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Basic Concepts for Designing a Fundamental Information System

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In the last issue this author presented the case for basing the structure of the corporate information system on the 'single information flow' philosophy of data processing. Now he tells how to go about designing such a system.

BASIC CONCEPTS FOR DESIGNING A FUNDAMENTAL INFORMATION SYSTEM

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Analyzing a corporate data system is still a primitive process. Although the computer has revolutionized data systems in the past decade, there has been no corresponding revolution in the procedures for installing and operating them. The rationale for determining what data to analyze and how to go about it and the basic techniques for interviewing, documenting, flow charting, and analyzing have changed little since the advent of the computer. Indeed, they have not changed greatly since the nineteenth century.

The large size, complexity, and variety of modern data systems cause continuing difficulties for the systems analyst. Two to eight years, depending on the scope of the application, can elapse from the initiation of a data systems study to its implementation. During this period the systems analyst is beset by continual pressures to get the system operating. Meanwhile, policy changes and personnel rotation are playing havoc with the systems planning.

In general, four major problems handicap present-day systems analysis: (1) a large workload, (2) a long span of elapsed time, (3) a lack of explicit directions both for conducting the study and for using the results, and (4) the lack of a technique to control changes in the data system throughout its life.

These problems are far from being solved. Some new techniques, however, offer promise of alleviating some of them. Data network analysis, which incorporates a method of using the electronic data processor to prepare many of the systems analyses automatically, reduces the total workload and the time span from inception of a study through the preliminary phase. Source input/output analysis facilitates development of the essential information that each functional group within the company needs to operate efficiently. Simulation permits study of the operation of the information system in the form of a model.

This article describes these techniques and explains how they can

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be applied to the design of an information system, specifically a so-called fundamental information system based on the "single information flow" concept of data processing.

Information systems

An information system may be defined as the procedures, methodologies, organization, software, and hardware elements needed to insert and retrieve selected data as required for operating and managing a company. In this article no distinction is made between so-called management information systems and other kinds of information systems. The term is used to include all specific data required to conduct the business of the company regardless of whether the data are classified as operating, management, accounting, or any other kind of data.

In many companies the information systems are systems by courtesy only. In the early days of computer technology the components or subsystems approach prevailed. An integrated business system was thought to exist when pieces of information were introduced into the information flow and perpetuated there with a minimum of manual intervention. Mechanization of existing operations — or of data for specific random jobs — resulted in a multiplicity of relatively static systems put together on a piecemeal basis.

Now there is a growing recognition that the interactions and interdependencies among components of a system are more important than the components themselves. Managements are beginning to realize that the information system must be integrated lest data processing become a giant papermill so complex in structure that it is impossible to control.

As Richard E. Sprague has pointed out,[1] fundamental economic and system pressures are fostering a management desire for clean and uncomplicated information systems. Economic pressures include the need for functional and geographic integration of data and the pressure for sharing of computer equipment by users. System pressures, based on the desirability of carrying the processing of data to the user and in other ways making service to him more rapid and more meaningful, include the desire to mechanize data at the source; the need to solve the problems of sharing time on computers that operate on a batch processing basis; and the attractiveness of incorporating on line-real time data processing with current feedback of information to assist management in its decision making function.

These pressures do not operate on every company with equal force, of course. The organization that is considering the design of a new information system should first consider the following questions:

1. How satisfied are people throughout the organization with the existing input and output of information?
2. Have the most recent important changes in data processing operations — manual or computer — been fully "digested" as yet?
3. Have major new technical improvements in systems hardware and software recently become available?
4. Are operating management personnel receptive to new and important changes in the future?
5. Does the organization have designers with the skill and experience needed to develop a new information system?
6. Are the probable time schedules for such a project satisfactory?
7. Are financial budgets adequate?
8. Does the potential payoff justify the effort? Cost and benefit elements of both the present and the proposed system should be analyzed and compared. Exhibit 1 on page 39 lists the payoff elements normally considered.

If the design of a new information system seems worthwhile, the next question is, "What kind of information system?" As an earlier article in this magazine pointed out,[2] two alternative concepts are being proposed by data processing specialists today. They are the "total" information system, based on the "total systems" approach, and the "fundamental" information system, based on the "single information flow" philosophy.

The total information system, a logical extension of the present subsystems approach, is an attempt to unite all existing information subsystems in the company into a single integrated system. The intent is to include all data for all the needs of all levels of management and operations. Each piece of data is entered in each information subsystem that may need it, with multiple records of similar data as a result.

The fundamental information system, on the other hand, is limited to data considered absolutely essential to the operation of the company. Other data needed for one reason or another by specific user groups are recorded and processed outside the fundamental information system. The fundamental data themselves are recorded only once and stored in a central location.

These two systems are compared in Exhibit 2 on page 40. Since the author considers the single information flow concept the most promising route to simple and efficient data processing, the remainder of this article will be concerned with the design of a fundamental information system.

Design principles

The following generalizations represent principles[3] that should be

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[1] Richard E. Sprague, *Electronic Business Systems,* The Ronald Press Company, New York, 1962.

[2] A. F. Moravec, "Basic Concepts for Planning Advanced EDP Systems," MANAGEMENT SERVICES, May-June, 1965, p. 52.

[3] R. J. Chambers, "The Role of Information Systems in Decision Making," *Management Technology,* Vol. 4, No. 1, June, 1964.

kept in mind when designing the information system:

• An information system is a system for supplying information to users who must take coordinated action. If effective communication is to take place, the language used must be such that response will be identified by all members of the organization. If action is to be coordinated, the information system cannot be treated as a group of independent subsystems.

• The information system must remove all doubt about data, that is, the system must be so reliable that the user will depend upon it rather than upon his own observations. For example, information will fail to evoke response (decisions) relevant to the pursuit of its ends if it is found by receivers to be inconsistent with their own direct observations. In this case the system which produces the information will serve to increase rather than to reduce doubt; it will cloud rather than clarify issues confronting decision makers.

• There is a point at which the marginal cost of differentiation of information and comprehensiveness of information exceeds the marginal utility of information to the receiver, i.e., an individual's capacity for making sound judgments about a complex situation may be seriously impaired by supplying him with a lot of information which he believes would be relevant but whose influence on the situation is not clear to him.

• Thus, the information system is an abstracting system. Its justification lies in the reduction of the information available to the information that is relevant to action. But abstraction should not be carried to the point where differences in the significance of data are obscured.

• An information system is a device for continually bringing under notice new facts and new knowledge. It must provide not only the premises of decisions but also a feedback so that decisions may be reaffirmed or abandoned in favor of others. The development of an organization and the development of the judgment of its agents alike depend on this feedback.

• Since both the capacity and the time available for observation are limited, an information system must provide a formal record to guard against misinterpretation of past experiences. The records of an organization are its memory. Therefore, all records and communications at any time serve not only their immediate function but also the function of memory.

• The information system must be regarded as a continuously developing instrument, in much the same way as an organization is constantly developing.

• It is a matter of experience that information processing is done according to habitual modes far more commonly than according to deliberate assessment of the user's requirements.

Requirements

For the fundamental information system to do its job properly, it must meet these requirements:

1. It must provide all the data essential to the operation of the company. These data should include both planning data and performance data. Performance data must measure both planned and present status and must indicate the probable future impact. Cost and financial data should be compared with budget or target dollars; operational schedules should be compared with planned completions; technical quality assurance data should be compared with established standards.

2. The system must be responsive to management needs. This responsiveness can be obtained by "designing in" the flexibility and adaptability needed to re-allocate resources as required. By means of computer simulations of management decision making requirements, for example, the type and frequency of changes in programs and resource allocations can be tested, and likely condition boundaries can be established.

3. It should be capable of "dynamic self-reprograming," i.e., able to reprogram itself to meet the ever changing demands of the company. (This is a part of the single information flow concept and its design.)

Systems analysis

To analyze the interaction of functions and departments using today's methods of operation and then to design the optimum system for mechanization using tomorrow's methods is a complex task involving complex human factors.

A completely new method of analyzing systems and describing information requirements is needed. Such a method should fulfill two requirements:

EXHIBIT I

SYSTEM PAYOFF

SYSTEM COSTS

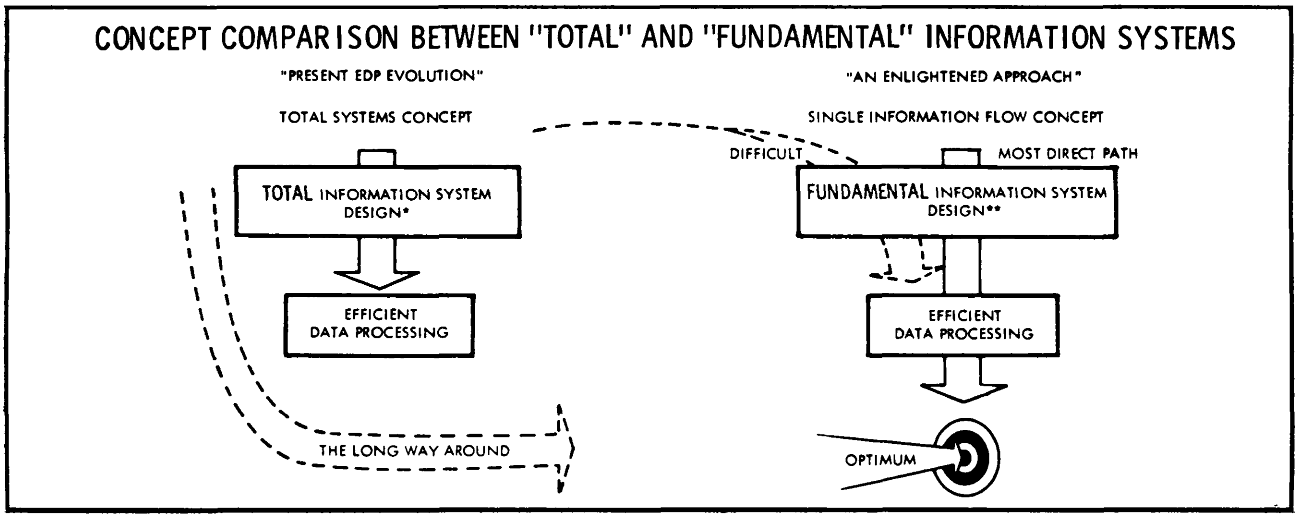
Hardware:
- Basic processor
- Storage devices
- Peripheral equipment
- Communication equipment
- Facilities
- Input/output devices
- Equipment maintenance
  - Total

Operating Expenses:
- Program maintenance
- Equipment operators
- Media preparers (key punchers)
- Data collectors
- Data control & correction
- Utilities
- Cards, paper, etc.
  - Total

Development Costs:
- Hiring & training of programers & analysts
- Salaries
- Disruption of normal operations
- Retraining displaced personnel
  - Total

SYSTEM BENEFITS

Decreased Operating Costs:
- Fewer people
- Less inventory
- Fewer penalties for late payment or delivery
- Lower transportation or purchasing costs
- Fewer shortages to interrupt production
- Better scheduling of production
- Better service (internal-external)



FOUNDATION FOR:
"Total" Information System

1. Includes all basic interacting and interrelating data in attainable subsystems.
2. It attempts to satisfy all data requirements for all levels of management and for all operating needs.
3. All required or desired data will be included in the information data reservoir.
4. It is envisioned that this data reservoir or data bank will certainly be the larger of the two.
5. Record lengths will be smaller but the system will include multiple records of similar data.
6. Because of tradition and the desire to use what one already has developed, this kind of an information system will be difficult to construct. Many obstacles including complex data integration and handling will have to be hurdled.

FOUNDATION FOR:
"Fundamental" Information System

1. Includes only "essential" or "fundamental" data required to effectively operate the firm as a complete entity.
2. It satisfies only the basic data needs of the firm to accomplish its mission and provides the "selective" feedback information necessary for management decisions at its proper level and station.
3. "Nonessential" or "secondary" classed data desired by some operation or by some level of management will be processed off line by peripheral equipment and will not be included in the primary information data reservoir. (Until full conversion, most "secondary" type data will be processed in their present fashion as subsystems.)
4. It is envisioned that this data reservoir or data bank will be the smaller of the two.
5. Record lengths will be long and many, but only single records will prevail.
6. Since this system involves a completely new development approach, ties with the previous EDP environment are severed making this the most direct and hence the shortest path to the target of optimum data processing.

EXHIBIT 2

EXHIBIT 3

ESSENTIAL DATA SINGLE RECORD LAYOUT - EXAMPLE

A PORTION OF SINGLE RECORD

MANUFACTURING	PART/ MATERIAL DESC'PT	REQUIREMENTS				ON ORDER			INVENTORY STATUS				NET STATUS	FINANCE
		PROD.	SPARES	OTHER	TOTAL	TOTAL P.O.'s	TOTAL RECEIPTS	BAL ON ORDER	CUMULATIVE ISSUES: PLAN	UN-PLAN	TOTAL	ON HAND		
	1+2	3	4	5-6-7-8	9	10	11	12	13	14-15	16-17	18	19	
		20	4	1	25	15	5	10	3	—	3	2	-1)	

REPORTS GENERATED:

FINANCIAL COMMITMENT REPORT	REQM'TS (UNITS) OR COST (DOLLARS) TO COMPLETE BY CONTRACT/PROJECT	PROJECT USAGE UNITS - DOLLARS
10-11-12	9-12-13-18	9-10-13-14-15-16-17-18

Two new systems analysis techniques are available . . . .

1. For understandability and workability, the method should present the system in the form of a network in order to permit visual display of data dependencies and interactions, in order to pinpoint communication requirements (volumes, load, frequencies, stations, and the like), and in order to facilitate mathematical treatment (network theory, traffic or queueing theory, linear programing, PERT/Time/Cost, and the like).

2. The principle of data feedback must be incorporated in order to ensure the availability of those data required for management decision making and also to provide a basic structure for decision making simulation programs.

Data network analysis

Two new systems analysis techniques are available that meet these requirements. They are data network analysis – for the synthesis phase of the systems study – and source input/output analysis – for the information-gathering phase.

Data network analysis[4] is illustrated in Exhibit 3 on page 40, Exhibit 4 on page 42, and Exhibit 5 on page 43. With this technique, data storage points in the system are analyzed and converted to single records as indicated in Exhibit 3; each record's characteristics, the activity in and out, and the data elements it contains are detailed.

With this method of analysis, the analyst prepares a flow chart of "event chains" and activities rather than of documents. In this way he can trace the flow of data and actions throughout a data network as they are created and as they respond to events instead of trying to categorize them into arbitrary segments of an information system under such nebulous labels as "applications." Exhibit 4 shows a simple data network; Exhibit 5 shows the same data network in conjunction with a computer communication network. One advantage of this technique is that the computer can be programed to prepare much of the initial systems analysis and documentation automatically.[5]

This data network methodology provides a visual representation of data and action dependency and interdependency, time sequencing of both data and action, load and volume analysis for communication and equipment purposes, and, as a by-product, automation of analysis and documentation. Using the computer to prepare systems analyses automatically – although it does not relieve the systems analyst of any of his usual analysis and design responsibilities – speeds up the preliminary analysis phase of the study and at the same time makes possible a more thorough analysis than can be prepared with present methods.

Determining records and data characteristics, volumes, relationships, and data storage needs gives the analyst a sound basis for design of a new data system. In addition, the data network analysis technique permits the tracing of data and their highly intricate chain reactions throughout the structure of the organization; in the process, user demand and users' effects on each other can be measured.

Because of the complexity of the task of defining a fundamental information system that crosses department lines and includes many functions, data network analysis should be preceded by source input/output analysis.[6] Assuming the systems designer has postulated that all information to be inserted into or withdrawn from the system by each point of origin (source) will be stored centrally and will be available on a real time basis as needed, the procedure for conducting input/output analysis is as follows:

Source input/output

- The characteristics (functions, departmental mission) of each point of origin are identified. The true source of information generated at each point of origin (station) and the information required by each are described in detail.
- The information that must be held in central storage to satisfy all operating and management requirements is specified in detail. For management-type information a set of decision rules based on the objectives, policies, and procedures of the organization is inserted into central storage.
- For communication purposes, the message formats and lengths for transmission to and from each point-of-origin central point are defined. In addition, the information volumes, i.e., the number of messages per hour for each hour and for each point of origin, are estimated.
- The sum total of all information generated, stored, and processed for each point of origin and each communication channel and for the central computer location is computed.

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[4] Arthur D. Hall, *A Methodology for Systems Engineering*, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1962.

[5] With some modifications, this technique is similar to Autosate, an automated data systems analysis technique developed by the Rand Corporation.

[6] Gregory and Van Horn, *Automated Data Processing Systems – Principles and Procedures*, 2d ed., Wadsworth Publishing Company, Inc., Belmont, California, 1963.

These data are then placed on a network for the synthesis phase of the systems study.

The basic steps in designing the information system may be summarized as follows:

1. Determine management's needs to monitor the enterprise as a whole.

2. Design the fundamental information flow, indicating the relationships among the major functions and data, for example, engineering, manufacturing, procurement, marketing, and finance.

3. Develop in detail the "essential" information that each function requires to operate efficiently.

4. Determine each function's data and action requirements and each function's dependence upon other functions' actions and/or information.

Administratively, the plan for conducting the systems study breaks down into three time phases. The first phase, investigation, consists of construction and testing of a simulation model of the system and of source input/output analysis. The second phase, that of preliminary design, includes merging and synthesis of the information gathered in the first phase, preparation of a composite data network analysis, complete initial design of the overall system, and design and testing of a workable automated system. The final phase, final design, consists of complete initial design of system details, selection of equipment configuration, and preparation of a plan for implementation of the information system.

Investigation phase

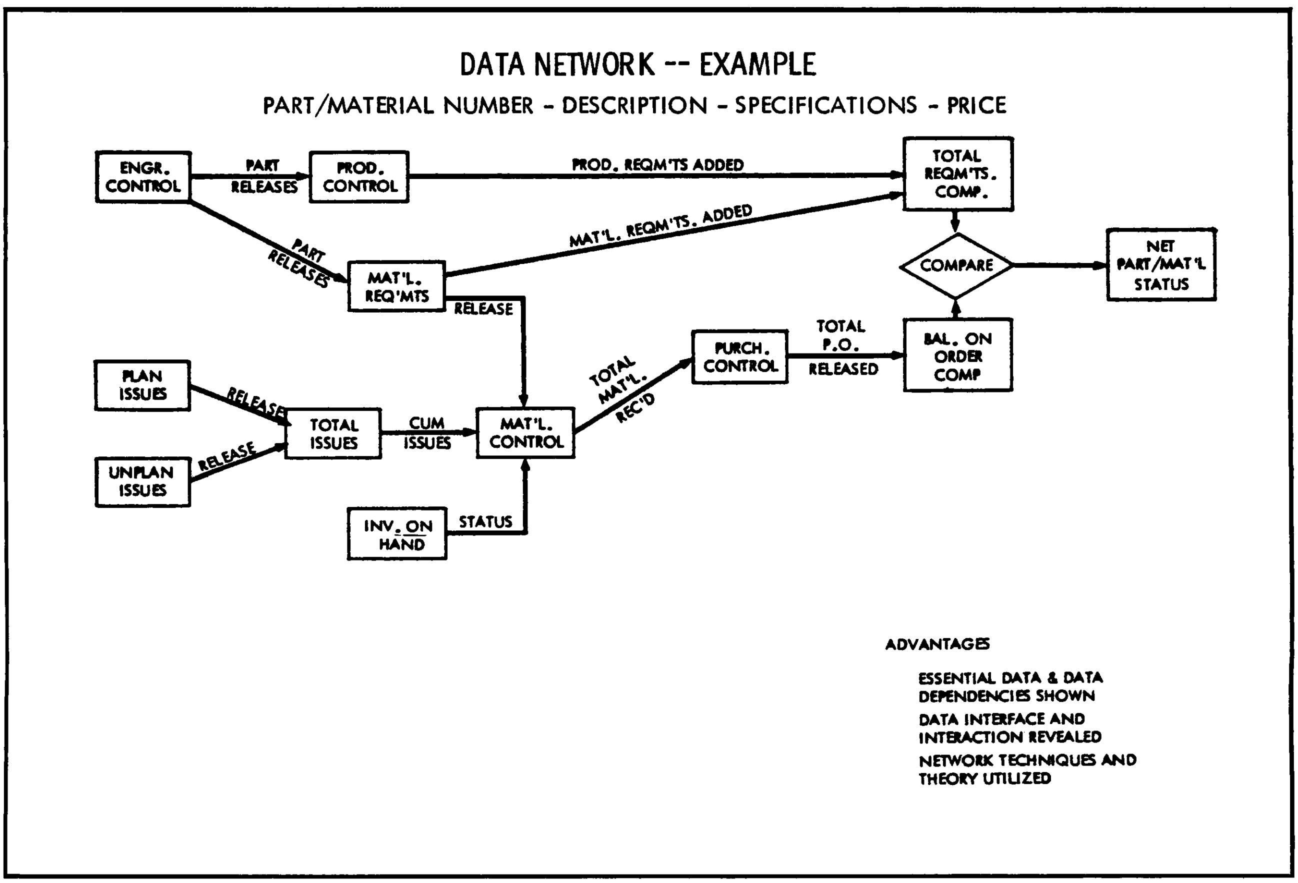
The initial investigation — the first phase — calls for a simultaneous two-pronged attack. One group, composed of operations analysts, is responsible for preparing an information system model with a resultant computer simulation model. This process is illustrated in Exhibit 6 on page 44.

Simulation is a technique whereby a system and its associated sequence of events are reproduced in the computer, that is, the computer is made to act like the system being studied. These simulation programs are usually referred to as "models" since they are representations of the real system.

At the same time another group, composed of systems analysts, is responsible for preparing an information system based upon review and analysis of present operations, subsystems, and data flows. Using the source input/output systems analysis approach, they determine and define "essential" data and secondary data, review present subsystem applications, prepare a network indicating data dependencies and interactions, design a single-record layout and data flow processing scheme, prepare preliminary conversion specifications, prepare a data and communication network flow, and prepare and assemble documentation.

Both groups must operate under

EXHIBIT 4



the same systems objectives, goals, and criteria. These are established early in the study and revised as required. Examples follow:

Objectives

- Determine management's needs to monitor the whole enterprise.
- Provide for single-transaction and complete processing of "essential" data and complete single records and data storage.

Capabilities

- Include planning and performance data within single records of essential data.
- Provide for timely responsiveness to dynamic management needs, including self-reprograming abilities.

Criteria

- Does the system automatically provide for dependency tests of needed data by the user? That is, how long will these data be required?
- Do outputs result in the required coordinated action?
- Does the cost difference for data exceed the marginal utility of the information to the user?
- Does the system provide for selective data feedback for operational needs and management decisions?

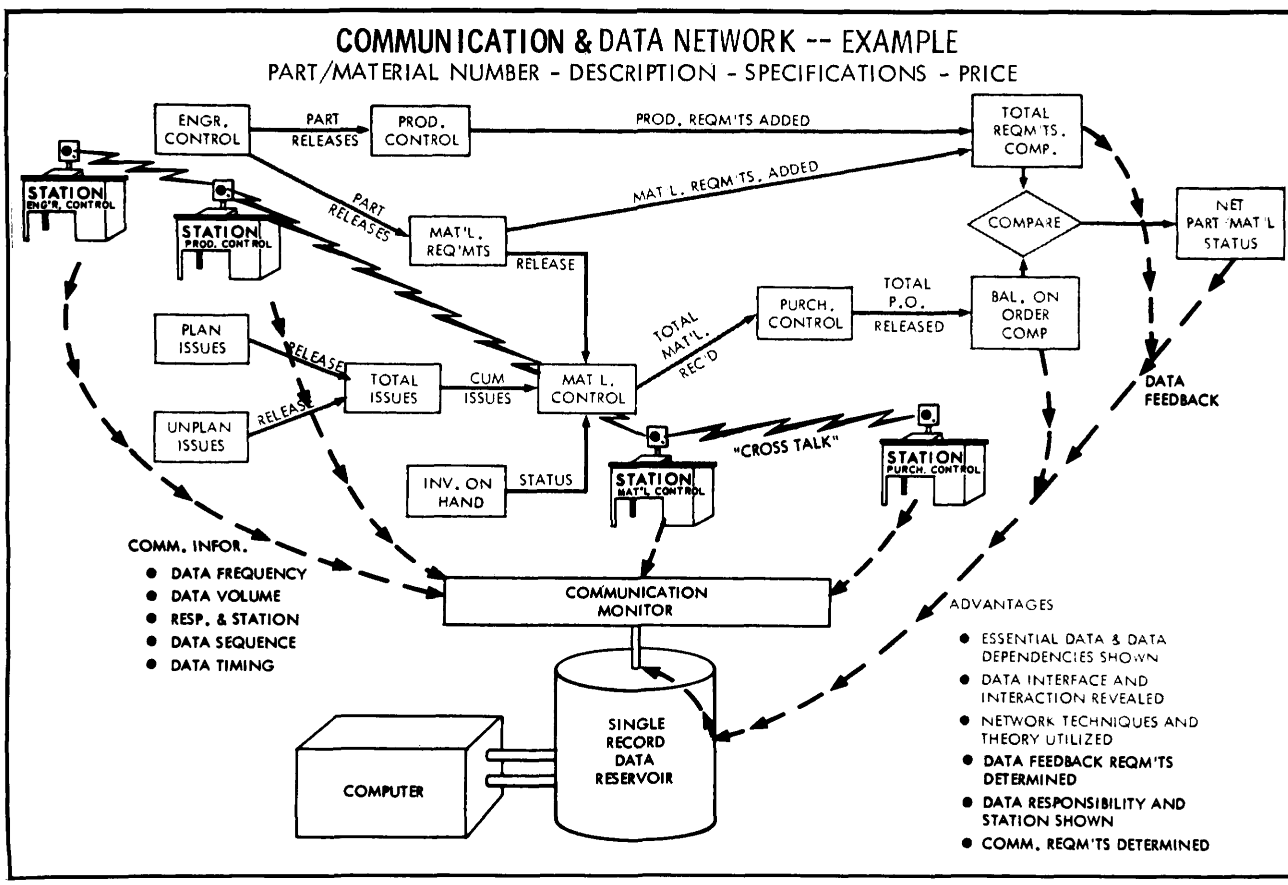
Modeling techniques

The operations analysts are responsible for preparing an optimum information system based upon the analyses of the total requirements of the organization. Their output is a network simulation model with computer programs. The model and programs are then tested by management to assure their practicability and management's understanding and acceptance of them.

This effort need not start completely from scratch. Modeling techniques have already been developed, programed, and tested by various commercial and governmental organizations. As a result, various state-of-the-art modeling "disciplines" are available for use by the operations analysts. These include such networking techniques for both data and communications as PERT/Time/Cost-Performance methods; such operations research techniques as traffic analysis, queueing theory, linear programing, and the like; decision table techniques; and business simulators and gaming techniques such as the University of California's business game, the General Purpose Simulator, SIMPAC, SIMSCRIPT, and the like. Many of these management science techniques have been described at some length in previous issues of MANAGEMENT SERVICES.

Use of these more or less standard tools will substantially reduce the time required for systems de-

EXHIBIT 5



PLAN FOR DESIGNING AN INFORMATION SYSTEM

OPERATIONAL ANALYSIS EFFORT

PHASE I "INVESTIGATION"

OPERATIONAL ANALYSIS GRP.		GROUND RULES		SYSTEMS GROUP
Model Construction Model Network Computer Simulation	↔	Objectives Capabilities Criteria	↔	Source Input- Output Analysis Data Flow Analysis Documentation

TASK

- CONSTRUCT AN ALGORITHM AND MODEL AT AN OPTIMUM SYSTEM
- PREPARE A DATA NETWORK FLOW OF THE MODEL
- PREPARE A COMPUTER SIMULATION PROGRAM OF THE MODEL
- WITH THE SIMULATOR CONDUCT MANAGEMENT TESTING AT THE WORKING MODEL TO GAIN USER UNDERSTANDING AND ACCEPTANCE

TECHNICAL SUPPORT WITHIN PRESENT STATE-OF-THE-ART

- DEVELOPED AND PROGRAMMED NETWORKING TECHNIQUES (PERT/TIME/COST/PERFORMANCE -- NETWORK COMMUNICATION METHODS AND MATHEMATICS)
- TRIED AND TESTED OPERATIONAL RESEARCH TECHNIQUES (TRAFFIC AND QUEUEING -- LINEAR PROGRAMMING -- ETC.)
- DECISION TABLE TECHNIQUES AS AN AID TO DIRECT PROGRAMMING
- AVAILABLE SIMULATORS FOR DIRECT USE (THE GENERAL PURPOSE SIMULATOR, THE SIMPAC SIMULATOR, THE SIMSCRIPT SIMULATOR)
- ON THE SHELF BUSINESS GAMING PROGRAMS (THE "A" GAME, UNIVERSITY OF CALIFORNIA)

EXHIBIT 6

sign and thus decrease its cost. With their aid the task becomes an applied science rather than a research and development project. The significant part of the effort will be to determine the fundamental requirements of the particular organization and its management's essential decision-making requirements and then to fit these requirements or parameters within the appropriate "disciplines."

Meanwhile the systems analysts have the mission of preparing, as an output, a network reflecting present mechanized data dependencies, data interactions, and data flow and of defining "essential" and "secondary" data. The use of source input/output analysis and data network analysis will greatly aid them in this effort — and will speed their work.

When both groups have completed their assigned tasks, their next step is to unite their efforts to produce the initial data network or preliminary information system. The operations analysts will attempt to adhere to their streamlined model while the systems analysts will attempt to utilize, insofar as is possible, the "best aspects" of the installed applications and subsystems that are currently in operation.

This preliminary design will be reviewed, analyzed, and modified as necessary. Then a second-cut data network, reflecting the anticipated equipment configuration and required equipment capabilities, will be produced in the final design phase. All three phases of the plan for systems design are illustrated in Exhibit 7 on the opposite page.

A fundamental information system, designed with the aid of these new systems techniques, should go a long way toward solving the problem of the information explosion. Present-day data processing systems are pouring forth more information than anyone can ever hope to assimilate under present circumstances. The ability to generate information has outrun the ability to comprehend it.

Existing information subsystems and application-oriented techniques are not organized so as to permit effective study of the business complex in proper depth. Hence, it is nearly impossible to arrive at solutions revealing the optimum business decisions and the lowest-cost alternatives.

The time and money spent in designing a fundamental information system as outlined here should produce many benefits:

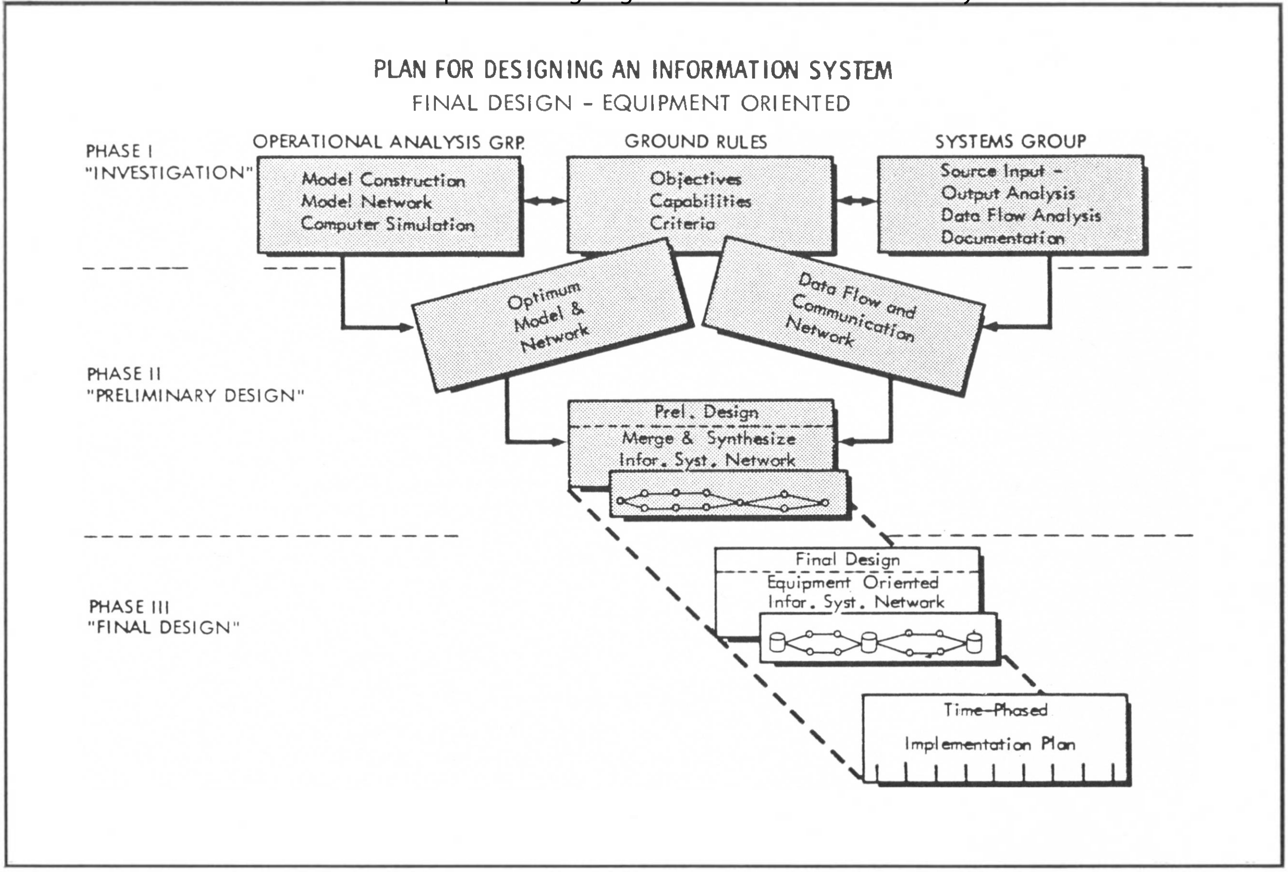


EXHIBIT 7

• By means of these techniques, the entire fundamental concept of operating the company is studied, perhaps for the first time. The result should be a single-thread flow of information.

• Previously unrecognized problem areas and bottlenecks will be uncovered. Data processing activities, manual or mechanized, which are now efficient and should continue despite the adoption of new methods will be isolated. The number of reports and the demand for meaningless data can be reduced, to everyone's relief.

• The study should produce a data processing system that justifies its cost since it will be based on solid present and future requirements. One objective of the study must be to find that point of balance at which the payoff expected from the data, documents, reports, and analyses produced is at least equal to — if not greater than — the quantity and cost of data processing to be produced. Since every step taken to improve the accuracy of data transmission increases the cost, the study must include determination of the degree of data accuracy actually required for effective management.

• The study — as a catalyst — will help to initiate new systems thinking throughout the organization to match third-generation computer equipment capabilities. It will incorporate or at least foster such scientific techniques as simulation and decision tables, standards engineering, operations analysis, and cost/performance effectiveness analysis.

Management decision making in the new era can be made at a level of information availability never before dreamed of. This means not just more information faster but mathematically pre-analyzed and pre-selected information from which meaningless data have been culled.

To maintain control and measure the results of business activity is management's responsibility. To do this within a complete information system, the manager must understand the model construction so well that he can assure himself that the solutions coming from these models will reflect policies that will lead to minimum operational costs. Otherwise a manager may be forced into rubber stamping a computer solution. If management is to manage, the decision makers must take the lead in understanding, designing, and approving the model of the fundamental information system.