Computers may use the information supplied by various sources, such as the Teletype, to determine the most economical practice. Memory cells will tell the price of particular products a year ago. Computers will list the various possibilities for decision from which the farmer can select an answer. The computer does not and will not think—the farmer must do that.

Who will put these new ideas—supplied by many farmers, engineers, scientists, manufacturers—into practice?

Scientists discovered that planting corn kernels with the small end down produces higher yields. Engineers will develop the equipment for seeding to exploit this principle and to make it useful to agriculture. In research, a new kind of engineer—the engineer-scientist—is developing. He will link science and agriculture closer together.

Agricultural engineers will have more concern with the overall farming operations, not just the small components of particular machines, as now generally approached.

Many of the possible developments of the future demand that farm operators have engineering ability. High school training for those going into agriculture must include more of the basic areas for engineering, such as mathematics. These courses will cover those subjects recently covered in more advanced educational studies.

Engineers will help shorten the time between discovery and application of a new principle of finding. America has been made great by the scientific discoveries and the engineering advances of the past century. Underdeveloped areas can make use of this scientific and engineering knowledge and we have a responsibility of helping to disseminate this information to others.

Progress depends on multiplying our efforts in agriculture.

Mainly through mechanization, the efforts of farmers can be multiplied. Automation will follow in many specialized areas. Training in applying engineering to agriculture offers a great hope and challenge. We now have the most efficient agriculture in the world, with the lowest cost of food to the consumer, in terms of hours required to earn food. And the percentage of income devoted to food has decreased in spite of more expensive tastes.

We cannot stop now. We must continue to search, investigate, analyze, and apply our findings for improvement, just as industry keeps looking for fuel and ore deposits and searching for new and more efficient methods of manufacture. We must be ready for these new challenges.

**Systems Engineering in Agriculture**

L. L. Sammet

Systems, defined in terms of "an assemblage or set of correlated members," have been with us for a long time. This quality in a general way describes the universe itself. It characterizes any complex plant or animal organism. More recent than the origin of systems, yet not at all new, is man's recognition and use of the systems concept. This was an important part of early developments in astronomy, physics, and the biological sciences.

Early scientific observers studied natural systems. They focused attention on discovering natural laws as to the behavior of these systems and on explaining the relationships and interaction of many separate parts. This remains the central interest of many scientists, but the growing application of science and technology to man's activities has developed a new interest—that of systems building.
It involves the creation of new assemblies, achievement of improved correlation, and the development of new types of systems members. The procedure, in fact, may extend to the creation of completely new types of processes and products.

Systems characteristics are seen in modern industrial organization as applied, for example, in the manufacture of farm tractors and trucks. We know that this involves design and production scheduling for hundreds of individual parts and that intricate coordination is required to maintain an efficient flow of parts and subassemblies into the fabrication of a final product. This necessary coordination of many separate activities of men and machines creates an assemblage of correlated members, which constitute a system in the sense defined here. Growing attention to the task of coordinating industrial operations has created there a new field of endeavor—systems engineering.

The need for systems engineering in modern industry is easily established with respect to an automated factory or a telephone system. To work at all, such facilities require perfectly integrated performance of many individual parts. Planning and engineering of the system as a whole—as well as attention to individual components and their relation to it—cannot be avoided.

In many industries—and in agriculture—the processes are not rigidly controlled from a single point or otherwise organized as to require an absolutely integrated performance. Instead, there is some adaptability in the process and component parts. This time lapse between certain stages—as, for example, between planting and harvesting a crop or between harvesting and processing—lessen the urgency for perfect integration of system components. Greater concentration on individual parts of the system, with reduced interest in the system as a whole, often is evident in such circumstances. But this may bring neglect of important interactions that are present in a comprehensive process.

Neglect of this aspect is not necessarily fatal. Many systems created without comprehensive planning are effective. The case for systems engineering then must be made on the ground that deliberate and comprehensive planning can develop sufficiently improved systems to compensate for the added efforts of systems research and planning.

Wherever applied, systems planning is likely to be difficult. It may require great proficiency in particular fields as well as a broad understanding of major systems objectives. This is especially true in agriculture, where mechanical and electrical processes—those most commonly dealt with in the industrial sphere—are merely important supplements to plant, animal, chemical, bacterial, and many other types of processes involved in agricultural production.

Systems design in this broad framework evidently includes engineering. But the engineer contributes best as one of a team of specialists, each highly skilled in a special field. His concern in agriculture is with materials, machines, labor, and energy and their use to modify natural processes and to control environmental factors in the production of livestock and crops and storage of crops.

The boundaries of agricultural systems may be drawn differently by different observers. If viewed narrowly, many single units of farm equipment may themselves be regarded as "systems." This is true, for example, of a farm tractor, which may be described correctly as a complex, unified system for converting liquid fuels to mechanical power. But this system takes on other dimensions as part of an integrated assembly of tillage and other tools, and it becomes a component of a still larger system when applied in farm operations.

In the production and utilization of forage crops, for example, we have a system composed of major subprocesses or stages, such as soil preparation, planting, harvesting, transporting, stor-
In these separate stages, the tractor-tool unit serves not as a "system" but as a tool or component. Each production stage includes numerous separate operations and may require the services of many individual components.

Interdependencies among production stages and stage components, a major attribute of systems, are easily recognized in forage production. There are, for example, fixed mechanical interdependencies such as are found in the tractor-tillage unit. There are interdependencies in product form and quality. The harvesting method determines whether materials are produced in loose, chopped, baled, or pelleted form. Selection of harvesting method thus predetermines the opportunities and limitations in subsequent materials handling and storage and may condition usefulness in feeding. The causal relation may, of course, run the other way. Selection of a particular method of handling or storing forage at the farmstead may specify the method of field harvesting.

Other interdependencies in the use of equipment arise when given equipment units—for example, the tractor—are employed in successive stages of the process. This quality is a major consideration in regard to capital investment in machines or structures. Investments in such facilities, made in one time period, are recovered only through their use in several different periods. The possibilities of introducing changes in methods in later periods therefore depend partly on previous technical and investment decisions.

Many other systems of single-crop production could be described, and the concept is easily extended to the production of several different crops on a single farm. Moreover, developments in the procurement of farm supplies and in marketing farm products suggest that some farm systems may extend beyond the farm gate.

A growing number of farm-supply services affect farm operations and equipment. These include bulk feed delivery and custom services for the application of fertilizers and insecticides and for pruning and cultural operations. In the sale and distribution of farm products, similar developments include the use of tank trucks in the farm-to-market transportation of milk and the use of pallet-bins in coordinated grower-processor harvesting of fruit and vegetables, their transportation, and their handling and storage at the processing plant.

Less obvious but important is the growth of contract and specification buying by food processors and distributors whereby type and quality of product as well as on-farm production and cultural practices are specified. The case for extension of system boundaries beyond the farm gate is clearest with respect to integrated production-processing-distribution operations under a single management. Examples of this type of organization are found in some parts of the canning industry and in the production and marketing of poultry.

In agriculture, as in other lines of production, there is evident need to coordinate the many individual operations and stages. When there are numerous alternative techniques for performing particular tasks in the various stages of such systems, it is commonly assumed that the optimum technique should be determined. This implies the selection, from all available methods of performing particular operations, of the particular combination of methods that will most satisfactorily meet predetermined systems goals. Intensive study of individual components and their relation to the system as a whole involves systems analysis.

Systems analysis begins with the selection of performance goals and criteria for judging their attainment. These vary with the type of problem under study.

Agricultural systems analysis, for example, might be aimed at minimizing soil loss, maximizing output, minimizing the costs of given outputs or—if
directed toward a solution for an individual firm—maximizing profit.

Such goals might be considered singly, or there could be a primary goal modified by subordinate objectives. One could have the single goal of maximum immediate output from given resources, or this goal might be conditioned by certain restraints as to acceptable limits of soil loss.

In any event, the systems visualized, the criteria for judging them, and the optimum solution very likely will be different, depending on the goals sought. Their definition is, therefore, an essential prelude to systems studies.

Systems analysis must also emphasize the fact of numerous production stages with the possibility in each stage of two or more techniques for performing given tasks. This is particularly true in agriculture, where alternative technique must be broadly defined to include different work methods and equipment, different soil and fertilizer treatments, alternative plant and animal strains, and so on.

With the wide range in form of production organization this suggests, some difficulties may be anticipated in finding the optimum solution. With exceedingly simple problems, the alternative forms of process organization could be compared on the basis of controlled experiment. Only a little growth in complexity, however, could make necessary the comparison of many different alternative combinations—usually so great a number as to prohibit comparisons of alternative systems through controlled experiment. Only a little growth in complexity, however, could make necessary the comparison of many different alternative combinations—usually so great a number as to prohibit comparisons of alternative systems through controlled experiment. For example, a relatively simple five-stage process with two alternative techniques per stage—if all possible combinations of stage techniques are considered—can be arranged in 32 different system organizations. If there were 10 stages and 4 alternatives per stage, the possible number of different combinations would total more than 37 thousand.

When we recognize that the systems of interest generally involve the operating procedures of entire farms and may extend beyond farm limits to include

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activities in farm-services supply or in processing and marketing, controlled experiment with respect to alternative system organization does not seem a promising means of study.

Synthesis, or model building, offers a useful alternative to experimental comparison of entire systems.

Direct experiment and observation in this procedure is applied at the level of individual operations and stages—that is, to the component parts of the system. Such experiments provide information as to equipment and method of performance; the type, timing, and rate of use of the various inputs; and quantity, type, and quality of output.

From such results, estimates can be made of the type of inputs, their rate of use, and the costs of inputs in a particular operation or stage required to yield a particular system output. This kind of determination with respect to each operation and stage and with respect to alternative techniques in each stage provides a set of building blocks, which can be assembled in different combinations, each representing an alternative system organization.

If the basis of system evaluation is cost minimization, comparison of estimated total costs of given outputs from all alternative technical combinations then provides a basis for selecting the optimum system organization. This procedure is not strange to engineers. It has a close parallel in machine or structural design, but with important differences in objectives.

One procedure—synthesis—simulates real systems as a means of evaluating alternative forms of production organization. The other procedure—design—simulates physical equipment and structures as a basis for manufacture and construction.

Interaction and synthesis, the first representing the necessity for systems analysis and the second describing a method of systems evaluation, are illustrated in studies of alternative methods of harvesting and plant-as-
assembly of lima beans and peas for freezing. The studies were reported by the California and Oregon Agricultural Experiment Stations in 1958. The harvesting and assembly activities link together two major phases, farm production and processing, in the production-processing-marketing system for these products.

In the farm production phase, broad categories (or stages) of operation may be recognized, such as soil preparation, planting, cultivation, dusting, irrigating (in some areas), and harvesting. Similarly, within the processing plant, major process stages include receiving the raw product, dumping it into the process flow, cleaning, quality grading, blanching, filling and wrapping containers, preparing for freezing, transporting to freezer, and freezing.

We know that alternative methods are available for performing the various operations in this long sequence. We know also that complexity of analysis grows at an accelerating rate with increase in the number of alternatives considered simultaneously. The problem is simplified, therefore, if the total process can be divided into subprocesses for separate analysis. This can be done if there is no significant interaction between the subprocesses so defined.

This question was considered in comparisons of costs with existing methods of performing the various operations in vining and hauling. Three principal variations in method were observed. All include the same basic operations of cutting, shelling, and transporting. The methods differ with respect to type of equipment, sequence, and location of certain operations.

One method uses mechanical viners fixed in location at a point near the farm producing center. Vines, cut by machine, are draper-loaded into trucks for transportation to the vining center. Here they are unloaded and fed into viner-shellers which remove peas (or beans) from the vines and pods and discharge the vines into a silage pit. Shelled product is delivered to containers and later loaded for transportation to the processing plant.

In a second method, the operations are essentially the same, except that the viner-sheller equipment is located adjacent to the processing plant rather than in the field. Shelled product is delivered by conveyor or flume directly to the receiving room of the plant for processing.

A third method involves drawing mobile viner-sheller equipment through the field. The vines, previously cut and windrowed, are collected on a drum which feeds them to a conveyor leading to the separator. Shelled beans are collected on a side-delivery conveyor, elevated to a hopper, and periodically dumped into a bulk truck for delivery to the processing plant. The vines are discharged to the ground as the machine moves through the field.

The threshing and separating equipment used with all three methods is essentially the same as to performance characteristics. The principal differences—as indicated in the process chart—are in the handling and hauling operations.

To study the relative costs with the three methods, work measurement procedures as applied in industrial engineering were used to determine output capacities of individual workers on particular jobs and of the various types of equipment.

Standard performance rates per worker and per equipment unit thus determined were the building blocks for synthesis. These were used to estimate the number of workers and quantities of equipment and other services required to produce shelled peas or beans at a given rate per hour. With such estimates of physical requirements, costs were easily computed by the application of appropriate cost rates.

The studies were designed to show the effect on costs of variation in several factors. Length of haul, for example, was considered important in view of differences in density of load in the field-to-plant transportation of field-shelled product, as compared with the
Process-flow diagram with three methods of harvest and plant-assembly of peas and lima beans for processing.
hauling of low-density loads of vines to vining equipment stationed at the processing plant.

The possibilities of operating economies with a large-scale installation (where scale was measured in terms of output capacity of shelled product per hour) as compared with small-scale installations were considered.

The substantial differences among methods as to investment requirements for installations of the same scale were also regarded as an important variable.

Still another consideration grows out of the investment problem. Investment costs, which appear in the cost calculations as fixed costs per year, decrease per unit of output as the annual volume produced in an installation increases.

With an installation of given size—and therefore of given investment outlay with respect to each method—an annual volume in the fixed harvest season of a given location is varied primarily by variation in hours worked per day. This leads to the problem of optimum adjustment with respect to capacity output rate and hours of daily operation. Since these relationships differ in regard to field and plant operations, solution of this problem requires that vining and processing plant operations be considered jointly. Problems such as the foregoing were considered in these studies.

Comparison of the two methods of field vining showed the mobile viner to be at a slight cost disadvantage when rate of vining is low and hours operated per season small. Mobile vining, where adaptable, offers substantial savings, however, when the size of installation is large and hours operated per season relatively high. As might be expected, at-plant as compared with field vining faces an increasing cost handicap as length of haul with the relatively low-density load of vines increases. Economies gained through direct delivery of shelled product to the plant receiving tanks may be dissipated as size of processing plant grows and its supply area and hauling distance increase.

In the studies, no difference in the methods of farm production before harvest or in plant operation after the receiving stage were attributed to differences in method of vining.

The possibility of subdividing the production-harvesting-processing operations for detailed study then hinge on the extent to which the determination of optimum combination of field and plant capacities and daily operating hours require that these phases be studied jointly. They also hinge on the difference in plant receiving operations with the alternative methods of field harvest.

The first of these problems, while quite important in principle, was found not to be of sufficient practical significance to require simultaneous determination of economical technique in the field and plant operations.

The second consideration may conveniently be handled by defining three major sectors of analysis: Field production; harvesting, hauling, and plant receiving; and plant processing, excluding receiving. In this way, interdependencies in field and plant operations in this example may be adequately treated in the analysis without making the problem unnecessarily complex.

Systems development, involving the creation of new types of equipment, improved farm production methods, and new concepts of process organization, appears to be a logical outgrowth, if not an inseparable companion, of systems analysis.

Ideally, evaluation and comparison in systems analysis would be used to highlight areas within the present systems that offer special promise for more intensive study and development of new technique. In the illustration, for example, measurements of the adverse cost-effect of short-season operation demonstrate potential economies from extending the harvest and plant operating seasons. This suggests plant breeding investigations as a means of developing new varieties for given producing regions that mature at different dates. Or it may be appropriate to consider
the production of alternative crops and the construction of processing plants adaptable to several lines of output.

Successful developments of this type would imply important effects on the optimum technical organization of both field and plant organization as well as on costs. They might lead to review and modification of procedures for the coordination of the operations of processors and farmers, and these might call for new forms of contractual relations between growers and processors or even bear significantly on the possibilities and benefits of the integration of growing and processing activities under a single management.

Other illustrations of the possibilities of systems development can easily be visualized. Many of them also would suggest the possibility that systems analysis may stimulate technical developments, which, in turn, create possibilities for new forms of technical organization.

Interaction among the various operating components of agricultural systems evidently has a parallel in the relationship of analysis and development in systems studies.

Comprehensive systems in agricultural production and marketing evidently provide extremely wide possibilities for investigation and analysis and for extending the results of such work into the applied area of systems development.

Such studies embrace the subject matter of many different fields and this suggests the research team as a productive—even necessary—approach. If well organized, such teams would have the capability of deep penetration in special problem areas. They would be equipped for exhaustive search for significant interrelationships among individual system components, but also be prepared to set aside those likely to be of little significance in overall systems operation.

The growing complexity of farm production and marketing operations and the need for improved coordination of existing system organizations and for the development of new process methods and organization may provide a new role—or at least expansion of an old one—for engineering in its service to agriculture.

Machines for New Crops

Leonard G. Schoenleber

We call castorbeans, kenaf, safflower, sesame, and canaigre new crops because of the new interest farmers and industry have in them.

To produce and sell them and other new crops profitably, new or modified machines usually must be developed to produce, harvest, and process them.

Success in establishing a new crop depends also on efforts of plant scientists, who work to change characteristics of the plants to make them better suited to accommodate limitations of machines and increase efficiency. Developments in machinery likewise take into consideration the characteristics and limitations of the plants.

Such factors as the nature and potential value of the crop, climate and soil conditions, and annual use of the machine dictate which, how, and whether new machines are developed or old ones are adapted. Development of a new machine often requires years of research by agricultural engineers, individual enterprises, and manufacturers.

When the potential acreage or value of a crop does not justify the expense of developing a machine by industry, public institutions may initiate and carry on the development work.

Castorbeans contain an oil that is used in the production of more than