Management and Engineering Information Systems

Considerations for Their Implementation

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Recent experiences have given pause to those engaged in developing information systems for application to management and operational control. Although many new diverse development efforts have been undertaken to exploit computers, new patterns of implementation have not yet clearly emerged. Nor have the operating results adequately met the aspirations proposed by specialists in the field over the past few years. There remains ample agreement that the promises still hold, but their realization is more complex to achieve than has been anticipated. Judging from the variety of activities in the field, the baffling problems of realization are benefiting from developments on several fronts. These range from factors of management commitment to the technical aspects of computer performance.

Reconsideration of these factors appears to be timely now. Many users of information services and suppliers of services and equipment appear capable of combining their recent experiences to exploit the advanced capabilities being offered by a "new generation" of computers. Close cooperation will remain a key factor although the vexing problem of determining respective roles in development and implementation efforts requires further resolution.

This paper outlines the fundamental information requirements for serving complex operations in developmental/manufacturing organizations, and finally describes some of the data-processing techniques requiring continuing development to better serve these needs.

Conflicts in Implementation

Perhaps the most evident manifestation of disappointments which can arise in newly developed information services for management control is to discover that initially specified needs are subject to rapid change. The result is that information services always appear inadequate to the needs of the moment. This symptom of trouble traces to these basic causes:

- At the present state of art, the implementation of highly automated information systems requires much time and precise, detailed work. Present techniques depend on explicit definition and coordination of basic data organizations and procedures to derive the information structures relevant to the users in their operational situations. The delays in a protracted implementation program tend to induce changes in requirements which, in turn, compound the detailed work of re-definition in a pernicious cycle. The information system appears to the users to be too static in capability, dealing adequately with well-structured, historical information, but faltering in the face of rapid change.
- The present practices of management tend to induce rapid changes in information needs. This is due in part to vague understandings and definitions of the interactions of the many functional activities in an enterprise. These functions are organized to set up manageable operating units but they also create disruptive interfaces. Frequently, too, there is pressure to implement information services in a piecemeal fashion in operating units which *may* appear capable of generating early payoffs, but which may induce disruptive changes when integrated with the information requirements of other operating units if not carefully planned.
- However, rapid change is also due in part to an intrinsic need for change be-

cause of genuine improvements in management practices, and these improvements must be accommodated in a viable information system. In the long run this area holds the greater promise since management's ability to change can be a measure of the vitality of an enterprise. This highlights the notion that the information system is a servant of the users and must be responsive to their needs.

Aims of Systems Design

A good appreciation has been developed for the power of computers in the fast and accurate handling of large amounts of interacting complex information. Yet the design of information systems must still be regarded as a compromise between the specification of information requirements and the application of data-processing techniques, involving considerable judgment to optimize the system.

The aims of systems design may be highlighted by contrasting how the data organizations and procedures are viewed. From the standpoint of applying data-processing techniques, the definitions of data organizations aim at minimizing the costs of storing and retrieving large volumes of data through the use of efficient coding and data traffic-handling techniques; the definitions of procedures aim at minimizing costs and time in deriving and translating the information structures into the relevant framework required by the users through the development of compact algorithms and data processing programs.

From the users' standpoint, information requirements focus on the over-all information structures which can be directly linked to operational functions. A good exposition of arguments on this concept can be found in an early but enduring paper in Reference 1. It follows then that the definitions of data organizations aim at maximizing the symbolic relationship between data and operations so as to facilitate communication with the data base; the definitions of procedures aim at maximizing the flexibility in deriving new information structures relevant to changing operational situations.

A few guidelines may be drawn from these factors to aid further development:

- Suppliers of information-handling services and equipment must continue to stress the development of technologies which facilitate interaction between the users and the machines so as to accommodate readily the reorganization of data and procedures. This activity must be supported by the development of system design methodologies which aid in the more direct synthesis of designs, relying less on the elements of intuition.
- With the aid of suppliers, users should define information requirements in a broad, fundamental way to ensure that excessive changes, due to a hasty implementation program, do not paralyze the information system.

That is, with the present state of the art, the specification of requirements and the capabilities of technology must meet halfway to ensure success. Too many systems have been implemented to the outcries of "no flexibility," on the part of the users; and on the other hand, "they can't settle on what they want," on the part of the suppliers or implementing groups.

Since the development of highly automated information systems is in a transition phase, it seems unreasonable to expect implementation of finely detailed information services to the largest possible variety of users in a system. A more reasonable task, as a next step, is to stress the implementation of well defined basic requirements which integrate the basic information flows of the functional units of an enterprise, and which can then serve as the basis for more advanced services in an orderly progression.

Objectives and Roles in Implementation

Experience has shown that a reasonable chance of success in achieving effective information systems depends heavily on the objectives and roles of several participating parties. Results of a study of such experiences are described in a well noted paper cited in Reference 2.

The key roles to be discussed here are played by controlling management, operating management and staff specialists in user organizations, and also by the suppliers of information services and equipment.

Although some writers (Reference 3) have attempted to draw a sharp, absolute stratification between controlling and operating managements, it is proposed here to treat the relationship in relative terms.

Management is a multi-ordinal concept with similar relative requirements for integrating information flow in both the horizontal sense between operating functions, and in the vertical sense between levels of management. As one writer implies this (Reference 4), "The information needs of the rank and file deserve at least as much if not more attention as those of management." The important relative distinctions to note are these:

- The lower ranks of operating management and personnel are more concerned with detailed, internal operating information which deals with narrower scopes of operations. The data contents may change relatively quickly but are more stable in information structure.
- The higher ranks of management, where longer-range strategic planning is a greater part of their responsibilities, are concerned with mixtures of abstracted operating information and external information. The data contents may change more slowly but the information is not well structured, and ready re-structuring is a vital requirement to derive relevance to the user's broader needs.

Guidelines for implementation derive from the following propositions:

- Controlling management must take responsibility for the leadership of the implementation plan.
- Staff specialists must act as agents of controlling management in developing the plan.
- Operating managements must assume responsibility for carrying through the plan.
- Suppliers should work closely through the complete implementation program.

These propositions are supported by the following arguments:

Controlling management must indicate, by its active leadership, a strong commitment to innovation in information services which sets the pace for operating managements to follow. It must determine, by working through the staff specialists, the scope of the information services to ensure that the vital information flow is properly integrated with the total management process. Their own information needs are provided for, and the information system is thus a tool for defining the responsibilities of operating managements by specifying the flow of information to and from these positions. Controlling management must also apply and monitor the controls to ensure that the implementation program is maintaining momentum and achieving feasible results. A well planned sequence of steps is required which can be digested by operating personnel and which meets the objective of growing payoff with minimum disruption.

Although the role of controlling management to ensure success is quite clear, the interplay of staff specialists and operating management is a sensitive area. Operating managements, because of their drive and budgetary responsibilities, must carry through the program, drawing on the skills of the staff specialists in the technical areas of management sciences and computer systems. A step-by-step plan aids in assigning responsibilities to those operating groups which are users of the services.

However, the staff specialists, working closely with controlling management, are in a better position to specify the over-all architecture of the basic information system. Nevertheless, the operating groups must assume key roles in specifying and evaluating detailed requirements to exploit their knowledge of detailed operational functions, and to accept commitment to the plans. The systems studies of the staff specialists yield broader and more objective recommendations which integrate the activities of the operating function for better over-all management control. There are information flows which are beyond the scope of individual operating managements, or which may affect them in ways that they are reluctant to implement themselves. The scopes of interest of operating managements are usually to improve their local information services in ways that they can unilaterally get feasible results or optimize their own operations.

Suppliers can give aid beyond advising on the technical problems of computer application. Experience has shown that innovations are always being developed through serving in the role of a close consultant who can objectively view the internal operations of an organization.

Examples

The effect of these factors can be put into perspective by examining several examples.

In recent years computers have been applied to information systems serving the customer service functions in airline operations. These systems emerged after broad thinking defined the fundamental purposes of the selling functions and their relation to other operations, i.e., providing selling agents ready accessibility to information on available airline space for offering to prospective passengers, and the recording and processing of book information for dissemination to airlines operating personnel for operations planning. Earlier efforts focused on the narrower problems of message communication—a responsibility of a communication facilities engineering group in another operating division. Improvements in these functions did not materially aid the selling functions which continued to support large clerical staffs to process booking information manually. Redefinition of the operating functions has led to the implementation of on-line information systems where the selling agents are directly aided in their jobs, and thus become the direct source of operational control information through integration in a computer-based system. Here the information flow cuts across operating groups in a way that required controlling management, working with staff specialists, and the consultation of suppliers, to broaden the scope of the information systems development. However, responsibility for implementation was undertaken by operating management.

Another example is in the control of developmental/manufacturing operations. Information services grew out of the application of computers to the accounting functions which provided performance reports to operating managements as byproducts. These reports were quickly recognized as inadequate, needing re-interpretation by operating managements because the information was structured in accounting terms and its timing was not usually consistent with the dynamics of operations control. Early efforts of operating managers focused on narrow problems most pressing to them, such as the development of on-line information systems to keep track of production order status for quickly locating jobs in fabrication and assembly operations to aid short-term dispatching and expediting functions. In the broader fundamental problem, it appears that fabrication and assembly operations are affected more by the long-range effects of operations outside these functions, e.g., an expediter trying to break a bottleneck in assembly may use the information system to determine quickly that the purchase or fabrication of parts has not been completed, but this does not get the assembly operations moving.

Better long-range scheduling and job status keeping are needed to point up incipient problems or unrealistic planning so that pressure can be applied in other departments long before the short-range crisis can occur. In this case, the need for quick, on-line communication may be alleviated and the expediter becomes a "puller," systematically working from well analyzed job status reports rather than a "pusher," interrogating the information system and chasing jobs through the operations. The effectiveness of the system, however, hinges on the ability to maintain an accurate, timely data base through carefully designed transaction reporting services.

Information Requirements

This section of the paper outlines the basic information requirements for serving complex operations in developmental/manufacturing organizations. What is proposed is aimed at meeting the requirements that a basic architecture be specified to minimize change during implementation, and to serve as the basis for accommodating innovations and additional services.

Environment

The operations of complex developmental/manufacturing organizations are strongly influenced by the product development and engineering activities:

- At the strategic business planning level, the acquisition of new business is derived both from the contract bidding of highly customized products to customer specifications, as well as from the product planning of proprietary product families offering optional configurations to meet varying customer needs. Because of innovations in design and usage, costing and pricing are complicated.
- Complexity of the products requires continuity in maintenance of the records of all product configurations throughout their life cycle in the field.
- The large efforts in engineering design

are usually organized on a project basis, and must be scheduled to overlap the manufacturing activities heavily in order to achieve acceptable over-all delivery schedules. A careful control of engineering operations and placement of an additional burden on the planning of manufacturing is required to minimize the impact of engineering changes.

- Because of the stress on innovation, engineering design must have freedom to create new designs. This freedom must be coupled with a careful evaluation process to determine acceptable product configurations and the responsibility to document them carefully.
- Frequently, because of relatively smaller manufacturing quantities and small common usage of parts and innovations in processes, learning curve effects do not come into full play, and therefore more detailed instructions are required.

Scope

The over-all scope of the information services, outlined in Figure 1, shows the relationship of information flow to the operational activities. On the left are the creative activities which produce value-adding outputs flowing from higher management business planning through the product definition and manufacturing operations. It should be noted that an appreciable part of the productive effort, especially in the product definition functions, yields information which is in itself a tangible asset and forms part of the information base for controlling physical manufacturing operations. These functions will be described further. On the right are the related information services, flowing from the operational planning through the operational control and management data.

The information flows can be described in terms of closed control loops. The boxes represent the procedures of the operational, planning and controlling functions; the circles represent major files forming the data base. A long-range control loop is formed by linking the operating and financial information flow to the project and master scheduling function where it is combined by higher management with external information to establish over-all business strategy. This loop aids in contract bidding, in product and market planning, and in capital and resource allocations.

Short-range loops are formed to plan manufacturing operations by linking the order control and inventory control functions with the requirements generation function. Here they are combined with the product definition information and the master schedules to generate work orders to authorize and schedule purchasing and manufacturing operations. In addition, the requirements generation function derives short-range forecasts of facility, labor and cash requirements to aid in resource, production and purchase planning.

A short-range operational control loop is formed by linking the inventory and activity transaction reports from manufacturing operations to the order control function. Here they are combined with order status information to evaluate progress, and generate dispatching and expediting orders to sustain manufacturing plans.

Product Definition

The purposes of the product definition functions are to:

- Capture and structure all design information defining the product specifications
- Evaluate all design proposals and select the effectivity of chosen configurations to the particular end products
- Define the manufacturing processes and tools required

These purposes are accomplished as described below and as shown in Figure 2.

- Engineering design data are recorded in two parts by separate handling of the digital descriptive data and the pictorial drawings. The digital data are captured in computer storage for manipulation, including the bill of material data and all control data specifying engineering change variations and end item effectivity. The pictorial information is either retained on conventional drawings or captured on reduced film copy for mechanized handling. Changes to the drawings are thereby reduced since many of the changes occur in the descriptive data.

Convenient cross-reference numbers link the mechanized descriptive data to the appropriate pictorial drawings.

- All designs and changes are recorded in a common data organization in the engineering parts list file (EPL). Each part or assembly is assigned a symbolic identifica-

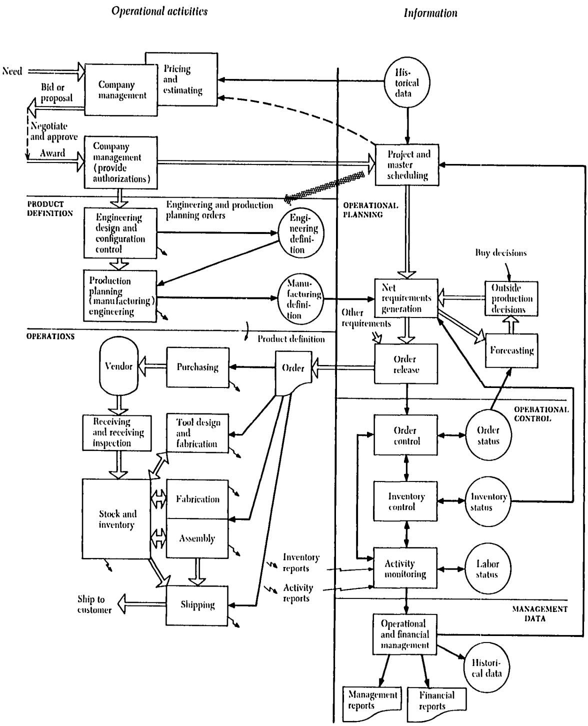


Figure 1 Advanced Information System Overview

tion number and a record with fields. These fields list a bill of materials for all material descriptions or component part numbers and component assemblies numbers which are ever proposed as a part of the subject part or assembly. Each proposed configuration is assigned an engineering change number and correlated to the component bill of material data by status codes which may be represented compactly in a matrix form. This arrangement aims at extending the conventional level-by-level method of handling bill of material descriptions to include the complete chronology of design. Engineering is thereby given complete freedom to design and clearly record new designs independently of later end item effectivity decisions.

● An engineering change suspense file (ECSF) is maintained for aiding the review and approval of proposed changes. The release and configuration control function re-

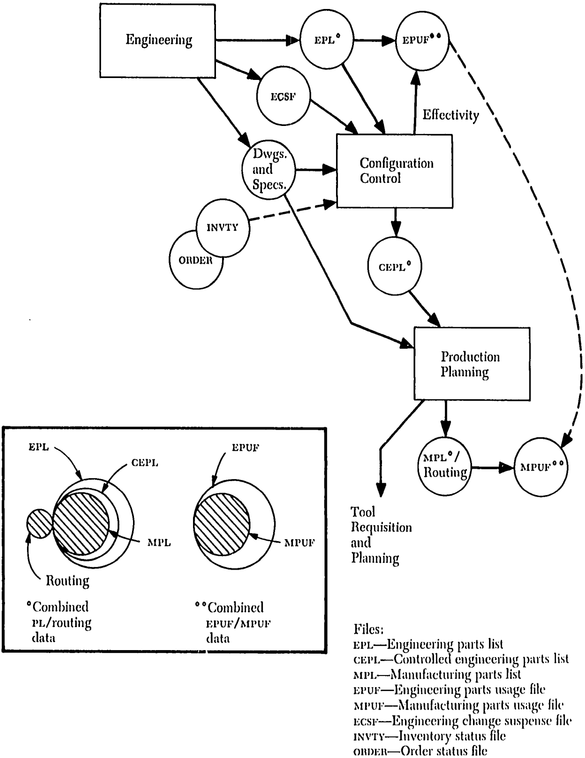


Figure 2 Product Definition Subsystem

views designs and changes. The configuration status codes are revised to reflect the approvals of particular change variations, and this subset of the EPL file becomes the controlled engineering parts list (CEPL). However, the complete chronology of design is maintained in the common parts list file.

- The configuration control coding is carried over to the engineering parts usage file (EPUF) which is constructed from the parts list file. Approval of engineering changes is usually restricted to effectivity on certain end items. The control coding in the EPUF correlates the change variation numbers to end item serial numbers.

• A closed-loop control is formed by linking the configuration control function with the inventory and order control functions to evaluate the impact of proposed engineering changes on operations, and to issue new orders to stop or expedite manufacturing operations.
• The coding of engineering change variations and end-item effectivity provides change variations to be reflected through all higher-order assemblies. The operational users of the end items are provided with complete information on servicing and interchanging at all levels of assembly.
• The manufacturing and tool engineering functions have direct accessibility to the structured CEPL files to create the manufacturing parts list (MPL), routing data and tool specifications. The MPL is created by recording the CEPL file, using the common format and providing for proper cross-referencing where new synthetic manufacturing assemblies are specified to replace engineering assemblies. The MPL routing file also contains the material routing and operation time estimates and historical time data. The manufacturing parts usage file (MPUF) is based on the EPUF and the manufacturing configurations in the MPL.
• The MPUF file is a key input to operational planning and should be kept as current as possible by short-cycle file maintenance runs to quickly propagate the effects of engineering changes.

Operational Planning

The purpose of operational planning is to determine and issue instructions directing manufacturing, tool design, and procurement functions to perform the actions required to satisfy authorized end item delivery schedules. These functions are accomplished as shown in Figure 3. The lettered circles identify the files used in processing; the numbered circles are logical interconnections.
• Master scheduling is derived from the over-all project and product scheduling for engineering and manufacturing. The use of PERT and related scheduling techniques would be an aid in these activities. Three files are derived, which can be readily changed to accommodate changes in business planning. These are: final assembly position start-schedule for each end item; end item allocation to market authorizations and breakdown by end item lots.

Spare parts orders are converted to a similar format for concurrent scheduling.
• Net requirements are determined by scanning the end-item usage of all parts, as specified in the parts usage files (MPUF), and by comparing the lead time requirements specified in the routing or planning file with the master scheduling files to generate requirements for the current planning cycle. The gross requirements thus derived are netted against the inventory files and consolidated into job or purchase orders which may then cover several authorizations.
• Orders so generated may be selectively released on an automatic basis or made subject to human review, particularly where completion dates cannot be met by routine scheduling. This release may occur frequently in connection with engineering changes or master rescheduling, and this process may be used as a planning tool to evaluate the effects of proposed changes to the schedule.
• Advance material requirements for pre-released items can be derived to aid the procurement functions in negotiating firm delivery commitments from vendors.
• The load forecasting function generates requirements over a longer planning horizon to aid in forecasting detailed needs for labor, facilities and purchasing. Detailing needs at the part number and department level can also aid in decisions on outside production to relieve overloads. Adjustments to the longer-range operational planning depend primarily on human judgment to select the alternate courses of action so that the forecast information serves chiefly as a guideline and evaluation tool.

Operational Control

The purposes of the operational control functions are to:
• Monitor the execution of operational plans
• Maintain operational data files
• Assist operational activities by evaluating and reporting deviations from plans
• Create transaction records for management and financial uses

As shown in Figure 4, these functions are accomplished as follows:
• The order control function creates and maintains data images of all authorizing

documents in the order file. These records contain the authorizing document identity, source of authorization, object of work, type of action required, location of work, and action schedule. It is scanned on a short-term cycle to produce operational listings for guiding each work center in dispatching its short-term action schedule or expediting particular jobs requiring special attention.

- The inventory control function creates and maintains inventory records using the order control function as a source. Information is maintained on current stock levels and also on future actions to aid in requirements planning. This requires additional information on cumulative counts of inventory actions and entries on the effects of outstanding orders. Debit/credit transactions against inventory records are reported to financial data processing to adjust authorization charges. Some inventory items are also handled by an automatic re-order procedure generating orders for replenishment.
- The activity monitoring function closes the operational control loop by reporting all actions against the authorizing control files in the form of labor reports, material actions, and status changes such as completions of task orders. Because of the volume and dynamics of operational actions, timely and accurate reporting is vital. These reports generate transactions for financial data processing and operations analysis in the management data subsystem and also update operational status.
- The procurement support function obtains request-for-purchase orders from order control to be used as a guide for buyers. Considerable judgment is needed since vendors must be selected from filed rosters, quotations may be required, and negotiations may follow. Purchase orders actually issued are captured by order control for follow-up action in reminders to vendors and receiving notices to manufacturing operations.

Management Data

Much of the management data for controlling performance and shorter range planning is imbedded in the functions previously described. The lower ranks of management are more concerned with time as a performance measure, although the effective use of their assigned resources implies cost effectiveness as well. The higher ranks of management are explicitly concerned with both time and cost data to measure current performance, and to combine these current data with historical versions to project long-range plans.

Much of the management data processing then is aimed at converting operational reports into cost figures, and at distributing these costs by product and organizational categories. Analysis of product categories can be made directly in the parts lists file structure, and can be utilized for detailed cost control in operations and pricing of product end items. Historical data on product category costs can be used in estimating new products costs and in the master scheduling of new product programs. Historical trends in product deliveries aid in decisions on phasing out old products.

The analysis of project categories aims primarily at evaluating the performance of operating managers in project progress. Distributions of cost data and analysis of scheduled performance are done against functional departments and project authorizations. Flexibility is needed in establishing and reporting against a diverse set of authorizations specifiable by management. There are diverse strategies in organizing productive effort among functionally oriented operations and project orientations, and these strategies are constantly shifting. In certain cases of contracted developments, the project is completely identifiable with the product, permitting compact reporting and analysis information structures. However, in general, the responsibilities are delegated to functional operations and project authorities under a network of authorizations which can be combined in many ways to analyze performance.

Data Processing Requirements

This section of the paper describes some of the data-processing techniques requiring further development by examining some of the key information handling requirements.

The parts list data, with all the variations, are the most fundamental and vital element on which the information services for developmental/manufacturing control are designed. The sheer volume of data to

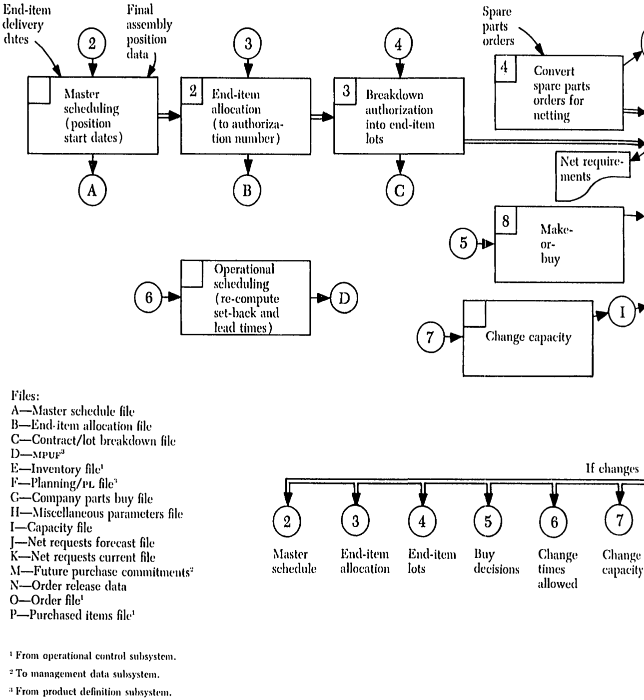
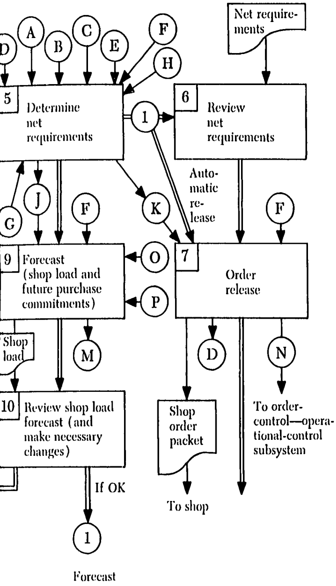


Figure 3 Operational Planning Subsystem

be handled and the roles these data play in deriving the information structures relevant to operations dictate most careful design. The data organizations and procedures exemplify the development of a generic class of data-handling techniques that have wide application.

Network Structures

Parts lists data are organized by users into network or "tree" structures to aid in conceptualizing the product structures. In the most complex cases where there are extensive engineering change variations, many configurations of end item effectivities and high common usage of parts, the structures are multiply-linked networks. To aid in the operational handling of individual parts or assemblies, each of these can be linked only to its next level of components. But to aid in establishing relationships of the complete product structure, each part or



assembly may be linked to its fellow components in any assembly, in usages at the next level of assemblies, in usages at higher levels of assemblies, and in final end items including spare parts.

Similar network conceptualizations can be extended to operational structures linking the product definition structures to operational control activities, and linking the operational activities to one another. For example, each part number can be linked to inventory control records which may in turn be linked to work order records controlling several outstanding work orders. These work orders, in turn, may be linked to several authorizations, and so on through a very complex network of relationships.

Two requirements of the information systems design are to develop data organization and procedural techniques to retain symbolic representations of this network conceptualization and to derive efficient methods for manipulating them. Because the network representation implies linkages threading in many directions, the data organization must define elemental definitions of records readily accessible on an individual basis. The linkage pointers must be defined as symbolically identified fields associated with these records in varying numbers as required to define all required linkages.

Random Access

The over-all data organizations obviously imply the need for random access storage which offers several advantages to users. Direct accessibility to the data base permits fast responses to inquiries of users who must perform timely analyses and actions within the dynamic flow of operations. A parallel capability is the updating of the data base to maintain currency of information. These services can be very important, for example, in aiding fast-moving fabrication and assembly operations. Even where fast responses to meet operations are not required, the direct manipulation of the data base by users offers advantages. Human operators can combine their intellectual skills with simple, standardized data manipulation programs to perform complex data-processing procedures with immediate displays to guide processing and check validity of results. Here the interaction is conversational in nature, and the fast responses work within the thought cycle of the operators. As an example, much of the structuring of the complex network linkages in the product definition files can be handled this way.

Again, in both automatic and human-aided data processing, efficiency is gained by having ready accessibility along any of the threaded linkages in the data organizations. For example, after the configuration codes have been set for basic engineering

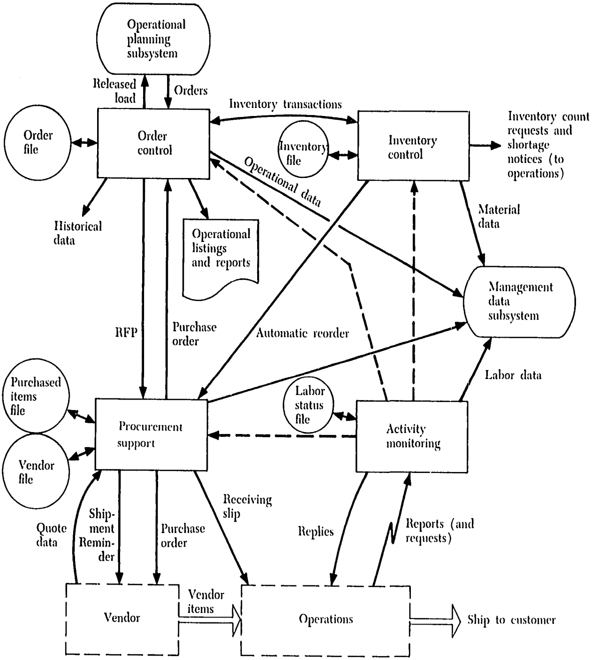


Figure 4 Operational Control Subsystem

changes by human operators, these changes can be correlated by automatic processing to establish new change codes for propagation to the higher levels of assemblies affected.

Symbolic Referencing

The design of random access storage systems requires the development of storage allocation schemes for mapping data records into available storage space and for referencing these records symbolically. The logic of the procedures does not specify particular schemes, but does stress the use of symbolic identifications which permit flexibility in modifying linkages between records without disturbing the internal data storage allocation. Allocation is determined by a compromise between data traffic-handling requirements and the performance characteristics of storage devices. Usually designers use an intuitive design process to specify organizations of files consisting of records with compact aggregations of data fields which are frequently used in executing common procedures. However, these fields may be used in independent procedures, and they may have independent linkages to other records. The use of symbolic linkages, then, implies the need for a directory to translate the symbolic identifications of records to internal storage addresses.

Although the aggregation of data fields into records does compact the files and does improve handling efficiency, it tends to freeze the record structures by fixing the field locations within them. The burden of identifying fields is shifted to the procedures, which are then frozen to the internal record addressing structure. Changes to the record structures have a very disturbing effect. This effect may be resolved by retaining symbolic identification in the procedures and by providing a format identification table for each class of record to be consulted at execution. The processing flexibility may be improved by a combined programming system which provides this interpretive addressing capability, as well as the conventional compiling techniques. This approach may justify development.

Present methods for defining data organizations into files, records and fields, and for allocating data storage are largely intuitive compromises between logical representations of operations and data-handling capabilities of equipment. Although some of the procedures can be handled by manipulating the threaded linkages in the files, some of the processing can more efficiently be handled by sequentially organized files. A further requirement is implied for addressing directories which permits records to be organized by arbitrary sequences but preserves their accessibility by direct symbolic reference.

Procedural Languages

Given the data organizations described above, the development of procedural languages aims at designing a set of high-level operators for retrieving and manipulating these data structures by way of the threaded linkages. Here again, there is the need for retaining a close symbolic relationship to users' operations by designing procedural operations closely related to the language of operations so that little training and effort are required to prepare programs. Each operator implies powerful capabilities in processing sets of related data specifiable by the symbolic linkages without requiring the programming of a step-by-step data-handling procedure. These operators are implementable by independent, interpretive subroutines callable at execution time and designed to maintain separation between data organization and procedural logic.

Design Methodologies

There is also a need for the development of design methodologies which allocate storage to data organizations based on traffic requirements. Each type of storage device has characteristic performance capabilities for handling volume and traffic. The traffic requirements of various files and even of records logically defined to be part of a common file differ widely, and may require distribution over several classes of file devices. The design methodologies, therefore, aim at aiding in the basic definition of data organizations and in following through the specifying of storage allocation.

Conclusion

Experience has proven the value of implementing information services with computer-based systems. Early successes have resulted from applications in areas which are somewhat peripheral to the mainstream of management and operational activities. These areas have been easier to isolate, define, and keep stable for implementation. This has tended to mask the difficulties in serving those areas where information flow is a vital part of the complex and dynamic interaction of operations.

Success in these areas requires a greater management commitment and more careful planning to better serve the total management process. A deeper understanding of user operations is required on the part of suppliers, to guide the development of equipment and data processing techniques which directly aid users in their operations and which are responsive to their changing needs.

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