIB-array for use later in filing real events.

2) It computes the start-of-the-day indicator (the NACT attribute of Figure 9), and places it in KTRIB(8). The composition and use of this indicator will be discussed forthwith.

3) It files a dummy event (using subroutine DUMFIL) for all entities that will be available for assignment or use throughout the day.

EXEC1 is now ready to assign a man to perform the first activity of the day, i.e., it is now ready to file the first real event of the day.* This is done with subroutines ASIGN1 and/or ASIGN2 for harvest-time handling options 1 and 4, respectively.

The ASIGN-routines use the special start-of-the-day indicator NACT = ABCDE for determining <u>what</u> event to schedule first (or next). The individual digit-positions previously defined by EXEC1 were:

A = 1, indicating that the combine must be prepared and/or moved to the initial start-harvest point before harvest can begin.

B = NVEH2, the number of transport sets that must be prepared and/or spotted in the field prior to the time they are first needed for combine unloading.

C = KSILO, where a non-zero value indicates that the silo-filling equipment should be moved from one silo to another, at the present high-moisture storage site, before any corn from today's harvest can be stored.

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* If NQ(1), the number of entries in file 1, is greater than NDUM at this point in time (see Figure 10), then subroutine SCHEXC <u>must</u> have filed at least one EXEC1-event. This means that there are two or more men in today's work force, at least one of which is scheduled to begin working at some later time, or he is scheduled to quit working at some time prior to TFIN. As was noted earlier, the model cannot presently deal with this type of multi-schedule work force.

D = NVEH1, the number of transport sets that must be unloaded (they held corn overnight) which may be zero or non-zero.

E = N, where a non-zero value indicates that a tractor being used for farmstead work (the $NTITY_5$ tractor) should be serviced before it is used today.

These start-of-the-day activities are considered by the ASIGN-routines in reverse order, e.g., the E-activity is done first if needed, then the D-activity(s) if needed, then the C-activity if needed, then the B-activity(s) which are always needed, andfinally the A-activity which, also, is always needed.

The ASIGN-routines perform the following functions: 1) they decide what activity to do next, 2) they decide what entities will be involved in the activity, 3) they remove the dummy events for those entities from file 1 and store the state-(delay) time information for them (with a call to subroutine STATE1), 4) they set the appropriate (next) activity-state for the entities, i.e., the activity-state in which the entities will exist from TNOW until the event about to be filed occurs, and 5) they file an event for the entities, i.e., compute and/or define attribute values (event code, event time, etc.) and place an entry in file 1.

The event(s) thus filed will be subsequently removed from file 1 by subroutine MYGASP, and control, through subroutine EVNTS, will be directed to a particular event-routine designed for start-of-the-day event codes. These routines, except for the one which handles movement of the combine to the initial start-harvest point, will perform the required accounting functions, place the entities back in dummy-delay (file dummy events), and again call the appropriate ASIGN-routine for scheduling the next start-of-the-day activity.

As the ASIGN-routines schedule activities (file events), the value of the appropriate digit-position in the NACT indicator (ABCDE) is adjusted. When the E-activity has been scheduled, for instance, the value in the E-digit position is set to zero. When the unloading of a transport set has been scheduled, the value in the D-digit position is reduced by one. Thus, the value of the NACT-indicator eventually reaches 10000, indicating that all that remains to be done is prepare the combine and move it into position to begin harvest.

The event routine that handles this combine activity (the one called at the conclusion of the activity) resets the NACT indicator to 1, 2 or 3 (see Figure 9), depending on the mode of operation that will be in effect when harvest begins. It also performs a number of accounting functions and, finally, calls a special routine which schedules the first harvesting activities of the day.* The event-oriented activity-simulation thus started is self-sustaining from this point on.

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*If the combine happens to be positioned <u>precisely</u> at the initial start-harvest point for the day, <u>i.e.</u>, if it was stored there overnight, then ASIGN1 automatically increases its x-coordinate by 1 rod, thereby insuring that the combine will <u>have</u> to perform a travel activity (one that may require only a second or two) to move into position to begin harvest, and thereby assuring that this special event routine <u>will</u> be called at the start of each day, and the first real harvesting activities <u>will</u> be scheduled.

Special start-of-the-day considerations

The assignment routine called by EXEC1 for handling option 4 (subroutine ASIGN2) when transport sets must be unloaded at the start of the day is used only to schedule these unloading activities. ASIGN2 uses a special-purpose routine (subroutine TRSET6) to do this. TRSET6 is also used at other times throughout the day. When TRSET6 is called, the ATRIB/JTRIB array must contain the attribute information required of a 98-event transport set delay, i.e., a dummy event designating an idle transport set with the driver present. This may be done with assignment statements to setup the ATRIB/JTRIB arrays, or by actually removing a 98-event from file 1 (with subroutine RMOVE). TRSET6, then, automatically schedules the travel activity to the appropriate delivery point, the unloading activity at the delivery point, and the return travel activity to the appropriate point. Transport sets that are moved off-farm for unloading at the start of the day are always returned to the base farmstead (designated by the model-user) to await further assignment.

When handling option 4 is in effect, the C-digit and E-digit positions of the start-of-the-day indicator (NACT) are always zero, since farmstead activities are not involved with direct-from-the-field off-farm marketing. Subroutine ASIGN2, in this case, is used to schedule transport set unloadings, if any, while subroutine ASIGN1 is used to schedule the initial in-field positioning of transport sets, preparatory to the start of harvest, and to schedule combine movement to the initial start-harvest point in the field for both handling options (1 and 4). Both ASIGN1 and ASIGN2 are currently operational for the multi-man (common work schedule), single-combine situation.

With a 1-man work force, of course, the single man available is assigned to perform all activities at the start of the day. With a multi-man work force, however, the ASIGN-routines are designed to use the combine operator (only), which is known by the job priority information supplied by the model-user, to perform all D-type and E-type activities (NACT = ABCDE), even though other men are available.* If more than one transport set must be unloaded (D-type activities), they are unloaded in sequence, one unit at a time, by the combine operator.

If the silo-filling equipment must be moved, ASIGN1 uses the combine operator, plus 1 or (up to) 2 other men to perform this activity, if available, depending on the number of men needed, as specified by the model-user. If less than the required number of men is available to perform this job, the time required to do it (supplied by the model-user) is increased appropriately.

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* It was feared that the event-routines, which had not been entirely conceptualized when the ASIGN-routines were developed, would not be able to handle the situation in which the combine operator went directly to the combine at the start of the day, while the other men busied themselves with the "other" jobs to be done. In that case, because of the need for transport set or farmstead tractor repairs, or other factors, a situation might develop in which the combine moved to the field, harvested until the grain tank was full, and then had to wait several hours for a transport set to arrive in order to unload and continue harvesting.

With the multi-man situation, initial in-field positioning of transport sets (B-type activities) and combine preparation (A-type activities) are done in sequence by the combine operator until the number of jobs that remain to be done is equal to the size of the day's labor force, i.e., until K + 1 = NQ(6), where K is the number of transport sets that still have to be positioned in the field, and NQ(6) is the number of entries in file 6, the labor file. At that time men are assigned to all remaining jobs and the appropriate start-of-the-day events are filed by ASIGN1. For instance, if two transport sets are needed (MDMP(1) = 3, STOP-unloading) and a 2-man labor force is available, the combine operator will be assigned to move the first transport set to its in-field position while the other man sits idle. At the conclusion of this activity (at the event time), the combine operator will be assigned to the combine and the other man will be assigned to the second transport set.

The need to service a farmstead tractor (refueling plus maintenance) at the start of the day (E-type activity) is determined, in subroutine EXEC1, by checking the fuel level of the tractor. If the fuel tank is within one gallon of being full, servicing is not required. This same technique is used, in ASIGN1, to determine the service needs of the combine, and of transport sets, prior to their in-field positioning.* When

* The need for servicing of transport sets is <u>not</u> checked prior to start-of-the-day unloading activities (D-type activities), since in some situations all the transport sets used on one day may not be needed on the next.

servicing is needed, the EPM-attribute value is also checked. If it is negative (the EPM job is past due), then the time required to perform the EPM job is added to the normal service time requirement, and the EPM-attribute value is updated (the EPM service time and next attribute value is obtained using subroutine MAINT).

One time requirement that might be important at the start of the day is ignored by (has not been incorporated into) subroutine ASIGN1: the time required for men to move from one job to another. With the one-man system, for instance, the time required for the man to move from a transport set that has just been positioned in the field to another transport set or to the combine, which may be back at the farmstead, is not accountable with the present version of ASIGN1. With a multi-man system this may be more than offset, in terms of the amount of harvesting that can be done on a given day, by the "extra" work assignments given the combine operator, as noted earlier.

Concluding an activity-simulation day

Activity-simulation, once started, continues throughout the day, under the control of subroutine MYGASP, until the NACT-indicator is again reset (to 4 or 5), at which time events are scheduled (begin to be scheduled) for the purpose of moving the entities to their overnight or long term storage locations, i.e., for concluding the day's activities. The need to reset the NACT-indicator is recognized in the routine which schedules harvest (combine) activities, when any one of the following conditions is met:

1) When operating time for the day has all been used, i.e., clock-time will exceed TFIN at the conclusion of the next full harvest pass.

2) When a non-tractable field section is encountered.

3) When a field section is encountered in which the kernel moisture of the corn is outside the desired moisture range.

4) When harvest is completed in the current field.

At this time, a special event code is set (a special event routine will be called) which will initiate the end-of-the-day procedure.

When clock-time (TNOW $\geq$ TFIN) is the reason for terminating harvest activities, the event routine which schedules combine events is designed to schedule enough events to move the combine to the end of the field, i.e., the combine is allowed to finish a harvest pass once it has been started. In this case, TNOW will always be greater than TFIN when the overall activity-simulation for the day does indeed come to an end -- TNOW may exceed TFIN by a large amount if a combine repair or adjustment activity is needed on the final harvest pass, or if a transport set repair is required while these units are moving to their overnight storage locations.

The combine grain tank is always emptied at the end of the day. Transport sets that contain some corn at the end of the day are not allowed to unload (at a farmstead or an off-farm location), if they leave the field when TNOW is greater than TFIN. If they leave the field with TNOW $<$ TFIN, destined for an off-farm market, then they are allowed to unload and return, to the base farmstead, even though TNOW may exceed TFIN before they get back. If they leave the field with TNOW$<$TFIN, destined for a farmstead delivery point, then they are allowed to unload only if TNOW$<$TFIN when they arrive at the farmstead -- otherwise the corn is left on the transport set overnight.

Should the need to terminate harvest activities be signalled by one of the latter three reasons noted previously, then, in the absence of major repairs, TNOW will sometimes be less than TFIN when the overall activity-simulation for the "day" ends. As such, additional activity-simulation (harvesting) may be feasible in another field on that same calendar day. As was noted previously, this determination will be made upon return to the daily simulation loop of Figure 1.

In this case (TNOW$<$TFIN at the "day's" conclusion), all transport sets <u>will</u> be unloaded, and all mobile entities (combine and transport sets) <u>will</u> be moved to their overnight storage locations, even if that happens to be at a farmstead (rather than in the field). If it is then determined that additional activity-simulation will be allowed, the start-of-the-day procedure as previously discussed will again be followed. This technique, as with some of the others noted previously, is <u>not</u> a true representation of what would probably happen in the real world. The farm manager, for instance, would probably have the combine and transport sets moved directly to the next field. Transport sets, especially those containing only a small quantity of corn, would probably not be unloaded prior to the move to the other field, unless of course the corn had to be kept separate because of some special circumstance (seed corn, high lysine corn, special owner-tenant agreement, etc.).

The initial setting of TFIN, to the latest scheduled quitting time of the labor force, is in fact the setting of a target quitting time, as is now obvious, due to the particular end-of-the-day procedures being used. On some days the men involved may be able to quit early. On other days they may be required to work beyond their scheduled quitting time. This is realistic in terms of present-day practices.

EVENT SCHEDULING

There are five broad categories of field-related activities (and associated events) which an event-oriented simulation model of a corn harvesting and handling system should deal with. These are:

1. Start-of-the-day activities. These activities involve the preparation of equipment, the positioning of equipment, and related activities in anticipation of beginning the day's primary activity -- harvesting.

2. Field preparation activities. Before "normal-pattern" harvesting can begin in a given field, end rows (turn rows or headland rows) may have to be harvested, if any were planted, to provide a turning strip for the combine and a place where transport units may be positioned to receive corn from the combine. This "opening-up" of a field may involve collection of a small quantity of corn in the combine's grain tank from <u>all</u> sections of the field, it may involve a full harvest pass or two in one or both border-sections of the field (depending on the number of turn rows planted at one end, or both), and it may involve a number, type and transport set positioning technique different from that to be used with normal-pattern harvesting.

3. Transitional activities from opening-up to normal pattern harvesting. These activities involve, again, the positioning of equipment preparatory to the start of normal-pattern harvesting. In addition, if a transport set is nearly full at the conclusion of the opening-up procedure, for instance, then it may be taken to an out-of-field point for unloading before normal-pattern harvesting begins (or as it is beginning in the multi-man situation). Note that, in general, the corn harvested from end rows during the opening-up procedure will be of the same type, and at about the same moisture content and yield level as that planted in the <u>last</u> field

section to be planted. This may be quite different from that collected with the initial normal-pattern pass in the first field section if planting in this field required several calendar days.

4. Normal-pattern harvesting activities. These activities are the combine and transport set movements required as harvesting progresses in a more or less "normal" fashion, utilizing the combine unloading pattern and vehicle positioning techniques previously discussed.

5. End-of-the-day activities. These activities refer to those things required to conclude a harvest day, i.e., the movement of equipment to its overnight storage location, and in some cases the unloading of transport sets.

In addition to these field-related activities, the model should have the capability (but does not presently) of dealing with another broad category of activities -- that of on-farm drying, handling and storage.

If end rows are not planted, then field preparation and the subsequent transitional activities are not required on the first day in which harvesting is to be done in a given field, i.e., the combine may proceed directly to normal-pattern harvesting. In this case, it is assumed that a turn strip exists outside the boundary of the field. Though considerable effort was expended in developing the opening-up procedure and transitional activities for both the one-man and multi-man (single combine) situations, this aspect of the model was not entirely developed and is not presently operational. Thus, the model-user is not permitted, with the present model, to specify end rows as a part of the planting policy specifications requested on the input form.

With the three remaining categories of field-related activities (start-of-the-day, normal-pattern harvesting and end-of-the-day activities) a number of event scheduling techniques could have been used. For a one-man system, for instance, all activities to be simulated must be done, in sequence, by the single man that is available for assignment. As such, each and every event that is to occur between TNOW and TFIN could be scheduled at the start of the day without a great deal of programming difficulties. This would, however, result in an extremely large storage space requirement for file 1, the events file, in the GASP filing array. This same programming technique, applied to the multi-man situation where two or more activities can be carried-out simultaneously, would be quite cumbersome.

The other extreme would be to schedule only one event at a time throughout the day, i.e., the event routines would be designed to schedule only the very next event for the entity(s) involved. This would require a minimum of storage space for the GASP filing array, since no more than one GASP column (one real or dummy event) would be needed at any point in simulated time for each man, equipment set or transport set in the system. On the other hand, duplicate programming and/ or a considerable increase in the COMMON requirements would probably be needed with this approach.

A compromise event scheduling technique was selected for use with the model developed, as is illustrated for the one-man situation in Figure 12. Each box in Figure 12 indicates

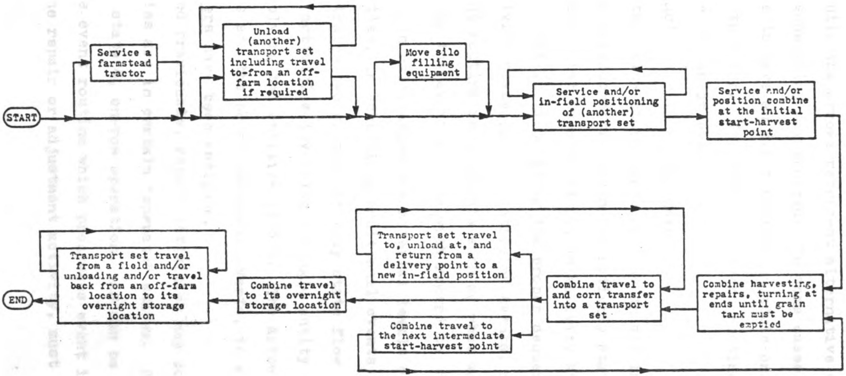


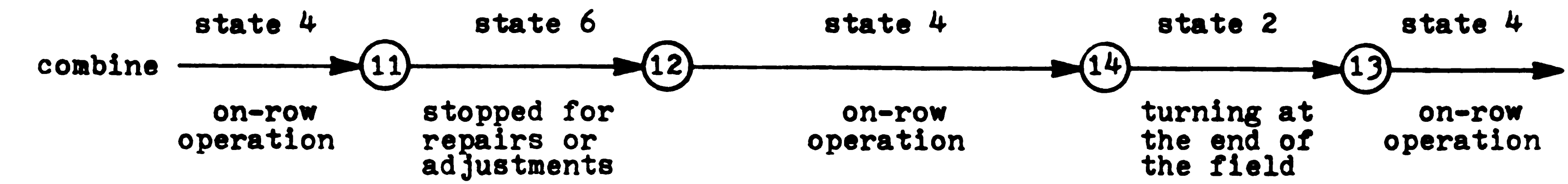
Figure 12. Event Scheduling Sequence for Corn Harvesting and Handling Activities for a One-Man System Without On-Farm Drying.

the type of activity or activities for which events are to be scheduled, while the arrows represent alternative sequences in which event scheduling may proceed. In some cases it was found desireable to have an event routine schedule only the very next event to occur. In others, an event routine may schedule a whole series of events.

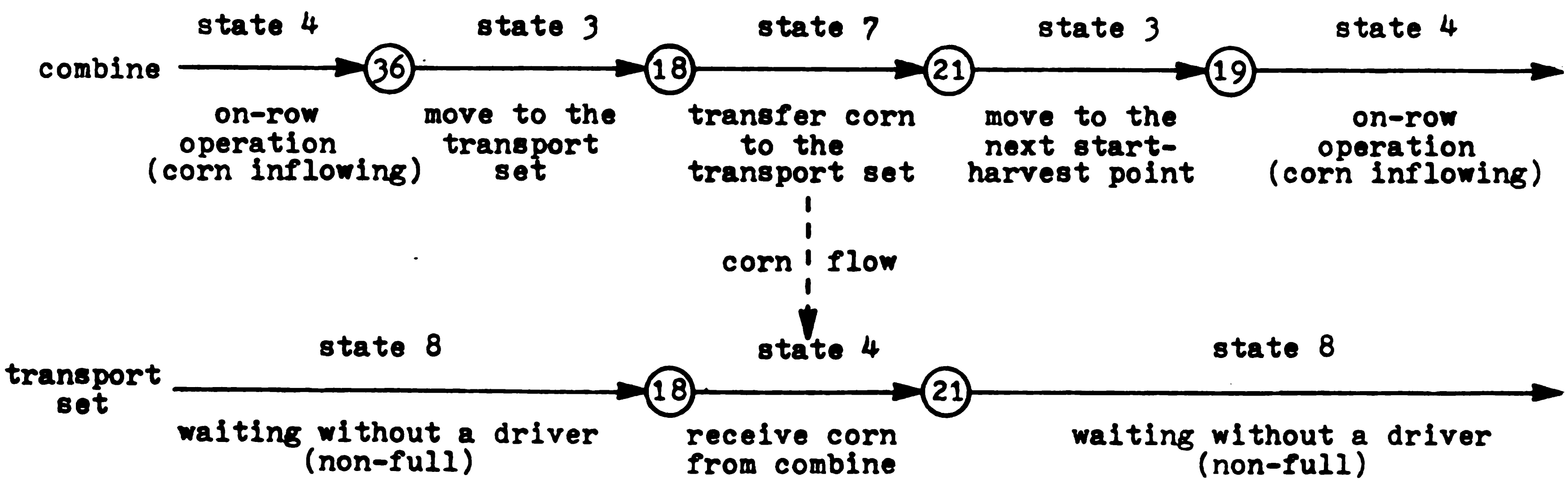
Activity State Flow Charts

Activity state flow charts were used as an aid in the event scheduling development. Given the activity states in which entities can exist (see Table 3), an activity state flow chart is helpful in visualizing the proper sequence of activities (activity states), in identifying events, and in determining event routine requirements such as what action should be taken by the event routine with regard to changing activity states, in calculating the material levels or the location of entities, in scheduling additional events, etc. Figure 13 illustrates two simple activity state flow charts for a series of activities involving a single entity (13a.) and for one involving two entities (13b.). The arrows designate activities and the nodes designate events, to which event code numbers have been assigned.

As was noted previously, repair activities may occur only when entities are in certain "operate" states. For the combine this is state 4, on-row operation. As can be seen in Figure 13a., the event routine which processes event 12, the conclusion of the repair or adjustment activity, must return



a) Combine interruption and normal turn at the end of the field.



b) Corn transfer from a combine to a transport set that can hold all of the grain tank's current contents(STOP-unloading).

Figure 13. Simple Activity State Flow Charts.

the combine to state 4.* Another important function of this particular event routine is to reset a value for the combine repair attribute that became zero, thereby indicating the need for the repair activity just concluded. Thus, in addition to the event code, the event time, and the time at which the combine last changed states, an entry in file 1 for event code 12 must also have one attribute (one of the ATT_i cells of Figure 9) which is the accumulated hours of use until the next repair of this type will be needed.

Other event routine requirements can be determined by studying Figure 13. These include:

1. Event routines for events 11, 14 and 36 should adjust the repair and EPM attribute values of the combine. They should also update the corn level and moisture content in the grain tank, and the acres harvested in this field (file 10) and for this field operation (file 9).

2. Event routines for events 11, 14, 36, 18 and 19 should adjust the fuel level in the combine fuel tank, and update the combine's current location.

3. Event routines for events 18 and 21 should change the activity state of both the combine and the transport set involved, and the event routine for event 21 should also adjust the corn level and moisture content of the combine (reduce the level) and of the transport set (increase the level by an equal amount).

The event routine for event 21 must also recognize the situation in which the transport set cannot hold all of the grain tank's current contents. In this case, rather than the transport set being placed in dummy-delay and the combine moving back to the corn to continue harvest, the combine must be

*An operate interruption for a transport set may occur when the unit is in state 1 (out-of-field travel) or state 2 (in-field travel).

placed in dummy-delay, the operator transferred to the transport set, and a series of events scheduled to move the transport set to the corn delivery point and then back to the field. This is illustrated in Figure 14.

With the aid of activity state flow charts, 56 real events (event codes 5 through 60) were identified for the one-man and multi-man (one combine) situations in which corn could be stored on-farm in high-moisture storage structures or marketed off-farm at harvest. Of these, it was determined that 29 real events, and event routines to process them, were required for the one-man situation (see Table 6). The event routines designated for specific events in Table 6 fall into one of three categories: 1) the routine is required only for the one-man situation and presently operational; 2) the routine is required for both the one-man and multi-man situations but is presently operational for only the one-man situation, or 3) the routine is required for both situations and is presently operational for both. The file 1 entry requirements for the events listed in Table 6 are presented in Appendix E.

Computing Real Event Attribute Values

The routines that schedule real events are designed to compute certain types of floating-point attribute values:*

1. In-field coordinates. The new x,y-position which an entity will occupy at the occurrence of an event. Out-of-field positions are designated by location codes only (1-6 for farmsteads, 11-16 for off-farm locations).

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*In addition to assigning all necessary fixed-point attribute values, i.e., the event code, the required entity-ID information, and the current mode of operation indicator -- see Figure 9 and Appendix E.

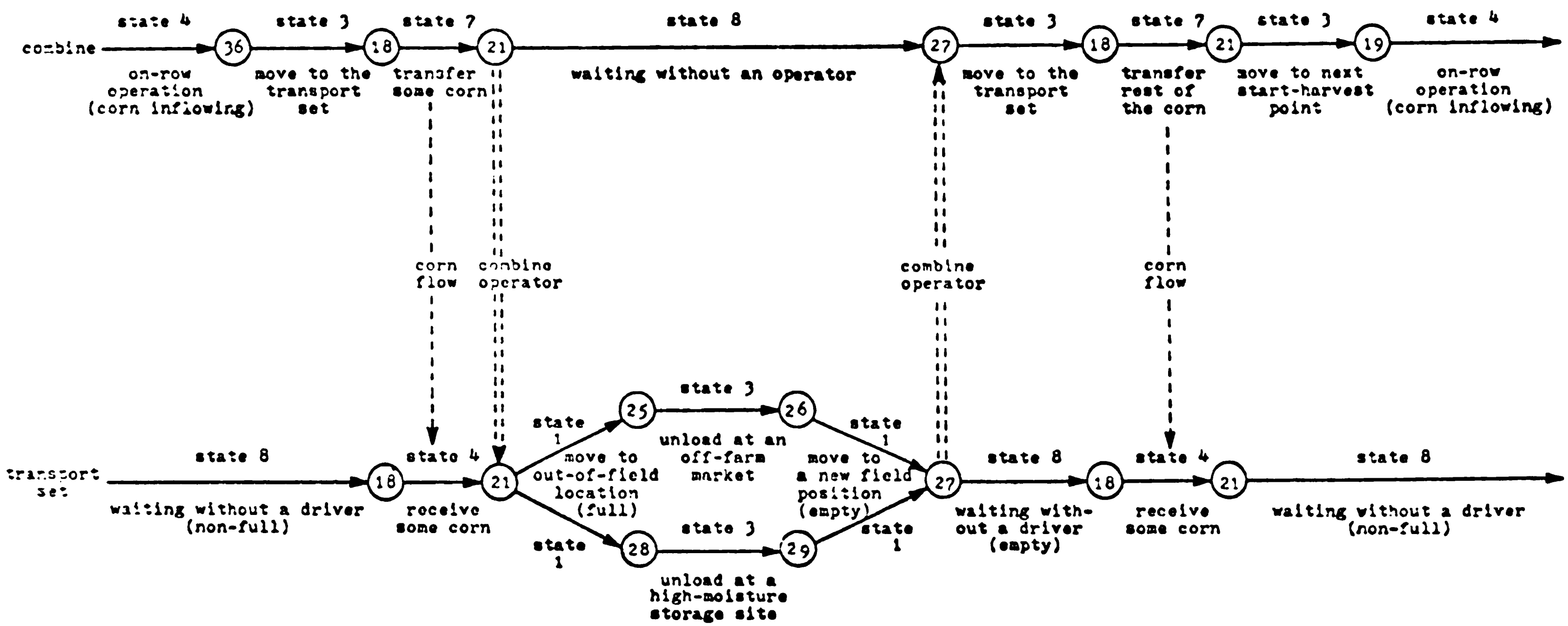

Figure 14. Activity State Flow Chart for Grain Tank Unloading That Fills A Transport Set(One-Man System).

Table 6. Real Events for A One-Man Corn Harvesting and Handling System Without On-Farm Drying.

Event Code	Event Type*	Event Routine**	Activity Terminated by the Occurrence of this Event
5	S	SVC1	Servicing a tractor used for farmstead duties.
6	S	UNLOD1	Transport set unloading at a high-moisture storage site.
7	S	SILOMV	Moving silo filling equipment.
8	S	SPOT1	Transport set travel to its initial in-field position.
9	S	HARV1	Combine travel to the initial start-harvest point.
10	N	SVC1	Servicing the entity designated by $NTITY_5$.†
11	N	RPR1	An "operate" activity (a repair activity begins).
12	N	RPR2	A repair activity.
13	N	TURN1	Combine travel on the headlands.
14	N	END1	On-row combine operation (grain tank is not full).
15	N	SVC1	Servicing the entity designated by $NTITY_6$.†
18	N	STOP2	Combine travel to a transport set.
19	N	HARV1	Combine travel to the next start-harvest point.
20	N	SVC1	Servicing the entity designated by $NTITY_7$.†
21	N	DUMP2	Corn transfer from combine to a transport set.
25	N	UNLOD2	Transport set travel to an off-farm market.
26	N	UNLOD3	Transport set unloading at an off-farm market.
27	N	SPOT2	Transport set travel to its next in-field position.
28	N	UNLOD4	Transport set travel to a high-moisture storage site.
29	N	UNLOD5	Transport set unloading at a high-moisture storage site.
30	E	SPOT10	Transport set travel to a combine waiting to unload.
36	N	END4	On-row combine operation (grain tank full, NCMP(1) = 1,2).
37	N	END5	On-row combine operation (grain tank full, NCMP(1) = 3).
38	E	END6	On-row combine operation (end of harvest for today).
50	E	DUMP11	Corn transfer from combine to a transport set.
53	E	WAIT2	Combine travel to its overnight storage location.
54	E	SPOT12	Transport set travel to its overnight location
55	E	UNLOD5	Transport set unloading at a high-moisture storage site.
60	S	SPOT14	Transport set (return) travel to its overnight location.

* S = special start-of-the-day events, E = special end-of-the-day events, and N = all others.

** Called by subroutine EVNTS. Note--A complete listing of these subroutines, and all others used with the model, may be obtained from the Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.

† $NTITY_i$ = the entity-ID information (column and file number) contained in the ith fixed-point attribute cell of the event column.

2. Activity times. The time of occurrence of an event, TNEW, is the current clocktime, TNOW, plus the time required by the entity(s) involved to perform the activity, T_a (TNEW = TNOW + T_a).

3. Harvested-crop values. The adjustments to be made in the grain tank attributes of the combine (bushels, cubic feet, moisture content) at the conclusion of a harvest pass will depend on the existing attributes of the crop in the particular field section (potential harvestable yield, current moisture content, amount of stalk lodging), on certain attributes of the combine (on-row operating speed), and on the interface between these two (machine losses).

The following discussion details the computational techniques employed.

In-field coordinates for combine harvesting

With normal pattern harvesting (continuous alternating field pattern), the combine moves (simulated movement) as indicated by the arrows in Figure 15, when harvest is proceeding away from the field origin side of the field. This movement is interrupted only by the need for repairs or adjustments, or by the need to unload the grain tank. In the former case, the combine is stopped in-place, and then proceeds from there at the conclusion of the repair activity. In the latter case, the combine moves to the appropriate transport set, unloads the grain tank, then moves back to the corn to continue harvesting.* The point to which the combine moves when it moves (back) to the corn to continue harvesting is called a "start-harvest" point.

*The x,y-coordinates of the combine are assumed to coincide with the x,y coordinates of the transport set during the grain transfer activity.

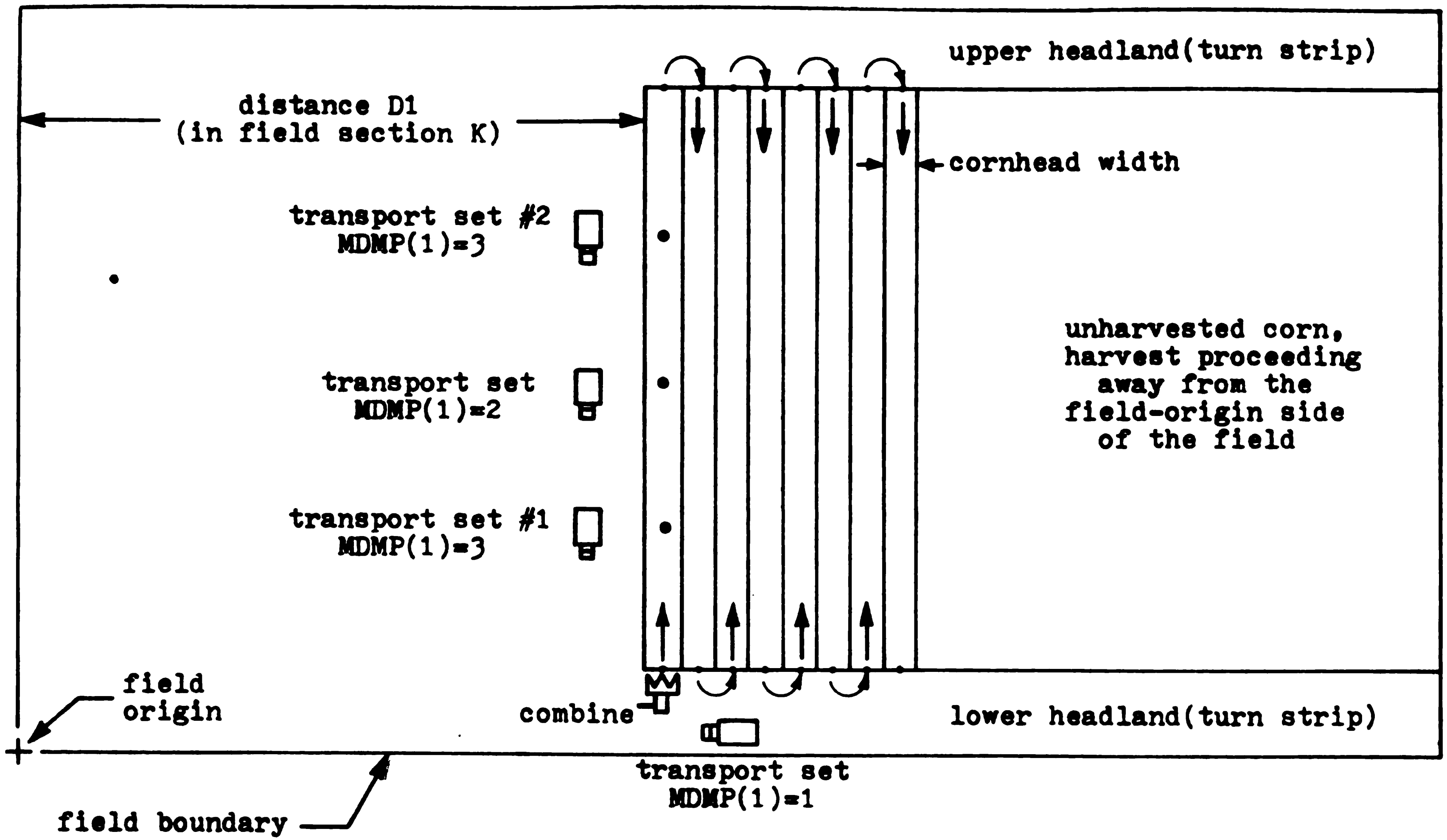

Figure 15. Sample Entity Positions and Movements for One-Man Harvesting Systems.

The x, y-coordinates, with respect to the field origin, of the next start-harvest point, and the field section number in which it resides, are required at the start of the day (the initial start-harvest point), when the combine turns at the ends of the field, and for the "return" event following grain tank unloading. Two subroutines, MVOVER and WISE, were developed to assist with the computation of x,y-coordinates of this type.

Subroutine MVOVER (NF, NL, NN, XN, MP, D, ND, XD, JJ) is used for x-coordinates in a field in which NF and NL are the first and last sections, and x-coordinate XN is known to reside in section NN. If it is desired to move over a distance D (rods) from XN, then MVOVER returns

XD = XN + D, for a move to the right (MP = 2),

or XD = XN-D, for a move to the left (MP = 3),

and ND = the section number in which XD resides.

If XN ± D is within the field boundaries, then JJ = 1 is returned. Otherwise, MVOVER returns JJ = 2, XD = the x-coordinate to the appropriate field boundary, and ND = NL (for MP = 2) or NF (for MP = 3).

In determining the x-coordinate of the initial start-harvest point for the day, one sets NF, NL, NN, XN and MP based on the attribute information stored with the field to be harvested (in file 10).* Then before calling MVOVER, D

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* The setting of XN is based on D1 (see Figure 15 and file 10 in Appendix B), the horizontal distance between the appropriate field boundary and the nearest edge of an area of unharvested corn. D1, and its corresponding field section number, is updated as needed by the routines that process harvesting events.

is defined as one-half the cornhead width. The returned value of XD is the desired x-coordinate. In determining a new x-coordinate for turning at the end of the field, X_N and NN are based on the combine's existing location prior to the turn, and D is defined as the whole cornhead width.

Subroutine WISE (NF, ND, XD, Y1, Y2, Y3, Y4) is used for y-coordinates (y's) in a field in which NF is the first section. Given the x-coordinate XD of a line which resides in section ND of that field, WISE returns y-coordinates for

Y1 - the lower field boundary

Y2 - the lower edge of the unharvested corn, i.e., Y1 plus the headland width

Y3 - the upper edge of the unharvested corn

Y4 - the upper field boundary.

Note that if no turn rows were planted, which is a requirement with the model in its present stage of development, then Y1 = Y2 and Y3 = Y4. Note also that subroutine WISE is much more useful for irregularly shaped fields than for rectangular fields like the one illustrated in Figure 15.

The initial start-harvest point for the day is always at the lower end of the field, e.g., the combine in Figure 15 could be positioned at the initial start-harvest point for the day if some harvesting had already been done in this field. The x,y-coordinates of this point would be (XD,Y2), as found by using subroutines MVOVER and WISE as indicated.*

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* Subroutine GOFLD2 is called at the start of each activity-simulation day to, among other things, compute the x,y coordinates of the initial start-harvest point for the day.

If the combine unload pattern for the day were MDMP(1) = 2 (see Figure 15), then the initial harvest pass by the combine would be from point (XD, Y2) to point (XD, Y'), where Y' = Y2 +(Y2 + Y3)/2. Following grain tank unloading into the transport set, the combine would then harvest from point (XD, Y'), to point (XD, Y3) at the upper end of the field, then return (harvest back) to the midpoint of the field for the next grain tank unloading activity. If the combine unload pattern for the day were MDMP(1) = 3 (Figure 15), the first grain tank unloading, into transport set #1, would occur after the combine had harvested from point (XD, Y2) to point (XD, Y'), where Y' = Y2 + (Y2 + Y3)/4, while the second unloading, into transport set #2, would occur after the combine had harvested from point (XD, Y') to point (XD,Y"), where Y" = Y2 + 3(Y2 + Y3)/4.

<u>In-field coordinates for transport sets</u>

When a transport set is to be positioned in a field, it is always done so in relation to the combine's current x-coordinate, or the next x-coordinate along which the combine will be harvesting, if it is not harvesting at the time the positioning event is being scheduled. The x,y-coordinates of transport sets are computed, with the aid of subroutines MVOVER and WISE, as follows, where XX is the x-coordinate of the current or next combine harvest pass, and Y1, Y2 and Y3 are as defined in the preceeding discussion:*

1. MDMP(1) = 1. One transport set required, one extra transport set may be used for multi-man systems. Define position 1 at 2 rods (position 2 at 4 rods) <u>beyond</u> line XX, 1/2 rod above Y1 at the corresponding x-coordinate(s). <u>Beyond</u> line XX means to the right of XX for MP = 2 (harvest proceeding away from the field origin side of the field), or to the left of XX for MP = 3. If 2 rods beyond XX is outside the field, then reset position 1 at 1/2 rod from the edge (side) of the field, 1 rod above Y1. If 4 rods beyond XX is outside the field, then reset position 2 at 1/2 rod from the edge of the field, 1/2 rod above Y1.

2. MDMP(1) = 2. One transport set required, one extra transport set may be used for multi-man systems. Define position 1 at 1 rod (position 2 at 2 rods) <u>behind</u> line XX, midway through the field at Y2 + (Y2 + Y3)/2. If 2 rods behind XX is outside the field, but 1 rod is not, then reset the x-coordinate of position 2 only, at 1/2 rod from the edge (side) of the field. If 1 rod behind XX is outside the field, then reset both positions at 1/2 rod from the edge of the field, the first 1/2 rod above, the second 1/2 rod below the midpoint.

3. MDMP(1) = 3. Two transport sets required, one extra transport set may be used for multi-man systems. Define all positions at 1 rod <u>behind</u> line XX, the third position (extra unit) 1/2 rod above Y1, the second position 1/4-way through the field at Y2 + (Y2 + Y3)/4, and the first position 3/4-way through the field at Y2 + 3(Y2 + Y3)/4. If 1 rod behind XX is outside the field, then reset the x-coordinate of all positions at 1/4 rod from the edge (side)of the field.

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* Subroutine GOFLD3 is designed to compute, and return to the calling program, up to three x,y-coordinates as indicated. A new in-field position is computed each time a transport set unloads at an out-of-field delivery point. Transport set positions are set somewhat differently by GOFLD3 for on-the-go combine unloading and when a field with turn rows has not yet been opened-up.

Activity times for daily maintenance and refueling

Daily maintenance and refueling of tractors, combines and trucks was assumed to require 10 minutes plus refueling time at a rate of 250 gallons per hour. The need for this type of service activity, as was discussed previously, is determined at the start of each activity-simulation day by comparing the current fuel level with the fuel tank capacity of the entity.* A difference of one gallon or more indicates a need for daily servicing. If an EPM job is also needed, then the time required to perform it is added to the daily servicing time.

Activity times for on-farm transport set unloading

On-farm transport set unloading with the present model refers to unloading at a high-moisture storage site (a silo). The total time required is computed as $T_a = T_{sk} + (Q/TR)$, where T_{sk} is the setup and knockdown time (hours per load) specified by the model-user, TR is the actual corn transfer rate (bushels per hour) specified by the model-user, and Q is the load size (bushels). Unloading activites of this type may be interrupted only by the need to repair a tractor used to operate silo-filling equipment, if one is used -- it is assumed that the silo being filled can hold all of the current contents of the transport set.

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* With the model in its present stage of development this check is made only at the start of the day, i.e., a fuel level checking procedure throughout the day has not been incorporated into the event routines. Consequently, certain entities may have a negative "current fuel level" at the end of an activity-simulation day.

Activity times for off-farm transport set unloading

The time needed to unload transport sets at off-farm markets requires a simple "look-up" technique with the present model. One first determines the clock-time at which the transport set will arrive at the off-farm location, then selects the total unload time from the appropriate column in file 11 if arrival is before 9:00 a.m., 9:00 - 11:30 a.m., 11:30 a.m. - 1:30 p.m., 1:30 - 4:00 p.m. or after 4:00 p.m. These "total unload times" are supplied by the model-user and should reflect the time required for weigh-in, weigh-out, sampling, waiting in line, actual unloading, and all other relavent activities at the particular site.

Activity times for grain tank unloading

The time required to transfer corn from the combine to a transport set depends on the quantity of corn transferred and the transfer rate. The quantity of corn to be transferred for a given transfer activity is computed as $\min(Q_c, Q_t)$, where Q_c is the current grain tank contents (cubic feet), and Q_t is the unused corn transport capacity (cubic feet) of the particular transport set. The number of bushels to be transferred (equivalent No. 2 bushels) is computed using the kernel moisture-volume relationship noted previously. "Overloading" of transport sets is not permitted, even if only a bushel or two of corn remains in the combine grain tank. With the one-man system, the combine is not allowed to continue harvesting until the grain tank has been emptied.

The transfer rate for a particular combine is computed as: $TR = 36 * HP + 360$, where TR is the transfer rate (cubic feet per hour), and HP is the rated engine horsepower of the combine. This relationship assumes that most combines are designed to unload their standard-size grain tank in about 1.5 minutes, and that the unloading unit is a volume measuring device. It was developed using standard grain tank sizes and engine horsepowers of combines commercially available in 1967.

Activity times for grain tank unloading (in hours) is computed as $\min(Q_c, Q_t)/TR$.

Activity times for transport set travel

In the real world transport sets may have occasion to travel between two in-field points in the same field, two in-field points in different fields, an in-field point and and out-of-field point, or two out-of-field points.* In addition, the travel characteristics, especially speed, of the two types of transport sets, truck-powered and tractor-powered, are quite different. To simplify activity time calculations within the event routines, a group of four subroutines were developed: TRAVEL to compute and return the minimum travel time required, DISTI to compute in-field

* All of these different types of travel are not possible with the restrictions and limitations presently imposed on the model. Travel between two in-field points in the same field, for instance, would be needed for a multi-man system with on-the-go combine unloading, but is not needed for a one-man system, i.e., the combine always moves to the transport set for unloading, rather than vice versa, with the event routines presently developed for the one-man system.

distances, DISTO to lookup out-of-field distances, and SPEEDT to lookup or compute travel speeds.

Subroutine TRAVEL (KCOL, LTO, XTO, YTO, TVT, NSET, QSET) computes and returns the minimum travel time required (TVT in hours) for the transport set in column KCOL of file 8 to move from its present location to a new location LTO. LTO may be off-farm locations 11 - 16 (coded 211 - 216), farmsteads 1 - 6 (coded 101 - 106), or fields 1 - 30. In the latter case, (XTO, YTO) must define the x,y-coordinates of the in-field point to which the transport set is to be moved.

The term "minimum" refers to the minimum of the travel times for the various paths which the transport set may follow to get from one point to another. When at least one of the two points is within a field, then two or more travel paths may be possible. Figure 16 illustrates this: Fields 1 and 2 are adjoining fields with a secondary entry point between them, and each has one principal entry point onto the same road.* In moving from its present location in field 1 to the desired location in field 2, the transport set may follow path 1 (a combination of in-field and out-of-field travel) or path 2 (consisting wholly of in-field travel).

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* See Appendix C for a discussion of principal and secondary field entry points.

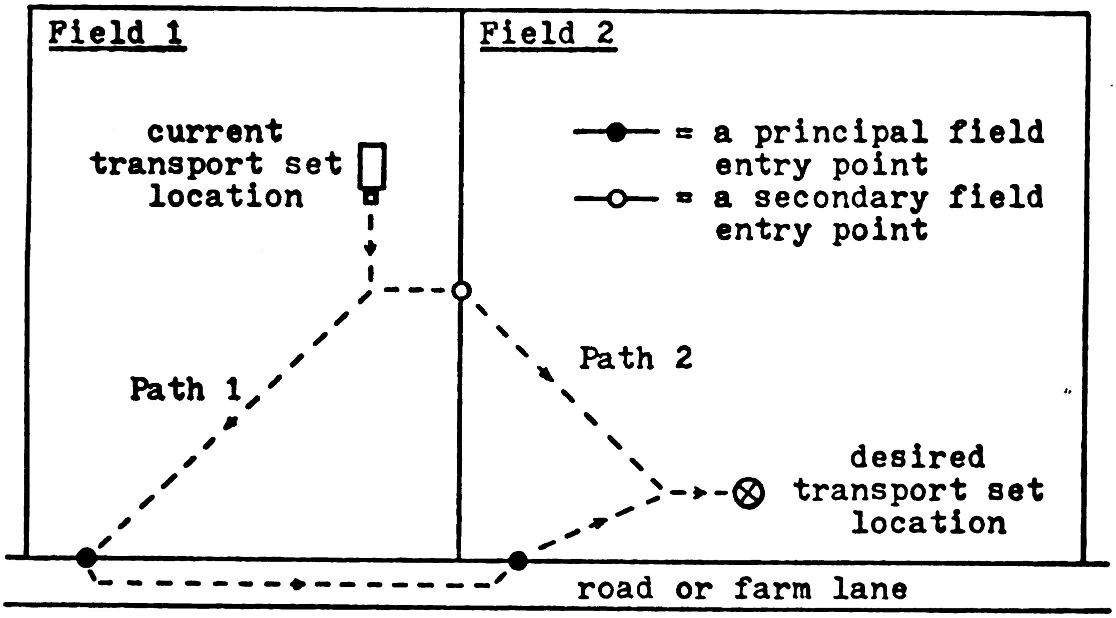

Figure 16. Alternative Travel Paths Between Two Points in Different Fields.

Subroutine TRAVEL is designed to explore a number of alternative travel paths, and return the minimum time required, when one or both of the two points are in a field.* When travel is between an in-field point (in field A) and a farmstead or off-farm location (some out-of-field travel <u>will</u> be required), subroutine TRAVEL considers those travel paths

* In the real world the driver of the transport set will decide which path to follow based on his knowledge of the alternative routes, the terrain, existing surface conditions, and the capabilities of the transport set given its existing state of loading, i.e., empty, partially loaded or fully loaded.

leading to a roadway through the principal field entry points of 1) field A, 2) B-type fields, those that may be entered from field A through a common secondary field entry point, and 3) C-type fields, those that may be entered from B-type fields through common secondary field entry points. When travel is between two in-field points in different fields, subroutine TRAVEL considers out-of-field travel paths between all principal field entry points found by the above procedure (for both fields), and by those in-field travel paths that use no more than two secondary field entry points.

Subroutines DISTI, DISTO and SPEEDT are subordinate to TRAVEL. Subroutine DISTI (N, XA, YA, XB, YB, D, NSET, QSET) computes and returns the distance (D) between point A (XA,YA) and point B (XB,YB) within a given field (N). The points may be anywhere within the field, including principal and secondary entry points on the field boundary. In its present (simplified) version, DISTI assumes that if the line connecting point A and B is the hypotnuse of a right triangle, then travel will be along the legs of the right triangle, i.e., vertical and horizontal travel with a right-angle turn.*

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* DISTI computes D as ABS(XA - XB) + ABS (YA - YB). This method can result in significant travel distance error, especially in irregular shaped fields where the upper and lower field boundaries are not horizontal and/or parallel. Also, application of this driving technique is unrealistic in many real world situations (irregular shaped fields) as it could result in the transport set traveling across unharvested areas of corn rather than around them.

Subroutine DISTO (NA, NB, C, D, E) looks-up and returns the paved road distance (C), the gravel road distance (D) and the farm lane distance (E) that will be encountered when traveling between two out-of-field points (NA and NB). These points may be off-farm locations 11 - 16 (coded 211 - 216), farmsteads 1 - 6 (coded 101 - 106), or principal field entry points 1 - N, where N is the total number of principal field entry points on the farm. The various types of distances, taken from the model-user's specially coded farm map (see Appendix A), were stored in the X-array by initialization subroutine FARM2, which also assigned code numbers to the various principal field entry points.

Given the in-field and/or out-of-field distances of a particular travel path, the travel time can be computed directly if the travel speed is known. Subroutine SPEEDT (KCOL, R, S, F, G, H, NSET, QSET) was developed for this purpose. SPEEDT determines the type of transport set in GASP column KCOL, and its current loading, then returns the maximum (average) speed that could be expected if the unit were traveling on a paved road (S), and the decimal fraction of S that could be expected if it were traveling on a gravel road (F), on a farm lane (G), or from one point to another within a field (H) -- see Table 7.*

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* Actually, F, G and H are returned as the inverse of the decimal fraction of S, which may be interpreted as the miles of travel at S that would be equivalent (in time required) to one mile of travel on the other type of surface at the lower speed. List variable R is required only when subroutine SPEEDT is used for combine travel, as discussed later.

Table 7. Travel Speeds for Various Mobile Entities.

Type of Equipment or Transport Set	Paved Road Speed Range(S)	Fraction of S Possible on Other Surfaces: Gravel Roads	Farm Lanes	In Fields
	(mph)			
Tractors with implements	19	0.90	0.75	0.50*
Self-propelled combines	12 - 16	1.00	0.70	0.50*
Tractors with wagons	16 - 19	0.90	0.70	0.45
Trucks	35 - 50	0.85	0.65	0.45

* Applicable only to non-operate travel, i.e., does not apply to on-row operation in the field.

The maximum (average) speed actually returned by SPEEDT is somewhere in the paved road speed range shown in Table 7, depending on the current loading situation, and for tractor powered units, the tractor size. For trucks the speed is computed as: 50-15(QHAUL/QMAX), where QHAUL is the actual bushels of corn (or pounds of production supplies) being hauled, and QMAX is the maximum bushels of corn (or pounds of production) supplies that could be hauled. For tractor-powered units, the speed is computed as: 19-(19-SS)(QHAUL/QMAX), where SS is computed as min(max(0.286HP+14.43,16),18) and HP is the rated PTO horsepower of the tractor.*

* This relationship was developed using several different sized tractors that were being marketed in the U.S. in 1970, and their advertised speeds for the fastest transmission setting (gear n) and the next slowest setting (gear n-1).

Activity times for combine travel

Activity times for combine travel (non-operate travel) are computed or set in different ways depending on the type of travel involved. Activity times for all travel required before harvesting activities actually begin, and after they are concluded on a given day, are computed by subroutine TRAVEL and its subordinates DISTI, DISTO and SPEEDT. Subroutine SPEEDT returns a maximum (average) speed for paved road travel in the range shown in Table 7 based on the row width and size of the cornhead being used: 12, 14 or 16 miles per hour for 2-row, 3-row or 4-row and larger "wide row" cornheads (row widths greater than 30 inches); 12, 13, 15.5 or 16 mph for 3-row, 4-row, 6-row or 8-row and larger "narrow row" cornheads (row widths of 30 inches or less).*

During normal-pattern harvesting, the travel times associated with unloading the contents of the grain tank onto a transport set (travel to the unit, then back to the corn) are based on a 3 mph travel speed, and a travel distance as computed by subroutine DISTI. All such travel activities are assumed to require a minimum of 15 seconds of clocktime. Combine turning at the ends of the field is

* These speeds were developed using the advertised speed ranges of different sized combines marketed in the U.S. by several manufacturers in 1970.

assumed to require 30 seconds for the continuous alternating field pattern.

Combine operating times and harvested-crop values

The activity time required for a given combine harvest pass depends on the on-row operating speed of the combine and the length of the harvest pass.* The amount of corn to be added to the grain tank at the conclusion of a harvest pass (at the event time) depends on the area covered (in acres) and the "grain tank yield" (in bushels per acre), where "grain tank yield" is the potential harvestable yield of the particular field section in which the harvest pass is being made (as computed by subroutine YIELD2 at the maturity date of the corn in that section) minus preharvest losses and machine losses.

Subroutine SPEEDH (NCODE, NSECT, NDIR) was developed to assist with event-attribute computations of this type. When called, SPEEDH computes (or sets) values for a number of variables related to combine NCODE (271 - 275), harvesting

* The length of a particular harvest pass can be computed as illustrated in the preceeding discussion of in-field coordinates. The area harvested is proportional to this length and the width of the cornhead.

in field section NSECT (1 - 100), and traveling in direction NDIR (1 = +y direction, 2 = -y direction).* These include:

1. Kernel moisture (decimal, wet basis) of the corn in field NSECT.
2. Amount of stalk lodging (decimal) present in section NSECT.
3. Potential harvestable yield (bushels per acre) in section NSECT.
4. On-row combine operating speed (mph) for normal pattern harvesting.
5. On-row combine operating speed (mph) applicable during on-the-go grain tank unloading activities only.
6. Preharvest loss (bushels per acre).
7. Gathering loss component (bushels per acre) of machine loss.
8. Cylinder loss component (bushels per acre) of machine loss.
9. Separation loss component (bushels per acre) of machine loss.
10. Grain tank yield (bushels per acre).

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* SPEEDH, and the model input form, was originally developed to accommodate up to 5 different self-propelled combines. The NDIR list variable simply designates one of two storage locations (for the values computed) in the X-array. This feature, the capability of having two sets of values stored at any given time, was designed to minimize the need for recomputation of values when a "land" pattern of some type is specified by the model-user for harvesting. In that case, alternate harvest passes by the combine might be in different field sections (with different yield, moisture and lodging characteristics). The feature is also useful when a given harvest pass involves the gathering of corn from two adjacent field sections.

Preharvest loss was modeled as a function of stalk lodging only, cylinder and separation losses as a function of kernel moisture, and gathering loss as a function of both stalk lodging and ground speed. The specific loss relationships used, along with combine power-requirement relationships, were those developed by Parsons et al. (1971).*

In setting the normal on-row operating speed, SPEEDH is designed to recognize three alternative speed-setting policies that can be specified by the model-user. A tentative speed is initially set as follows:

1. Constant speed policy. SPEEDH sets the tentative speed to a value specified by the model-user.

2. Variable speed policy based on power requirements. SPEEDH increases the speed by increments until the total power requirements are within ± 0.5 hp of 0.95AHP, where AHP is the rated engine horsepower of the combine.

3. Variable speed policy based on gathering loss. SPEEDH increases the speed by increments until a further increase would cause the actual (computed) gathering loss to exceed an "acceptable" gathering loss value, with the existing amount of stalk lodging in this field section, as computed from model-user input values.

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* The power requirements for harvesting were divided into three main components: 1) That required to propel the combine (ground drive hp) which was modeled as a function of ground speed, for a given combine; 2) That required to gather the corn (cornhead hp) which was modeled as a function of feed rate; and 3) That required to process the corn (cylinder and separator hp) which was also modeled as a function of feed rate. Feed rate was defined as the rate of material delivered to the cylinder, which is a function of speed, cornhead width, harvestable yield and gathering loss.

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For policy No. 2, this tentative speed setting is also the (final) on-row operating speed stored in the appropriate X-array location.* For policies No. 1 and 3, however, the tentative speed is used to compute the total power requirements. If they exceed 0.95AHP, then the tentative speed is reduced by increments to arrive at a (final) on-row operating speed with acceptable power requirements, i.e., within ± 0.5 hp of 0.95AHP.

The speed applicable to on-the-go unloading is set by SPEEDH even though this may not be a viable operating procedure for the system under study. To do so, the extra power required to convey the corn from the grain tank is computed. If this extra increment of power causes the total power requirement to exceed 0.95AHP, then the on-row operating speed previously set is adjusted downward. Otherwise, the on-the-go unloading speed is set equal to the normal on-row operating speed.

With all three "normal" speed policies, SPEEDH bypasses the tentative speed-setting procedures outlined above if the amount of stalk lodging present in the field section exceeds a "severe-lodging" limit specified by the model-user. In this case, the on-row speed is set to a (usually lower-than-normal) value specified by the model-user. This speed-setting option was originally planned for use with a harvesting simulation technique in which the combine would be allowed to

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* Where it is available to event routines for computing the activity time of a particular harvest pass.

move only short on-row distances before being interrupted by a minor repair or adjustment activity, thereby simulating the frequent cornhead plugging problems associated with harvesting severely lodged corn, which is a common mode of operation in the real world under these conditions. This feature, however, has not been developed.

Machine losses, and grain tank yield, are computed by SPEEDH before or during the speed-setting procedures as required. Subroutine SPEEDH has a "quick-return" capability to avoid unnecessary, duplicate computations if the kernel moisture, harvestable yield and stalk lodging of section NSECT are within certain tolerances of what they were the last time computations were made.*

Sample output of event sequencing

Subroutine PRINT4 was developed to print an event log for certain specified fields and/or on certain days. The event log lists the events that occur (event code and description), the time of occurance (clock-time), and the activity time of the activity just concluded. Figure 17 presents sample event logs.

* Values of the 10 variables previously listed remain unchanged in the x-array locations where they are available to event routines for defining the required event attributes.

CLOCK TIME	EVENT CODE	THIS EVENT SIGNALS END OF WHAT ACTIVITIES FOR WHAT ENTITIES	DURATION OF THIS ACTIVITY HRS	MIN	SEC
7.00	8	TRANS SET 1-INITIAL SPOTTING IN THE FIELD..........................	0	0	14
7.01	9	COMBINE 271-INITIAL SPOTTING IN THE FIELD TO BEGIN HARVEST......	0	0	36
7.07	14	COMBINE 271-HARVESTING ON-ROW......	0	3	28
7.08	13	COMBINE 271-TURNING AT THE END.....	0	0	30
7.14	36	COMBINE 271-HARVESTING ON-ROW......	0	3	28
7.14	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD......................	0	0	15
		TRANS SET 1-DELAY..................	0	5	17
7.16	21	COMBINE 271-CORN TRANSFER INTO TRANS SET 1......................	0	1	3
7.16	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
7.22	14	COMBINE 271-HARVESTING ON-ROW......	0	3	28
		• • •			
7.63	11	COMBINE 271-DUE TO BREAKDOWN, OR NEED FOR MACHINE ADJUSTMENT TERMINATE ON-ROW HARVESTING......	0	0	51
7.78	12	COMBINE 271-REPAIR OR ADJUSTMENT RESUME ON-ROW HARVESTING........	0	8	58
7.82	14	COMBINE 271-HARVESTING ON-ROW......	0	2	37
7.83	13	COMBINE 271-TURNING AT THE END.....	0	0	30
		• • •			
13.52	38	COMBINE 271-HARVESTING ON-ROW......	0	3	28
13.54	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD......................	0	1	14
		TRANS SET 1-DELAY..................	0	4	57
13.54	50	COMBINE 271-CORN TRANSFER INTO TRANS SET 1......................	0	0	15
13.55	53	COMBINE 271-TRAVEL TO A FRMSTD.....	0	0	37
13.56	28	TRANS SET 1-TRAVEL TO A FRMSTD.....	0	0	16
13.67	55	TRANS SET 1-UNLOADING CORN AT A HIGH MC SILO.....................	0	6	35

TRANSPORT SETS IDENTIFIED ABOVE WERE COMPOSED OF THESE ENTITIES -- 1 = 341 0 0

a) Combine Unload Pattern 1, On-Farm Storage Option.

Figure 17. Sample Event Scheduling.

CLOCK TIME	EVENT CODE	THIS EVENT SIGNALS END OF WHAT ACTIVITIES FOR WHAT ENTITIES	DURATION OF THIS ACTIVITY HRS	MIN	SEC
7.13	6	TRANS SET 1-UNLOADING CORN AT A HIGH MC SILO......................	0	7	42
7.14	8	TRANS SET 1-INITIAL SPOTTING IN THE FIELD..........................	0	0	43
7.47	15	COMBINE 271-SERVICING..................	0	19	30
7.49	9	COMBINE 271-INITIAL SPOTTING IN THE FIELD TO BEGIN HARVEST......	0	1	12
7.54	36	COMBINE 271-HARVESTING ON-ROW......	0	3	27
7.55	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD......................	0	0	15
		TRANS SET 1-DELAY......................	0	24	25
7.56	21	COMBINE 271-CORN TRANSFER INTO TRANS SET 1.........................	0	0	31
7.56	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
7.62	14	COMBINE 271-HARVESTING ON-ROW......	0	3	27
7.63	13	COMBINE 271-TURNING AT THE END.....	0	0	30
7.68	36	COMBINE 271-HARVESTING ON-ROW......	0	3	27
7.69	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD......................	0	0	15
		TRANS SET 1-DELAY......................	0	7	55
7.71	21	COMBINE 271-CORN TRANSFER INTO TRANS SET 1.........................	0	1	3
7.71	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
7.77	14	COMBINE 271-HARVESTING ON-ROW......	0	3	27
7.78	13	COMBINE 271-TURNING AT THE END.....	0	0	30
		⋮			
14.11	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
14.13	11	COMBINE 271-DUE TO BREAKDOWN, OR NEED FOR MACHINE ADJUSTMENT TERMINATE ON-ROW HARVESTING......	0	0	53
14.35	12	COMBINE 271-REPAIR OR ADJUSTMENT RESUME ON-ROW HARVESTING.........	0	13	37
14.40	14	COMBINE 271-HARVESTING ON-ROW......	0	2	35
14.40	13	COMBINE 271-TURNING AT THE END.....	0	0	30
14.46	36	COMBINE 271-HARVESTING ON-ROW......	0	3	28
		⋮			
18.37	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
18.43	38	COMBINE 271-HARVESTING ON-ROW......	0	3	28
18.45	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD......................	0	1	17
		TRANS SET 1-DELAY......................	0	5	0
18.46	50	COMBINE 271-CORN TRANSFER INTO TRANS SET 1.........................	0	0	32
18.49	53	COMBINE 271-TRAVEL TO A FRMSTD....	0	1	43
18.50	54	TRANS SET 1-TRAVEL TO A FRMSTD....	0	0	44

TRANSPORT SETS IDENTIFIED ABOVE WERE COMPOSED OF THESE ENTITIES -- 1 = 341 0 0

b) Combine Unload Pattern 2, On-Farm Storage Option.

Figure 17 (cont'd.)

CLOCK TIME	EVENT CODE	THIS EVENT SIGNALS END OF WHAT ACTIVITIES FOR WHAT ENTITIES	DURATION OF THIS ACTIVITY HRS	MIN	SEC
10.69	29	TRANS SET 1-SERVICING..............	0	10	21
10.73	8	TRANS SET 1-INITIAL SPOTTING IN THE FIELD......................	0	2	14
10.79	8	TRANS SET 2-INITIAL SPOTTING IN THE FIELD......................	0	3	38
11.05	15	COMBINE 271-SERVICING............	0	16	8
11.10	9	COMBINE 271-INITIAL SPOTTING IN THE FIELD TO BEGIN HARVEST......	0	2	26
11.17	37	COMBINE 271-HARVESTING ON-ROW.....	0	4	46
11.18	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD.................	0	0	15
		TRANS SET 2-DELAY................	0	23	36
11.19	21	COMBINE 271-CORN TRANSFER INTO TRANS SET 2...................	0	0	43
11.19	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
11.35	37	COMBINE 271-HARVESTING ON-ROW.....	0	9	32
11.36	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD.................	0	0	15
		TRANS SET 1-DELAY................	0	37	59
11.38	21	COMBINE 271-CORN TRANSFER INTO TRANS SET 1...................	0	1	25
11.39	19	COMBINE 271-TRAVEL BACK TO THE CORN TO BEGIN MORE HARVESTING...	0	0	15
11.47	14	COMBINE 271-HARVESTING ON-ROW.....	0	4	46
11.47	13	COMBINE 271-TURNING AT THE END....	0	0	30
		⋮			
12.22	38	COMBINE 271-HARVESTING ON-ROW.....	0	4	30
12.25	18	COMBINE 271-TRAVEL TO A TRANS SET TO UNLOAD.................	0	1	59
		TRANS SET 2-DELAY................	0	6	44
12.26	50	COMBINE 271-CORN TRANSFER INTO TRANS SET 2...................	0	0	15
12.3[illegible]	53	COMBINE 271-TRAVEL TO A FRMSTD....	0	2	31
12.52	25	TRANS SET 1-TRAVEL TO AN OFF-FARM MARKET LOCATION............	0	13	16
12.64	26	TRANS SET 1-UNLOADING CORN AT AN OFF-FARM MARKET LOCATION........	0	25	0
13.15	54	TRANS SET 1-TRAVEL TO A FRMSTD....	0	12	57
13.71	25	TRANS SET 2-TRAVEL TO AN OFF-FARM MARKET LOCATION............	0	33	48
14.3[illegible]	26	TRANS SET 2-UNLOADING CORN AT AN OFF-FARM MARKET LOCATION........	0	35	0
14.82	54	TRANS SET 2-TRAVEL TO A FRMSTD....	0	31	33

TRANSPORT SETS IDENTIFIED ABOVE WERE COMPOSED OF THESE ENTITIES -- 1 = 341 0 0
2 = 71 331 321

c) Combine Unload Pattern 3, Off-Farm Marketing Option.

Figure 17 (cont'd.)

DEMONSTRATED USE OF THE MODEL

To demonstrate the use of the model an example 320-acre farm was devised. The physical layout of the farm was as shown in Figure 18, with the individual field characteristics given in Table 8. The particular combinations of row length and yield potential were chosen so that all three combine unloading patterns would be required for a 6-row (30-inch) combine with 120-bushel grain tank.

Planting of the sample farm was done with a 6-row, 30-inch planter at 5 mph planting speed with 70% field efficiency, i.e., about 6.4 acres per hour. Planting policy specifications included an April 24 preferred starting date, a May 5 mandatory starting date (even if soil temperature was not up to 50 degrees), and hybrid information as follows: 250 acres of a full-season hybrid, the rest to be planted to a medium-season hybrid based on central Indiana heat unit requirements.

The weather data used were composed of actual rainfall records kept by a farmer-cooperator in west-central Indiana in 1970, and daily observations of average temperature, pan evaporation and wet-bulb temperature from the nearest U.S. Weather Bureau substation.

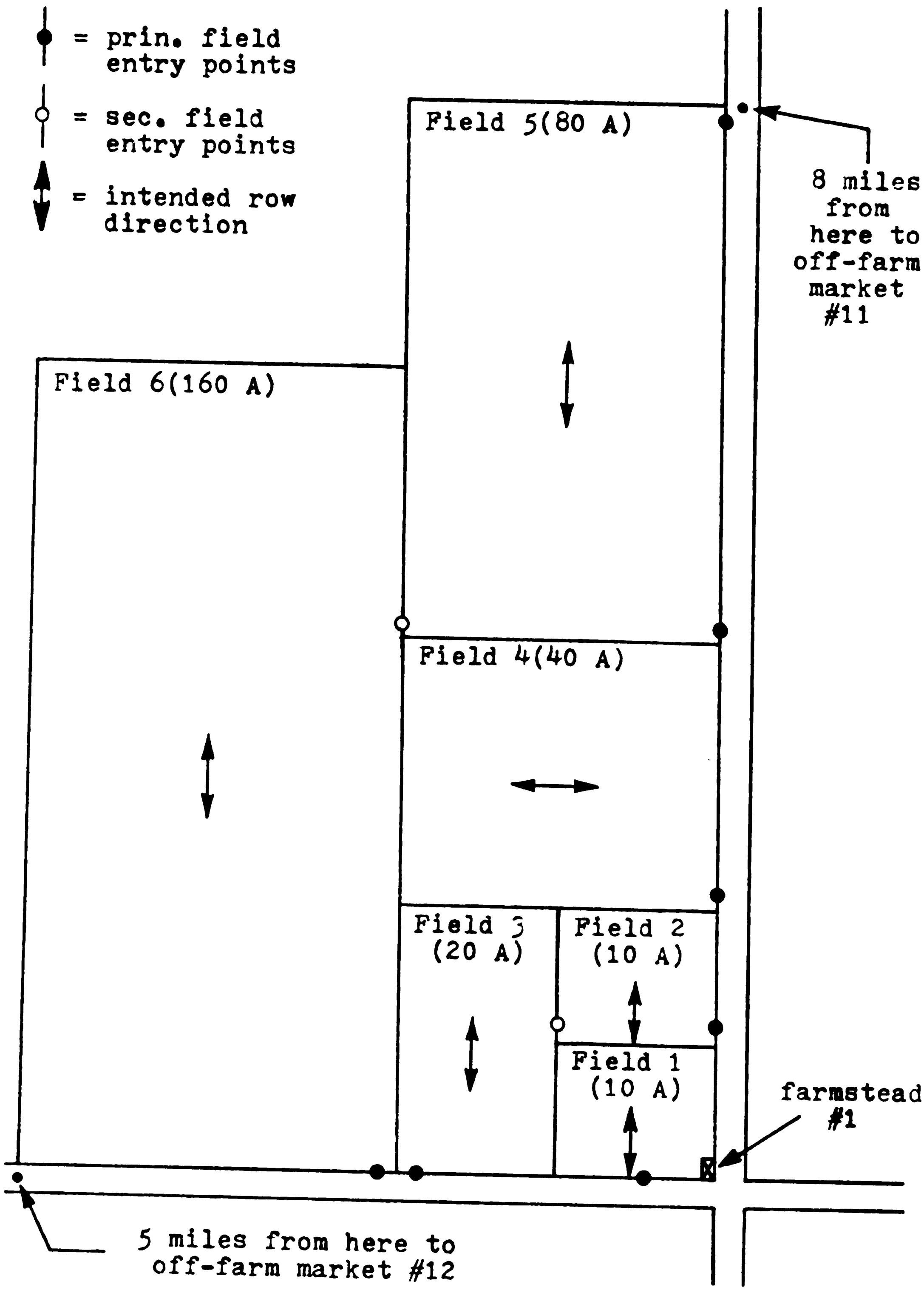

Figure 18. Physical Layout of Example Farm.

Table 8. Field Characteristics of the Example Farm.

Field	Row Length (rods)	Average Yield Potential (bu/acre)	Soils Information	Preferred Planting Sequence
1	40	125	100% Type 6	1st
2	40	125	100% Type 6	6th
3	80	125	100% Type 6	2nd
4	80	100	80% Type 7 20% Type 6	3rd
5	160	120	40% Type 7 60% Type 6	5th
6	240	115	60% Type 7 40% Type 6	4th

Four different system variations were simulated with the basic harvesting and marketing policy (and equipment alternatives) shown in Table 9. The mandatory start-harvest date was specified as October 1 (regardless of kernel moisture), with a 22-28% preferred moisture range for high-moisture on-farm storage, and a 28% maximum moisture for corn to be marketed off-farm. Other specifications included: the combine and transport sets were to be stored overnight at the base farmstead; corn could be unloaded on-farm at 1000 bushels per hour plus 10 minutes setup-and-knockdown time per load; corn marketed off-farm, at either of the two locations specified, required 45 minutes if the load arrived

Table 9. Harvesting and Marketing Alternatives Examined.

Item	System			
	A	B	C	D
Combine	6-row, 30-inch 120-bu tank 350 bu/hr	Same as A	Same as A	4-row, 30-inch 120-bu tank 275 bu/hr
Transport Vehicles	350-bu truck 300-bu wagon unit (2-150 bu wagons w/tractor)	Same as A	300-bu truck 200-bu wagon unit (1-200 bu wagon w/tractor)	Same as C
On-Farm Hi-Moist. Storage Provided*	40,000 bu	5,000 bu	Same as B	Same as B

* Rest to be marketed off-farm by random selection of a market each day.

before 9:00 a.m. or after 4:00 p.m., 25 minutes if it arrived between 11:30 a.m. and 1:30 p.m. and 35 minutes otherwise.

The one-man labor-force for the systems was scheduled to work 11 hours per day Monday through Friday, 10 hours on Saturday, and 5 hours on Sunday. Off-farm markets were assumed to be open on Sunday during the harvest season.

Planting and Crop Development Results

Planting and crop development results were identical in all 4 simulations. The first planting was done on April 26, two days later than the preferred starting date due to the soil being too cool (less than 50 degrees) or untractable on April 24 and 25. Fields 1, 3 and about three-fourths of 4 were planted on the first day. Additional planting was not done until a week later, on May 3, when field 4 was finished, and about one-third of field 6 was planted. The next three days, May 4 - 6, were also declared work days, which allowed planting to be completed for the farm at about 3:00 p.m. on May 6. After planting about one-third of field 5, on May 5, seeding was switched from a full-season to a medium-season hybrid.

Though planting spanned an 11-day period (April 26 to May 6), all field sections of the farm were declared mature over a 6-day period (September 2 - 7). This small range in maturity dates was due to the use of a medium-season hybrid on the last 70 acres planted. Planting and maturity information is given in Table 10. Potential harvestable yields, set by subroutine YIELD2, were above average for this particular year.

Activity Simulation Results

The four system variations (see Table 9) were devised to illustrate the following comparisons:

System A vs. B -- Both utilized the same harvesting and transport equipment. With system A most of the corn was to be stored on-farm as high-moisture corn (short transport distances,

Table 10. Planting and Crop Development for Example Systems.

Field	Section Size	Section Numbers	Planting Date	Hybrid Type	Maturity Date	Maturity Yield
	(acres)					(bu/A)
1	3.3	1 - 3	4/26	Full	9/2	138.4
3	3.3	7 - 12	4/26	Full	9/2	138.4
4	3.1	13 - 22	4/26	Full	9/2	110.8
		23 - 25	5/3	Full	9/6	110.7
6	3.2	51 - 69	5/3	Full	9/6	127.3
		70 - 92	5/4	Full	9/7	127.3
		93 - 100	5/5	Full	9/7	127.3
5	3.2	26 - 32	5/5	Full	9/7	132.9
		33 - 39	5/5	Medium	9/3	126.2
		40 - 50	5/6	Medium	9/3	126.2
2	3.3	4 - 6	5/6	Medium	9/3	131.5

relatively fast vehicle unloading). With system B only a small portion of the crop (about 5000 bushels) was to be stored on-farm, the rest was to be marketed off-farm (longer transport distances, relatively slow vehicle unloading).

System B vs. C -- Both utilized the same harvesting equipment and basic handling options (about 5000 bushels delivered to on-farm, high-moisture storage, the rest moved off-farm). With system C, however, the capacity of the transport equipment was reduced (truck size from 350 to 300 bushels, tractor and wagon(s) from 300 to 200 bushels).

<u>System C vs. D</u> -- Both utilized the same basic handling options and (smaller) transport equipment. With system D, however, harvesting capacity was reduced from about 350 bushels per hour (6-row combine) to about 275 bu. per hr. (4-row combine). Both combines were assumed to have the same size grain tank.

A general summary of the results is presented in Table 11. As was expected, each succeeding system change required more operating days to complete harvest. As the season was extended, stalk lodging increased, as did preharvest and machine (harvest) losses -- total harvest volume (bushels) and average kernel moisture both decreased. Since a variable combine speed policy based on power requirements was in effect, the lower (harvested) yield and kernel moisture allowed a slightly higher on-row operating speed (average) to be used with each succeeding system change.

The labor utilization information (Table 11) helps explain the operating-day differences in these particular systems. Handling activities (corn transport, unloading and associated activities) required about 69 hours when most of the corn was stored on-farm (system A). When the same transport subsystem was used to move most of the corn off-farm (system B), the time requirements nearly tripled, to 179 hours. Using slightly smaller transport units (15-35%

Table 11. Summary of Activity Simulation Results (One-Man Systems).

Item	System A	System B	System C	System D
Length of Harvest (operating days)	18 days	27 days	35 days	37 days
Corn Production and Disposition				
High-moisture	37,180 bu @ 25%	4,760 bu @ 27%	4,480 bu @ 27%	6,080 bu @ 27%
Off-farm (mkt.11)	0	14,340 bu @ 23%	10,020 bu @ 22%	11,920 bu @ 22%
(mkt.12)	1,215 bu @ 20%	18,450 bu @ 22%	22,250 bu @ 21%	18,610 bu @ 21%
Harvested total	38,395 bu @ 25%	37,550 bu @ 23%	36,750 bu @ 22%	36,610 bu @ 22%
Harvest Statistics				
Kernel moisture	20 - 28%	19 - 28%	19 - 27%	19 - 27%
Stalk lodging	0 - 17%	0 - 44%	1 - 51%	1 - 51%
On-row speed	2.16 - 2.70 mph (2.44 avg.)	2.16 - 2.72 mph (2.47 avg.)	2.16 - 2.76 mph (2.49 avg.)	2.50 - 3.02 mph (2.62 avg.)
Machine losses	1975 bushels	2579 bushels	3180 bushels	3300 bushels
Labor Utilization				
Harvest activities	113.1 hrs.	112.5 hrs.	116.3 hrs.	152.5 hrs.
Handling activities	68.6 hrs.	178.6 hrs.	275.9 hrs.	254.7 hrs.
Misc. activities	2.0 hrs.	0.0 hrs.	0.0 hrs.	0.0 hrs.
Season total	183.7 hrs.	291.1 hrs.	392.2 hrs.	407.2 hrs.
Accumulated Equipment Use				
Combine	95.0 hrs.	93.8 hrs.	94.1 hrs.	127.7 hrs.
Truck	5.8 hrs.	34.9 hrs.	101.3 hrs.	103.1 hrs.
Tractor	6.4 hrs.	42.0 hrs.	48.0 hrs.	36.2 hrs.

smaller in system C) added another 97 hours of labor time. While harvest labor increased substantially with the smaller combine of system D, handling activities actually required slightly less time. This was probably due to the transport sets being more fully loaded at the end of each day, and a few more loads being delivered on-farm rather than off-farm.* Since these were 1-man systems, the time required for handling activities subtracted directly from the time available for harvesting. Had one additional man been available for assignment to the transport sets, then fewer operating days would have been required for each system.

In studying the detailed event logs (see examples in Figure 17) it was apparent that the number of (combine) operating days would have been less if the model accounted for performing corn transport and transport set unloading on days when combine operation was not possible. In several instances where an activity-simulation day followed a non-activity-simulation day, considerable man-time (and potential harvesting time) was lost due to unloading activities involved with transport sets that had held corn since the previous activity-simulation day.

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* Recall that the model does not allow switching from on-farm, high-moisture storage to off-farm delivery in the middle of an activity-simulation day. As a result, the model stored about 1000 more bushels of high-moisture corn than was desired (or possible) with system D.

Accumulated equipment use (Table 11) indicates the approximate hours of use that would have accumulated on engine hourmeters if the combine, truck and tractor had been so equipped. For the combine, in a 1-man system, this is simply the labor time required for harvest activities minus the time required for combine repairs and adjustments, and for combine refueling and servicing activities. For transport sets it is the accumulated hours in which the unit is nonidle (loaded transport or unloaded travel).

Activity-simulation days determined by the model are presented in Table 12. September 6 - 12, 16-21, and 30 were declared activity-simulation days with all four systems, as was October 1-4. Harvest (and the overall simulation) was completed on October 4 with system A. With the remaining three systems, October 5-7, 18-19, 26-27 and January 2-3 were all declared activity-simulation days. The long period of inactivity from the last of October until early January indicates untractable soil conditions due to frequent rains and poor drying conditions, since kernel moistures were well within the desired range by late October. The soil became frozen on January 2, allowing harvest to be completed.

With systems C and D, two additional dates (October 25 and November 1) were declared activity-simulation days. To do so, however, it was necessary to move the harvesting activities from field 6 to field 5, the next field in the

Table 12. Comparison of Activity-Simulation Days.

System A

Harvest Field	Unload Pattern	Handling Option	Calendar Date(s)
1	1	On-farm	Sep 06
3	2	On-farm	Sep 06,07
4	2	On farm	Sep 07,08,09
6	3	On-farm	Sep 09,10,11,12, 16,17,18,19, 20,21
5	3	On-farm	Sep 21,30, Oct 01,02
5	2	On-farm	Oct 03
2	1	Off-farm	Oct 04

System B

Harvest Field	Unload Pattern	Handling Option	Calendar Date(s)
1	1	On-farm	Sep 06
3	2	On-farm	Sep 06,07
4	2	On-farm	Sep 07
4	2	Off-farm	Sep 08,09,10
6	3	Off-farm	Sep 10,11,12, 16,17,18, 19,20,21, 30, Oct 01,02,03, 04,05,06
5	3	Off-farm	Oct 06,07
5	2	Off-farm	Oct 18,19,26, 27, Jan 02
2	1	Off-farm	Jan 03

System C

Harvest Field	Unload Pattern	Handling Option	Calendar Date(s)
1	1	On-farm	Sep 06
3	2	On-farm	Sep 06,07
4	2	On-farm	Sep 07
4	2	Off-farm	Sep 08,09,10,11
6	3	Off-farm	Sep 11,12,16,17, 18,19,20,21, 30, Oct 01,02,03,04, 05,06,07,18, 19
5	2	Off-farm	Oct 25,26,27, Nov 01, Jan 02,03,04,05, 06
6	3	Off-farm	Jan 06,07,08
2	1	Off-farm	Jan 08,09

System D

Harvest Field	Unload Pattern	Handling Option	Calendar Date(s)
1	1	On-farm	Sep 06
3	1	On-farm	Sep 06,07
4	1	On-farm	Sep 08
4	1	Off-farm	Sep 09,10
6	3	Off-farm	Sep 11,12,16, 17,18,19, 20,21,30, Oct 01,02,03, 04,05
6	2	Off-farm	Oct 06,07,18, 19
5	2	Off-farm	Oct 25,26,27, Nov 01, Jan 02,03,04, 05,06,07
6	2	Off-farm	Jan 07,08,09, 10
2	1	Off-farm	Jan 11

preferred planting (and harvesting) sequence. The harvest activities were then moved back to field 6 after field 5 was completed.

Table 12 illustrates another interesting aspect of model behavior. With the bigger 6-row combine (systems A, B and C), combine unload pattern 2 was required in fields 3 and 4. With the smaller 4-row combine (system D), however, it was possible to use combine unload pattern 1 in these fields. This variation in simulated operation occurred because both combines had the same size grain tank (120 bushels), but the 4-row combine collected less corn per unit length of on-row operation than the 6-row combine.

This same type of shift in (simulated) operating procedure, from combine unload pattern 3 to combine unload pattern 2, can be noted in field 5 with systems A and B, and in field 6 with system D. In these cases (with a given combine), the shift in procedure was due to the particular harvested yield-kernel moisture combinations which permitted the combine to travel a greater on-row distance (before grain tank unloading was required) on one day than was possible on a previous day.

The detailed activity state-time information maintained by the model is illustrated in Figure 19 for system A. Additional information, based on these state-time values, is presented in Table 13. Note that combine field efficiency generally increased with increasing field size (row length) for system A, but this is influenced by the stochastic nature

TIME PROFILE FOR THE HARVEST SEASON 1970 CORN CROP

CORN HARVESTING -- COMBINE 271

FIELD NO.	HOURS IN ACTIVITY STATES 1	2	3	4	5	6	7	8	FIELD TOTAL
1	.0	.2	.3	2.6	.0	1.4	.4	1.9	6.7
2	.0	.2	.3	2.2	.3	.1	.3	3.3	6.7
3	.1	.4	.5	5.2	.7	.9	.8	3.8	12.2
4	.2	.7	1.0	8.3	1.1	.7	1.2	6.7	20.0
5	.5	.7	1.8	18.1	1.9	1.9	2.5	17.1	44.5
6	.9	.9	2.6	36.8	3.8	5.4	5.5	36.8	92.7
STATE TOTAL	1.8	3.0	6.4	73.2	7.8	10.3	10.6	69.6	182.8

CORN TRANSPORT -- TRUCK 341

FIELD NO.	HOURS IN ACTIVITY STATES 1	2	3	4	5	6	7	8	FIELD TOTAL
1	.0	.0	1.8	.4	.0	.0	.0	4.4	6.7
2	1.1	.0	2.2	.3	.0	.0	.0	3.1	6.7
3	.2	.0	3.5	.8	.0	.0	.0	7.6	12.2
4	.6	.0	5.7	1.2	.3	.0	.0	12.0	19.9
5	1.3	.0	6.8	1.3	.5	.0	.0	34.7	44.6
6	2.6	.0	13.6	2.8	1.0	.0	.0	72.7	92.7
STATE TOTAL	5.8	.0	33.6	6.8	1.9	.0	.0	134.6	182.7

CORN TRANSPORT -- TRACTOR 71 + WAGON 331 + WAGON 321

FIELD NO.	HOURS IN ACTIVITY STATES 1	2	3	4	5	6	7	8	FIELD TOTAL
1	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.0	.0	.0	.0	.0	.0	.0	.0	.0
3	.0	.0	.0	.0	.0	.0	.0	.0	.0
4	.0	.0	.0	.0	.0	.0	.0	.0	.0
5	2.2	.0	6.0	1.1	.5	.0	.0	30.4	40.2
6	4.2	.0	13.2	2.6	1.2	.0	.0	71.4	92.7
STATE TOTAL	6.4	.0	19.2	3.8	1.7	.0	.0	101.8	132.9

Figure 19. Activity State-Time Information for System A Equipment.

Table 13. Harvesting and Hauling Statistics for System A.

Field	Harvest Factors				Transport Factors†		
	Field Eff.*	Repair Time**	Combine Capacity† On-row	Combine Capacity† In-field††	Delivery Point	No. Used ‡	Hauling Capacity ‡‡
	(%)	(%)	(bu/hr)	(bu/hr)			(bu/hr)
1	54.0	54	505	274	On-farm	1	692
2	65.0	5	551	357	Off-farm	1	368
3	63.0	17	505	317	On-farm	1	692
4	64.0	8	505	322	On-farm	1	629
5	67.5	10	530	357	On-farm	2	558
6	67.0	15	528	354	On-farm	2	542
Average	66.0	14	521	344			560

* Computed as 100·(state 4/state 2+3+4+5+6+7), i.e., does not include out-of-field travel (state 1) nor in-field waiting (state 8), but does include daily maintenance and refueling (state 5) which was performed at the farmstead at the start of each day when needed.

** Computed as 100·(state 6/state 2+3+4+5+6+7).

† Based on average harvested yield in each field.

†† Based on the total time used to compute field efficiency.

‡ 1 = the truck only, 2 = the truck plus the tractor and wagon(s).

‡‡ Based on the total time charged to each field, not including state 8 (waiting without an assigned driver).

of repair and adjustment activities, and the combine unload pattern required. The lowest effective combine capacity (274 bu/hr in field 1) is 20% below the farm average (344 bu/hr). The highest capacity (about 355 bu/hr in fields 2, 5 and 6) is 3% above the farm average.

Using the state-time information of Figure 19, it can be shown that if a multi-man labor force had been used with system A, with an adequately sized transport subsystem, i.e., no combine delays waiting for transport sets to return to the field, then effective combine capacity could be increased by nearly 18% with on-the-go unloading. This would be due to elimination of the corn transfer activities in fields 1 and 2 (resulting in a 10-12% capacity increase for these fields), plus elimination of the extra travel required for grain tank unloading in fields 3 through 6 (net 17-21% increase in these fields).

The effective capacity of the transport subsystem with system A (Table 13) decreased in almost direct proportion to the transport distances for each field. The range was from 692 bu/hr in fields 1 and 3 (corn delivery on-farm) down to 368 bu/hr in field 2 (corn moved off-farm).

SUMMARY AND CONCLUSIONS

A computer simulation model was developed for evaluating the physical performance of the corn production, harvesting and marketing system of an individual firm. The model was structured to provide the capability of evaluating numerous user-specific variations in land base, equipment inventory, labor force, and management policy. The model developed utilizes two basic modes of operation: 1) a daily simulation technique for environmental and management factors associated with the system -- soil and crop attributes (weather based), and operating procedures or labor availability (management based) may change from day to day; and 2) an event-oriented simulation technique for the performance of functional activities associated with the system -- tillage, planting, harvesting, crop or supply transport, and other activities. The development of this latter aspect of the model was completed only for a one-man system, and only for the field shelling (combine harvest) operation and the hauling activities associated with it for high-moisture storage (on-farm) and off-farm marketing direct from the field.

The model consists of a very small main program and 130 subroutines that are called as needed.* Of these, about 45 could be classified as input-output routines or those involved with the daily simulation aspect of the model. The remaining subroutines were required for the detailed activity-simulation, which utilized the filing system and event control features of the GASP II simulation language.

In developing the subroutines, each was tested individually, or with a few related subroutines, using a special program designed to test the mechanics and logic of the particular routine. Even with this approach, numerous errors were discovered in the first attempts to run the model as a whole. In the author's judgement, however, testing of individual subroutines is essential with a program of this magnitude.

Certain unique features of the model appear to be adequate, and necessary, for realistic performance results with complex multi-man, multi-machine corn production, harvesting and marketing systems -- even though the current development was not sufficiently complete to adequately test them. These include: 1) the definition of activity periods based on weather, soil, crop and/or management factors which permits the specification, and determination, of field operations and other activities that are feasible at any point

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* This program was so large (about 18,000 punched cards, including COMMENT cards) that it could not be run on the CDC-6500 systems at Michigan State University or Purdue University without utilizing an OVERLAY programming technique. Even then it required a maximum field length of 36,500 (octal) to load, and 115,100 (octal) to run.

in simulated time; and 2) the definition of a field-operations-status array, or similar accounting device, to facilitate scheduling and to maintain the current work/no-work status of fields that are to receive various field operations.

The input specifications to describe the physical aspects of the farm, the equipment, the labor and the management policies to be used appear to be adequate for using the model as a research tool. From a practical standpoint, however, farm managers are not yet ready, or willing, to spend the time needed to supply the information requested on the input form -- it simply requires too much detail.

In demonstrating the use of the model with the example farm and systems devised, the daily simulation portion of the model performed in a reasonable and realistic manner for the single crop-year simulations. It sequenced through the required activity periods (planting and harvesting), maintaining and adjusting soil and crop parameters, and updating labor and management factors to allow a realistic declaration of activity-simulation days, and reasonable results for harvest conditions (yield, kernel moisture, stalk lodging, etc.).

Similarly, the event-oriented portion of the model performed in a reasonable manner, given the limitations and shortcomings previously discussed. The accumulated times recorded for the combine and transport equipment in the various activity states were quite comparable to those one might expect in the real world. The stochastic technique used to schedule repair (or adjustment) activities adds a spontaneity to the simulation that is quite realistic -- the farm manager cannot predict with certainty when a repair or adjustment activity will be needed (until it is needed) or how much time will be required to perform it (until it is performed). On-row operating speeds and field losses determined for the combines were well within the range of on-farm values with present-day equipment.

Another unique feature of the model, the provisions made for declaring an activity-simulation day on days when field work cannot be done, is also an important concept for realistic simulation results -- though use of this feature was not made with the present model. In the real world non-field activities do occur on days when field work cannot be done (equipment refueling and maintenance, corn handling, off-farm marketing, etc.) which permits a more efficient utilization of available field time on those days when it can be done.

Use of the event-oriented, discrete-object simulation technique (with GASP) provides an effective means of analyzing the state-time characteristics of equipment systems operating under specific management rules. As it developed in this study, however, it was quite a complicated programming technique. It's use can probably not be justified for analyzing a simple one-man, one-combine system with no on-farm drying or storage. Its capabilities should prove extremely useful, though, if the model is expanded to facilitate the analysis of more complex systems.

The example systems devised to demonstrate the use of the model each required about 60 seconds of execution time with the CDC-6500 system in-place at Purdue University in September, 1974 -- 51 seconds for system A, 55 seconds for system B, 64 seconds for system C and 65 seconds for system D. If the capabilities of the model are expanded in the future, then execution time requirements will also increase, which may be a deterrent to the model's use.

Certain features of the model developed are unique in comparison to other simulation models that have been developed for crop production systems. For example, the capability of simulating a series of several field operations (and their necessary support functions) rather than just the so-called key operations (planting and/or harvesting). The capability of realistically evaluating the interaction of field equipment and/or transport subsystems and/or grain receiving facilities under specific operating policies and with specific physical constraints (field shapes, field arrangements, road networks, etc.) is another example.

These capabilities, however, were not without certain "costs": complexity in specifying input information, complexity in programming, especially for the activity-simulation, and relatively high computer storage and execution time requirements. Because of these factors, the potential use of the model is probably not, as was initially hoped, as a management tool for practicing farm managers.

Rather, its most important future role may in developing realistic performance coefficients for other simulation or optimization models -- particularly field efficiency values for equipment operating in specific situations. Another important use may be for sensitivity analysis, to determine what policies, procedures, characteristics or other factors significantly affect the performance of complex crop production systems. Such information could be used to establish criteria for developing simpler models for research and/or practical management purposes.

RECOMMENDATIONS FOR FUTURE RESEARCH

The simulation model, in its present stage of development, is not a very useful research or management tool because of the major limitations imposed on the types of corn production, harvesting and marketing systems with which it can deal. In order to approach some significant degree of usefulness the activity-simulation portion of the model must be expanded in the harvesting and handling area (event routines developed) to accommodate the following:

1. A multi-man labor force (single combine) situation.
2. Equipment maintenance and other activities on days not suitable for field work.
3. On-farm drying and storage with batch and continuous flow driers, and/or with in-bin layer driers.
4. Off-farm marketing of farm-stored corn.

The first and third of these will require major programming efforts; the second and fourth very little.* Activity-simulation for production field operations should also be developed if the potential of the model is to be fully realized. The model-framework to allow this expansion is presently in-place.

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* As was noted previously, an additional 27 or 28 events were identified (and flow charts developed for the event routines) for the multi-man, single-combine system (with no on-farm drying). The development of these subroutines should constitute a "major programming effort".

Two of the programming techniques utilized should be seriously re-evaluated if the model is to be developed further. These are: 1) the partitioning of the farm into 100 field sections of approximately equal size, and 2) the generation of repair intervals and repair times as needed during execution. In the first case it is felt that the arbitrary partitioning is unnecessary, and results in duplicate computations for too many field sections that have a common soil type, a common planting date, and a common corn hybrid type. With the (GASP) field file, and the D_i attributes being used, section boundaries are only important to the activity-simulation in regards to on-row length, tractability and the potential harvestable yield-kernel moisture combination. The following alternative scheme is proposed: Basic field sections should be defined for the farm on the basis of field boundary deviations (row length) and soil type. Subsections would then be defined during the planting operation (a maximum of 100) based on planting date and hybrid type. In sequential-year simulations the subsections would be redefined each year during planting.

In the second case, the present method of generating repair intervals and times makes it difficult to compare two or more runs in which performance or management coefficients are varied. A better technique would be to generate an array of random numbers for each equipment item that is subject to repair (or adjustment) activities that could be used on a whole series of runs. This would eliminate the situation, for instance, of the nth repair of a combine occurring after p-hours of use on one run, and the nth repair of the same identical combine occurring after q-hours of use on the next run.

In developing the daily simulation loop of the model, provisions were made for inserting a block of programming instructions to collect and/or analyze cash flow data on the last day of each month. The development of this portion of the model, plus the inclusion of other economic aspects (fixed and variable costs, corn prices, etc.), would greatly enhance the ultimate usefulness of the model.

In addition to these programming needs, much research is needed to document performance and activity-time coefficients of field and farmstead equipment, both operating and non-operating (repairs and adjustments), for simulation programs of this type. Management policies regarding the assignment of men and machines to perform alternative activities also need to be studied, interpreted and modeled.

APPENDICES

APPENDIX A

APPENDIX A

COMPUTER MODEL INPUT FORM

The input form is divided into three basic parts to obtain three general types of information. Its organization is as follows:

Farm Layout Specifications

Section 1 -- Geographic Farm Description
Section 2 -- Field Size, Yield Potential and Soils

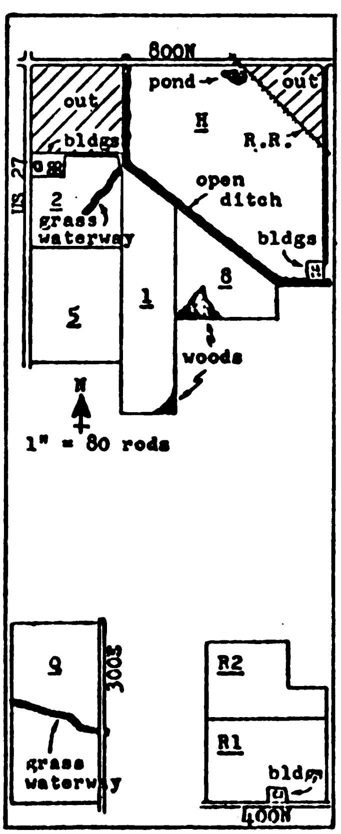
Production Specifications

Section 3 -- Field Operations and Operating Policy
Section 4 -- Listing Available Field Equipment
Section 5 -- Allocating Equipment for Field Operations
Section 6 -- Production Labor Force

Harvesting and Marketing Specifications

Section 7 -- Harvesting Policy and Equipment
Section 8 -- Corn Handling and Marketing Methods
- 8-1 Wet (High Moisture) Storage Options
- 8-2 In-Bin Layer Drying Option
- 8-3 Batch or Continuous Flow Drying Option
- 8-4 Direct-from-the-Field Market Option

Section 9 -- Corn Transport Equipment and Policy
Section 10 - Harvest Labor Force



SECTION 1 -- GEOGRAPHIC FARM DESCRIPTION

A farm map similar to the one at the left is required for developing computer input. Features of your map should include:

1) Drawn approximately to scale, and the scale noted on the map.

2) All fields are shown and identified with letters or numbers.

3) All roads and farm lanes are shown where they are.

4) Physical obstructions within fields which tend to reduce the efficiency of farm equipment are shown in their approximate position,

e.g. the woods in fields 1 and 8
the pond in field H
the buildings in fields H and R1
the grassed waterways in fields 2 and 9
etc.

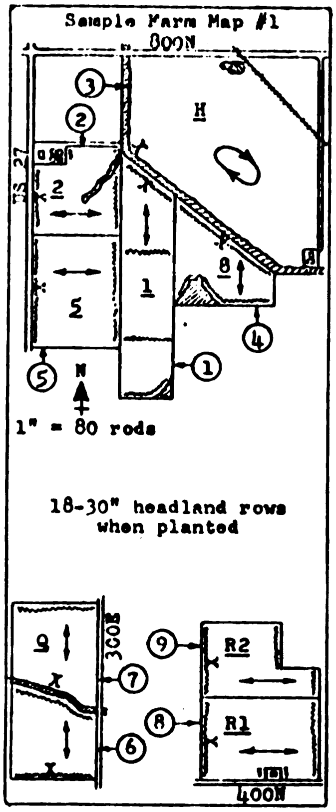
Note -- Obstructions that are not easily identifiable on the maps submitted should be labeled as they are here.

TWO COPIES of your farm map must be submitted with the following information noted:

Farm Map #1 Coding of fields and planting policies.

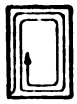
Farm Map #2 Coding of transport and travel distances and routes.

The technique for doing this is explained on the following pages.



Coding Fields and Planting Patterns and Policies -- Farm Map #1

1) Planting Pattern. Indicate the planting pattern used in each field. Two patterns are possible:



Continuous, circular pattern as indicated in field H. The pattern is limited to clockwise planting and harvesting.

Continuous, alternating pattern as indicated in the rest of the fields. The arrow should show the principal row direction.

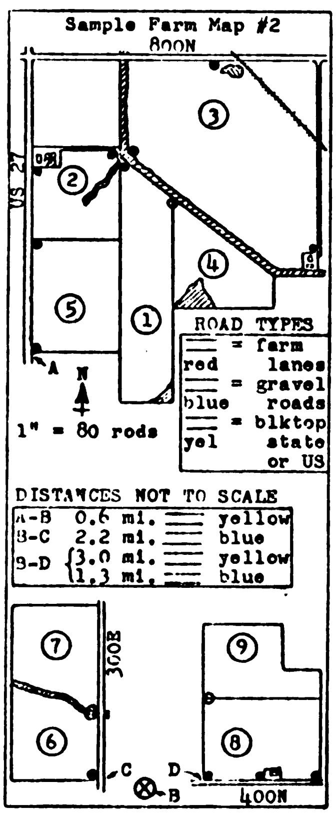
2) Headland Rows--Where. Indicate for each field where headland (end) rows or turn rows are planted with the symbol ~~~~~ (as illustrated). Turn rows established for harvesting in "long" fields may be indicated at the halfway point, or at the 1/3 and 2/3 point in the field, as illustrated in field 1. When headland rows are not indicated in a place where a turning area of some type will be needed, for instance along the north edge of the grassed waterway in field 9, then a turning strip will be assumed to exist outside the tillable boundary of the field.

3) Headland Rows--How Many. Indicate on the map the number of headland rows planted, when planted--fixed for the whole farm.

4) Planter Supply Vehicle Location. For alternating patterns, put an X along the end of the field where planter refills are made. For circular patterns, put an X in the general location of the field entry point used for the planter supply vehicle.

5) Field Number Coding. Computer-code "fields" by numbering consecutively from 1--up to a maximum of 30, then circle the new number for each field. A field currently identified by a single symbol, number or letter, should be divided into 2 or more "computer fields" if the field is not planted in a continuous manner. For instance, field 9 at the left has been coded as "fields" (6) and (7), i.e. the grassed waterway must have been too deep or too rough to cross with equipment so the field is planted in two parts.

Note -- This completes the information needed on Farm Map #1.



Coding Transport and Travel Distances and Routes -- Farm Map #2

1) Field Numbers. Cross out or remove the old field identification symbols from this copy of your farm map, and enter the new coded "field" numbers assigned on the other copy. Use these new field numbers throughout the rest of the input form.

2) Road Types. Use a 3-color code to indicate road types. Note on the map a legend of what the colors stand for. The road types of interest for the computer are:

farm lanes--the road actually is, or is equivalent to, a basically solid, narrow, all-weather road, but with a few soft spots(after rains), rough spots, or sharp turns which limit both farm equipment and trucks to about 8 to 12 mph average, or less.

gravel roads--the road actually is, or is equivalent to, a solid, all-weather road with only occasional "wash-boards" such that the road itself does not limit farm equipment speeds, and trucks typically average 20 mph, on short runs or when full, up to 30 mph, on long runs or when empty.

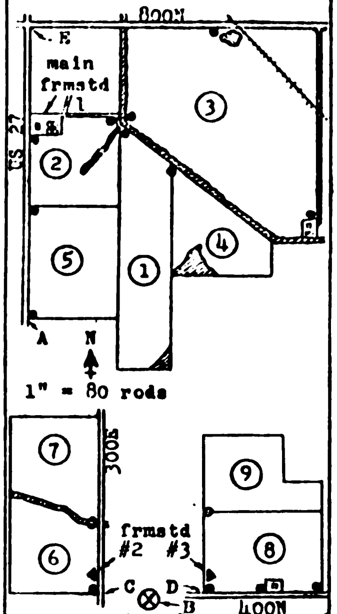
hard surfaced roads--the road actually is, or is equivalent to, a good country blacktop, with very little "wash boarding", or a state or federal highway such that trucks may average 30 mph, on short runs or when full, up to 40 mph, on long runs or when empty.

3) Field Entry Points. Mark with a black dot, ●, the location of entry points into each field from a farm lane or public road. Mark with a white dot, -O-, the locations where one field may be entered from another. Do not mark entry points, even though they do exist, if they are never used or shouldn't be used. Each field must have at least 1 entry point of one type or other.

4) Unscaled Distances. If fields or farms are not connected by roads on your farm map, like fields 6,7 and fields 8,9 at the left, then identify reference points, like A, B, C, and D at the left, and indicate the travel distances and types of roads between these reference points.

(continued)

Sample Farm Map #2 (cont.)



Note--The points marked ◀ were designated "farmstead" here to use the policy of storing field equipment at the nearest "farmstead" at night, i.e. it will be left in the field when working at the two outlying farms.

Coding Transport and Travel Distances and Routes (continued)

5) Designation of "Farmsteads". You may designate up to 6 different "farmsteads" to be used later in communicating various policies to the computer. These policies will relate to:
- the out-of-field location where tractors, combines, trucks, etc. may be refueled, maintained, or stored overnight.
- the location where field equipment or supply vehicles must go to get additional supplies of seed, fertilizer, etc.
- the location where harvested corn is to be taken for on-farm drying, handling, or storage.

For some policies you may want to indicate a specific location, while for others you may indicate simply the nearest "farmstead" to where activities are taking place(see note at bottom-left).

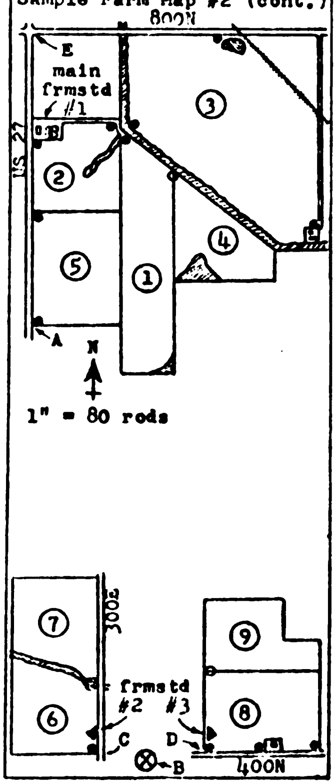
"Farmsteads" that you feel will be needed should be coded in the table below, and noted on your farm map. They need not be physically located adjacent to one of your fields. If a "farmstead" location cannot be shown to scale on the farm map, then indicate in the table the distance(and road types) to reference points on the map: | #4 | Joe's storage bins | 2.0 mi. (yel.) 1.2 mi. (blue) } to point E |

You may wish to come back here and identify more or different "farmsteads" when the policy decisions are actually being made in later sections of the input form.

Frmstd	Description or Other ID	Distance and Road Type*
#1		
#2		
#3		
#4		
#5		
#6		

*To reference points on your farm map, only for "farmsteads" that cannot be located to scale on your map.

Sample Farm Map #2 (cont.)



Coding Transport and Travel Distances and Routes (continued)

6) Designation of Off-Farm Locations. As with "farmsteads", you may designate up to 6 off-farm locations. These will be used in much the same way as the "farmsteads", except that the policy decisions of interest are only those dealing with the transport of production supplies and corn:
- the off-farm locations(if applicable) where field equipment or supply vehicles must go to get additional supplies when needed for a particular field operation. (Note--The computer program is not concerned with supplies that you obtain off-farm in the "off-season", just with those that you might get off-farm while the field operation is being done.)
- the off-farm locations(if applicable) where corn may be transported: directly from the field, after drying, or after storage on the farm.

Off-farm locations that you feel will be needed should be coded in the table below. If their location can be shown to scale on your farm map, then do so. Otherwise, indicate in the table the distance(and road types) to reference points on your map: | #13 | Daly elevator | 6.0 mi. (yel.) 0.7 mi. (blue) } to pt. E |

You may want to come back here and identify more off-farm locations when the policy decisions are actually being made in later sections of the input form.

Off-Farm	Description or Other ID	Distance and Road Type*
#11		
#12		
#13		
#14		
#15		
#16		

*To reference points on your farm map.

SECTION 2 -- YIELD SIZE, YIELD POTENTIAL, AND SOILS

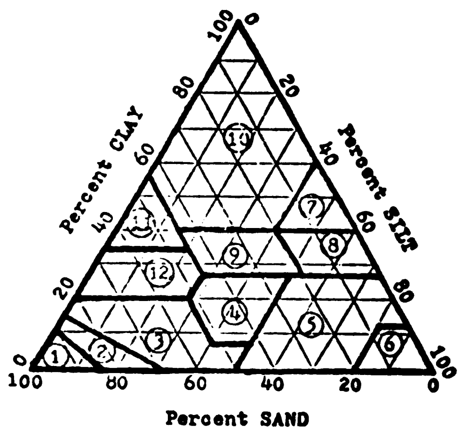
Three additional types of information must be supplied in the table on the following page:

1) Tillable Acres. The dimensions for each field will be taken from your scaled farm map and used as input to the computer. The computer will automatically make minor adjustments on these dimensions to obtain the specified tillable acres.

2) Yield Potential. During computer runs the net corn yield for each field will be determined by:
   -- planting date and hybrid planted
   -- growing season temperatures and moisture stress, and
   -- the harvest date and harvest losses.
   In order to make this accounting, a maximum yield potential is needed for each field. Because of the factors just listed, you've probably never seen the maximum potential from any of your fields -- it may be 5 to 20% higher than the highest yield you've ever harvested. What is needed is a realistic, "no-holds-barred" estimate of maximum yield potential
   -- assuming "ideal" or optimum" planting time
   -- assuming a good yielding full-season hybrid is planted
   -- assuming "ideal" or "optimum" growing conditions
   -- assuming your current fertility level or program (this will be held constant for all computer runs)
   -- and assuming zero harvesting losses.
   Give your best estimate for each field with these assumptions in mind.

3) Major Soil Type(s). The water holding capacity of the soils in each field is important from the computer standpoint in determining moisture stress during critical periods of corn development, and in determining how soon field equipment can operate after rainy spells. This may be indicated by giving one or two soil type codes for each field. Soil type codes to be used are:

Code 1 = SAND
2 = loamy sand
3 = sandy loam
4 = LOAM
5 = silt loam
6 = SILT
7 = silty clay
8 = silty clay loam
9 = clay loam
10 = CLAY
11 = sandy clay
12 sandy clay loam

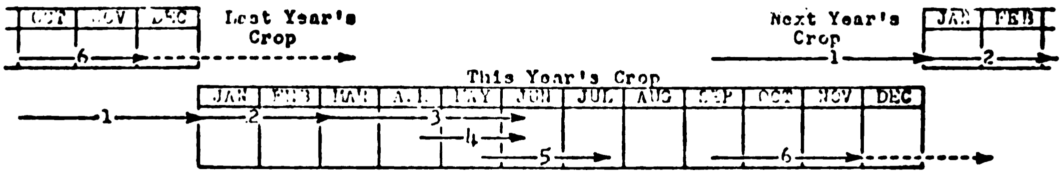


Field No.	Number of Tillable Acres	Est. Max. Yield Potential (bu/acre)	Major Soil Groups: Soil Type Code	% of This Type	Soil Type Code	% of This Type
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Field No.	Number of Tillable Acres	Est. Max. Yield Potential (bu/acre)	Major Soil Group: Soil Type Code	% of This Type	Soil Type Code	% of This Type
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

SECTION 3 -- FIELD OPERATIONS and OPERATING POLICY

So that realistic policy decisions can be handled(and communicated to the computer), the crop-year is divided into 6 activity periods -- 5 for producing the crop, and 1 for harvesting and marketing it. The beginning and ending of these activity periods have been defined so that they depend on weather and crop development factors(see table). As such, some of them may overlap, and their actual calendar dates will change from year to year in the computer. This is illustrated below.



1:Fall Land Preparation
2:Winter Land Preparation
3:Pre-Plant(Spring) Land Preparation
4:Planting Period
5:Post-Plant Tending Period
6:Harvest and Marketing

Activity Periods		Beginning/Ending	Various Activities Possible
Production Periods	#1	Begins 1st harvest date of last year's crop. Ends when soil freezes.	All tillage and land preparation jobs including fert. application of all types--spread, plowdown, knifedown.
	#2	Begins with soil freeze. Ends with spring thaw.	Stalk chopping or shredding plus spreading fert., but no tillage.
	#3	Begins with the spring thaw. Ends when all the corn is planted.	All land prep. jobs not "tied to" the planting--those that could be done a few hours or a few weeks before plntg
	#4	Begins with potential date you specify. Ends when all corn planted.	Planting plus those jobs to be done "right before" and "right afterwards"; i.e. separate but "tied to" planting.
	#5	Begins when any corn reaches 4" height. Ends when all corn reaches layby height.	Operations to control weeds and other pests--rotary hoe, cultivate, and spray--plus knifedown nitrogen application.
Harvesting and Marketing	#6	Begins when you specify. Ends when all corn is harvested.	Harvesting and hauling, plus any on-farm drying, handling, and storage operations.

Define Field Operations. On the following page you may define a maximum of 5 different field operations for each production activity period. All operations listed should be done, either totally or in part, by your equipment or your labor force -- do not list operations that are done entirely by a custom operator. You must list planting as one of the operations in period #4. Beyond this requirement, you may list operations for all or none of the other periods.

Enter a name or brief description of each operation you want the computer to perform in each activity period -- either on the total or part of your corn acreage. You will have a chance later to restrict certain operations as to acreage or fields in the various periods. So if an operation could potentially be done(or you would allow it to be done by the computer) in one of the activity periods, then list it for that period. A number of operations might be listed in more than one period. For instance, bulk spreading P and K and chopping stalks could be listed in periods #1, #2, and #3; plowing could be listed in periods #1 and #3; or knifing-in anhydrous could be listed in periods #1, #3, and #5. In listing operations, keep in mind that with this computer program you may apply a maximum of one material--fertilizer, herbicide, etc.--with each operation, except for planting where the maximum is 4 materials, including seed corn. If you plan to cultivate your corn twice, then list 1st and 2nd cultivation as separate operations.

Assign Field Operation Code Numbers. Next, assign a code number to each field operation--number consecutively from #1 up to the maximum number of different operations listed. The same operation listed in more than one activity period should carry the same code number in all periods.

Ordering Field Operations. Next, assume for the moment that one of your fields is to receive all of the operations listed. For each operation listed, enter the code number of other operations that it should follow(Do Aftr Oper), and which it should precede(Bef Bfor Oper). Use the following where appropriate: e.g. discing stalks or spreading P and K may be done anytime after the field is harvested; cultivating or sidedressing N must be done before the corn gets too tall.

Oper 0 = Do anytime after last year's crop harvested.
Oper 99 = Do anytime before corn reaches layby height.

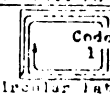
Indicate Field Pattern Used. Next, enter a field pattern code number for all operations except planting, which was previously specified for individual fields on your farm map. The field pattern specified for these other operations will be used on all fields where applicable(see box).

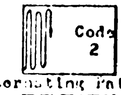
Maintenance and Overnight Storage of Equipment. Next, indicate a location code for each operation (see box) which describes your policy for refueling and performing routine daily maintenance on field equipment. Then enter a location code for the overnight storage of field equipment, if you assume the equipment will be used the next day. Your policy regarding these two items may change over the season for an operation that can be done in more than one activity period.

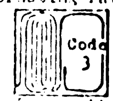
(continued behind the table)

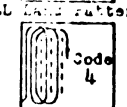
Act. Period	Field Operation Name or Description	Fld. Oper. Code No.	Order to Do (1st oper.)	[illegible]	Fld. Pattern Code No.	Equipment: Power & Imt. Code	Equipment: Over-Night Code	Idle Time /Meal (min)	Limit Daily Oper. To: Labor Hours Avail.	Or These Times (use AM or PM): Start	Quit
#1 Fall Land Prep									☐		
									☐		
									☐		
									☐		
									☐		
#2 Winter Land Prep									☐		
									☐		
									☐		
									☐		
									☐		
#3 Spring Land Prep									☐		
									☐		
									☐		
									☐		
									☐		
#4 Plant. Period									☐	For Period #4 use table on next page for the operations restricted to certain hours each day.	
									☐		
									☐		
									☐		
									☐		
#5 Post Plant. (after emerg.)									☐		
									☐		
									☐		
									☐		
									☐		

Field Pattern Codes:


Code 1
Circular Pattern


Code 2
Alternating Patterns*


Code 3
ALL Land Patterns*


Code 4
Overlap Patterns*

*Not available for circular-planted fields, where a circular pattern must be used for all operations.

Location Codes:
0=in the field where used.
1-6=at the farmstead (#1 to #6) which you specify.
7=at the farmstead nearest the fld. where used.

(main field operation table continued)

Idle Time for Meals. The computer will schedule a meal-stop at 12 noon and 6 PM for all field equipment operating at these times each day. Any value you enter which is 5 minutes or larger will be charged to the equipment and driver(s). You may indicate that a relief driver(s) takes over a certain operation during meals by entering a value of 4 minutes or less for it. If you do this, and then a relief driver is not available, an idle time of 30 minutes will be used. This policy also may change over the season for an operation done in two or more activity periods.

Potential Daily Operating Hours. Each operation will be performed by the computer each day only as long as there is labor available to do it. (Labor hours are specified in Section) However, for some operations you may wish to restrict them to certain hours each day. For instance, a fertilizer application job may be limited to the hours when the dealer is open, or you might want to limit planting or another operation to daylight hours only. In these cases there may be other jobs which available labor could do to finish-out the day. For each operation, in each activity period, either 1) check the Labor Hours Available box, OR 2) enter the particular hours when the operation can be done. If you restrict planting, and associated operations, to certain hours each day, then you might want to alter this some to reflect the importance of timeliness, e.g. you might be willing to run the equipment longer hours each day if planting is still going-on, in the computer, in early June. This can be shown here, IF it applies:

Act. Period	Fld. Oper. Code No.	Limit Daily Oper. To These Times*: Before May 3 (use AM or PM) Start	Quit	May 3 - May 24 (use AM or PM) Start	Quit	After May 24 (use AM or PM) Start	Quit
#4 Plant. Period							

*Do only for those operations it applies to, if any.

Note -- If you enter starting and quitting times for an operation, but fail to indicate enough labor in the labor section to run this many hours, then the operation will be limited each day by labor hours.

Note -- The planting period is broken-down into the three time periods shown at the left in the labor section also.

Other policy decisions for the field operations you have defined are continued on the next page. Go there only after completing the table on the previous page (and the one above, if applicable).

Restrictions Based On Erosion Hazards. (Skip if fall and winter operations not planned.) You may restrict certain operations planned for the fall and winter activity periods due to the erosion or run-off potential on part of your acreage. For instance, you might limit the application of fertilizer, or fall plowing to only a few fields. Enter the field operation code number(s) and the code number(s) of the fields where the operation can be done.

Fld. Oper. Code	Only these fields may receive the operation during the Fall and winter activity periods.*				
/					
/					
/					
/					
/					

*Enter field code numbers possible.

Restrictions Based On Management Planning. (Skip if not applicable.) You may plan to perform certain operations on only part of your total acreage each year, but you rotate this acreage so that eventually the total acreage is covered. Examples: bulk spreading P and K on only half or a third of the total acreage each year, moldboard plowing or chisel plowing only a portion of the total each year, etc. Enter the field operation code number(s) and the per cent covered each year, or the number of years required to get over the whole acreage.

Fld. Oper Code	Oper. Freq. (yrs)	Yrs Reqd To Cover Whole A.	Field Numbers Grouped As You Wish To Have Them Done First year fields grouped together, 2nd year fields grouped together, etc.
/			
/			
/			
/			
/			

Restrictions Planned, But Somewhat Random. (Skip if not applicable.) You may plan to perform certain operations on only part of your total acreage each year, but the part covered will depend on weather, soil, and crop conditions. Examples: Rotary hoeing, first or second cultivation, spot-treatment with a late spraying, etc. Enter the field operation code number(s) and the per cent of total acreage to be covered per year. This acreage will be chosen randomly on a field basis each year, or you may indicate(optional) certain "problem" fields that should receive the operation every year.

Fld. Oper Code	% of Total Each Year	Fields "Most Likely" To Receive This Operation*				
/	%					
/	%					
/	%					
/	%					
/	%					

*Entering field numbers optional.

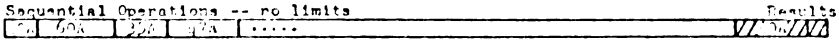
Complementary Field Operations. (Skip if not applicable.) Certain field operations may be complementary in the sense that if a field receives one, then it should not receive another one. Examples: You may want to moldboard plow part of your acreage, and chisel plow another part, but no field should receive both. Also, the various methods of applying bulk nitrogen should be indicated as complimentary -- surface spread or spraying, plow-down with a moldboard or chisel plow, and knife-down application(preplant or sidedress). Enter the appropriate field operation code numbers, if any.

Pairs of Fld. Op. Code Numbers			

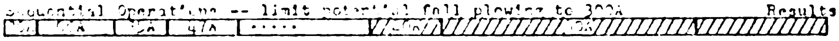
Priority of Field Operations Within Activity Periods. (Skip if only one operation has been specified for each activity period.) When two or more operations are possible within a given activity period, then these may be carried-out, by the computer and in actual practice, in a number of ways depending on your labor, equipment, and acreage limitations. The following example illustrates the type of information needed:

> Assume that a farmer has 600 acres of corn, and that he has listed discing stalks and moldboard plowing as two operations that could be done in the fall activity period. Assume further that in the equipment section(Section) he lists a single tractor for fall operations that can disc stalks at 8.5 A/hr, and plow at 2.5 A/hr. Then the computer program might simulate the following, if 80 hours of field time were available before the ground froze(after harvest was completed), in fields of size: 20A, 60A, 35A, 47A, etc. Let _____ = hours spent discing stalks, and ////// = hours spent plowing.

Sequential Operations -- no limits — Results: Disc 600A, Plow 24A



Sequential Operations -- limit potential fall plowing to 300A — Results: Disc 300A, Plow 113A



Concurrent Operations — Results: Disc 152A, Plow 151A

In other words, the computer program may perform the various operations(two or more) in sequence, concentrating your labor and equipment on one job until it is finished, and then concentrating on the next job to be done, etc. Or it may perform the operations in an approximately concurrent manner, so that at the end of the activity period all operations possible have been done on about the same number of acres, in so much as your labor, equipment, and acreage limits will allow. The computer program requires that all operations listed for the planting period be done with the concurrent mode of operation. You must decide, however, which mode of operation, sequential(Seq.) or concurrent(Con.), should be used in the other activity periods which have more than one operation possible. Check the appropriate boxes above.

Activity Period	Priority Seq.	Priority Con.
#1(Fall)........	☐	☐
#2(Winter).......	☐	☐
#3(Spring).......	☐	☐
#5(Post-Emerg)...	☐	☐

SPECIFIC PLANTING AND PLANTING POLICY INFORMATION

Planting Row Width. Specify the planter row width, i.e., the row width of planters, cultivators and other row-crop equipment.............................. ☐ inches

Seedbed Preparation For Planting. (Skip if not applicable.) If you have defined a field operation involving some tillage to be done "right before" planting--in activity period #4, then you may want to complete the policy statements at the right for this preplant operation. This field operation may be moldboard plowing if you use a wheel-track planting system, or it may be some secondary tillage operation if you use a more conventional tillage system. Regardless, estimate the values requested as nearly as possible based on your experience with your soils. Enter values only where appropriate for your system.

> If this amount of rainfall...... ☐ in. received after seedbed is prepared on a certain number of acres, but before planting can be done, then on those few acres.....
> ....repeat seedbed preparation field op (secondary tillage only)
> ....or, if it is moldboard plowing, then do fld. oper...... ☐# instead before planting. This may be a field operation defined only for this purpose, and not normally used with your tillage-planting system.

Starting Date for Planting. Enter the dates you prefer at the right. If soil temperature does not influence your start-of-planting decision, then enter the same date in both boxes.

> Start planting no sooner than. ☐
> If the soil temperature has not warmed-up to 50° by this date(at the 3-4" depth), then delay planting for awhile, but no later than............ ☐ / date /

If all the field operations scheduled to be done in activity period #3(Spring Land Prep) have not been completed by these dates, then check the optional mode of operation which you prefer:

Types of Hybrids Planted. Use the hybrid type codes to describe your hybrid policy. Use only as many lines as needed. Remember, your total corn acreage will be planted to corn every year by the computer. So in years with a "late spring", the last hybrid type listed in the box will be used to finish-up with.

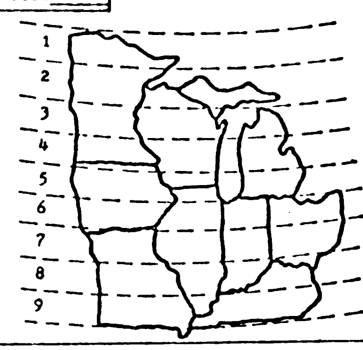
Hybrid type codes:
1 = Short season hybrid
2 = Medium season hyb.
3 = Full season hybrid

	plant this many acres	of hybrid type code
first	______	______
then	______	______
then	______	______
then	______	______
then	______	______

(regardless of the planting dates)

DO NOT WRITE HERE

Latitude Code ______



Planting Sequence. You may (optional) specify the sequence or order in which fields should be planted. This is the only field operation for which this may be done. All other operations used to produce the crop will generally follow this same order, or the order in which fields are harvested. Check the appropriate boxes.

☐ No particular planting sequence desired. Go to the next section.

☐ Plant this sequence: 1st 2nd 3rd 4th 5th .... ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ / ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ (field code numbers)

The computer should follow this sequence...

☐ EXACTLY

☐ WHENEVER POSSIBLE, but if the next field to be planted is not tractable (cannot be worked in) on a given day, the computer will scan the rest of the list. If another field is found to be tractable that day, then plant in it. Return to the next field in the sequence as soon as it dries enough to work in.

SECTION 4 -- LISTING AVAILABLE FIELD EQUIPMENT AND NEEDED SPECIFICATIONS

Each and every piece of field equipment to be used in producing the corn crop should be listed on the next 2 pages. Use a separate line for each item.

Tractors. On the following page, enter a description name (for your use) for each tractor that is used in some way for the corn enterprise. If a tractor is not used for field work, but is used, say, for hauling supplies to the field, for hauling corn at harvest, for running an auger at the farmstead at harvest, etc., then it should be listed. Next, enter a size code for each tractor based on its rated PTO horsepower (see box). Then enter a fuel type code for each tractor, and the size of its fuel tank in gallons.

Implements. Enter a descriptive name for each field implement and the appropriate type code from the box. When more than one unit of a given type is listed, then enter a "unit number". For instance, your first planter should be coded as 191 (type 19, unit #1), a second planter as 192 (type 19, unit #2), etc. Next, enter the width or size of each implement using the designation illustrated in the box for each.

Vehicles. Enter a descriptive name for each vehicle that will be used to haul production supplies to the field. Next, enter for each vehicle a vehicle-type code, and a unit number (if more than one of the same type). If the vehicle will be used to haul water, or bulk or bagged fertilizer, then enter the transport capacities requested. For water and bulk fertilizer, enter an estimate of the rate at which these materials can be conveyed or transported on-to and off-of the vehicle. Give this type of information only for those materials that will actually be hauled by each vehicle.

Note -- See equipment codes on the next page.

TRACTORS

List All Tractors	Tract. Size Code	Fuel Type Code	Fuel Tank (gal)

(Use back if needed)

IMPLEMENTS

List Field Implements	Code No. Impl. Type	Code No. Unit No.	Width or Size

(Cont'd)

List Field Implements	Code No. Impl. Type	Code No. Unit No.	Width or Size

(Use back if more space is needed)

SUPPLY VEHICLES

Supply Transport Vehicles	Code No. Veh. Type	Code No. Unit No.	Transport Capacity of Various Materials (if used) — Water Tank: Total Carried (gal)	Water Tank: Apprx. T.R. In (GPM)*	Water Tank: Apprx. T.R. Out (GPM)*	Bulk Fertilizer (dry or liquid): Total Lbs	Bulk Fertilizer: T.R. In (PPM)*	Bulk Fertilizer: T.R. Out (PPM)*	Total Lbs Bagged Fert.

* T.R. = Transfer rate, gallons per min. of water, pounds per min. of fert.

In = Loading material onto the unit at some refill location.

Out = Moving material from the unit to field implement or applicator in the field.

(Use back if more space is needed)

EQUIPMENT CODES

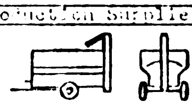
Tractor Size Codes		
01 =	20-49	PTO HP
02 =	50-59	PTO HP
03 =	60-69	PTO HP
04 =	70-79	PTO HP
05 =	80-89	PTO HP
06 =	90-99	PTO HP
07 =	100-109	PTO HP
08 =	110-119	PTO HP
09 =	120-299	PTO HP

Fuel Types
1 = Gasoline
2 = Diesel
3 = LP Gas

Implement Types	Give width or size as:
10 = Rotary Stalk Chopper......	actual width, feet
11 = Flail Stalk Shredder......	actual width, feet
12 = Moldboard Plow............	4-bot., 14-inch; etc.
13 = Chisel Plow...............	actual width, feet
14 = Powered Rotary Tiller.....	actual width, feet
15 = Heavy Tandem Disc.........	actual width, feet
16 = Standard Tandem Disc......	actual width, feet
17 = Field Cultivator..........	actual width, feet
18 = Spring Tooth Harrow.......	actual width, feet
19 = Corn Planter..............	6-row, 30-inch; etc.
20 = Rotary Hoe................	4-row; 6-row; etc.
21 = Row Crop Cultivator.......	4-row; 6-row; etc.
22 = Field Sprayer.............	boom length, feet
23 = Dry Bulk Fert. Spreader...	spread width, feet
24 = Knifedown N Applicator....	5-knife, 40-inch; etc.
25 = Nitrogen Nurse Tank.......	none

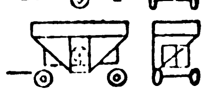
Vehicles for Production Supplies & Hauling Corn

Type 30
Augered Feed Cart Trailer



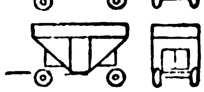
PTO driven unload auger front or back.

Type 32
Side Dump Gravity Wagon



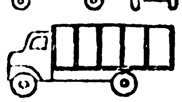
Fertilizer auger can be fitted on either side.

Type 33
Center Dump Gravity Wagon



Fertilizer auger can be fitted on either side.

Type 34
Truck with Grain Bed



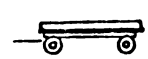
Hydraulic hoist, fertilizer auger can be fitted to the tailgate.

Production Uses:
All types--Hauling dry bulk fertilizer to the planter. Type 34 only--Hauling bagged materials and supplies to the planter or other implements, or hauling a water or liquid fertilizer tank to the field.

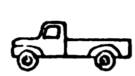
Vehicles for Production Supplies Only

Type 36
2-wheel Trailer

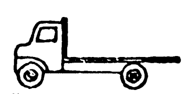
Type 37
Flatbed Wagon



Type 38
Pickup Truck



Type 39
Flatbed Truck



Vehicles or beds have no sides, or very short sides and tailgate (18" or less).

Principal Uses:
All types--Hauling bagged materials and supplies to the planter or other implements, or hauling a water or liquid fertilizer tank to the field.

SECTION 5 -- ALLOCATING EQUIPMENT for VARIOUS FIELD OPERATIONS

In this section you must match-up the tractor sizes and individual items of equipment listed in the previous section to form equipment sets for doing various field operations. A maximum of 5 equipment sets may be specified as being potentially available for an operation. If a material is applied with a particular operation -- herbicide, fertilizer, insecticide, e.g., then you must also supply information about the materials handling system used. With planting you may apply up to 4 different materials(one of which must be seed), but with all other operations you may apply a single material only. Instructions are given below and on the next page.

Equipment Sets. Each equipment set should consist of a tractor plus 1 or 2 implements. Illustrated below is an 80-89 PTO HP tractor (05) pulling a moldboard plow(121 = type 12, unit #1), and a 100-109 PTO HP tractor(07) pulling a rotary stalk chopper(101) and a tandem disc(162). List all equipment combinations, equipment sets, from your equipment inventory that could potentially be used for each field operation.

Typical Performance Rates. For each equipment set give typical performance figures by entering how many acres were(or could be) covered, in so many hours of operation, in a particular field. If a material is applied with the operation, then these figures should include any lost time for material refills. that take place in the field. Estimate the usual or normal speed of operation with each equipment set.

	Fld. Oper Code	Equip. Sets: Trct Size Code	1st Impl Code	2nd Impl Code	Typical Rate: This Many Acres	This Many Hours	In Fld No.	Est. Speed (mph)	Material Applied: Name of Matl	Matl Code No.	Total Carried (Units)	Appl Rate (Un/A)	Matl Supp Srce	In-Field Supply Vehicle: Trct/Truck Code	1st Veh. Code	2nd Veh. Code	Matl Supp Srce
Example:	6	05	121		17	5	14	4.5	[illegible]	5	[illegible]	110	0	nurse	tank→		8
Example:	2	07	101	162	45	8.5	5	5.0	Herb	2	250	8.5	0	39			7

Material Application. (Do only for those field operations where appropriate.) Write a name or abbreviation for the material, then the appropriate code number for it. Next, indicate the total units of the material which can be carried by the equipment set, and the application rate in units per acre. Use the same units for the amount carried and applied -- see Matl Code box on next page. Next, enter a code number(Matl Supply Source) where the field equipment must go to get additional supplies for refills -- see Matl Supply Source box.

In-Field Supply Vehicles. (Do only if the material supply source for the field equipment is Code 0) A supply vehicle stationed in the field may consist of a tractor with 1 or 2 trailing vehicles, or a truck with 0, 1, or 2 trailing vehicles. One vehicle may supply all equipment sets doing a given field operation, or you may specify a different vehicle for each equipment set. Enter the tractor and/or vehicle code numbers, then a code where the supply vehicle must be taken to get additional supplies.

Other Field Operations Besides Planting: Use a maximum of 5 lines(equipment sets) per operation.

Fld. Oper Code	Field Equipment — Equip. Sets: Trct Size Code	1st Impl Code	2nd Impl Code	Typical Rate: This Many Acres	This Many Hours	In Fld No.	Est. Speed (mph)	Material Applied: Name of Matl	Matl Code No.	Total Carried (Units)	Appl Rate (Un/A)	Matl Supp Srce	In-Field Supply Vehicle*: Trct/Truck Code	1st Veh. Code	2nd Veh. Code	Matl Supp Srce

Note -- Any material applied with a field operation must be applied with all sets of equipment you specify for that operation and at the same rate. You may use one supply vehicle for all sets of equipment you specify for each field operation, or a different one for each equipment set.

Matl Code Nos.
2=Water
3=Bulk fert
4=Bagged fert
5=Bulk N
6=Seed corn

Matl Supply Source
0=An in-field supply vehicle
1-6=At a certain farmstead
7=At the nearest farmstead
8=Dealer delivers material
11-16=At an off-farm location

* Do only if the Matl Supp Srce=0 for the field equipment.

Matl Code No.

2 = Water. Water used for herbicide or insecticide spraying. Use total gallons carried by each set of equipment, and gallons per acre applied.

3 = Bulk Fertilizer. Liquid or dry bulk fertilizer -- P, K, starter, pop-up, etc. Use total pounds carried and pounds per acre applied.

4 = Dry, Bagged Fertilizer. Starter or pop-up fertilizer. Use total pounds carried in the hoppers, and pounds per acre applied.

5 = Bulk Nitrogen. Liquid or gas (NH_3) form. Use total pounds carried, either in equipment mounted tanks or in a pulled nurse tank, and pounds per acre applied. Use units or actual, but be consistent.

6 = Seed corn. Use total bushels carried and bushels per acre applied, or total pounds carried and pounds per acre applied, or total number of kernels carried and kernels per acre applied.

7 = Dry Herbicide or Insecticide (applied through a dry applicator). Use total pounds carried and pounds per acre applied.

8 = All Others.

Matl Supply Source Codes:	Specified for Field Equipment:	Specified for Supply Vehicles:
0 = From an in-field supply vehicle--which leaves the fld. for matls.	Field equipment and operator do not have to leave the field in order to refill the hoppers or tanks on the equipment.	Code 0 not applicable here. Use for field equipment only.
1-6 = At the farmstead (#1 to #6) which is specified. 7 = At the farmstead nearest the fld. where used. 11-16 = At the off-farm location(#11 to #16) specified.	Field equipment must leave the field and travel to the location indicated when the equipment's hoppers or tanks need to be refilled.	A field equipment operator(only one if 2 or more sets of equipment being used), or the man helping with material refills must drive the supply vehicle to the out-of-field location indicated when the quantity of material carried on the vehicle must be replenished.
8 = From an in-field supply vehicle--which a dealer keeps filled.	Code 8 not applicable here. Use for supply vehicles only.	Dealer delivers material to the field, either in a transport vehicle he leaves there(nurse tank or bulk spreader), or he transfers the material into one of your transport vehicles.

Planting Operation: Use a maximum of 4 lines(materials) for each planter.

	Planting Equipment												In-Field Supply Vehicle*			
	Planter Unit			Typical Rate				Materials Applied								
Plt Oper Code	Trct Size Code	1st Impl Code	2nd Impl Code	This Many Acres	This Many Hours	In Fld No.	Est. Speed (mph)	Name of Matl	Matl Code No.	Total Carried (Units)	Appl Rate (Un/A)	Matl Supp Srce	Trct/Truck Code	1st Veh. Code	2nd Veh. Code	Matl Supp Srce
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX
											XXXXX	XXXX				XXX

Note -- If more than 3 planters are to be specified, use back of this page. You may specify a maximum of 5 planters.

Note -- Any materials applied with one planter must be applied with all planters, at the same rates. You may use one supply vehicle for all planters, or a different one for each. Or you may use one supply vehicle for all materials applied, or a different one for each.

Note -- You must indicate seed(code 6) as one of the materials applied with the planter.

Matl Code Nos.	
	2=Water
	3=Bulk fert
	4=Bagged fert
	5=Bulk N
	6=Seed corn

Matl Supply Source	
	0=An in-field supply vehicle
	1-6=At a certain farmstead
	7=At the nearest farmstead
	8=Dealer delivers material
	11-16=At an off-farm location

* Do only if the Matl Supp Srce=0 for the planting equipment.

Multiple-Planter Options. (Skip if not applicable.) When you specify multiple sets of equipment for a particular field operation, except for planting, the computer program assumes that all the sets specified may operate in the same field at the same time, i.e. 2 or more plows, 2 or more cultivators, etc. may all run in the same field together. Check the policy to use for planting:

☐ One planter to a field only. Planters will be allocated to consecutive fields in the planting sequence. When a planter finishes one field, it will be assigned to the next field in the planting sequence which is not occupied by another planter at the time.

☐ Two planters to a field. With an alternating field pattern, one planter will start from each side of the field so that any point rows will be in the center part of the field. All planters may work together in circular-planted fields.

SECTION 6 -- LABOR FORCE for PRODUCING the CROP

The next 5 pages correspond to the 5 activity periods used for producing the crop. Skip those, if any, in which you have not planned to do field operations. The information you must supply:

Labor Force Codes. In each activity period you may identify up to 10 individuals that might be available for field work. Enter a name for each(optional). This gives each one a man(or code) number. Whenever possible, you should code an individual with the same code number in all activity periods in which he may work.

Code each man further by type:
(Enter in the F/P column)
1 = full-time family labor
2 = part-time family labor
3 = full-time hired labor
4 = part-time hired labor

Job Priority Codes. Each man should be assigned priorities for performing or helping with the field operations that can be done during each activity period. This is done by entering the field operation code numbers in the desired priority positions. The illustration below-left might indicate the following for man #1:
1st 12 = spray herb. after the planter
2nd 110 = help with planter refills
3rd 11 = run the planter
Man #1 would have other priorities assigned for other jobs in the rest of the activity periods.

The tractor operators for each field operation will also be responsible for support activities such as equipment maintenance, material refills, getting supplies to the field, etc. For anyone else that helps with these support activities, the field operation code number, followed by a zero, should be entered(like code 110 above).

Labor and Job Priority

Man No.	Man's Name	F/P	Job Priority Codes 1st	2nd	3rd		
1	Jimmy	1	12	110	11		
2	John	3	10	12			
9							
10	Frank	1	11	12			

Work Hours of Labor

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☑ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	8	11				
2	4	9	8	11		
10	9	4:30				
	8	11				

Labor Work Schedule. Indicate the potential daily hours of field work for each man by entering starting and quitting times in the Mon-Fri columns. Circle a for AM(or cross-out p) or p for PM(or cross-out a) with each entry. For Saturday or Sunday work use the following:
a) Check the box at the top, nothing else. The computer will use the same hours as for Mon-Fri.
b) Check the box, enter times only for those men that work different hours on the weekend. The computer will use the same hours as for Mon-Fri for all other men.
c) Do not check the box at the top. Enter the times for all men that could work on the weekend.

Activity Period #1 -- Fall Land Preparation

Field* Operation	Code No.
	#
	#
	#
	#
	#

*This table for your use and convenience--it is not part of computer input.

Job Priority Codes

Man No.	Man's Name	F/P	-Harvest Not Done- 1st	2nd	3rd			-Harvest Finished- 1st	2nd	3rd		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

└See Note 1.

Note 1 -- Enter H for harvest in this column(leave other columns blank) for those men, if any, that will be busy with harvesting activities, and not available for land preparation jobs until after harvest.

Labor Work Schedule:

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Note 2 -- As long as corn from last year's crop remains to be harvested, the Labor Work Schedule(hours) which you specify in the harvest section will take precedence over the one given at the left here.

← Note 3 -- For those men with priority H above, if any, enter the potential hours of field work for land preparation activities only, i.e. to be applied after harvest has been completed.

Activity Period #2 -- Winter Land Prep

Field* Operation	Code No.
	#
	#
	#
	#
	#

*This table for your use and convenience--it is not part of computer input.

Job Priority Codes

Man No.	Man's Name	F/H	-Harvest Not Done- 1st	2nd	3rd			-Harvest Finished- 1st	2nd	3rd		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

└See Note 1.

Note 1 -- Enter H for harvest in this column(leave other columns blank) for those men, if any, that will be busy with harvesting activities, and not available for land preparation jobs until after harvest.

Labor Work Schedule:

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat ☐ Quit	Sun ☐ Start	Sun ☐ Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Note 2 -- As long as corn from last year's crop remains to be harvested, the Labor Work Schedule(hours) which you specify in the harvest section will take precedence over the one given at the left.

← Note 3 -- For those men with priority H above, if any, enter the potential hours of field work for land preparation activities only, i.e. to be applied after harvest has been completed.

Activity Period #3 -- Spring (Pre-Plant) Land Preparation

Field* Operation	Code No.
	#
	#
	#
	#
	#

*This table for your use and convenience--it is not part of computer input.

Man No.	Man's Name	F/P	Job Priority Codes 1st	2nd	3rd		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Labor Work Schedule:

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat ☐ Quit	Sun ☐ Start	Sun ☐ Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Note -- On the first day that planting can be done each spring, the Labor Work Schedule you specify on the next page for the planting period will over-ride the one specified at the left. The same is true for Job Priorities.

Activity Period #4 -- Planting Period

Field* Operation	Code No.
	#
	#
	#
	#
	#

*This table for your use and convenience--it is not part of computer input.

Man No.	Man's Name	F/P	Job Priority Codes 1st	2nd	3rd		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Note -- If the planting operation itself was not restricted to certain hours in Section 3, then you may want to enter longer hours (or Sunday work) for certain men if planting were still going on in late May or early June.

A labor work schedule for the middle period below(May 3-May 23) must be filled-in. The other two periods are optional.

Labor Work Schedule:

Planting BEFORE May 3

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Planting May 3-May 23

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Planting AFTER May 23

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Activity Period #5 -- Post-Emerge(Tending) Period

Field* Operation	Code No.
	#
	#
	#
	#
	#

*This table for your use and convenience--it is not part of computer input.

Man No.	Man's Name	F/P	Job Priority Codes 1st	2nd	3rd		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Labor Work Schedule:

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

Note -- This Labor Work Schedule will stay in effect each year until all field operations planned have been completed, or until all corn reaches layby height -- whichever comes first.

SECTION 7 -- HARVESTING POLICY and EQUIPMENT

High Moisture Storage Option

Complete this part only if you plan to store high moisture shelled corn on the farm. Enter the moisture content range you prefer the computer to use when storing high moisture corn:

GUIDELINES	
Ideal kernel moisture:	26-28%
Recommended range:	25-30%
Recommended limits:	25-33%

[ ]% m.c. to [ ]% m.c.
(lowest) (highest)

Kernel Starting Requirements

Complete this part for corn to be dried on-farm or moved off-farm at harvest-time, if any. Enter the desired starting moisture and a mandatory starting date:

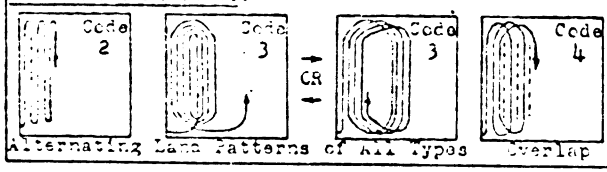
Begin harvesting for this purpose when kernel moisture content gets down to.................. [ ]% m.c.

If kernel moisture doesn't get this low, then begin harvesting anyway on or after............ [ ] (enter date)

Harvesting Field Pattern

Enter the code number of the field pattern to be used......... [ ]

Field Pattern Codes:*



*These patterns not available for circular-planted fields, where a circular pattern(Code 1) must be used.

Field Equipment Locations

Routine maintenance jobs, refueling and overnight storage of the combines and tractors used for hauling corn may be in the field or at a farmstead. Enter the location code for your policy.

Refueling and maintenance of combines and tractors......... [ ]

Overnight storage--combines...... [ ]

Overnight storage--trucks and tractors used for transport...... [ ]

Location Codes:
0=In the fld. where used.
1-6=At the farmstead(#1 to #6) which you specify.
7=At the farmstd. nearest the field where used.

Combine Idle Time for Meals

Combines and their operators will be scheduled by the computer for a meal-stop at 12 noon and 6 PM if operating at these times*. Any value you enter here which is 5 minutes or larger(per meal) will be used as is. Entering 0-4 minutes will indicate that a relief driver takes over the combine(s) at meal time. If you enter this, and then a relief driver is not available, an idle time of 30 minutes will be charged to the combine and its operator.

Idle time for meals, minutes per meal.................. [ ] min

* Men involved with harvesting activities, but not with operating the combine, will not be charged meal-stop time. These other men may serve as relief drivers for combines.

Grain Tank Unloading Options

Check the type of unloading to be used:

- [ ] Use STOP unloading only(combine stopped during corn transfer).
- [ ] Use ON-THE-GO unloading if labor and vehicles are available in the field when needed.

The computer may need to spot transport vehicles to receive corn. Check one box(for fields that are not circular-planted):

- [ ] Spot vehicles at the ends of the field only.
- [ ] Spot vehicles out in the field(away from ends) if needed.

Combines and Specifications

Enter a descriptive name for each combine to be used, and the other values requested. Type 27 designates a self-propelled combine--maximum of 5 units permitted. Cylinder length is approximately the same as separator width on most combines.

List All SP Combines	Code No. Comp Type	Code No. Unit No.	Cyl. Len. (in)	Grain Tank (bu)*	Rated Engine HP	Fuel Type Code	Fuel Tank (gal)	Cornhead No. Rows	Cornhead Variable Speed?	Est. Cap.** (bu/hr)
	27	1							[ ] Yes	
	27	2							[ ] Yes	
	27	3							[ ] Yes	
	27	4							[ ] Yes	
	27	5							[ ] Yes	

Fuel Types:
1 = Gasoline
2 = Diesel
3 = LP Gas

*Approx. bu. of No. 2 corn without stop to level the load by hand.

** Under average conditions using normal practices (on-the-go or stop unloading, etc.)

On-Row Harvesting Speed Policy

Combine Code Number	Speeds (mph)			
	1st Gear		2nd Gear	
	Min	Max	Min	Max
271				
272				
273				
274				
275				

Give the minimum and maximum forward speed for two different gears that might be used for harvesting operations. List the speeds given in the Operators Manual for the tire sizes actually used. For hydrostatic transmissions, give speed information for one gear only--enter this in the 1st-gear column.

Check the speed policy that is closest to the one you use:

☐ Constant Speed. Harvest at a fairly constant speed throughout the harvest season. Change to a lower(but constant) speed, as indicated, if stalk lodging reaches the level shown--"severe" or "excessive" lodging policy is covered in the box at the bottom of the page, so give "normal" policy information here.

Normal constant speed...... [ ] mph Reduced constant speed....... [ ] mph If lodging reaches, or above.... [ ] %

☐ Variable Speed--Load Level. Vary harvest speed as often as is necessary to maintain a fairly constant load on the combine. This policy will be based on the "Rated Engine Hp" given on the previous page for each combine, and other factors(yield, mc, etc).

☐ Variable Speed--Loss Level. Vary harvest speed as often as is necessary to keep gathering(header) losses at some "acceptable" level. The value of an "acceptable" gathering loss level may increase as lodging increases(as the season progresses). Unless you indicate otherwise, an "acceptable" gathering loss level will be assumed to be 3% of harvestable yield when lodging is less than 10%, increasing up to 10% of harvestable yield when lodging reaches 50%. Your "acceptable" header loss values:

[ ] % if lodging less than 10%, [ ] % if it reaches 50%

Severe Lodging Limits (fill-in if applicable, regardless of the normal speed policy chosen above)

When lodging gets extremely bad, many operators find they can only go a short distance before having to stop and unplug the cornhead, regardless of how slow they try to operate. This results in intermittent rather than continuous operation down through the field. If this "limiting case" is consistent with your experiences, estimate:

Minimum amount of lodging that will cause this..... [ ] % Speed possible(or used) between stops when this happens.......... [ ] mph

Daily Harvesting Hours

If the harvesting operation is limited each day only by the availability of labor, then skip this part. However, if you wish to limit daily operation for some reason, then enter the daily starting and quitting times for the combine(s) below. These may reflect the desire to harvest only during daylight hours, the closing time of a local elevator, etc.

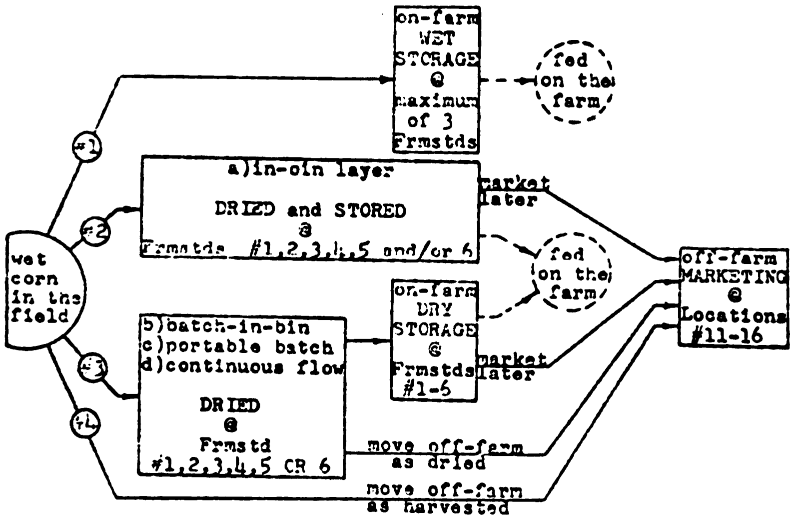
Approximate Calendar Dates	"Normal" Morning Conditions		"Heavy" Frost* Mornings	"Heavy" Dew ** Mornings
	Starting Time ***	Quitting Time ***	Starting Time ***	Starting Time ***
Sep,Oct,Nov	a p	a p	a p	a p
Dec,Jan	a p	a p	a p	a p
Feb,Mar	a p	a p	a p	a p

* Enter same as "normal" morning if your harvest operation is unaffected by "heavy" frost.
** Enter same as "normal" morning if your harvest operation is unaffected by "heavy" dew.
***Circle a for AM, or p for PM.

SECTION 8 -- SHELLED CORN HANDLING AND MARKETING METHODS

The various ways that corn may be handled as it comes from the field at harvest-time are illustrated below. These 4 basic handling and marketing options are explained on the next page. Study them and decide how you want your crop handled.

Alternatives for Moving Shelled Corn from Various Fields or Farms 1/



1/ Flow patterns that are simulated by the computer program are indicated by a solid line(——). Those that are assumed to take place, but are not actually simulated by the computer program are shown by dashed lines(-----), i.e. on-farm feeding.

Note -- The words "wet" and "high moisture" are interchangeable here. Thus, wet storage = high moisture storage = corn storage for a moisture level that is too high for safe "dry corn" storage.
Note -- You may not use more than one drying method with the current computer program. For instance, if you choose in-bin layer drying for part of your corn crop, then one of the other 3 drying methods may not be chosen for another part of the crop, and vice versa.
Note -- Corn that is moved off-farm at harvest-time may not be moved back to the farm during the harvest period. It may, however, be moved back later, say for feeding.

Basic Handling and Marketing Options

Check the one(s) to be used for all or part of your crop:

☐ Option #1 Move Corn To Wet Storage Facilities On The Farm.

Silos for wet-corn storage may be located on a maximum of 3 farmsteads. All corn wet-stored must be fed-out on the farm. Any production in excess of wet storage capacity may be handled with any of the other 3 options. This option will be satisfied by the computer with the first corn harvested each year, regardless of the other options selected, if any.

☐ Option #2 Move Corn To In-Bin Layer Drying Facilities On The Farm.

Drying(and storage) bins may be located on any or all of the farmsteads. All corn that is dried must be stored "in place" for a period of time. Stored corn may be marketed off the farm, or fed on the farm. Any production in excess of storage capacity must be moved directly off the farm as harvested(Option #4 below). If harvesting and hauling capacity exceeds daily drying capacity, then a load or two of corn may be moved off-farm each day to expedite harvest.

☐ Option #3 Move Corn To Batch or CF Drying Facility On The Farm.

ALL drying equipment must be located at the same farmstead year after year. The drying method may be batch-in-bin, portable batch OR continuous flow. The latter two methods may be used with or without dryeration. If harvesting and hauling capacity exceeds drying or wet-holding capacity, then a load or two of corn may be moved off-farm each day to expedite harvest.

Alt. A Move Dry Corn To On-Farm Storage.

Dry corn storage may be located at the drier site, or at any of the other farmsteads. Stored corn may be marketed off the farm, or fed on the farm. Any production in excess of storage capacity may be moved directly off-farm as harvested, Option #4 below, or dried first and then moved off-farm, Alt B.

Alt. B Move Dry Corn Off-Farm As Dried.

The corn may be sold at the time, or commercially stored for later sale(or movement back to the farm for feed).

☐ Option #4 Move Corn Directly To An Off-Farm Market As Harvested.

This may be a primary option, or an alternative for excess production or harvest capacity for the other options. Corn may be sold, or commercially dried and stored for later sale.

If the first option checked above is:
Option #1, then go to Section 8-1 next
Option #2, then go to Section 8-2 next
Option #3, then go to Section 8-3 next
Option #4, then go to Section 8-4 next

SECTION 8-1 -- WET (HIGH MOISTURE) STORAGE OPTION

This option will be satisfied first by the computer each year(if other options are also used) beginning when the corn gets down to the "starting" moisture specified in Section 10. Enter below the equipment, facility, and policy information requested for the farmsteads(max of 3) where high moisture corn will be stored.

Frmstd	Total Bushels of Storage*	Total No. of Silos (Max)	Approx Daily Usage (bu)≠	Filling Equip. Limiting Capacity (bu/hr)**	Filling Equip. Trct Size Code##	Corn Put Into Wet Storage Should Come From: Field Numbers *≠				
#										
#										
#										

* Actual storage space available or the amount of corn to be added each fall, equivalent bushels of No. 2 corn.

≠ Approximate amount usually fed each day during the normal harvest season at this location, equivalent bushels of No. 2 corn.

** Estimate the effective rate at which transport vehicles could be unloaded at the silo if corn at 25% mc were being brought-in. The limiting capacity may be the blower, feed-apron, corn flow rate from the transport vehicle, etc.

\## Enter the size code number of the tractor used to run the filling equipment(if any). See Section 6 for tractor size codes.

*≠ If the amount of corn wet stored is a relatively small portion of your total crop, then you may(optional) specify which fields are to be used for this. These fields will be used by the computer whenever possible, but if their moisture falls below the desired range before wet storage is full, then others with a bigger moisture will be substituted.

The amount of time charged to a driver for dumping a load of corn will be based on the size of each load brought-in, and the unload rate(s) indicated above(limiting capacity of the filling equipment). But this value will not include any extra time that might be required to "jockey" the vehicle into position for dumping, starting and stopping the filling equipment, hoisting a truck bed or tailgate, clean-up after dumping, etc.

Estimate the extra driver time required per load.........[ ] min

If two or more silos use the same filling equipment, then estimate the amount of man-time required to move this equipment from one silo to another(skip if not applicable).

No. of men needed....[ ]; Time required per man........[ ] min

> Note--If this is the only option to be used, then you must have specified enough wet storage capacity to handle the largest crop that will ever be produced. If there is a chance that a bumper crop will exceed your storage capacity(plus normal feed-out rate), then provide for handling this "excess" corn by filling out Section 8-4, Option #4 for direct-from-the-field marketing.

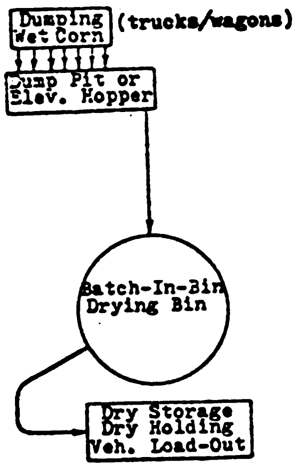
> If a part of your crop is to be:
> - in-bin layer dried, then go to Section 8-2 next.
> - batch or CF dried, then go to Section 8-3 next.
>
> If the rest of the crop is to be:
> - moved directly off-farm, then go to Section 8-4 next.
>
> Otherwise, go to Section 9 next.

SECTION 8-2 -- IN-BIN LAYER DRYING OPTION

(not developed)

SECTION 8-3 -- BATCH OR CONTINUOUS FLOW DRYING OPTION

Batch-In-Bin Drying Method



Drying Bin Data

Location.................. Frmstd # ____

Bin size...................... ____ bu (dry bu equiv--total)

Bin diameter................ ____ ft

Max daily batch depth....... ____ ft

Drying cycle:

____ hrs to dry (max batch depth)

____ hrs to cool (25 down to 15%)

Automatic controls: (check)

Burner shut-off....... ☐ yes ☐ no (end of drying cycle)

Fan shut-off.......... ☐ yes ☐ no (end of cooling cycle)

Daily Batch Unloading

Man-time, if any, to install and/or start bin sweep....... ____ min. avg.

Unloading rate with bin sweep in use.......... ____ bu/hr (same or different than rate in Hdlg Equip Data section on next page for paths B, C, and/or D)

Is shut-off of the bin unloading equipment ☐ automatic or ☐ manual? (check one)

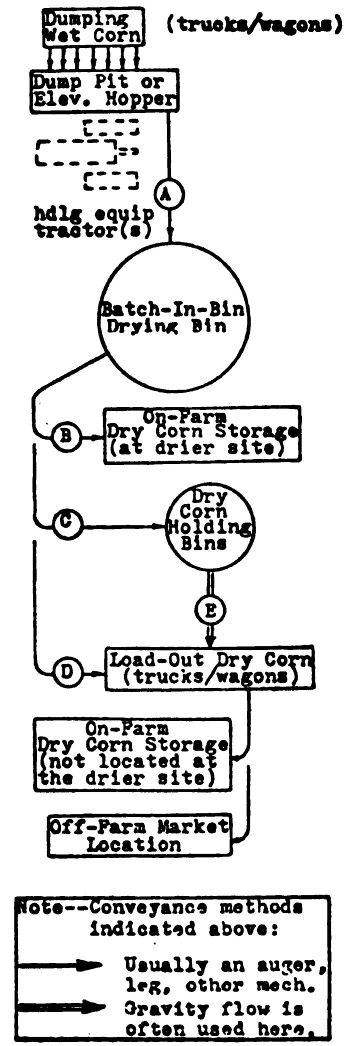
Daily Harvest/Drying Policy

Answer the following if your daily harvest capacity exceeds the maximum daily batch size:

- ☐ Suspend harvest when the maximum batch size is reached.
- ☐ Fill drying bin(to max batch size) then haul wet corn direct to an off-farm marketing location the rest of the harvest day.
- ☐ If harvest is permitted after the closing time of local elevators, schedule loads to off-farm locations throughout the day so that the maximum batch size is reached and full harvest potential is realized.

(Continued on the next page)

Corn Flow Alternatives at the Drier Site DURING HARVEST.



(Go next to page)

Handling Equipment Data

Tractors used as power source for handling equipment(zero if none):

☐ No. used(total for hdlg)

☐ Size code number(1-9) (all must be of the same size)

All handling jobs you intend to do (A,B,C,etc.) must be assigned to 1 or more pieces of handling equipment in the table below, including gravity flow jobs:

Type Code 1/	Unit No. 2/	Hdlg Jobs Done(Check) A	B	C	D	E	Rate (bu/hr) 3/	Time (min) 4/

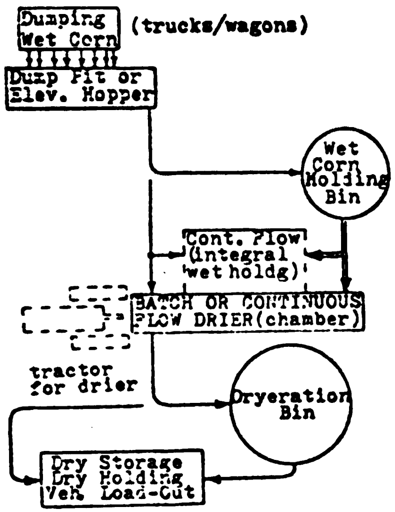
1/ Types: 1=vert. bucket elevator, 2=augers(all types), 3=belt conveyors, 4=all other mechanical conveyors, 5=gravity flow

2/ Unit number, e.g. type code #2, unit #1, unit #2, etc.

3/ If used for both wet and dry corn handling jobs, give the rate for wet(about 25% mc) corn.

4/ If used for more than one handling job, give the average man-time, if any, to switch the unit from one job set-up to another.

Batch-Type and Continuous Flow Drying Methods



Drier Data--More Specific

BATCH-TYPE DRIER:

Batch size........... [ ] bu

Drying cycle times:

Drying(25-15%).. [ ] minutes

Cooling(drier).. [ ] minutes (zero if dryeration used)

Automatic controls--leave boxes blank(automatic), or check(for manual control):

	Start It	Stop It
Drier filling.....	☐	☐
Drying cycle......	☐	☐
Drier unloading...	☐	☐

CONTINUOUS FLOW DRIER:

Integral wet holding.. [ ] bu

Drying chamber........ [ ] bu

Drier Data--General

Location............ Frmstd #

Tractor used(zero if none):

[ ] Size code number(1-9)

Estimated overall drying capacity........ [ ] bu/hr (25% down to 15% mo)

Wet Holding Bin(if used)

Total holding capacity.... [ ] bu (dry bu equiv--bin only--not including trucks, wagons, or dump pit)

Dryeration Bin(if used)

Size........................ [ ] bu (dry bu equiv--total)

Bin diameter............. [ ] ft

Is shut-off of the dryeration bin unloading equipment ☐ automatic or ☐ manual? (check one)

Is dryeration bin hopper-bottomed? ☐ yes ☐ no If not, continue:

Man-time, if any, to install and/or start bin sweep........... [ ] min. avg.

Bin unloading rate with bin sweep...... [ ] bu/hr (same or different than rate in Hdlg Equip Data section on next page for paths H, I, and/or J)

Dryeration bin unload policy:

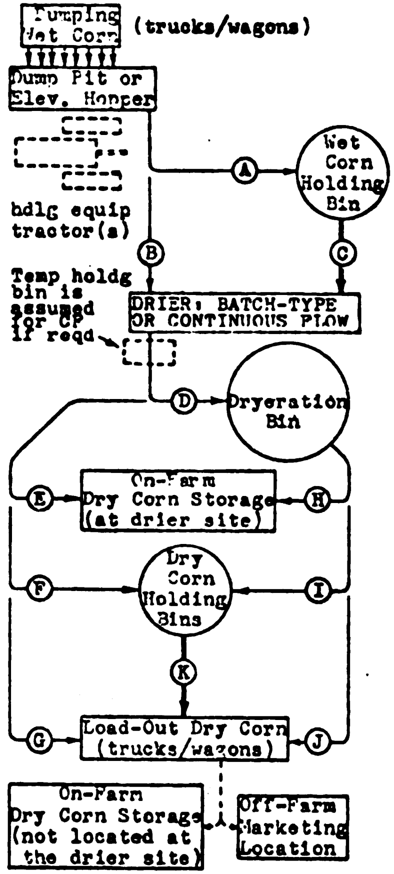
☐ Let the corn form a "hopper-bottom" each time unloaded.

☐ Use bin sweep to empty-out completely each time.

☐ Some of both--depends on how rushed at the time.

(Continued on the next page)

Corn Flow Alternatives at the Drier Site DURING HARVEST.



Note--Conveyance methods indicated above:
→ Usually an auger, leg, other mech.
➔ Gravity flow is often used here.

Handling Equipment Data

Tractors used as power source for handling equipment(zero if none):

[ ] No. used(total for hdlg)

[ ] Size code number(1-9) (all must be of the same size)

All handling jobs you intend to do (A,B,C,etc.) must be assigned to 1 or more pieces of handling equipment in the table below, including gravity flow jobs:

Type Code 1/	Unit No. 2/	Hdlg Jobs Done(Check) ABC DEF GH IJK	Rate (bu/hr) 3/	Time (min) 4/

1/ Types: 1=vert. bucket elevator, 2=augers(all types), 3= belt conveyor, 4=all other mechanical conveyors, 8=gravity flow

2/ Unit number, e.g. type code #2, unit #1, unit #2, etc.

3/ If used for both wet and dry handling jobs, give the rate for wet(about 25% mc) corn.

4/ If used for more than one handling job, give the average man-time, if any, to switch the unit from one job set-up to another.

Daily Harvest/Drying Policy

Answer the following if your daily harvest capacity exceeds your drying and handling capacity:

If all wet corn holding(bins plus vehicles) gets full--

☐ Suspend harvest until the drier/handling catches-up.

☐ Anticipate this and deliver a load or two of wet corn to an off-farm market location so that full harvest potential may be realized each day.

Dump Pit/Dumping Vehicles

Temporary storage capacity of the dump pit.......... [ ] bu

Extra driver-time(above actual dump-time) for each load.. [ ] min ("jockey" into position, check on the drier, mc sample, etc.)

Must driver wait until dump pit clears before returning to field? Check one. ☐ Yes ☐ No

Dry-Corn Holding Bin(s)

Total holding capacity.... [ ] bu

General Drying Policy

Moisture level desired for all farm-stored corn..... [ ] % (Enter 50% if no storage) (mc,wb)

Moisture level desired for all corn moved off-farm... [ ] % (If applicable) (mc,wb)

If you like, corn to be moved off-farm will not be put in drier at all if its moisture at harvest is at or below........... [ ] % (Enter 50% if not appl.) (mc,wb)

On-Farm Storage Facilities

Dry corn storage may be located on any or all of the farmsteads identified. With the current computer program, all of your dry corn storage capacity must be utilized each year that total production(bushels) is large enough. List below the total bushels of storage to be used at each farmstead: (enter 0 if no storage)

Farmstead	#1	#2	#3	#4	#5	#6	
Total Dry Storage*							bu

* Do not include the drying bins, dryeration bins, or dry corn holding bins that may have been listed earlier as part of drying set-up.

Corn going to storage located on the same farmstead with the drying set-up will be assumed to move directly from it(through augers or other conveyors) without being loaded back onto transport vehicles. Corn going to all other farmsteads will be hauled in transport vehicles. At these other farmsteads(if any are used), the handling equipment necessary for unloading the vehicles, and transfering corn into storage will be assumed to be in-place and ready for use at all times. Estimate the rate at which vehicles may be unloaded at these other farmsteads(only),i.e. estimate the capacity of the handling equipment to be used there.

Farmstead	#	#	#	#	#	
Unloading Rate						bu/hr
Extra Driver Time*						minutes

* Extra time required(above actual dumping time) per load of corn delivered to the farmstead for storage, if any, for such things as "jockeying" the vehicle into position for dumping, starting and stopping the handling equipment, hoisting the grain bed or a tailgate, clean-up after dumping, etc.

On-Farm Storage Policy

If you anticipate that total production will be greater in some years than total storage capacity, then decide here which part of the crop should be stored:(skip if not applicable)

(✓ one) ←—total bushels harvested—→ (after the wet storage you specified, if any, has been filled)

☐ Store early	store/early	move the rest off-farm	
☐ Mid-season*	move off-farm	store/mid-season	move off-farm
☐ Store late	move first part off-farm	store/later	

* Of the corn to be moved off-farm with this alternative, about half will go early, about half late(after storing).

If two or more farmsteads are to be used for dry corn storage, then continue here(otherwise see the Note below). In general, the various storage locations(two or more farmsteads) will be filled according to their distance from the drying set-up -- the closest filled first, the farthest away filled last. An exception to this, however, where a more distant storage may receive some corn before a closer one is full, has been built into the computer program. It is: corn will be "back-hauled" to a more distant storage location if it does not interfere with wet grain take-away from the combine, and, on days when harvesting cannot be done, yet corn is ready at the drier for storage, it will be hauled to the farthest storage location scheduled to be used that year. If you prefer to limit the storage allocation beyond this, then fill in as little or as much of the following as you wish(this is optional):

Fill available dry corn storage in the following complete or partial order:

Frmstd #___ first
Frmstd #___ next
Frmstd #___ next
Frmstd #___ next
Frmstd #___ next
Frmstd #___ last

The corn from certain fields should be stored at certain farmsteads as shown here:

Frmstd	Field Numbers				
#1					
#2					
#3					
#4					
#5					
#6					

Note--Either: Go to Section 8-4 next if some corn might be moved off-farm at harvest-time, either with or without drying, and supply the information requested about off-farm marketing locations.

Or: Go to Section 9 next if corn will never be moved off-farm at harvest-time, i.e. if you have enough storage to handle the largest crop that will ever be produced, and you did not check the option of moving a load or two of corn off-farm each day to expedite harvest.

SECTION 8-4 -- DIRECT-FROM-THE-FIELD MARKETING OPTION

This is: ☐ one of my primary ☐ an alternative for the "excess"
(✓ one) mrktg. options. corn only from another option.

Corn moved directly off-farm as harvested may go to any off-farm location you have defined for that purpose(maximum of 6). Give the information requested only for those that apply.

Off-Farm Location	Standard Opening Time (AM)	Closing Time: Harvest Season (PM)	Closing Time: Other Times (PM)	Total Time At The Location(min) If A Load Arrives There At: * Opening Time	Mid Morn	About Noon	Mid Aft	Closing Time
#11								
#12								
#13								
#14								
#15								
#16								

* Estimate the total time a driver and vehicle must spend at each location, per load, on a "typical" harvest day in late October, if they arrive there at the various times indicated. This estimate should include all time spent waiting in line to weigh-in, to dump, and to weigh-out, plus the actual weigh-in and sampling time, the actual time spent dumping the load, and the actual weigh-out time, collection of the scale ticket, etc.

If two or more off-farm marketing locations are to be used, then decide below how to allocate loads of corn to each one. Otherwise, skip over to the next part of this section. Check only one of the boxes below.

Randomly select one of the off-farm marketing locations for:
1☐ each individual load, 2☐ each individual field.

Deliver corn to the location with the shortest round-trip:
3☐ time from the field, 4☐ distance from the field.

5☐ Vary delivery so that over the season each location gets the following part of the total to be delivered off-farm at harvest:

_____% to #11
_____% to #12
_____% to #13
_____% to #14
_____% to #15
_____% to #16
(should sum to 100%)

6☐ Deliver corn from certain fields to certain off-farm locations:

	Field Numbers				
#11					
#12					
#13					
#14					
#15					
#16					

7☐ Vary delivery so that over the season each location gets at least the following amounts:

_____ bu to #11
_____ bu to #12
_____ bu to #13
_____ bu to #14
_____ bu to #15
_____ bu to #16
(rest, if any, will go as needed)

SECTION 9 -- CORN TRANSPORT EQUIPMENT and POLICY

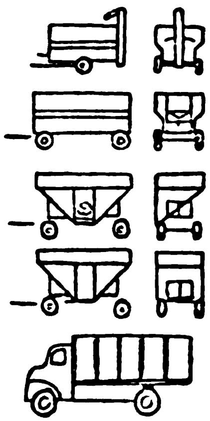
All transport vehicles to be used for hauling shelled corn at harvest-time, and which are under the control of the farm should be listed below. This should include farm-owned vehicles, and those that are leased or rented(but not custom-haul vehicles).

Enter first the information requested for those vehicles previously listed as supply vehicles in Section 4, but which can also be used here, if any. Then do the same for all other vehicles. When two or more units of the same vehicle type are listed, use a Unit No. in the code number: 1-Veh. Code No. 324 = Veh. Type 32 + Unit No. 4.

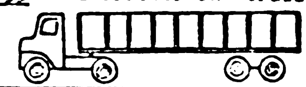
List Transport Vehicles	1-Veh. Code No. Veh. Type	1-Veh. Code No. Unit No.	Bushels No. 2 Shelled Corn	Min. Trct Size Code*

Corn Transport Vehicles:

Type 30 Augered Feed Cart Trailer
Type 31 Wagon with Grain Box
Type 32 Side Dump Gravity Wagon
Type 33 Center Dump Gravity Wagon
Type 34 Truck with Grain Bed



Type 35 Semi Tractor and Trailer



*For each wagon or trailer you list, give minimum tractor size code required--see Section 4.

From the above list of single vehicles, indicate below the 2-vehicle combinations that you might logically use at harvest-time. You need not list duplicates of the same size, e.g., list a 2-vehicle combination of 2-185 bu wagons only once even though you might have four or six 185 bu wagons.

2-Vehicle Combination	1st Veh. Code No.	2nd Veh. Code No.	Minimum Tractor Size Required*
1			
2			
3			
4			
5			

*Give minimum tractor size code where applicable.

Wet-Corn Transport. Regardless of the handling and marketing option you indicated in Section 8, there are two potential types of wet-corn hauling that may take place at harvest-time. The first is hauling corn from the field to an off-farm location. And, the second is hauling corn from the field to a farmstead(where it will be wet stored, layer dried, or put through a batch or continuous flow drier). It is assumed that all the vehicles and vehicle combinations listed on the previous page may be used for both types of hauling. You may (this is optional) put restrictions on this:

WET CORN	These vehicles may be used ONLY to haul from field to:								These vehicles may NEVER be used to haul from field to:							
	1-Vehicle					2-Veh.			1-Vehicle					2-Veh.		
Off-Farm Location																
Farmstead Location																

(enter applicable code nos.) (enter applicable code nos.)

All other vehicles and vehicle combinations may be used for both types of wet-corn hauling at harvest-time.

Dry-Corn Transport. (Do only if you use batch or continuous flow drying.) Dry corn may move directly from the drying facility into adjacent storage, or it may be loaded onto vehicles for transport to on-farm storage or to an off-farm market location. It is assumed that all the vehicles and vehicle combinations listed on the previous page may be used for both types of hauling(if both types are applicable to the policy decisions you indicated in Section 8). You may (this is optional) put restrictions on this: (do if applicable)

DRY CORN	These vehicles may be used ONLY to haul from drier to:								These vehicles may NEVER be used to haul from drier to:							
	1-Vehicle					2-Veh.			1-Vehicle					2-Veh.		
Off-Farm Location																
On-Farm Storage																

(enter applicable code nos.) (enter applicable code nos.)

All other vehicles and vehicle combinations may be used for both types of dry-corn hauling at harvest-time.

SECTION 10 -- LABOR FORCE for HARVESTING

Labor Force Codes. You may identify, again, up to 10 individuals that might be available for field work during the harvest period. These should be the same individuals as you listed for Activity Period #1(Fall Land Prep) in Section 6, plus any that will be involved only in harvesting activities. Code each man by type in the F/P column (see Section 6).

Job Priorities. Use the harvest operation codes in the box to assign job priorities to each man.

Man No.	Man's Name	F/P	Job Priority 1st	2nd	3rd		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

└See Note 1.

Harvest Operation	Oper Code
Operate Combine	#1
Haul Corn--Wet/Dry	#2
Haul Wet Corn Only	#3
Haul Dry Corn Only	#4
Oper. Drier/Hndlg.	#5

Note 1 -- Enter L for land preparation in this column(leave other columns blank) for those men, if any, that will be working solely on land preparation jobs, and not involved in harvesting and its related activities.

Labor Work Schedule. Indicate the potential daily hours of work for each man by entering starting and quitting times in the Mon-Fri column. Circle a for AM(or cross-cut p) or p for PM(or cross-out a) with each entry. For Saturday or Sunday work:

Man No.	Mon-Fri Start	Mon-Fri Quit	Sat ☐ Start	Sat Quit	Sun ☐ Start	Sun Quit
1	a p	a p	a p	a p	a p	a p
2	a p	a p	a p	a p	a p	a p
3	a p	a p	a p	a p	a p	a p
4	a p	a p	a p	a p	a p	a p
5	a p	a p	a p	a p	a p	a p
6	a p	a p	a p	a p	a p	a p
7	a p	a p	a p	a p	a p	a p
8	a p	a p	a p	a p	a p	a p
9	a p	a p	a p	a p	a p	a p
10	a p	a p	a p	a p	a p	a p

a)Check the box at the top, nothing else. The computer will use the same hours as for Mon-Fri.

b)Check the box, enter times only for these men that work different hours on the weekend. The computer will use the same hours as for Mon-Fri for all other men.

c)Do not check the box at the top. Enter the times for all men that could work on the weekend.

Note 2 -- Do not enter hours for those men, if any, with job priority L above.

APPENDIX B

APPENDIX B

COMPOSITION OF THE NON-EVENT GASP FILES

File No.	2	3	4	5	
File Name	Tractors	Implements	Combines	Transport Vehicles	
Unit Type	All	All	All	Trucks	Other
QSET(I)	---	---	---	---	---
2	---	---	---	---	---
3	RMAJ	$RMAJ_I$	RMAJ	RMAJ	---
4	RMIN	$RMIN_I$	RMIN	RMIN	---
5	EPM	---	EPM	EPM	---
6	---	---	RMAJC	---	---
7	---	---	RMINC	---	---
8	QFC	---	QFC	QFC	---
9	QFL	---	QFL	QFL	---
10	---	W_I	Q1CB	Q1CB	$Q1CB_I$
11	---	---	Q1CF	Q2C	$Q2C_I$
12	---	---	HP	Q35C	$Q35C_I$
13	---	---	SW	Q4C	$Q4C_I$
14	---	---	RW	Q2R	$Q2R_I$
15	---	---	---	Q35R	$Q35R_I$
NSET(I)	NUM	NUM_I	NUM	NUM	NUM_I
2	---	---	NTT	---	$MINT_I$
3	NFT	---	NFT	---	---
4	---	---	N	NUR	NUR_I
5	---	---	NT	---	---
6	---	---	---	---	---
7	---	---	---	---	---
8	---	---	---	---	---

Figure B1. Files 2 thru 5 -- Unassigned Field Equipment.

File No.	6	9	10
File Name	Labor	Fld Ops	Fields
QSET(I)	TS1	TMEAL	D1
2	TQ1	---	D2
3	TS3	---	D3
4	TQ3	TLIM	D4
5	TS5	TBEG	D5
6	TQ5	TEND	D6
7	---	TBEGF	PSTF
8	---	TBEGD	FW
9	---	PCIND	DS12
10	---	PST	DS34
11	---	---	DS56
12	---	---	---
13	---	---	---
14	---	---	---
15	---	---	---
NSET(I)	NOP	NFOP	NFLD
2	NTY	NFOPA	NFOP
3	JP1	NFOPB	LFSEC
4	JP2	NPATT	NPATT
5	JP3	LOCR	NSTR
6	---	LGO	NSSR
7	LOCNA	NPC1	NPEP
8	NAS	NPC2	NPES

Figure B2. Files 6, 9 and 10 -- Labor, Field Operations and Fields "In-Process".

File No.	2	7		4	7
File Name	Tractors	Equipment Sets		Combines	Eq. Sets
Unit Type	---	Planting	Other	---	Harvest
QSET(I)	S	X	X	---	X
2	APH	Y	Y	---	Y
3	---	RMAJ	RMAJ	---	RMAJ
4	---	RMIN	RMIN	---	RMIN
5	---	EPM	EPM	---	EPM
6	QN1C	$RMAJ_1$	$RMAJ_1$	---	RMAJC
7	QN2C	$RMIN_1$	$RMIN_1$	---	RMINC
8	QN3C	QN3C	$RMAJ_2$	---	---
9	QN4C	$RMIN_2$	$RMIN_2$	---	AMC
10	W_1	QFC	QFC	---	QFC
11	QN1R	QN1L	QN1L	---	Q1LB
12	QN2R	QN2L	---	HP	Q1LF
13	QN3R	QN3L	---	SW	Q1CB
14	QN4R	QN4L	---	RW	Q1CF
15	W_2	QFL	QFL	---	QFL
NSET(I)	NUM	---	---	NUM	---
2	---	NFOP	NFOP	NTT	NFOP
3	NFT	NUM	NUM	NFT	NUM
4	---	NUM_1	NUM_1	N	NDIR
5	JQN1	NUM_2	NUM_2	NT	NGEAR
6	JQN2	NOP	NOP	---	NOP
7	JQN3	LOC	LOC	---	LOC
8	JQN4	NST1	NST1	---	NST1

Figure B3. File 7 -- Assembled Equipment Sets (Including Information Retained in Files 2 and 4).

File No.	2	5	8	
File Name	Tractors	Tr. Vehs.	Transport Sets	
Unit Type	---	Trucks	Supplies	Corn
QSET(I)	---	---	X	X
2	---	Q2R	Y	Y
3	---	Q35R	RMAJ	RMAJ
4	$Q1CB_1$	$Q1CB_1$	RMIN	RMIN
5	$Q2C_1$	$Q2C_1$	EPM	EPM
6	$Q35C_1$	$Q35C_1$	Q1CB	Q1CB
7	$Q4C_1$	$Q4C_1$	Q2C	Q2C
8	$Q2R_1$	$Q2R_1$	Q35C	Q35C
9	$Q35R_1$	$Q35R_1$	Q4C	Q4C
10	$Q1CB_2$	$Q1CB_2$	QFC	QFC
11	$Q2C_2$	$Q2C_2$	---	AMC
12	$Q35C_2$	$Q35C_2$	Q2L	Q1LB
13	$Q4C_2$	$Q4C_2$	Q35L	Q1LF
14	$Q2R_2$	$Q2R_2$	Q4L	Q1CF
15	$Q35R_2$	$Q35R_2$	QFL	QFL
NSET(I)	NUM	NUM	0	1
2	---	---	NFOP	NFOP
3	NFT	---	NUM	NUM
4	---	NUR	NUM_1	NUM_1
5	$MINT_1$	$MINT_1$	NUM_2	NUM_2
6	NUR_1	NUR_1	NOP	NOP
7	$MINT_2$	$MINT_2$	LOC	LOC
8	NUR_2	NUR_2	NST2	NST2

Figure B4. File 8 -- Assembled Transport Sets (Including Information Retained in Files 2 and 5).

Unit Type	Dump Pit (and Frmstd Policy Info)	Conveying Metnods and Equipment	Drying and Cooling Bins		High Temperature Driers		Holding Bins (hopper-bottom)		Shelled Corn Storage		Tractor for Frmstd Equipment	Off-Farm Market Locations
			Dryeration (flat-bottom)	Drying Bin (batch-in-bin)	Portable Batch	Continuous Flow	Wet Corn	Dry Corn	High MC Silos	Dry Corn Bins		
QSET(I)	Q1CB	Q1RW	Q1CB	Q1CB	Q1CBS	Q1CBC	Q1CB	Q1CB	Q1CB	Q1CB	---	---
2	TDRV1	Q1RD	DIA	DIA	Q1RD	Q1RD	Q1CF	---	TDRV1	TDRV1	---	TOP
3	RMAJD	RMAJA	RMAJF	RMAJF	RMAJF	RMAJF	---	---	Q1RDI	Q1RDI	RMAJ	TCLH
4	RMIND	RMINA	RMINF	RMINF	RMINF	RMINF	---	---	Q1RDU	Q1RDO	RMIN	TCLO
5	---	TCHG1	Q1CF	Q1CFS	Q1CFS	Q1CFE	---	---	TCHG2	TOUT	EPM	TDRV2
6	---	---	QCRIT	QCRIT	RMAJH	RMAJH	---	---	QMEN	---	---	TDRV3
7	---	---	---	FEET	RMINH	RMINH	---	---	---	---	---	TDRV4
8	---	---	---	TDRYG	TDRYG	Q1CBD	---	---	---	---	---	TDRV5
9	---	---	---	TCOOL	TCOOL	Q1CFC	---	---	---	---	---	TDRV6
10	---	---	Q1LB	Q1LB	Q1LB	Q1LB	Q1LB	Q1LB	Q1LB	Q1LB	QFC	Q1LB
11	POL1	---	Q1LF	Q1LF	Q1LF	Q1LF	Q1LF	Q1LF	---	---	---	---
12	BUSH	---	POL5	POL6	POL7	POL7	AMC	---	AMC	---	---	AMC
13	POL2	---	QCRK	QCRK	PATH2	PATH2	---	PATH9	---	---	---	---
14	POL3	---	PATH4	PATH2	PATH3	PATH3	PATH1	PATH6	---	PATH8	---	---
15	POL4	---	PATH10	PATH7	PATH7	PATH7	PATH3	PATH11	---	PATH5	QFL	POL8
NSET(I)	1	2	3	3	4	4	5	5	6	6	NUM	NLOC
2	NT1	NT2	NT3	NT3	NT4	NT4	NT5	NT5	NT6	NT6	NUSE	NPOL
3	NTRA	---	---	---	NTRAC	NTRAC	---	---	NTRAC	NPRI	NFT	---
4	NFARM	---	NAUT2	NAUT3	NAUT4	---	---	---	NPOL1	NPOL1	---	---
5	NDRY	---	---	---	NPTH2	NPTH2	---	NPTH9	NFILL	---	---	---
6	---	NENT1	NPTH4	NPTH2	NPTH3	NPTH3	NPTH1	NPTH6	NSILO	NPTH8	---	---
7	NAUT1	NENT2	NPTH10	NPTH7	NPTH7	NPTH7	NPTH3	NPTH11	---	NPTH5	---	---
8	NST4	NST3	NST5	NST6	NST7	NST8	NST4	NST4	NST3	NST9	NST3	---

Figure B5. File 11 — Farmstead Equipment and Structures, and Off-Farm Markets.

Attribute Definitions

Note -- Subscript I = 1,2 denotes attributes of the first, second trailed implement of an equipment set, or of the first, second trailed vehicle of a transport set.

AMC..............Average moisture content (decimal, wet basis) of corn currently stored, or carried on mobile equipment (combines, transport sets).

AFH..............Theoretical field capacity in acres per hour.

BUSH.............Bushels of corn that remain to be marketed off-farm before on-farm storage begins (see POL1).

DIA..............Bin diameter (feet) of drying and cooling bins.

D1,2,...6........X-coordinates (rods) defining "unworked" areas of the field.

DS12,34,56.......Field section numbers (stored as AAABBB.0) corresponding to the D12, D34 and D56 distances.

EPM..............Hours of use before the next scheduled extended-period-maintenance.

FEET.............Maximum corn depth (feet) allowed with batch-in-bin drying.

FW...............Field width (rods) stored as WWWW.WW for regular fields, HHHHWWWW.WW for circular-planted fields where HHHH denotes field height (rods).

HP...............Rated horsepower of the combine engine.

JP1,2,3..........User-specified job priorities.

JQN1,2,3,4.......Material and supply source code information for production equipment sets (see related attributes QNKC, QNKL, QNKR). Stored as ABBB, where A = the material code (2-8), and BBB = the supply source code. BBB less than 100 means refill at a farmstead (1-6), at the nearest farmstead (7) or at an off-farm location (11-16); BBB greater than 300 means refill from an in-field supply truck whose code number is BBB; otherwise, refill supply vehicle attached to a tractor whose code number is CC, where BBB = 1CC or 2CC.

LFSEC............Field sections that comprise this field, stored as AAABB where AAA,BB = the highest, lowest field section numbers.

LOC..............Current location code for file 7 and 8 entities, stored as AABB where BB = the field number (01-30) in which the entity is or was last located, and AA = current location (00 = in field BB, 01-06 = at farmstead 1-6, 11-16 = at off-farm location 11-16).

LOCR.............Location code for refueling, maintenance and overnight storage of the equipment sets performing this field operation, stored as AB, where A = refuel and maintenance location code, and B = overnight storage code (0 = in the field where used, 1-6 = at farmstead 1-6, or 7 = at the farmstead nearest the field where used).

LOCMA............Current location code for this man (0 = currently assigned to an equipment or transport set, 1-6 = currently unassigned where LOCMA is the base farmstead number, or currently assigned to a non-field activity at farmstead 1-6).

MINT.............Minimum tractor size (1-9) required for corn transport, where zero implies the unit is never used to haul corn.

N................Cornhead size (number of rows).

NAS..............Current assignment status for this man (0 = unassigned, 1 = assigned to an activity of some type).

NAUT1............Automatic controls for dump pit unloading (1 = driver must wait until the dump pit "clears", 2 = he doesn't).

NAUT2............Automatic controls for dryeration bin unloading equipment (0 = automatic shut-off, 1 = manual shut-off) when transferring cooled-out corn directly to long-term dry corn storage.

NAUT3............Automatic controls for batch-in-bin drying operation, stored as ABC where A (0 = automatic, 1 = manual) designates burner shut-off at the end of the drying cycle, B designates fan shut-off at the end of the cooling cycle, and C designates handling equipment shut-off when transferring corn directly to long-term dry corn storage.

NAUT4............Automatic controls for portable batch drier operation, stored as ABCDEF where A (0 = automatic, 1 = manual) designates the beginning, B the end of the drier filling cycle, C designates the beginning, D the end of the drying cycle, and E designates the beginning, F the end of the drier unloading cycle.

NDIR.............Current harvest direction (0 = not harvesting, 1,2 = harvesting in the +y, -y direction).

NDRY.............High temperature drying procedures being used, stored as AB where B is the drying method (1 = batch-in-bin, 2 = portable batch, 3 = continuous flow) and A indicates the use of dryeration techniques (0 = not in use, 1 = in use).

NENT1,2..........Entities on the input or output side of this conveyer that depend on it (other conveyors, dump pit, drier, holding bins, etc.), stored as AABBCCDDEE where each pair of letters represent a GASP column number.

NFARM............Drier site location (farmstead 1-6).

NFILL............Use status (0 = unused, 1 = now being filled, 2 = full).

NFLD.............Field code number (1 - 30).

NFOP.............Field operation code number (1 - 25 for production fld ops, 30 for harvesting).

NFOPA............DO-AFTER fld op code number for production fld ops, i.e., a "prior" fld op, where 0 = do anytime after last year's crop has been harvested.

NFOPS...........DO-BEFORE fld op code number for production fld ops, where 99 = do anytime bebore the corn reaches "layby" height.

NFT.............Fuel type code (1 = gasoline, 2 = diesel, 3 = LPG).

NGEAR...........Current transmission setting (1,2 = first, second gear).

NGO.............GO-Indicator. Zero unless set to 1 by subroutine GOFLDS, designating this as the highest priority fld op for which GO-conditions were found.

NLOC............Off-farm market location code, stored as 2AA where AA = 11 -16, the off-farm market code.

NPATT...........Field pattern (to be) used where 1 = circular, 2 = alternating, 3 = land, and 4 = overlap pattern.

NPC1,2..........."Prior" complementary fld op code numbers.

NPEP............Principal entry point numbers for this field, stored as AABB where AA = the first, and BB = the last.

NPES............Secondary entry point numbers for this field, stored as AABB where AA = the first, and BB = the last.

NPOL............Corn from these fields is to be marketed here when market selection method 6 is specified. Stored as AABBCCDDEE, i.e., maximum of 5 field code numbers. See related attribute POL8.

NPOL1...........Corn from these fields is to be taken here for long-term storage. Stored as AABBCCDDEE, i.e., maximum of 5 field code numbers.

NPRI............Filling priority when dry corn may be stored at two or more farmsteads.

NPTH1,2...,11...Conveyors (maximum of 8) used in grain flow paths A,B,C,D,E,F, G,H,I,J and K, stored as PQRSTUVW where each letter represents a GASP column number. See related attribute PATH.

NOP.............Man or operator (1 - 10) currently assigned to this equipment or transport set, where 0 = none currently assigned.

NSILO...........Number of silos at this high-moisture storage site.

NSSR............Start-side of the field indicator (1 = field origin side, 2 = side opposite the field origin).

NSTR............Supply-side of the field indicator for production fld ops (1 = field origin side, 2 = upper end, 3 = side opposite the field origin, 4 = lower end), or the next start-harvest or current harvest field section number.

NST1,2,...9.....Current activity state of equipment sets (1); transport sets (2); conveyors, high-moisture storage sites and tractors doing farmstead work (3); dump pits and holding bins (4); dryeration bins (5); batch-in-bin drying bins (6); portable batch driers (7); continuous flow driers (8); and dry corn storage sites (9).

NT..............Cornhead type (1 = fixed-speed, 2 = variable speed).

NTRA............Tractors used for handling equipment at the drier site, stored as AB where A = the number required, B = the size code (1-9).

NTRAC...........Tractor size (1-9) used by the drier, where 0 = none required.

NTT.............Transmission type (0 = standard gear transmission, 1 = hydrostatic).

NTY.............Labor type code (1 = full-time family, 2 = part-time family, 3 = full-time hired, 4 = part-time hired).

NT1,2,...6......Type, unit number and/or location code of farmstead equipment and facilities, stored as AB where for NT1 (dump pits) A is always zero, B is the type (1 = gravity, non-mechanical, or part of a main conveyor, 2 = mechanical, separate from the main conveyor); for NT2 (conveyors) A is the type (1 = bucket elevator, 2 = auger, 3 = belt conveyor, 4 = other mechanical units, 8 = gravity flow designation, 9 = sweep auger for dryeration bin or drying bin), B is the unit number; for NT3 (drying-cooling bins) A is the type (1 = dryeration bin, 2 = drying bin), B is always one; for NT4 (high temperature driers) A is the type (1 = portable batch, 2 = continuous flow), B is always one; for NT5 (hopper bottom holding bins) A is the type (1 = wet, 2 = dry), B is always one; for NT6 (shelled corn storage sites) A is the type (1 = wet, 2 = dry), B is the farmstead number (1-6).

NUM.............Field equipment code numbers, stored as AAB where AA is the type (01-09 for tractor sizes 1-9, 10-25 for implements, 27 for combines and 30-39 for transport vehicles), and B is the unit number (1-5).

NUR.............Use restrictions for corn transport, stored as ABCDEFGH where A = 1 indicates this vehicle may only (B = 1 never) be used to haul wet corn from the field to an off-farm market, C = 1 indicates it may only (D = 1 never) be used to haul wet corn from the field to a farmstead, E = 1 indicates it may only (F = 1 never) be used to haul dry corn from the drier to an off-farm market, and G = 1 indicates it may only (H = 1 never) be used to haul dry corn from the drier to a distant on-farm storage site. A digit value of zero, rather than 1, indicates the vehicle is unrestricted for that particular type of corn transport.

NUSE............Use indicator, where 0 means conveyor operation (at the drier site), 11 means portable batch drier operation, 21 means continuous flow drier operation, and 11A means silo filling equipment operation (A = farmstead number).

PATH1,2,...11...Maximum handling rate possible (bushels per hour) of grain flow paths A,B,C,D,E,F,G,H,I,J and K, i.e., the minimum capacity of any conveyor in the grain flow path. See related attribute NPTH.

PCIND...........Prior complementary fld op indicator (0 = this fld op has no prior complementary fld ops, 1 = it has at least one that should have been done in an earlier activity period, 2 = it has at least one that is scheduled in the same activity period).

POL1............Marketing and storage policy when annual production exceeds on-farm capacity -- fill farm storage from the first (1), middle (2), or last (3) corn harvested.

POL2,3,4........General drying policies -- desired or acceptable moisture level (decimal, w.b.) for corn that is farm-stored (2), marketed off-farm at harvest after drying (3), or market off-farm at harvest without drying (4).

POL5............Dryeration bin unload policy (for flat-bottomed bins) -- unload only that corn which will "free-flow" to the center floor outlet (1), unload completely using a bin sweep (2), or some of both, depending on labor demands at the time (3).

POL6............Batch-in-bin harvest policy when daily harvest capacity exceeds the maximum daily batch size -- deliver all corn to the drying bin until the maximum batch size is reached, then suspend harvest (1) or continue harvest by directing all corn to an off-farm market (2); or, if harvest is possible after the closing time of off-farm markets, direct selected loads to off-farm markets throughout the day so that the maximum batch size is reached, and the maximum amount of corn can be harvested for the day (3).

POL7............Portable batch/continuous flow harvest policy when daily harvest capacity exceeds daily drying and handling capacity -- suspend harvest when wet corn holding is full (bin plus vehicles) until the drier "catches up" (1), or anticipate this and direct selected loads to off-farm markets throughout the day so that the maximum amount of corn can be harvested for the day (2).

POL8............Portion (method 5) or bushels (method 7) of the crop to be marketed off-farm that is to be marketed here when the market selection method specified is as indicated. See related attribute NPOL.

PST.............Current processing state of this fld op on the farm (total acres covered).

PSTF............Current processing state of this fld op in this field (total acres covered).

QCRIT...........A critical dry corn volume (cubic feet) computed as $\pi D^3 \cdot \tan 37° \div 8$, where D is the diameter (feet) of this flat-bottomed bin. If the volume of dry corn in the bin is greater than QCPIT, then the volume of corn that will not "free-flow" to the center floor outlet is two-thirds of $\overline{\text{QCRIT}}$. If the volume of dry corn in the bin (Q) is less than QCRIT, then the volume of corn that will not "free-flow" is $Q(1 - kQ^2)$, where k is the inverse of three $\overline{(3)}$ times QCRIT squared. k is stored as attribute QCRK. Note -- the corn that will not "free flow" must be removed from the bin with a "sweep auger".

QCRK............Constant k for this bin diameter -- see attribute QCRIT.

QFC, QFL........Fuel carrying capacity (FC) and current fuel level (FL) of this unassigned tractor, of this combine or truck, or of this equipment or transport set (gallons).

QMEN............Number of men required to move and/or setup the filling equipment for silos at this high-moisture storage site. See related attribute TCHG2.

QNKC,QNKL,QNKR..Total carrying capacity (QNKC), current level (QNKL) and application rate (QNKR) of the JQNK materials being applied with this production equipment set. Maximum of one material (NK = N1) may be applied with non-planting field operations, while a maximum of four materials (NK = N1, N2, N3, N4) may be applied with planting, one of which must be seed (material code 6).

Q1CB,Q1CF.......Corn (material code 1): Carrying or holding capacity (C) in bushels (B) or cubic feet (F) of the combine's grain tank, of individual vehicles or transport sets, of dump pits, of drying, cooling and holding bins, or of shelled corn storage facilities.

Q1CBC,Q1CBD.....Corn capacity in bushels of the drying chamber (CBC) and of the integral wet holding (CBD) of this continuous flow drier.

Q1CBS...........Maximum batch size in bushels of this portable batch drier.

Q1CFC,Q1CFE.....Total cubic feet of corn that may be "in" this continuous flow drier (CFC) at any one time (drying chamber plus integral wet holding), or that may be "in" the drying chamber (CFE) at any one time.

Q1CFS...........Maximum batch size in cubic feet of this drier (portable batch or drying bin).

Q1LB,Q1LF.......Corn (material code 1): Current level (L) in bushels (B) or cubic foot (F) in the combine's grain tank, in this transport set, in this drying, cooling or holding bin, in this drier, at this on-farm storage facility, or at this off-farm market.

Q1RD............Dry corn handling rate of conveyors (dry bushels per hour at 15% m.c.), or estimated drying rate of high temperature driers (dry bushels per hour from 25 to 15% m.c.).

Q1RDI...........Unloading rate (bushels per hour) of corn transport sets at an on-farm storage site. Not required for dry corn storage adjacent to the drying facility.

Q1RDO...........Corn transport set filling rate (bushels per hour) when loading-out corn for off-farm marketing.

Q1RDU...........Corn usage rate (bushels per day) for livestock feeding during the harvest season.

Q1RW............Wet corn handling rate of conveyors (dry bushels per hour at 25% m.c.).

Q2C,Q2L,Q2R.....Water (material code 2) for herbicide or insecticide spraying: Total carrying capacity (C) in gallons, current level (L) in gallons, and on-off transfer rate (R) in gallons per minute of this supply transport set or unassigned transport vehicle.

Q35C,Q35L,Q35R..Bulk fertilizer (material code 3) or bulk nitrogen (material code 5): Total carrying capacity (C) in pounds, current level (L) in pounds, and on-off handling rate (R) in pounds per minute of this supply transport set or unassigned transport vehicle.

Q4C,Q4L.........Bagged fertilizer (material code 4): Total carrying capacity (C) in pounds and current level (L) in pounds of this supply transport set or unassigned transport vehicle.

RMAJ,RMIN.......Hours of use until the next major, minor repair of the power-source unit of this equipment or transport set, of this unassigned tractor, combine or truck, or (when subscripted) of this field implement. Note -- Minor repair may be interrupted as an actual repair activity, or as a machine adjustment activity.

RMAJA,RMINA.....Hours of use until the next major, minor repair of (A) this
RMAJC,RMINC mechanical conveyor -- not applicable to type 8 -- see att-
RMAJD,RMIND ribute NT2; of (C) the combine cornhead; of (D) the dump pit
RMAJF,RMINF -- not applicable to type 1 -- see attribute NT1; of (F) the
RMAJH,RMINH fan, burner, controls, etc. for this drying unit (total operating hours); or of (H) the integral handling equipment for this batch drier (handling hours only) or continuous flow drier (total operating hours).

RW..............Theoretical harvest rate (acres per rod of forward travel).

S...............Speed of operation when performing NFOP (miles per hour).

SW..............Separator width (inches).

TBEG,TEND.......Earliest starting time, latest quitting time allowed for this fld op when labor availability is not limiting (see attribute TLIM).

TBEGF,TBEGD.....Earliest starting time possible for harvesting operations on "frosty" morning, on "heavy dew" mornings when labor availability is not limiting (see attribute TLIM).

TCHG1,2.........Total time required (man-hours) to (1) shift this conveyor from one type of handling job to another at the drier-site, or to (2) shift the silo filling equipment from one silo to another at this high-moisture storage site. See related attribute QMEN.

TCLH,TCLO.......Closing time of this off-farm market (H) during the harvest season, or (O) at other times. See related attribute TOP.

TDRY1...........Setup and knockdown time required (hours per load) when delivering corn to the drier-site (dump pit), to this high moisture storage site, or to this dry corn storage site (not located adjacent to the drying facility). This is <u>extra</u> driver time, above that required to actually unload <u>the transport</u> vehicle, for such things as maneuvering the vehicle into position for unloading, starting the handling equipment, checking on the drier, etc.

TDRY2,3,...6....Total unload time required (hours per load) when delivering corn to this off-farm market if the transport vehicle arrives before simulated clock-time of 0900 hours (2), 0900-1130 hours (3), 1130-1330 hours (4), 1330-1600 hours (5), or after 1600 hours (6).

TDRYG,TCOOL.....Estimated drying time, cooling time (without dryeration) for the maximum batch size when drying from 25 - 15% m.c.

TLIM............Hours of operation policy for this fld op (0.0 = limited by labor availability only, 1.0 = limited to specific hours of operation given by TBEG, TEND for production fld ops, and further limited by TBEGF and TBEGD for harvesting).

TMEAL...........Total time required for meal-stops (hours) at 12 noon and 6:00 p.m. when this fld op is being done. A value less than 5 minutes indicates that a relief driver should be assigned to equipment sets performing this fld op during these meal periods. If none is available, a default value of 30 minutes (0.5 hours) is assumed.

TOP.............Opening time of this off-farm market. See related attributes TCLH, TCLO.

TOUT............Setup and knockdown time required (hours per load) when loading-out corn for off-farm marketing. This is <u>extra</u> driver time, above that required to actually load the <u>transport</u> vehicle, for such things as manouvering the vehicle into position for loading, starting the handling equipment, etc.

TS1,3,5-TQ1,3,5.Scheduled starting time - quitting time of this man on (1) weekdays, on (3) Saturday, and on (5) Sunday.

W...............Rated implement width (feet).

X,Y.............Current x,y coordinates (rods) of this equipment or transport set if it is presently located in a field. These location coordinates are with respect to the field origin (x is always positive, y may be positive or negative).

APPENDIX C

APPENDIX C

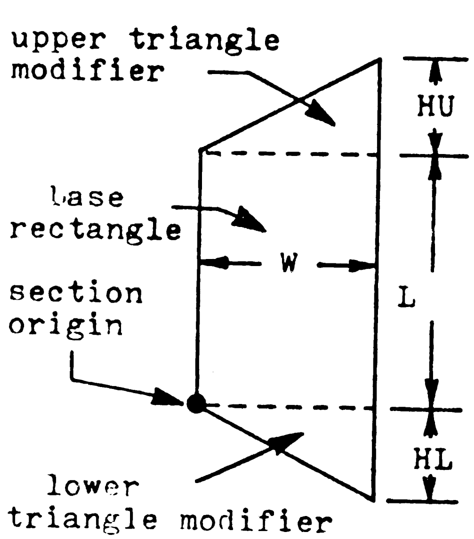
X-Y COORDINATE SYSTEM AND OTHER FIELD PROPERTIES

The basic accounting unit used by the model for weather related factors such as soil moisture, soil tractability, and various crop development items is the "field section". When developing input for the model, the user describes each field in terms of the field section(s) of which it is composed. At that time each field section represents a portion of the field that can be geometrically described (or approximated) by a base rectangle with an upper and lower triangle modifier. Figure C1. presents the basic properties of a field section, and illustrates the various shapes that a particular section may possess.

When the user is developing input, he must number the field sections in a given field from left to right. The section origin of the lowest numbered section in each field (the leftmost section origin) is designated the field origin. The field origin is point (0,0) for the x-y coordinate system for that field. Note that the x-coordinate of all points in the field is non-negative, while y-coordinates may assume any value. The x-coordinate of the section origin of the Kth section is

$\sum_{i=j}^{k-1} W_i$, where J is the lowest numbered section in the particular field, and $K > J$. The y-coordinate of all section origins in a given field must be supplied by the user --in addition to the properties L, W, HU and HL shown in Figure C1.

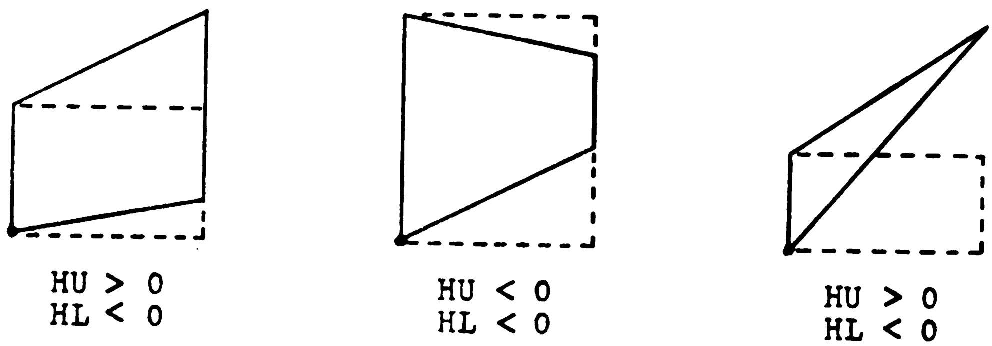
An additional field section property may be specified by the used: the location and size of no-till strips. A no-till strip is an area within the base rectangle of a field section in which planting, harvesting and other field operations cannot be performed, i.e., it reduces the effective row length of the section. Two types of no-till strips were identified: type 1 -- those through which field equipment could travel (but not "operate"), and type 2 -- those which could not be traversed by field equipment. A maximum of two no-till strips of each type may be specified for each field section. The specification for each requires two numbers: the vertical distance from the section origin to the lower edge of the no-till strip, and the amount by which the effective row length is reduced.



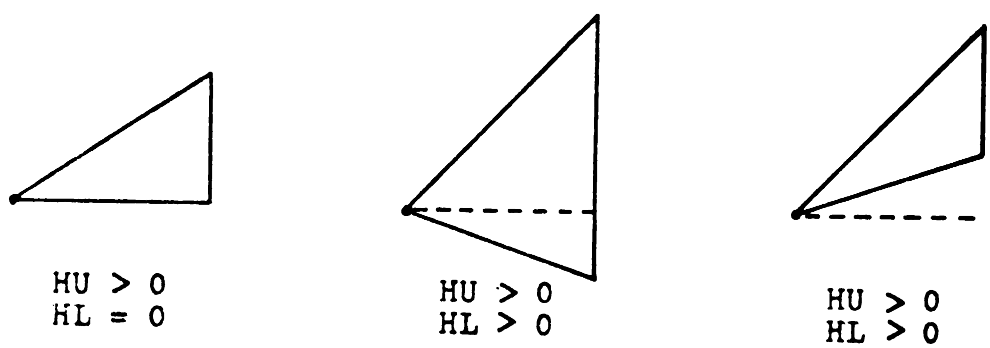
W,L = Width, length of the base rectangle, where L ≥ 0, W > 0(always). The lower-left corner of the base rectangle is defined as the section origin.

HU,HL = Height of the upper, lower triangle modifiers. Area of the section is the area of the base rectangle plus the areas of the triangle modifiers -- positive heights add area, negative heights subtract area.

a) Basic field section properties.



b) Sample field section shapes with L   0.



c) Sample field section shapes with L = 0.

Figure C1. Field Section Properties and Alternative Shapes.

Given this field section information for each field, and the field size (in tillable acres), initialization subroutine FARM1 is designed to reconcile any differences that may exist between the given tillable acreage and the field area as computed from the section dimensions (that are taken from a scale drawing of the farm). This is done by expanding (or contracting) each section in proportion to its area and that of the whole field in which it is located.

During this reconciliation process, the x-y coordinates of field entry points (supplied by the user) are also adjusted appropriately if need be. A field entry point is a point, located somewhere on the field boundary, at which entry to the field (with field equipment) is possible. Two types were identified:

1. Principal field entry point -- Field entry at this point is from a farm lane or public road (either gravel or paved).

2. Secondary field entry point -- Field entry at this point from another (adjoining) field.

Every field on the farm must have a minimum of one entry point, either principal or secondary. A principal entry point has three attributes: its x-y coordinates and the number of the field in which it is located. Secondary entry points always occur in pairs. Each has four attributes: its x-y coordinates, the field number in which it is located, and the adjoining field number.*

Following the area-reconciliation process, subroutine FARM1 partitions the whole farm into 100 smaller field sections of approximately equal size. With each field, two partitioning techniques are possible, depending on the field pattern which the model-user intends to use for planting, which must be supplied as input. The two techniques are illustrated in Figure C2, and proceed as follows:

1. Alternating planting pattern intended. The original field sections are simply partitioned into a whole number of smaller, standard sections using the nominal section area that will produce 100 whole sections on the farm. In this type of field, planting must be

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* Actually, when FARM1 reads the field-field entry point information from data cards, it sequentially numbers the principal entry points and the secondary entry points, and stores, in the x-array, as an attribute of each field, the lowest and highest numbered principal and secondary entry point for each field.

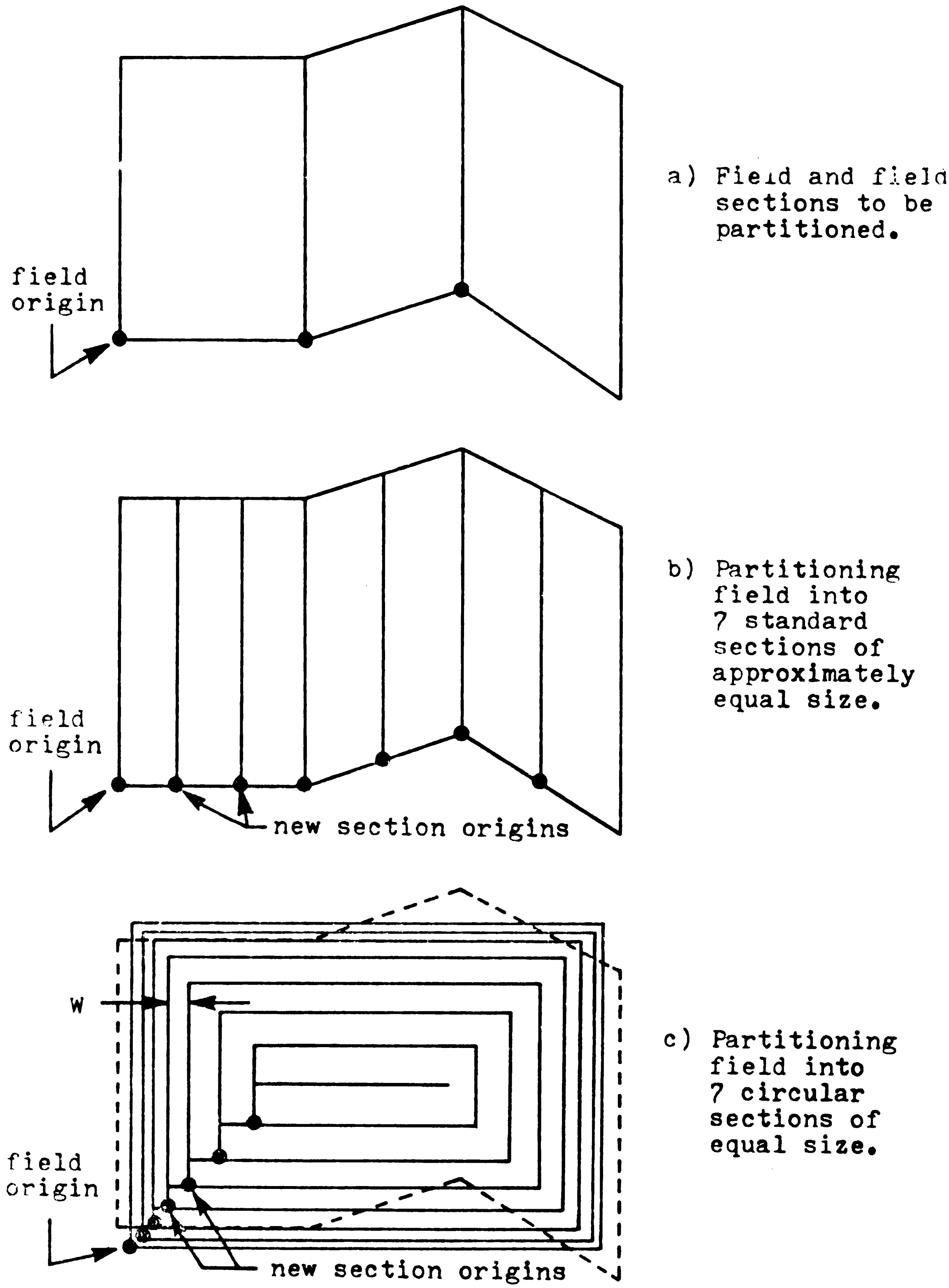

Figure C2. Partitioning A Field Into Smaller Sections.

performed with the continuous alternating field pattern, but other field operations (tillage, cultivation, harvesting, etc.) may be done with an overlapping field pattern or with a land field pattern of some type (see input form in Appendix A) as specified by the model-user.*

2. Circular planting pattern intended. The field is assumed to be a rectangular field of the same size as the original, with a width and height approximately the same as the original field.** The entire field is then partitioned into a whole number of smaller, circular sections using the nominal section area that will produce 100 whole sections on the farm. In this type of field, planting and all other field operations must be done with the circular field pattern.

Though circular field patterns are not permitted with the present model, subroutine FARM1 is operational for circular section partitioning. With circular field sections, HU and HL are always zero, the section origin and section width (base rectangle width)are as noted in Figure C2, and the section length (base rectangle length) is stored in the x-array as the composite number AAABBBB.BB, where AAA is the length of the vertical side of the section directly above the section origin (to the nearest whole rod), and BBBB.BB is the total outside (circumferential) length of the section. The x,y coordinates of all field entry points are also adjusted to put them on the new field boundaries in the same general location they were in with the original field shape. The y-coordinate of each circular section origin is stored in the x-array (as with standard field sections) though it, as well as the x-coordinate of the section origins, can be determined by the section widths.

*Use of a field pattern other than the continuous alternating field pattern is not permitted with the model in its present stage of development.

**A rectangle that will enclose the original field is first established. It is then shrunk until its area is equal to that of the original field.

APPENDIX D

APPENDIX D

ACTIVITY STATES PROPOSED FOR THE FILE 11 ENTITIES ASSOCIATED WITH ON-FARM DRYING

Type of Entity	Activity State No.*	Type of Activity
Dump Pits and Holding Bins	1	Inactive (empty, partially filled, full).
	2	Corn inflowing only.
	3	Corn outflowing only.
	4	Corn inflowing and outflowing.
Conveyors	1	Non-operate or idle.
	2	Operate or non-idle.
Dryeration Bin	1	Inactive (empty).
	2	Corn inflowing only.
	3	Temporary hold during filling (bin is non-empty).
	4	Cooling plus corn inflowing.
	5	Cooling only.
	6	Temporary hold during (or at the conclusion of) cooling.
	7	Corn outflowing by gravity (free-flow).
	8	Temprary hold during gravity outflow.
	9	Corn outflowing with bin sweep.
	10	Temporary hold during mechanical outflow.
Batch-in-Bin Drying Bin	1	Inactive (empty).
	2	Corn inflowing only.
	3	Temporary hold during filling (bin is non-empty).
	4	Drying plus corn inflowing.
	5	Drying only.
	6	Cooling only.
	7	Temporary hold during drying or cooling, or at the conclusion of the drying-cooling cycle.
	8	Corn outflowing by gravity (free-flow).
	9	Temporary hold during gravity outflow.
	10	Corn outflowing with bin sweep.
	11	Temporary hold during mechanical outflow.
Portable Batch Drier	1	Inactive (empty).
	2	Corn inflowing only.
	3	Temporary hold during filling (drier is non-empty).
	4	Drying only.
	5	Cooling only.
	6	Temporary hold during drying or cooling, or at the conclusion of the drying-cooling cycle.
	7	Corn outflowing only.
	8	Temporary hold during unloading (drier is non-empty).
Continuous Flow Drier	1	Inactive (empty).
	2	Corn inflowing only (at the start of the season or a new drying period).
	3	Temporary hold during filling (drier is non-empty).
	4	Drying (and cooling), corn outflowing (and inflowing).
	5	Temporary hold during drying.
	6	Corn outflowing only (at the end of the season or this drying period).
	7	Temporary hold during unloading (drier is non-empty).
Dry Corn Storage Site	1	Inactive (empty, partially filled, full).
	2	Corn inflowing only.
	3	Corn outflowing only.

* Values that the NST-attributes (in Appendix B) may assume during activity-simulation.

APPENDIX E

APPENDIX E

COMPOSITION OF THE GASP EVENTS FILE FOR REAL EVENTS

For a one-man harvesting and handling system (without on-farm drying) the entries shown in Figure E1 were required -- see Table 6 for additional information. Note that floating-point attribute cells 9 through 15 were not required for any real events. In fixed-point attribute cells 2 through 7, ID indicates the entity-ID information for the entities directly involved with the specific event. These include:

NSET(2) - an operator (man) in file 6

NSET(3) - a corn delivery point in file 11

NSET(4) - the harvest field in file 10

NSET(5) - a tractor (if any) doing farmstead work in file 11

NSET(6) - the combine in file 7

NSET(7) - a transport set in file 8

Entity-ID information is stored as AABB, where AA is the GASP column number, and BB is the GASP file number. Blank cells (2 through 7) will usually contain the designated entity-ID information, if it was available when the event was scheduled, even though the entity may not be directly involved with the event.

The values in fixed-point attribute cell 8 designate the following: 2,3 = normal-pattern harvesting activities are continuing; 4,5 = end-of-the-day (season) -- all activities now aimed at moving equipment units to their overnight (long-term) storage locations.

Cell	EVENT ENTRIES														
QSET(1)	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW
2	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD
3	--	--	--	FLDN	XNEW	--	--	RTIM	XNEW	XNEW	--	XNEW	XNEW	--	XNXT
4	--	--	--	XNEW	YNEW	--	--	STAT	YNEW	YNEW	--	YNEW	YNEW	--	YNXT
5	--	--	--	YNEW	FLDN	--	--	--	--	HVBU	--	--	--	--	TRBU
6	--	--	--	--	--	--	--	--	--	HVCP	--	--	--	--	TRCP
7	--	--	--	--	--	--	--	--	--	HVMC	--	--	--	--	TRMC
8	--	--	--	--	--	--	--	--	--	ACRE	--	--	--	--	--
NSET(1)	5	6	7	8	9	10	11	12	13	14	15	18	19	20	21
2	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	--	ID
3	ID	ID	ID	--	--	--	--	--	--	--	--	--	--	--	--
4	--	--	--	--	--	--	--	--	--	ID	--	--	--	--	--
5	ID	--	--	--	--	ID	ID	ID	--	--	--	--	--	--	--
6	--	IFIL	MAN2	--	ID	--	ID	ID	ID	ID	ID	ID	ID	--	ID
7	--	ID	MAN3	ID	--	--	ID	ID	--	--	--	ID	--	ID	ID
8	NS	NS	NS	0,NS	2,3	ISTA	NTYP	NTYP	2,3	2,3	ISTA	2,3	2,3	ISTA	2,3

Figure E1. Real Event Attribute Requirements.

Cell	EVENT ENTRIES													
QSET(1)	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW	TNEW
2	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD	TOLD
3	OMKT	TRBU	XNEW	FARM	TRBU	XNEW	XNEW	XNEW	XNEW	--	XNEW	--	TRBU	XNEW
4	--	TRMC	YNEW	--	TRMC	YNEW	YNEW	YNEW	YNEW	--	YNEW	--	TRMC	YNEW
5	--	--	FLDN	--	--	FLDN	HVBU	HVBU	HVBU	TRBU	CODE	FARM	--	CODE
6	--	--	XNXT	--	--	--	HVCF	HVCF	HVCF	TRCF	--	--	--	--
7	--	--	YNXT	--	--	--	HVMC	HVMC	HVMC	TRMC	--	--	--	--
8	--	--	--	--	--	--	ACRE	ACRE	ACRE	--	--	--	--	--
NSET(1)	25	26	27	28	29	30	36	37	38	50	53	54	55	60
2	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
3	ID	ID	--	ID	ID	--	--	--	--	--	--	--	ID	--
4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	0	0	--	--	--	--	--	--	--	--	--	--	--	IFIL
6	--	--	ID	--	--	ID	ID	ID	ID	ID	ID	--	--	--
7	ID	ID	ID	ID	ID	ID	--	--	--	ID	--	ID	ID	ID
8	--	--	2,3	--	--	4,5	2,3	2,3	2,3	4,5	4,5	4,5	4,5	NS

Figure E1 (cont'd.)

ATTRIBUTE DEFINITIONS

ACRE .... Acres harvested during this activity.

CODE .... Location code (1-30 = field 1-30, 101-106 = farm stead 1-6).

FARM .... Farmstead number (1-6).

FLDN .... Field number in which the entity will be located.

HVBU .... Bushels of corn harvested during this activity.

HVCF .... Cubic feet of corn harvested during this activity.

HVMC .... Moisture content of corn harvested during this activity.

ID ...... Entity-ID information for the man (cell 2), delivery point (cell 3), harvest field (cell 4), farmstead tractor (cell 5), combine (cell 6) or transport set (cell 7).

IFIL .... Filing indicator (0 = this transport set will not be needed today, 1 = it will be, file a dummy event for it).

ISTA .... Activity state of this entity for its next activity. The termination of its next activity has already been scheduled (an event filed).

MAN_i .... Zero, or the entity-ID information for a second, third (i = 2,3) man assigned to assist with the activity.

NS ...... Special start-of-the-day activity indicator.

NTYP .... Type of activity interrupted by this repair activity (1 = unloading a transport set at a high-moisture silo, silo-tractor repair, 2 = transport set travel, 3 = grain handling, conveyor repair, 4 = drying or cooling bin operation, 5 = on-row combine operation, 6 = portable batch or continuous flow drier operation, 7 = on-row tractor and implement operation, and 8 = on-the-go combine unloading).

OMKT .... Off-farm market number (11-16).

RTIM .... Accumulated hours of use until the next repair of this type will be needed.

STAT .... Activity state to which the transport set is to be returned (NTYP = 2 only). See attribute NTYP.

TNEW .... Time of occurence of this event.

TOLD .... Time at which the entities associated with this event last changed states.

TRBU .... Bushels of corn transferred from one entity to another.

TRCF .... Cubic feet of corn transferred from one entity to another.

TRMC .... Moisture content of corn transferred from one entity to another.

XNEW .... New x-coordinate of the entity.

XNXT .... X-coordinate of the next start-harvest point.

YNEW .... New y-coordinate of the entity.

YNXT .... Y-coordinate of the next start-harvest point.

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