# A General Approach to Information Systems Design

*The key to success in designing infor[illegible] type of business is recognition [illegible] information [illegible] of the organizational compon[illegible] business. Th[illegible]tion and storage can be elim[illegible] functional [illegible] files to integrate the system. [illegible] [fe]edback must be considered on [illegible] [c]ritical path methods can be [illegible] information system.*

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Direct system experience with the wide range of businesses represented by 50 of General Electric's 150 operating departments has enabled the company's Internal Automation Operation (IAO) to develop a generalized approach to the design of integrated business information systems.

To illustrate the breadth of experience on which this approach is based, GE's defense oriented businesses have as one of their major problems the allocation of engineers and development resources to the creation of complex electronic, radar, and missile guidance systems. The consumer product businesses find their largest problems in the control and distribution of finished goods inventories and the related problems of making short-range forecasts of consumer demands. In the heavy apparatus and producer goods departments, scheduling the manufacturing shop to reduce manufacturing cycle time and cut down the in-process inventory investment poses the largest problems.

To undertake a typical business information system design, IAO starts by organizing a combined study team. A team consists of four or five IAO systems designers—each with special experience in one of the functional areas of marketing, engineering, manufacturing, and finance—and a similar number of specialists drawn from the client department's organization. Thus the combined team has a background in depth of all major facets of the department's business.

Involving full-time specialists from the client department in such comprehensive studies insures that at the conclusion of the study the department has full knowledge of the special features of the total integrated system designed by the study team.

### General Electric's Internal Automation Operation

IAO was organized in 1959 as a component of the Industrial Electronics Div. Its mission: to reduce paperwork and improve management control by further automating the business systems of GE's operating departments. In addition, IAO was to help product departments pull together islands of automation in office and factory into integrated business information systems.

Since its inception, IAO has worked with 50 operating components of GE on a set fee basis. Because of the time required for full implementation of programs started, final figures on benefits are not available. However, conservative estimates place annual savings for typical departments in a range from \$150,000 to \$1.5 million net before taxes—with the average running at around \$700,000.

Systems Designers in IAO are drawn from the major disciplines of marketing, engineering, manufacturing, and finance. On the average, these men are 43 years old and have 16 years of experience in their functional fields.

It also is extremely helpful in gaining acceptance of any major system changes the team may propose because the changes are recommended by "native" department personnel rather than just by outsiders.

The study work for any business can usually be divided into three distinct phases: initial orientation and investigation, conception and design of the modified information system, and evaluation and scheduling of implementation.

## Orientation and investigation

What information now flows through the main stream of the business, where does it originate, who must have access to it, where is it filed, and how is it reported? To answer these and similar questions the combined IAO-client study team typically spends several weeks in research, investigation, and analysis. As many as 100 to 150 interviews might be conducted with key personnel in the various operating components of the department to get an understanding of present procedures, policies, and information needs of the business.

The objective in this phase of the study is to establish a sound foundation on which to build an integrated system for the main-line information flow of the business. What exactly is meant by main-line information flow? To define this concept clearly to its client departments, IAO has listed and defined the major subsystems that are involved directly in operating the department's main business—filling customer orders. The "Generic Business" of a typical department consists of most of the following subsystems.

*The pre-award subsystem.* Long-range forecasting, preparation of proposals, sales planning,

They've cut the wrong way — in some areas

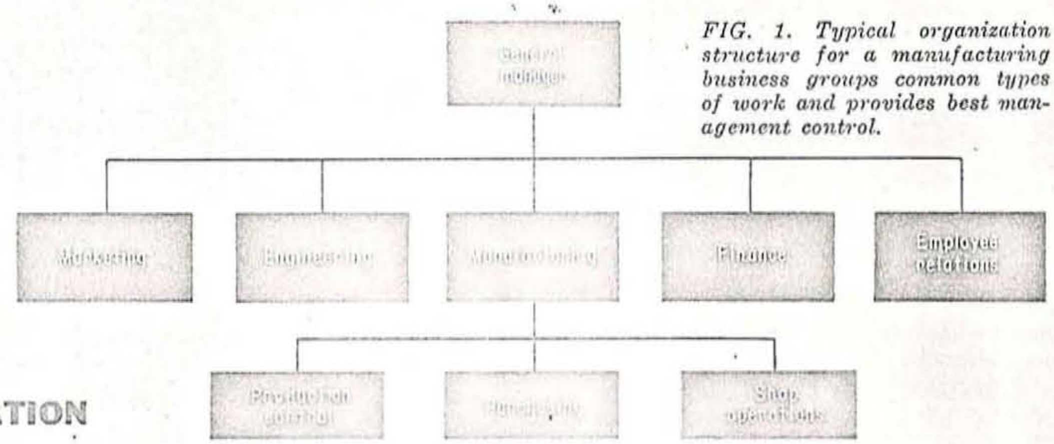



*FIG. 1. Typical organization structure for a manufacturing business groups common types of work and provides best management control.*

**BUSINESS ORGANIZATION COMPONENTS . . .**

**. . . SHARE INFORMATION SUBSYSTEMS**

| Information Subsystem | Organization component | | | | | | |
|---|---|---|---|---|---|---|---|
| | Employee relations | Engineering | Finance | Marketing | Production control | Purchasing | Shop operations |
| Pre-award | | X | | X | | | |
| Order processing | | X | | X | X | | |
| Design and documentation | | X | X | | | | |
| Make | | | | X | X | | X |
| Buy | | | X | | X | X | |
| Personnel acctg | X | | X | | | | |
| Finance | | | X | | | | |
| Distribution and service | | X | | X | | | |
| Management planning and control | | X | | X | | | |
| Management reports | X | X | X | X | X | X | X |

*FIG. 2. The information subsystems through which the business operates in almost every case involve more than one of the organizational components. For example, orders received by Marketing are designed by Engineering and promised for delivery by Production Control.*

selling, and the accumulation of marketing intelligence for better planning.

*The order-processing subsystem.* Editing, pricing, order input, transmission, credit check, open order file entry, order acknowledgment and promising, and editing for design if necessary.

*The design and documentation subsystem.* Information storage and retrieval, preparation of parts and material lists, regeneration of design from structure tables, and reproduction techniques.

*The "make" subsystem.* Short-range forecasting, finished goods inventory control, raw and in-process inventory control, operations and quality planning, scheduling, dispatching, production feedback, packing, traffic, shipping, and billing.

*The "buy" subsystem.* Soliciting and receiving quotations, selecting vendors, placing purchase orders, maintaining open-order records, receiving, stocking, invoice matching, payment and vendor rating.

*The personnel accounting and employee relations subsystem.* Payroll, labor distribution, employee histories.

*The finance subsystem.* Cost accounting, general and tax accounting, product cost structuring and analysis, cash collection and customer statements.

*The distribution and service subsystem.* Distribution logistics, field service, product performance reporting and analysis.

*The management planning and control subsystem.* Multiple contract program planning, resource allocation, master scheduling, budgeting and control.

*The management reports subsystem.* Selection and arrangement of information from all other subsystems into forms useful to top management for control.

One of the first problems, then, is to establish the relationship between the management organization, shown typically in Figure 1, and the subsystems of the generic business. Which organization components are involved in order entry and order filling? Who has responsibility for shipping and billing? Figure 2 displays this relationship for a typical department. The pattern will vary depending on local practice and the type of business. In some consumer goods departments, for example, shipping and billing may be the responsibility of Marketing, while in a producer goods business, shipping may be assigned to Manufacturing and billing may be done by Finance.

Having established the functional responsibilities for each area of the business, the next step is a major one in integrating the information system. An integrated system, in the sense used here, is one in which information once used and recorded by one element of the system is available for reference, reuse, and updating by any other authorized system element.

very shortsighted … in present operation … consolidated files

In computer-based systems, integration is obtained by establishing a common set of computer master files which are available for processing data at any point throughout the total system. The study team's next objective is to define in detail such a set of master files for the entire department's business operation. In a comprehensive study for a large department, this phase of the work may require collecting hundreds of different forms, documents, and reports used in the business. Each form must be analyzed for the information elements it contains, for the source, use and destination of each element, and for the files referred to in its processing through the system. The volume of each form that flows through the system at both peak and average periods is determined, as well as the size of the reference files involved in the processing. How many orders per week? How many shipments per week? How many labor vouchers? How many purchase orders? How many customers records in file? How many active parts drawings in file? How many operations planning cards active? Answers to these and many other questions must be determined in this research phase of the study.

**CROSS-FUNCTIONAL USE OF MASTER FILES**

| Information Subsystems | Master files | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Customer file | Product file | Open order file | Master assembly and parts file | Labor planning file | Plant master schedule | Vendor file | Open purchase order file | Accts. receivable, credit and collections | Accounts payable | Employee master record | Product development resource file | General ledger and subledger accounts file |
| Pre-award | X | X | | X | | X | | | | | | X | |
| Order processing | X | X | X | | | | | | | | | | |
| Design and documentation | | | X | X | | | X | | | | | X | |
| Make | X | | X | X | X | X | | | X | | X | | X |
| Buy | | | | X | | X | X | X | | X | | | X |
| Personnel accounting | | | | | | | | | | | X | | X |
| Finance | X | | | | X | | | | X | X | | | X |
| Distribution and service | X | X | | | | | | | | | | | |
| Management planning and control | | | | | | | | | | | X | X | |
| Management reports | X | X | X | X | X | X | X | X | X | X | X | X | X |

*FIG. 3. The hallmark of an integrated information system is cross-functional use of master files. For example, to process a purchase order ("Buy" subsystem), vendor name and address are found in the vendor file, material description in the master assembly and parts file, and the required date in the plant master schedule file, and an open purchase order is recorded. On receipt of material an accounts payable record is established, and the proper subledger account is charged.*

As these answers start to develop, the set of master files can be outlined. For the major mainline information flow from customer order to final shipping, billing, and collection, the master files should contain all the information elements required for normal processing of data. In general, each file will be used in several subsystems of the business, as shown in Figure 3.

The significant benefits of an integrated system stem from elimination of redundant filing of data in each functional area. With master files available to the computer there is only one source of data, accurate and up-to-date, for all management reports. No more cross-checking of reports is necessary to insure against inconsistencies between different source files that may have been updated at different times. For example, the output reports of Manufacturing will always agree with the shipping, billing, and finished goods inventory reports of Finance, since they are both based on a common open-orders master file; planned operation labor will always agree with labor cost charged to each such part in inventory since both are based on one common parts-and-material master file.

There is an important implication here for the computer equipment. If paper or "hard-copy" files in the separate functional organizations are eliminated, the key personnel in the operating components must have access to up-to-date information on a timely basis. This implies that, hand-in-hand with design of the computer master files, the study team must be shaping up a set of computer equipment specifications scaled to meet the individual demands of the operating people. Thus there is no clear, sharp division between the investigation phase of the study and the system concept and design phase which follows.

## System concept and design

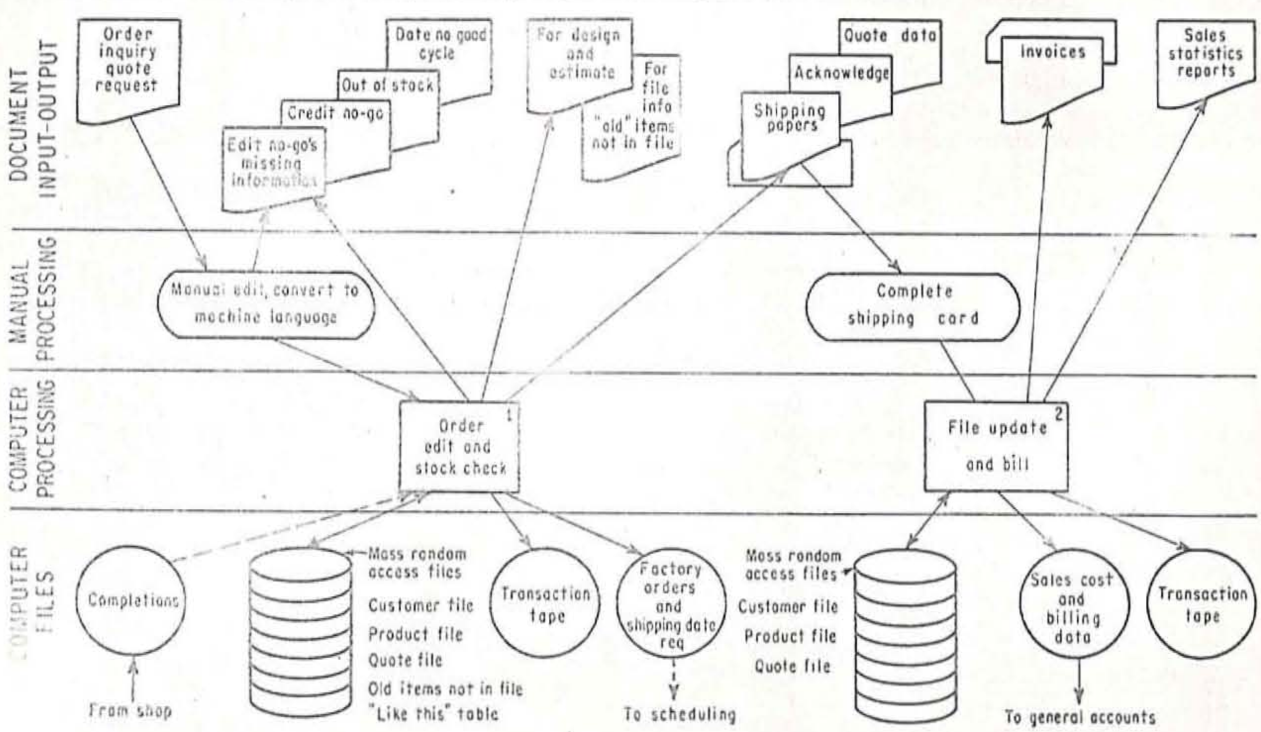
The intellectual process of developing the system design for an integrated business information system, like most inventive work, has no clearly established and defined pattern. There are however certain basic objectives which the system design study team keeps clearly in view during the design phase.

1. *The system should be totally integrated.* In developing concepts, no technically feasible approach to a specific subsystem problem should be discarded because it does not seem economically justifiable from the standpoint of its own subsystem. Its evaluation and justification should depend upon the effect on the entire business system; gains in one area may outweigh losses elsewhere. For example, the automatic on-line feedback of job completions in the shop might prove of little benefit to the shop foreman or dispatcher. But for production scheduling, payroll, cost accounting, and customer service in answering inquiries about orders, it can be extremely valuable.

Wow! This point sounds better than it is.

2. *Get data early and hold it.* At its first appearance in the business system, capture all possible data in machine language, punched cards, punched paper tape, or digital transmission signals that enter a computer directly. Recall of such data from the master files for subsequent use is more accurate and almost always more economical than recreating the data manually. For example, when customers' orders are received in the district sales office, convert them there (after edit) into digital codes by teletypewriter or other system that transmits them

*FIG. 4. Simplified flow diagram for typical order editing, stock shipment and billing functions shows various information processing stages and computer files involved.*



directly into the data processing system at the company's headquarters.

3. *Facilitate communication between men and machines.* Where manual activities must be interspersed among mechanized ones in the information system, provide a communication medium understandable to people but readable by the data processing equipment. For example, a job voucher for the shop should contain part number, operations, and required quantities in plain language for the workman's instruction. It should contain also, however, the same data in prepunched form. When the work is completed, the man can use the voucher card to transmit its prepunched data to the computer from a feedback device in his work area, adding his identification code and the quantity produced by simply setting a few dials.

Where is the overall system concept + framework —

With these fundamentals in mind, together with a seasoned knowledge of available techniques, the systems designers proceed, subsystem by subsystem, trying, evaluating, and compromising until the best over-all system is achieved.

The information systems of various businesses have much in common but there are very important differences too. A few examples of questions the systems designers must resolve will illustrate this.

BAKER -- SOP III DECISIONS

- Is unit forecasting of probable sales, item-by-item, needed for inventory control? The answer would be a definite "yes" in an appliance business but probably "no" for the large turbine or defense radar business.
- Should engineering design information for each end product be stored in part-by-part detail in the computer files or can parts lists and variable data for each order be generated from a set of structure tables covering a whole class of products? This depends upon how variable the designs have to be from order to order as well as the frequency of the orders received.
- Is immediate on-line communication of customer order data necessary? Will more conventional means do the job at less cost? The capabilities and costs of data communication facilities, the cost of inventories, and the demands of customers must all be considered here.
- Will fixed-cycle scheduling of work through the factory result in acceptable final delivery dates or must a more advanced scheduling rule be used? Should this be tested by simulation on a computer?
- Is it practical to close the supply loop from factory to distributor to factory by packing prepunched cards with the product so that, as the goods are sold, the cards can be returned to generate replenish orders automatically?
- What kind of feedback system is needed to get information on job progress back to the production control center in time for issuing the next schedule? Daily scheduling is frequently desirable. With a computer this is possible provided that the feedback system can keep pace.

Systems designers need solid technical knowledge to settle these questions but they also must be diplomatic so people in the client department will understand and accept their proposals for changes.

Flow diagrams in at least two levels of detail must be prepared to convey the designers' plan to client management on the one hand and to computer programmers on the other. Figure 4 is an example of the first, or top level kind. Viewed with similar diagrams for the rest of the system, it gives a broad but definite picture that management can quickly comprehend. It also serves as an assembly drawing for the more detailed diagrams.

The top-level flow diagrams show the generic types of data processing equipment used for the various operations but there is nothing to indicate how many duplicate equipment units will be needed to handle the volume of work. A minimum number may be dictated by parallel operation requirements (for example, computer tape handlers), yet this is not the whole story. The systems designers have to specify the size and content of each record being processed, as well as the number of records of each kind to be handled per day. Only then can they calculate the running time of alternate equipment configurations and ultimately select the arrangement that best meets the operational and cost objectives.

Flow charts and equipment lists are only expressions of a final goal; they do not show how to get there. The next step for the study team—an important one—is implementation scheduling.

## Implementation scheduling and financial evaluation

A schedule of the many tasks to be completed during the implementation of an integrated business information system is an essential part of the system design work. Master files must be set up, codes established, routines programmed, and the computer installed. All of these activities have to be scheduled in proper sequence, recognizing that certain ones must be completed before others can start. IAO has frequently utilized task event networks to define the precedence relationships of the several hundred tasks which may be required in implementing a major system. Such a network permits individual time estimates to be made on small finite elements of work, thus providing a better foundation for the scheduler. To analyze these task event networks, techniques such as PERT (Project Evaluation and Review Technique) and CPM (Critical Path Method) have been employed. With the time estimates and manpower required for each task nailed down, a standard computer run points out which tasks are on the critical path so that they can be given special attention. (Small networks can be analyzed manually). The analysis also helps in scheduling individual tasks to avoid sudden changes in work load on systems and programming personnel.

With an implementation schedule, the month-by-month costs of implementation personnel and the conversion dates for the various subsystems are established. Cost savings due to system improvements are estimated for each time period in the future as the improvements become effective. Added costs of operations are subtracted from these savings estimates, considering the scheduled date for added computer rental and the like. Subtracting the implementation and startup costs in the proper time periods yields the net savings before taxes—always one of the principal objectives of the study.