THE APPLICATION OF DIGITAL COMPUTERS TO THE TOTAL INTEGRATED MANAGEMENT SYSTEM'S CONCEPT

by

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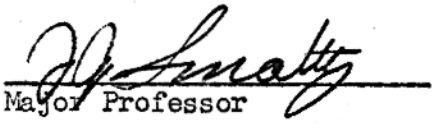

Major Professor

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INTRODUCTION

Background and a Working Definition

The use of electronic digital computers presents a very interesting paradox: Although it is a well-known fact that the computer is a powerful tool for processing the data of business, industry, and science, it is also true that many computer installations are losing propositions -- that is, they do not pay their own way in either increased profits or convenience and efficiency. The truth of the matter is that the computer, like any other machine, has the potential of doing a great deal of useful work -- but only if used according to an intelligent plan. A house is built correctly in a much shorter time if good blueprints are followed, or an experiment can be more meaningful if it is preceded by a good experimental design. In the case of the computer, following an intelligent plan means harnessing the power of this electronic tool in the framework of a well-designed, effective, data processing system. (In this context, a system is an assemblage of interdependent data processing functions, for example, order entry and invoicing, united by a regular and preconceived pattern of data flow.) Such an organized utilization of the computer's power eliminates inefficiencies and enables the user to realize both the profit and conveniences which the modern computer is so well equipped to provide.

A working definition of Integrated Data Processing, which has gained general acceptance, reads as follows: "Integrated Data Processing is the effective production, through the systematic organization of all related clerical routines, of a coordinated and uninterrupted flow of essential data (information) needed by management in its decision-making, control,

and planning functions" (22, pp. 7-8). To transform this definition into the context of this report, it would mean the ability to control operations, set policy and base forecasting upon data which have been systematically developed, not through a mere integration of clerical tasks, but through an integration of overall company functions (i.e.- Inventory control, production control and sales forecasting) which has the end result of producing integrated information. This will be, in effect, what we define the term "Total Integrated Management Systems Concept" to be. It is understood that this system or procedure will enable information to be captured in tape or card form so that it may be written over and over again, completely or in part, on the various types of machines which may be operated by the tape or card.

Evolution of Data Processing

Data processing methods are considered here in four general categories, roughly in the order of their development (24, pp. 7-15). The first category, whose development corresponded closely with the growth of first-generation equipment, comprises the use of computers to reduce the mountains of paperwork in the offices where they are installed. They are employed for mundane and obvious tasks, such as statistical compilations, billing, payroll, general accounting and limited scientific chores.

The second data processing category, whose development began approximately with the availability of solid-state hardware, extended the reach of computers into the area of management control applications; specifically, these include sales forecasting, inventory and production control, and advanced scientific work. A third set of methods, based on sophisticated mathematical techniques, has been developed; this category includes PERT,

operations research, simulation, and linear and dynamic programming functions (12, pp. 2-4).

A fourth method of processing data, whose primary function is management control, is currently evolving. In contrast with single, segmented applications, we now speak of an "integrated management information and control system," a "total system," or a "total integrated management system." Such a system comprises all of the previously developed methods, but it has a very important and unique characteristic: It is conceived and designed as a single, total system to control an entire organization, rather than evolving as a result of the development of many more or less independent applications. Such a system would obviously therefore contain subsystems; however, these differ from the independent application in that they are not designed only to meet the requirements of a restricted area of the organization at some particular point in time -- such restricted designs generally result in widespread redundancies of data between individual applications. Rather, in the total approach, each subsystem is an integral part of the over-all system. All are welded together by data flows which are designed as elements of the over-all system to prevent redundancy and to eliminate the transmission of useless information from one area of the organization to another. The total approach makes it possible to capture, manipulate, combine, calculate, evaluate, measure, and report all data necessary for the operation of a business, and do it efficiently.

Advocation of the integrated system should in no way be construed to mean that such a system can or should be installed as a complete package at one time. Organizational dynamics make it impossible to design a complete, detailed plan, and then to enact it in one step. Rather, the master

plan encompassing the entire system should include a general timetable for computerizing and integrating each component application. The priorities for such a timetable should be established according to the relative impact on profits of each application concerned. This concept brings the full power of superior computer systems design to bear first on those jobs whose efficient fulfillment is critical for business success. In this manner major functions or applications are developed and installed in a gradual evolutionary process, each one effective upon installation, but fitting into a completely envisioned master plan.

The Decision to Develop a System

Assuming there is a need or an interest in establishing a total integrated management system, the logical question to answer would be, "How does one go about developing such a system? What parameters should we consider and what blueprint should we follow?" We should recognize that the general principles of the total integrated management system's concept have great universality, but in its application there are many diverse factors which make it necessary to tailor each application to the specific organization and area concerned. Such factors might include the type of business, the traditional system built up over the years, the financial condition of the company, company policies and precedents, and such less tangible factors as personalities and management climate. Accordingly, each integrated system must be custom-built; there is no "packaged" universal system which can be bought and used.

Thus, since these systems vary so widely, before we can establish our integrated data processing program, we must analyze every step of our current operation, study the alternatives, and evaluate the results. Even

then we must redesign and be prepared to alter a suggested program until it covers our specific situation with a maximum of efficiency. It is for that reason that these seven essential steps for designing a business data processing system, integrated or not, should be followed (20, pp. 36-38; 22, pp. 22-24):

(1) Make a thorough analysis of the present system, charting every data processing step from the origin of the raw material to its final disposition.

(2) Develop a realistic set of objectives for the system employed, whether it be just a revitalized old one or a proposed integrated system.

(3) Plan creatively, with imagination. In the planning stage, even the wildest dream can give birth to the germ of a practical idea that can revolutionize the data processing system. Devise as many alternatives to those methods now in use. Work with each step and develop as many ideal approaches as possible. Then discard and eliminate steps that are unnecessary and choose the alternative that offers the best opportunity for reaching the objectives desired.

(4) Undertake a detailed machine research program. Having devised the type of program that will best suit the operations, study the wide variety of equipment that is available. Select the type which best suits the system that has been designed, keeping in mind any possible modifications or additions to the equipment that will have to be made in the future due to expanding requirements. (17, pp. 12-79).

(5) Lay out the specific steps by which the system will take shape.

Draw detailed flow charts of every function and operation and show all interrelationships. Compare these charts with those of the system you are changing. Key in the equipment at each step. Point by point, eliminate all alternatives and duplications. Take into consideration the volume of data at each step and the speed factors involved. Build in sufficient capacity to take care of peak periods and foreseeable growth. At each step, examine the forms to be used, which also must be completely engineered to take care of company needs and to use the new total systems concept.

(6) Prepare a complete cost analysis for the proposed system. Be realistic and include ranges of costs where exact estimates are not available. Compare the cost of the system with the worth of information that it is producing (10, pp. 354-365).

(7) Prepare a detailed schedule or master plan for converting to the new program and installing the system and equipment. This timetable will be implemented as soon as the system is approved and will provide the needed guidelines to insure proper implementation.

These steps have obviously been quite broad in nature, attempting to cover only the general situation. However, before delving into the design of the sample system itself, we will have to be more specific in our objectives than those noted in step (2). Accordingly, to elaborate on the objectives that must be set for the system, we would include:

(1) Improvement of customer service.

(2) Development of accurate costs to maximize profit and improve competitive position.

(3) Reduction of inventory obsolescence.

(4) Reduction of average inventory levels.

(5) Development of more efficient methods of modifying and disseminating product information.

(6) Improvement of manpower planning.

(7) Improvement of facilities planning.

(8) Improvement of market analysis capabilities.

(9) Increase in paperwork effectiveness.

(10) Reduction of clerical costs.

With these goals and procedures defined, an information and control system can now be designed which will integrate all of the information flow in the company and eliminate duplication of effort, while at the same time provide adequate, and timely information for proper exercise of the management control function.

SYSTEM DESIGN

Some Basic Assumptions

As was stated previously, the management information and control system in use in a specific company must be geared to the needs of the company if it is to be successful. Because sales patterns and production facilities vary so greatly, there is probably no such thing as a "typical" system. However, for purposes of illustrating the application of a mechanized system, the following assumptions will be made concerning the hypothetical company, its products, and its market:*

(1) The company manufactures a high volume, discrete product (as opposed to a continuous process such as chemicals) with numerous product modifications and new designs being added each year.

(2) A small (less than ten) number of segregated manufacturing facilities exist.

(3) All Plant administrative services, all receiving, issuing, and control of materials, all engineering services, all finished goods stocking, all order shipping, all fabricating operations, and the majority of assembly functions are centered in the home office, also the site of one of the manufacturing facilities.

(4) Distribution of products is by direct sales from the home plant to a chain of branch distributers.

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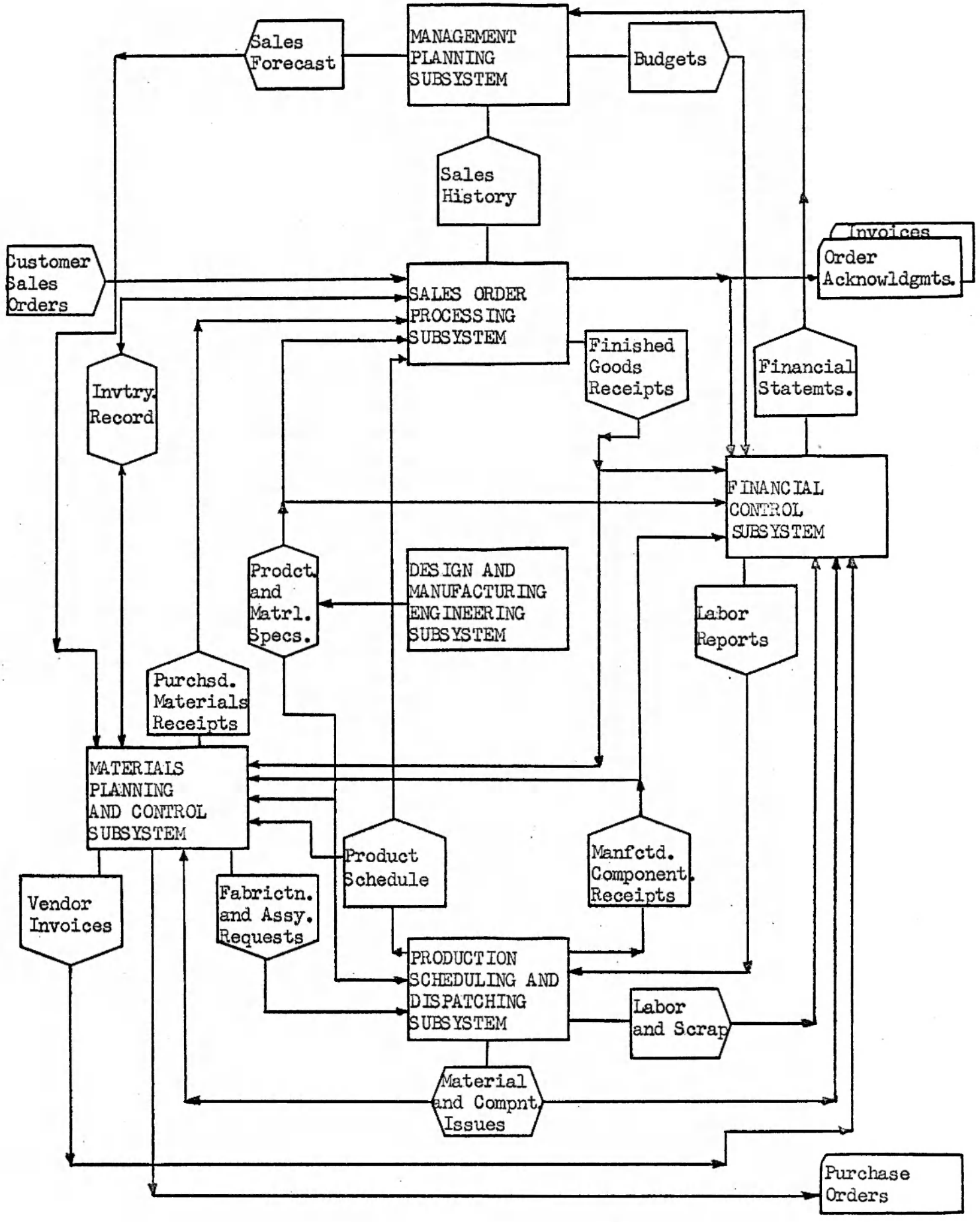
*The hypothetical system that will be illustrated was derived by combining the "best" features from a number of industrial systems that have already been implemented. Information concerning those systems was graciously furnished by: Air Reduction Company, Grumman Aircraft Engineering Corporation, Honeywell, International Business Machines Corporation, Lockheed-Georgia, Martin Company, Minnesota Mining and Manufacturing Company, United States Rubber Company, and Western Electric Company (See references 6, 8, 16, 12, 14, 21, 28, 11, 7, 1, 31, 23, and 27 respectively).

EXPLANATION OF PLATE I

The general data flow (non-detailed) in the total integrated management control system.


Sales Forecast
MANAGEMENT PLANNING SUBSYSTEM
Budgets
Sales History
Invoices
Order Acknowldgmts.
Customer Sales Orders
SALES ORDER PROCESSING SUBSYSTEM
Finished Goods Receipts
Financial Statemts.
Invtry. Record
FINANCIAL CONTROL SUBSYSTEM
Prodct. and Matrl. Specs.
DESIGN AND MANUFACTURING ENGINEERING SUBSYSTEM
Labor Reports
Purchsd. Materials Receipts
MATERIALS PLANNING AND CONTROL SUBSYSTEM
Product Schedule
Manfctd. Component Receipts
Vendor Invoices
Fabrictn. and Assy. Requests
PRODUCTION SCHEDULING AND DISPATCHING SUBSYSTEM
Labor and Scrap
Material and Compnt. Issues
Purchase Orders

(5) Production flow time for the product (which consists of numerous product families), from acquisition of a critical raw material to a finished product, ranges from less than one month to approximately four months for speciality items.

(6) The open order backlog is equivalent to about a month's sales volume.

(7) Sales for the near and the longer term are subject to fluctuations which can be predicted with reasonable, but not precise, accuracy. It is the practice of management to re-estimate and restate sales requirements on a monthly basis.

(8) Assembly of the end products is not difficult and does not require extensive machinery. The productivity of the assembly line is known within narrow margins, and scheduling of its work is not a difficult operation.

(9) The manufacture of certain products is fairly complex, moving through a number of departments and machine operations. Labor requirements are directly related to machine-hour requirements. (26, pp. 225-226).

Thus, one realizes that this description could encompass anything from the manufacture of telephones to tires to electric switches. But at least, the reader now has a general understanding of the type of industry and product the system will be designed for.

The Total Integrated Management Control System

The accompanying data flow diagram (See Plate I) provides a general picture of the total integrated management information and control system. Each box indicates a major functional subsystem comprising many lower

level functions. Only the more important elements of the information flow between subsystems are shown in the diagram. Succeeding sections describe subsystems and information flows in greater detail, followed by a detailed flow diagram of the entire system.

The key to the effective integration of the many separate parts of the total integrated management system is centralization of key information. Basic information about the business is contained in magnetic tape masterfiles which form the backbone of the entire information processing system (3, pp. 47-49). Use of masterfiles avoids duplication of data, in many cases eliminating completely the need for paperwork files, and markedly increases the speed of file updating. This point will be elaborated on later in this report. The six major subsystems forming a part of our total system include the Design and Manufacturing Engineering Subsystem, the Sales Order Processing Subsystem, the Materials Planning and Control Subsystem, the Production Scheduling and Dispatching Subsystem, the Financial Control Subsystem, and the Management Planning Subsystem.

Design and Manufacturing Engineering Subsystem

Design Engineering prepares complete product specifications, as well as individual product bills of materials and drawings. Product specifications are utilized in the Sales Order Processing Subsystem for screening customer orders.

Based on product specifications, bills of materials, and engineering drawings, Manufacturing Engineering prepares specifications describing the production of each item in terms of manufacturing departments and centers concerned, tooling and equipment required, operations to be performed and routing, and labor standards (26, pp. 90-111).

The bills of materials and manufacturing specifications are used in the forecasting phase of the Management Planning Subsystem, in the Materials Planning and Control Subsystem for exploding orders and preparation of manufacturing route sheets (work orders), and for calculation of standard costs in the Financial Control Subsystem. The Design and Manufacturing Engineering Subsystem will not be discussed further, as it is the least important subsystem from a data processing viewpoint.

Sales Order Processing Subsystem

Customer orders are screened and a sales order is prepared. New orders are recorded in customer sales records, and a sales order is printed, one copy of which is used as an acknowledgement. Orders which can be filled from stock are shipped and invoices are prepared and distributed. Inventory records are updated to reflect shipments and to make reservations against future stock for unfilled orders. These records are then analyzed in the Materials Planning and Control Subsystem to determine necessary stock replenishment activities.

Backlog, order, and sales statistics reports are prepared for management review and use in planning and in preparation of periodic sales forecasts.

Materials Planning and Control Subsystem

A forecast of the demand for finished products, generated in the Management Planning Subsystem, is received periodically. Information developed from this forecast is used in setting control values (i.e. - order points, order quantities, and safety stocking levels) for finished goods, component, and raw materials inventories (21, pp. 1-8).

The inventory records previously processed in the Sales Order Processing Subsystem are analyzed and manufacturing requests are issued to replenish the stocks of finished goods which have been depleted to the order point and to manufacture non-stock items in customer orders. These stock and make requests are exploded against product and manufacturing specifications to determine the subassembly, component, raw material, labor, and machine requirements for each item to be produced. Inventory records are updated to reflect the anticipated requirements for these items, and then further assembly and fabricating requests, and also purchase requests, are issued to initiate replenishment of the stocks which will be depleted to the order point by withdrawals (14, pp. 1-77).

Production Scheduling and Dispatching Subsystem

Fabricating and assembly requests contain information concerning the requested shipping or stocking date and the availability of components and raw materials required for the manufacture of the requested articles. On the basis of this data and current information about production line loading, the fabrication of components and assembly of finished goods is scheduled.

Assembly and fabricating centers are loaded, and production backlog records are updated. Periodic reports reflecting loading conditions are issued. In accordance with the established production, assembly and fabricating orders are issued, along with labor tickets, material requisitions, and other documents required in manufacturing operations and for reporting purposes.

Receipts are issued for items received in response to purchase requests and for completed lots of manufactured components and finished goods;

the items are inspected and placed in stock or shipped to customers. Receipts for manufactured goods initiate shipment of completed non-stock and deferred orders. Receipts for both purchased and manufactured items are used in the Financial Control Subsystem to update inventory records and for accounting purposes.

Labor and materials expended and scrap generated are reported to the Financial Control Subsystem for use in reporting variances from standard costs, work-in-process accounting, and labor reporting.

Financial Control Subsystem

This portion of the total integrated management system determines and reports the effects of the company's activities upon its financial position. In order to provide a yardstick for use in monitoring manufacturing activities, standard costs are developed from the product information records, purchased material costs, and product line labor and burden rates established by management. The established standards are used to cost inventory transactions recorded in the Materials Planning and Control Subsystem, and inventory accounting reports are prepared which reflect inventory balances by classification and distribution of charges by account number.

Weekly and semimonthly payroll operations include calculation of deductions and vacation time, payment of employees, control of employee reviews, and complete reporting of all payroll activities. Labor charges are accumulated against projects, work orders, accounts, and departments, and (hard copy) reports of these distributions are produced. Reports are also produced which cover variances between actual and standard costs of materials, labor, and burden.

Additional functions in the Financial Control Subsystem include pay-

ables, receivables, and fixed asset accounting. Each of the functions indicated above develops accounting transactions; these are used as input to the budget accounting and general ledger functions which in turn produces operating statements and departmental budget reports.

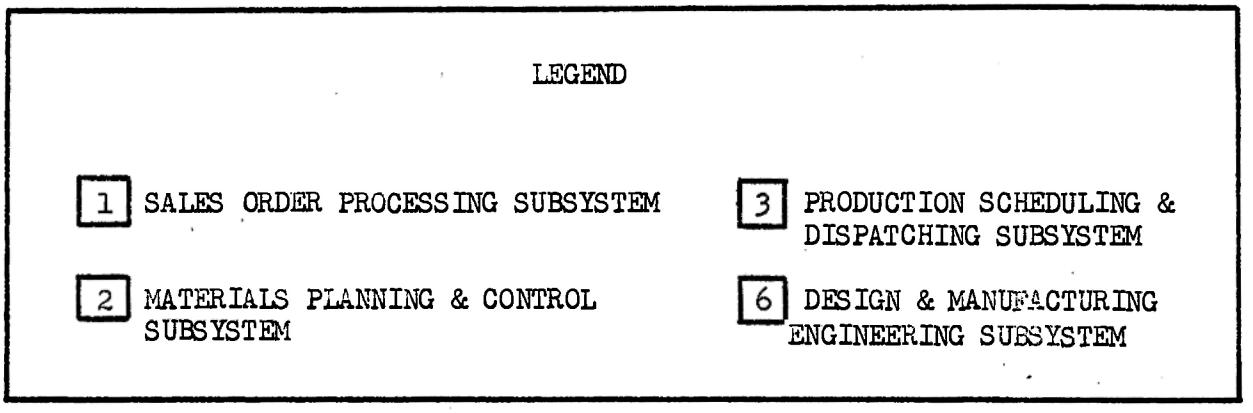
Management Planning Subsystem

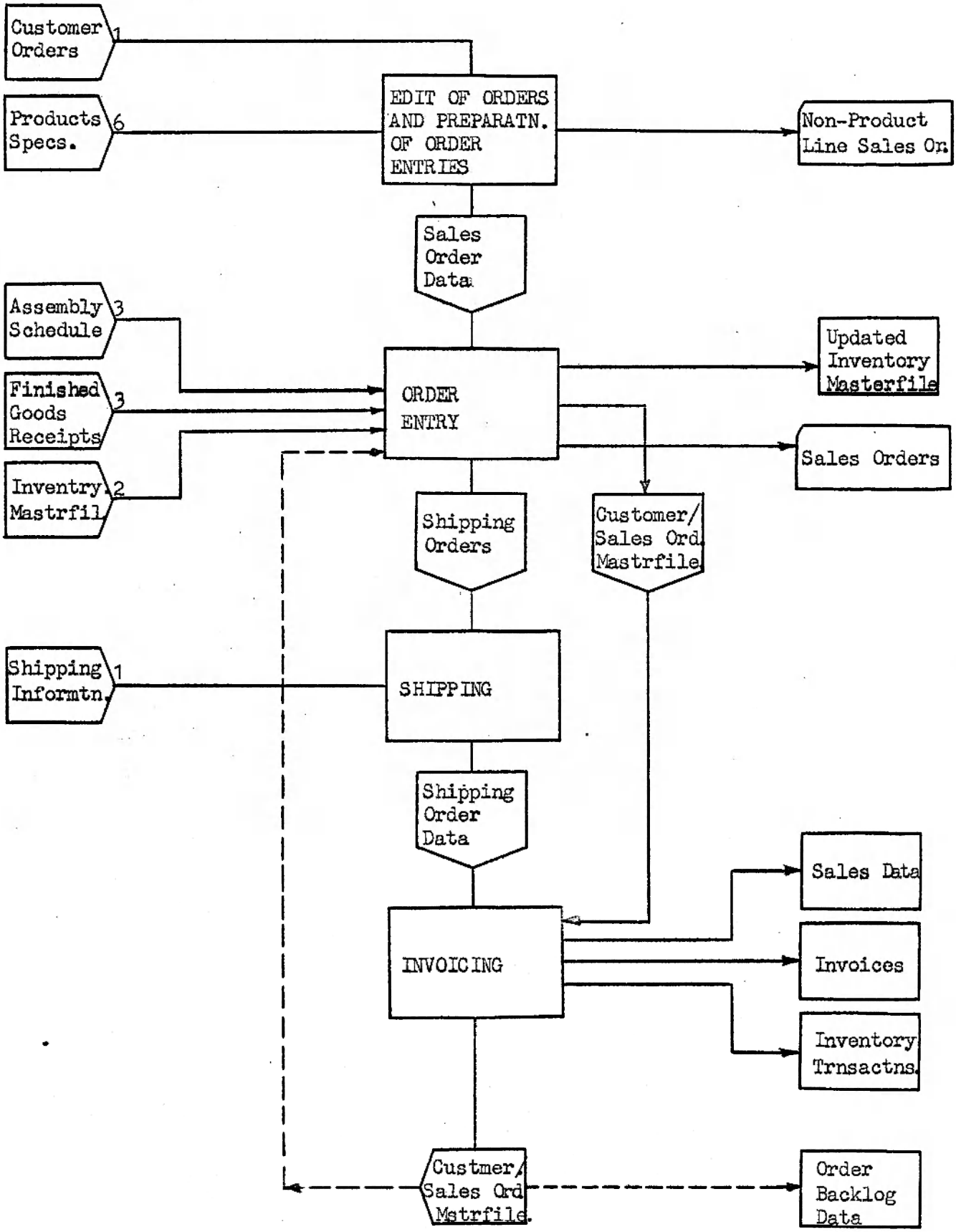
Management develops and maintains a master plan containing long-range goals and providing a framework for short-range decisions. Sales statistics and order backlog data developed in the Sales Order Processing Subsystem, along with forecast and market data from field offices and estimates of new product sales, form the basis for periodic sales forecasts. Such a forecast is exploded against production information records to determine manufacturing requirements. The forecast and the requirements for its manufacture are used in the Materials Planning and Control Subsystem to develop inventory control values. Annual forecasts are also made and exploded to obtain the data necessary for estimating future labor and equipment requirements and for setting labor and burden rates.

On the basis of the master plan, sales forecasts, and current and past financial statements, an annual profit-and-loss projection is made, and capital and operating expense budgets are prepared. Periodic reports supplied from all parts of the system are prepared on the basis of comparing actual operating performance with projected estimates; thus, they identify areas requiring attention.

EXPLANATION OF PLATE II

The data flow in the Sales Order Processing Subsystem.




Customer Orders
1
Products Specs.
6
EDIT OF ORDERS AND PREPARATN. OF ORDER ENTRIES
Non-Product Line Sales Or.
Sales Order Data
Assembly Schedule
3
Finished Goods Receipts
3
Inventry Mastrfil
2
ORDER ENTRY
Updated Inventory Masterfile
Sales Orders
Shipping Orders
Customer/ Sales Ord. Mastrfile
Shipping Informtn.
1
SHIPPING
Shipping Order Data
Sales Data
INVOICING
Invoices
Inventory Trnsactns.
Custmer/ Sales Ord Mstrfile
Order Backlog Data

THE SALES ORDER PROCESSING SUBSYSTEM

The primary functions of this subsystem are comprised of entering orders into the system, shipping and invoicing orders which can be supplied from stock, informing Materials Planning and Control of orders which require manufacture, and compiling order backlog and shipping statistics for Management Planning. (See Plate II).

Edit of Customer Orders and Preparation of Sales Order Entries

When a customer order is received, the first step is to assign it a control number. All further references to the order are made using this number. Each item in an order is then screened to determine whether it is in the product line. If not, or if a modified product is being ordered, the order is routed for engineering appraisal.

Sales order entries are prepared using a Flexowriter which combines input from its keyboard and from an auxiliary card reader and produces punched paper tape and hard copy output. Variable data about an order (e.g.- sales order number and quantity required) are entered from the Flexowriter keyboard. Fixed data about the customer and the products ordered are provided by prepunched cards selected from a file and fed into the card reader. (New customer cards are punched for a first order from a customer.) These cards are of two types: For each product line item, an Order Entry Master Card which includes such data as catalog listing, list price, Authorized Distributor discount, and data processing class and code; and for each active customer, a Customer Name Card which includes customer number, name and address. Separate name cards are included for each ship-to destination requested previously by a customer. As a check on the order entry operation

the hard copy output of the Flexowriter is audited using the original customer's order.

Order Entry - Recording and Updating of Finished Goods Inventory

This phase of Sales Order Processing consists primarily of a computer operation utilizing:

(1) Sales orders from the previous phase.

(2) Finished goods receipts from the Production Scheduling and Dispatching Subsystem.

(3) Assembly scheduling information.

(4) The Inventory Masterfile.

(5) The Customer/Sales Order Masterfile.

The Customer/Sales Order Masterfile contains pertinent information about each customer and complete details about all open sales orders. The Inventory Masterfile describes stocks of finished goods, components, and raw materials in terms of such parameters as inventory control values, flow and process times, prices, reservations against inventory, inventory balance data, and open factory orders.

New orders are entered in the Customer/Sales Order Masterfile. Each order item is analyzed to determine whether or not present or anticipated stocking levels are sufficient to cover the order on the required shipping date. If so, a reservation against stock is entered in the Inventory Masterfile and a sales order/acknowledgement is printed containing the expected delivery date. Shipping orders are issued to fulfill previously established deferred order schedules and to meet new order delivery dates requiring immediate shipment; a notation of the corresponding stock commitments are made in the Inventory Masterfile for a "make" (made-to-order)

order to be placed against the factory. Such orders result in the generation of assembly scheduling requests in a succeeding function. An expected delivery date is not given at this time on sales orders/acknowledgements for customer orders which trigger "make"orders. Copies of sales orders/acknowledgements are distributed to the branch sales offices, to customer service files, and to customers.

The input assembly schedule information is used in processing the Inventory Masterfile as a basis for establishing delivery dates for previously processed orders which could not be filled from stock. A new acknowledgement which contains the anticipated delivery date is issued for each "make" order.

A finished goods receipt indicates the completion of a product lot previously initiated to fill a "make" order or to replenish stocks depleted by customer orders. Such receipts are used to update the quantity-on-hand and open-factory-order sections of the Inventory Masterfile; they also trigger the issuance of shipping orders to fill open orders indicated in the Customer/Sales Order Masterfile.

Shipping and Invoicing

Upon issuance of shipping orders, the indicated items are packed and shipped. Each shipping order is then edited to indicate the mode and cost of transportation used and any variances between the actual shipping operations and the directions given in the order. Then, an invoice number is assigned to the shipping order, and it is converted to an input medium suitable for the invoicing operation.

The primary component of the invoicing phase is a computer operation utilizing shipping orders and the Customer/Sales Order Masterfile. The

Customer/Sales Order Masterfile has been updated by the order entry computer operation as was noted previously.

Items indicated by shipping orders are removed from open-order status in the Customer/Sales Order Masterfile and are added to sales history records. These records are used to develop sales statistics for use in the management planning function. The transfer of shipped items to sales history is recorded in an inventory transaction file for later processing in the Materials Planning and Control Subsystem.

Invoices are prepared and issued. Sales and order reports are also compiled and printed. The reports are input to the management planning function. Invoice copies are distributed to the customer and to the pertinent branch sales offices; invoice data is also used in the receivables function of the Financial Control Subsystem.

Order Backlog Reports

Four different sales order backlog reports are produced on weekly and monthly bases. The Customer/Sales Order Masterfile is analyzed and order backlog is reported by product class, by product item, by customer, and by date. Backlog is reported in terms of the sales orders (units and value) scheduled this month, scheduled next month and each succeeding month up to six, and scheduled more than six months ahead. Also given is a total of all orders for each report item. The daily invoicing operation is also set up to provide on-request order backlog reports.

EXPLANATION OF PLATE III

The data flow in the Materials Planning and Control Subsystem.

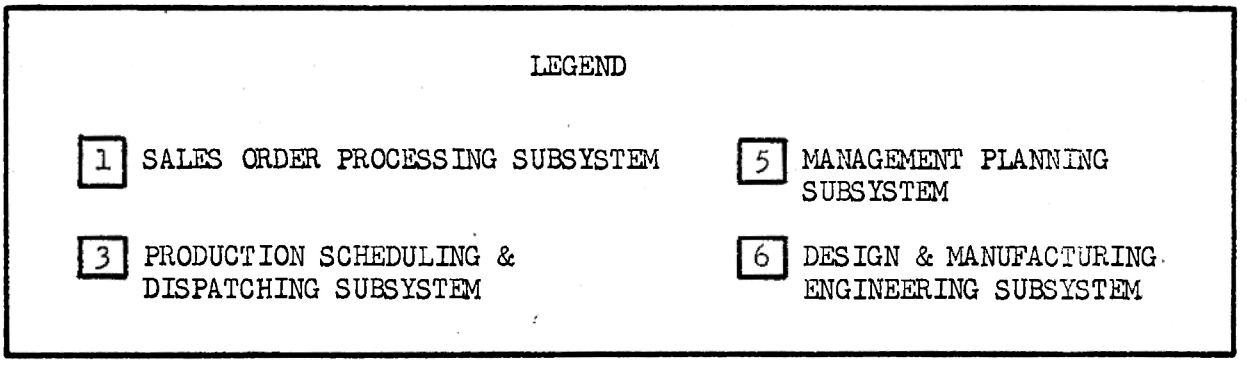
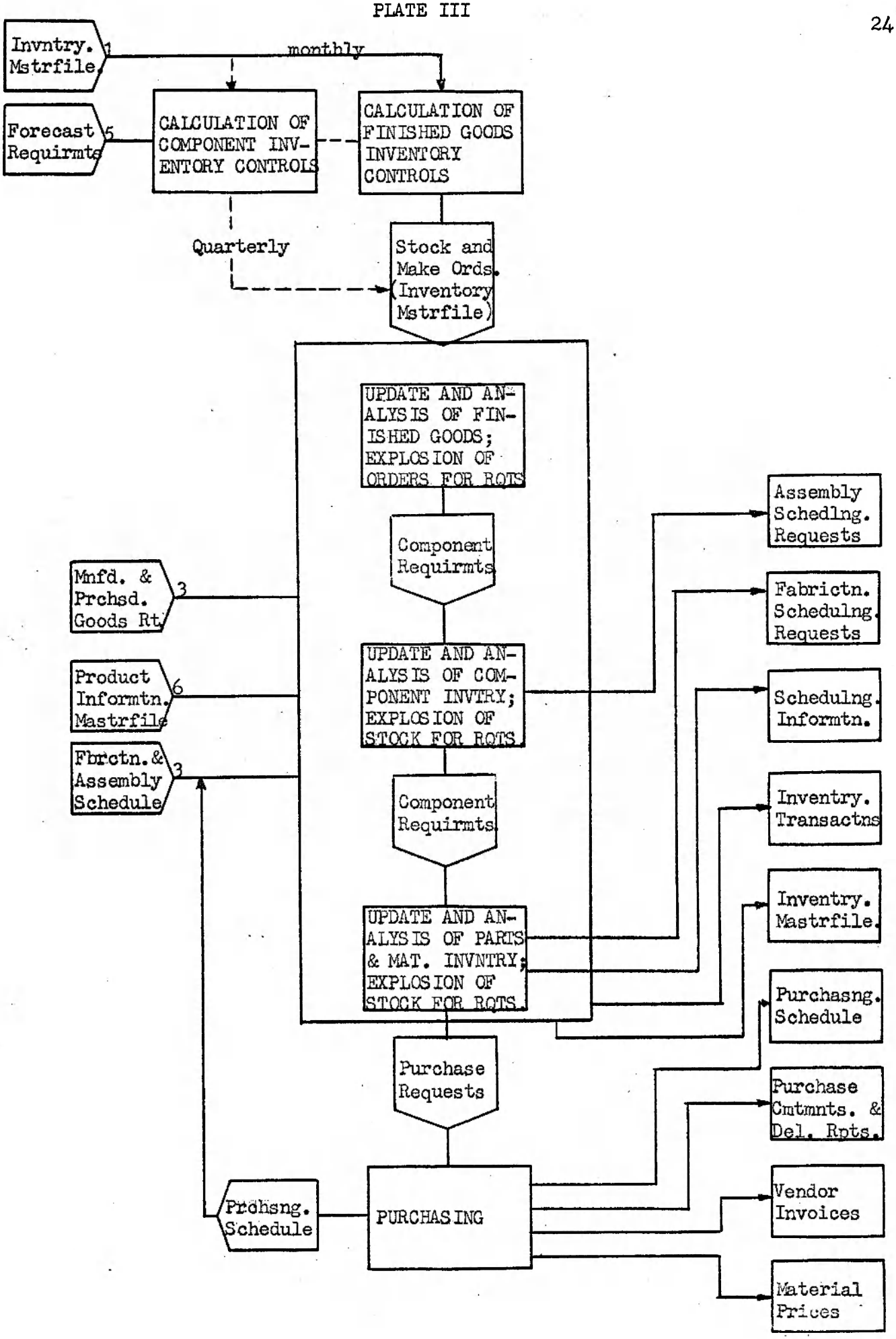


PLATE III


Invntry. Mstrfile
1
monthly
Forecast Requirmts
5
CALCULATION OF COMPONENT INV-ENTORY CONTROLS
CALCULATION OF FINISHED GOODS INVENTORY CONTROLS
Quarterly
Stock and Make Ords. (Inventory Mstrfile)
UPDATE AND AN-ALYSIS OF FIN-ISHED GOODS; EXPLOSION OF ORDERS FOR RQTS
Component Requirmts.
Mnfd. & Prchsd. Goods Rt.
3
UPDATE AND AN-ALYSIS OF COM-PONENT INVTRY; EXPLOSION OF STOCK FOR RQTS.
Product Informtn. Mastrfile
6
Fbrctn. & Assembly Schedule
3
Component Requirmts.
UPDATE AND AN-ALYSIS OF PARTS & MAT. INVNTRY; EXPLOSION OF STOCK FOR RQTS.
Purchase Requests
Prchsng. Schedule
PURCHASING
Assembly Schedlng. Requests
Fabrictn. Schedulng. Requests
Schedulng. Informtn.
Inventry. Transactns
Inventry. Mastrfile.
Purchasng. Schedule
Purchase Cmtmnts. & Del. Rpts.
Vendor Invoices
Material Prices

MATERIALS PLANNING AND CONTROL SUBSYSTEM

The primary function of this subsystem is to maintain inventories of manufactured items and raw materials at levels high enough to meet delivery schedules while at the same time preventing the unnecessary expenses of obsolescence and excessive carrying costs resulting from overstocking practices. (See plate III).

Calculation of Control Values

The maintenance of inventories at optimum levels hinges on obtaining satisfactory values with which to control stocking. That is, reorder point levels, safety stocks, and economic order quantities must be available for each stocked product, component, and raw material, and these values must reflect current market conditions. These conditions include trends in the demand for individual finished products kept on hand as well as the non-stock items.

The Materials Planning and Control Subsystem calculates control values for finished goods about every month on the basis of sales forecasts produced in the Management Planning Subsystem. Every three months, the current forecast is exploded against the Product Information Masterfile to determine the resources required for producing the forecast volume of finished goods. These requirements are in turn used in calculating control values for components and raw materials. The discussion of the Management Planning Subsystem includes a description of the computerized forecasting and explosion techniques used.

Inventory Update and Analysis

The Inventory and Product Information Masterfiles, plus inventory

transaction records generated in the Sales Order Processing Subsystem, are processed daily. Before other operations can be performed, the Inventory Masterfile must be updated with the entries in the transaction records. This updating operation consists of depleting finished goods inventory balances to reflect the latest order shipments. (5, pp. 16-21).

After the inventory transactions are entered, an analysis of the finished goods inventory is performed to identify the orders for items which are not stocked on the product level (make items) and to generate stock replenishment orders for items which have been depleted to their reorder points by stock issues or reservations against stocks to fill orders.

Generation of Production Scheduling Requests

The Product Information Masterfile contains a complete description of each product and the operations, labor, machines, and materials necessary for manufacturing it. Finished goods, stock replenishment, and make orders are exploded against this file in order to determine the requirements for their manufacture. Reservations are made against the inventories of required components. Replenishment orders are generated and recorded in the Inventory Masterfile for components whose stocks will be depleted below their reorder points upon the issuance of reserved stocks. Scheduling requests are issued for the assembly of the original "make" and stock replenishment orders. Then, the entire cycle is repeated: Replenishment orders generated to offset anticipated stock depletions are exploded against the Product Information Masterfile, reservations are made against the inventories of required components, new stock replenishment orders are generated, and scheduling requests are issued for the fabrication of the stock replenishment orders which initiated the current cycle. This process of explod-

ing orders, reserving against inventories, generating replenishment orders, and issuing production scheduling requests is carried down through as many as seven levels of increasingly more basic supporting items, the number of levels varying with the products ordered and the initial inventory conditions.

The scheduling requests produced by this process are utilized in a function of the Production Scheduling and Dispatching Subsystem. When a purchased part or material reorder point is reached, a purchase request is issued automatically for use in the purchasing function.

Assembly and Fabrication Scheduling Requests

As indicated above, assembly scheduling requests are triggered by orders for "make" and stock replenishment orders. Each request contains information from the Product Information Masterfile designating the assembly departments to perform operations and the total time required in each of them. If sufficient quantities of the components required for the completion of a requested lot are not in stock or on order, the assembly request also includes information concerning newly-issued replenishment orders and their scheduled delivery dates.

A fabrication scheduling request is generated for each component enumerated on an assembly scheduling request as being insufficiently stocked to meet assembly demands. Accompanying each fabricating request are separate scheduling cards for the work centers involved in the requested operations. Such a card designates the department and work center, and shows the number of parts to be fabricated, the work order number, the lot size, the labor hours required per thousand units, the extended labor and machine hours, and the required set-up time. These cards are used in the Production Scheduling and Dispatching Subsystem, in conjunction with a Schedugraph board,

for production line scheduling.

Purchasing Operations

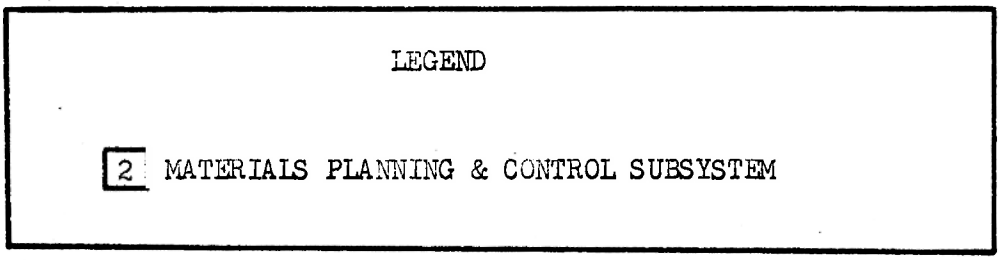
As indicated above, a purchase request is issued for parts and materials whose quantity in stock or on order is insufficient to meet the needs of assembly and fabricating requests. A purchase request contains a number which identifies the part or material requested, the quantity requested and the date on which the lot is required.

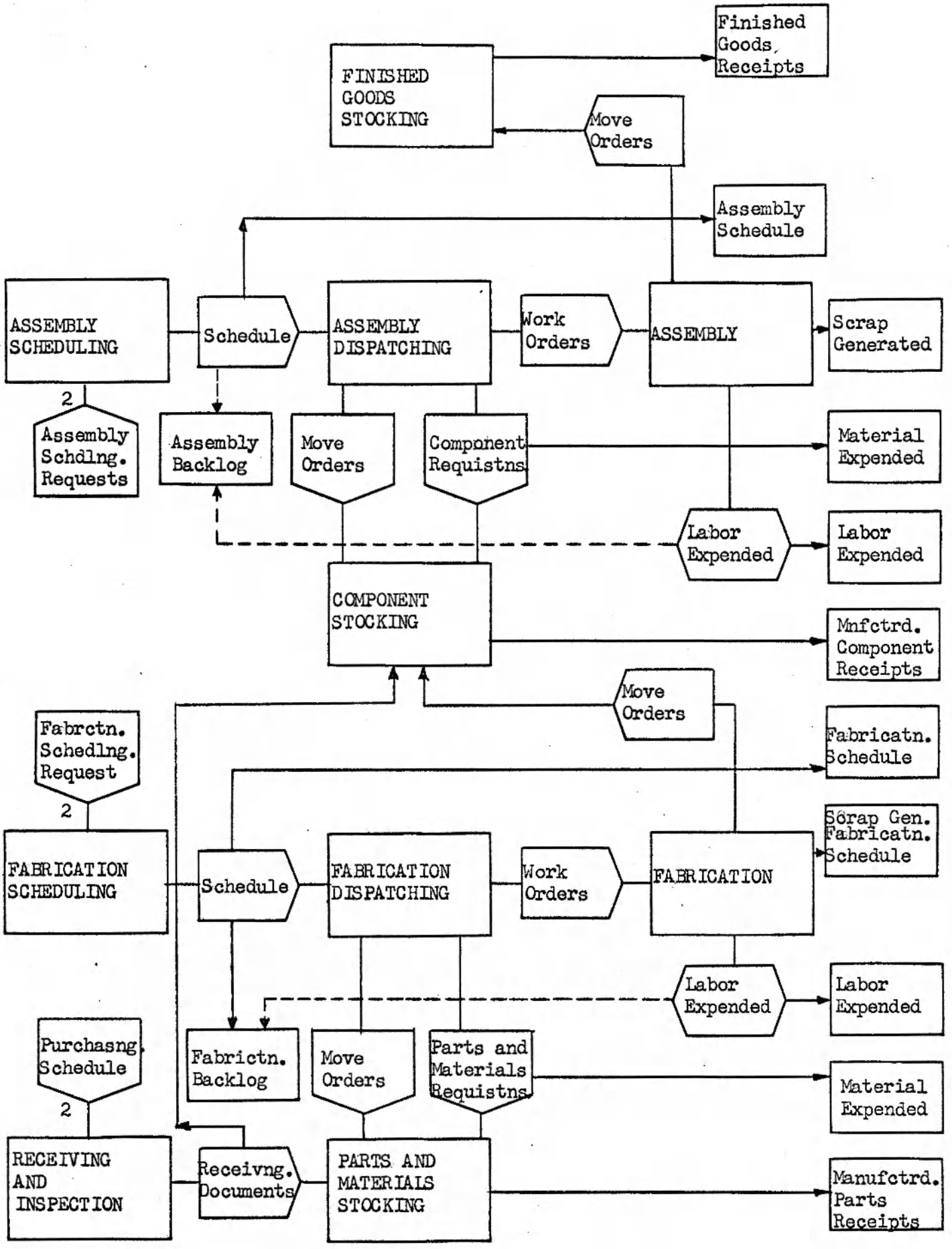
Based on the contents of a vendor history file, which shows performance in terms of quality, price, and speed of delivery, a vendor is selected, and a purchase order is prepared using a Flexowriter. This device combines input from its keyboard and from an auxiliary card reader and produces purchase orders as output. The card reader is used to enter fixed information, such as part number, description, and vendor name and address, from prepunched cards selected from a file. Purchase order copies are distributed to the vendor and to the receiving function of the Production Scheduling and Dispatching Subsystem. Cards are punched from the purchase orders and serve as input to a semimonthly operation which produces a purchase commitments report showing the backlog of purchase orders by month.

An invoice for purchased parts or materials is received in the purchasing function. The price charged for each item is checked to ensure that it is the same as the negotiated price. A receiving document is generated in the Production Scheduling and Dispatching Subsystem upon receipt of purchased items. This document triggers the release of the corresponding invoice to the Financial Control Subsystem for use in the payables accounting function. When the material has passed inspection, the Inventory Masterfile is updated to reflect the quantity of material which has moved into stock.

EXPLANATION OF PLATE IV

The data flow in the Production Scheduling and Dispatching Subsystem for both the assembly and fabrication manufacturing operations.




Finished Goods Receipts
FINISHED GOODS STOCKING
Move Orders
Assembly Schedule
ASSEMBLY SCHEDULING
Schedule
ASSEMBLY DISPATCHING
Work Orders
ASSEMBLY
Scrap Generated
2
Assembly Schdlng. Requests
Assembly Backlog
Move Orders
Component Requistns
Material Expended
Labor Expended
Labor Expended
COMPONENT STOCKING
Mnfctrd. Component Receipts
Move Orders
Fabrctn. Schedlng. Request
Fabricatn. Schedule
2
FABRICATION SCHEDULING
Schedule
FABRICATION DISPATCHING
Work Orders
FABRICATION
Scrap Gen. Fabricatn. Schedule
Labor Expended
Labor Expended
Purchasng. Schedule
Fabrictn. Backlog
Move Orders
Parts and Materials Requistns
Material Expended
2
RECEIVING AND INSPECTION
Receivng. Documents
PARTS AND MATERIALS STOCKING
Manufctrd. Parts Receipts

PRODUCTION SCHEDULING AND DISPATCHING SUBSYSTEM

Manufacturing includes both fabrication and assembly operations. These production areas are supported by scheduling (loading), dispatching, and stocking functions. The materials receiving function is also included in this subsystem (See Plate IV).

Scheduling of Assembly and Fabricating Operations

As indicated in the previous section, the assembly scheduling requests produced in the Materials Planning and Control Subsystem show the departments designated to perform the requested operations, the total assembly time required in each department, and the customer-requested delivery date on "make" orders or the required stock date on replenishment orders. On the basis of this information, plus data on current load conditions in the assembly departments, assembly operations are scheduled, and realistic shipping or stock dates are established for use in the Sales Order Processing and Materials Planning and Control Subsystems. By computer, production backlog records are updated and periodic reports reflecting actual load conditions are produced.

Fabrication scheduling requests are produced in the Materials Planning and Control Subsystem. As noted previously, these requests are accompanied by separate scheduling cards for each work center which show the labor, tooling, and equipment requirements for the jobs to be performed. Using this information, along with data concerning production hours available by critical machine centers, tooling limitations, and present load conditions by time period, fabricating operations are scheduled, and completion dates are provided as feedback information for use in the Materials Planning and Control Subsystem. The scheduling operation is performed by manually placing

the schedule cards described above in proper sequence on Schedugraph boards (which are essentially Gantt charts) by department and machine center, according to the required starting date and the available capacity or open time. The following ground rules are used in scheduling fabrication of items supporting "make" orders:

(1) Attempt to schedule on the requested starting date.

(2) If work already scheduled will not allow scheduling on the requested starting date, attempt to schedule in the week preceding the requested date.

(3) If work already scheduled will not allow scheduling in the preceding week, schedule in the week following the requested date, or as soon thereafter as possible.

In cases where these rules are not effective, a stock replenishment order is rescheduled to allow on-time completion of the "make" order being scheduled. The ground rules for scheduling the fabrication of stock replenishment orders are the same as those for the "make" orders except that the one-week allowable variance from the requested starting is raised to two weeks or more, and the latter two rules are reversed.

Upon completion of scheduling, production backlog records are updated by computer. Periodic reports reflecting actual load conditions are produced.

Assembly and Fabrication Dispatching

Assembly and fabricating orders are distributed to the various manufacturing departments in accordance with plans established during the scheduling process. On appropriate dates prior to starting the production of an item, work orders and corresponding move tickets, labor tickets, and other documents required for manufacturing and reporting are automatically prepared

by computer and released to the manufacturing departments. Material requisitions are also prepared by computer and released to the stocking facilities; at the same time, inventory records are updated to reflect the commitment of stocks to the work orders released.

A work order, or route sheet, contains information concerning the schedule dates assigned to the production of an item plus the routing, tools and materials to be used, the manufacturing operations to be performed, standard labor hours and set-up time, quality control inspections to be carried out, and the identification numbers of engineering and manufacturing specifications which may be referred to where more detailed instructions are required.

With the release of work orders to assembly and fabricating departments and materials requisitions to stocking facilities, manufacturing activity begins. Components and materials are delivered from stock to the manufacturing unit where the first operation of a work order is to start. As orders progress through production, data concerning materials and labor expended and scrap generated is transmitted to the Financial Control Subsystem. These data are recorded in the Work-in-Process Masterfile, which contains a perpetual inventory of all active work orders in the assembly and fabricating departments. Maintenance of this file aids in reporting and following the progress of orders through production. When products are completed, inspected, and sent to stocking facilities, receipts activate the updating of the Work-in-Process and Inventory Masterfiles.

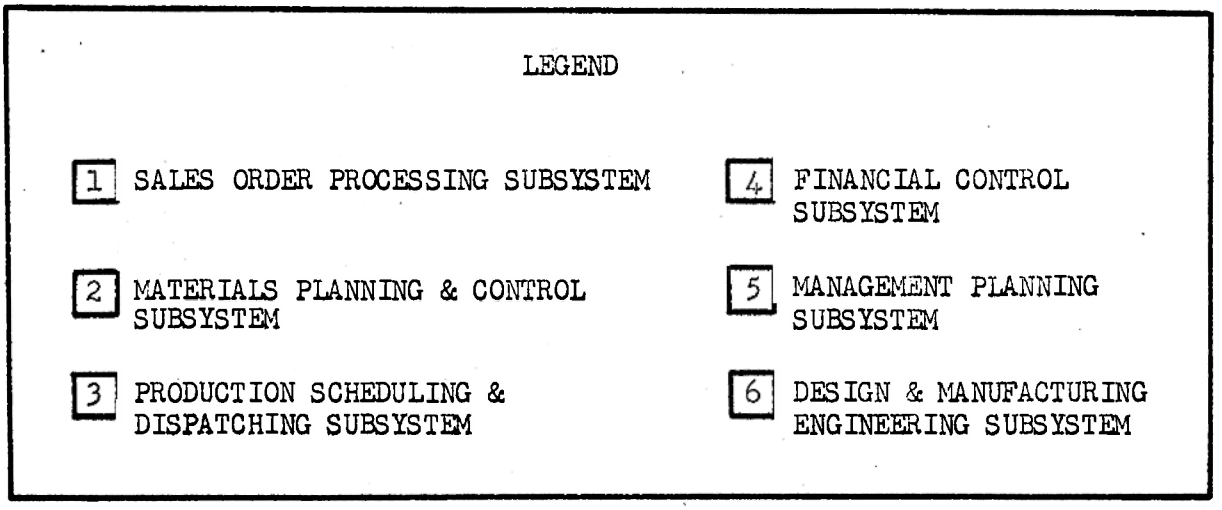
Receiving Operations

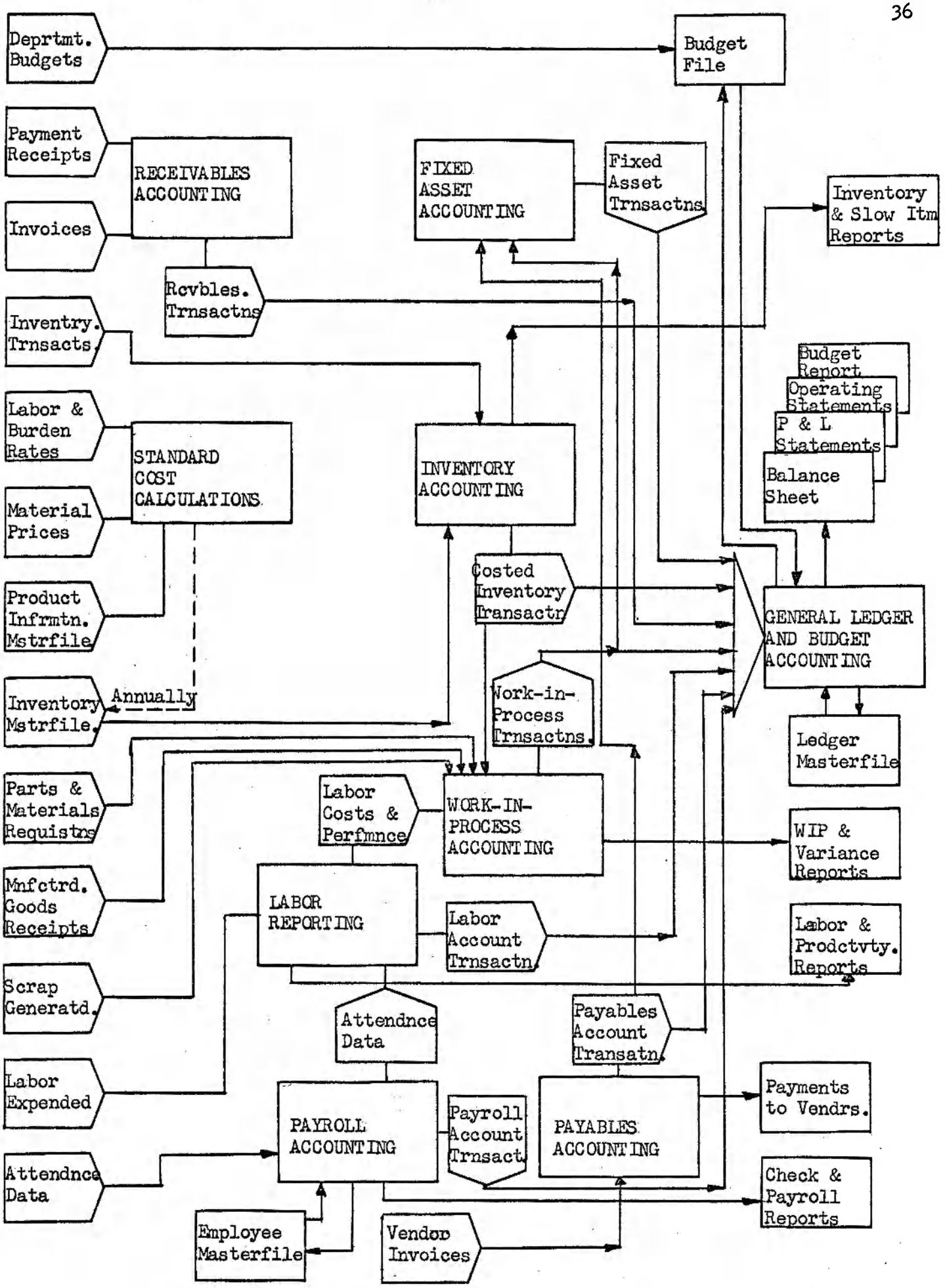
Purchasing operations are controlled by computer processing of the Inventory Masterfile to ensure maintenance of schedules. As purchased items arrive, the receiving facility prepares receipts and delivers the materials

for inspection. After inspection, the material is placed in stock. The receipts are used by Materials Planning and Control as a basis for updating the Inventory Masterfile, and the invoices are sent to Financial Control for use in payables accounting.

EXPLANATION OF PLATE V

The data flow in the Financial Control Subsystem.




Deprtmt. Budgets
Budget File
Payment Receipts
RECEIVABLES ACCOUNTING
Invoices
FIXED ASSET ACCOUNTING
Fixed Asset Trnsactns.
Inventory & Slow Itm Reports
Rcvbles. Trnsactns
Inventry. Trnsacts
Budget Report
Operating Statements
P & L Statements
Balance Sheet
Labor & Burden Rates
STANDARD COST CALCULATIONS
INVENTORY ACCOUNTING
Material Prices
Costed Inventory Transactn
Product Infrmtn. Mstrfile
GENERAL LEDGER AND BUDGET ACCOUNTING
Work-in-Process Trnsactns.
Inventory Mstrfile
Annually
Ledger Masterfile
Parts & Materials Requistns
Labor Costs & Perfmnce
WORK-IN-PROCESS ACCOUNTING
WIP & Variance Reports
Mnfctrd. Goods Receipts
LABOR REPORTING
Labor Account Trnsactn
Labor & Prodctvty. Reports
Scrap Generatd.
Attendnce Data
Payables Account Transatn.
Labor Expended
PAYROLL ACCOUNTING
Payroll Account Trnsact.
PAYABLES ACCOUNTING
Payments to Vendrs.
Attendnce Data
Check & Payroll Reports
Employee Masterfile
Vendor Invoices

FINANCIAL CONTROL SUBSYSTEM

The Financial Control Subsystem monitors all company activities, determines their effects on the financial position of the company, and produces reports concerning these effects for management's use. Several subsidiary functions are included in this subsystem, each of which reports activities in a given area and develops transactions which feed into the culminating function, general ledger and budget accounting. Each financial control function is described below. (See Plate V).

Calculation of Standard Costs

There is a comprehensive system available for providing the standard cost information necessary in inventory accounting, cost of sales analysis, and competitive pricing. A detailed recalculation of the standard cost of each of the product-line items and all of the resources going into their production is performed at the end of each year. In addition, product-line standard costs are calculated quarterly so as to make current information available for competitive pricing purposes. The procedure used in the annual standard cost determination, the more extensive of the two, is the only one that will be discussed in this report.

During the last or next to last month of each year, several operations are carried on concurrently: The Product Information Masterfile is audited, standard costs for purchased materials are established based on lot sizes needed to satisfy forecasted usage, and standard labor and burden rates are determined. The computer audit of the Product Information Masterfile ensures that all information is complete, uniform and correct. For example, conditions reported in this operation include the absence of specifications

for a part of material called for in another, higher-level specification, and the presence of specifications for unused parts or materials. Following this operation, the Product Information Masterfile is purged and corrected to remove any deficiencies picked up in the audit operation.

The costs of purchased materials, parts, and operations are developed in the purchasing function of the Materials Planning and Control Subsystem. This cost information, plus burden (overhead) and labor rate data established in the Management Planning Subsystem and manufacturing information from the Product Information Masterfile, constitute the input to the computerized costing operation. The cost of each individual unit of material, labor and burden going to make up an item is calculated, starting with those determined strictly by purchased resource costs, and proceeding upward to the finished goods level. As soon as all of the material, labor and burden costs for an item have been determined, a total cost for each of these resources is generated, which will then be used as input to costing operations for items at higher levels of completion. The following reports are produced in the course of standard costing operations:

(1) Cost Index Summary - Lists each raw material, purchased part, fabricated part, subassembly, and finished product, showing the material, labor, burden and total costs for each.

(2) Cost Sheets - Separate sheets for each fabricated and assembled item showing the resources required to produce each one and the material, labor, burden, and total costs for each resource.

After total costs for all items have been determined, these costs are entered in the Inventory Masterfile and are then used throughout the following year for the inventory accounting function.

Inventory Accounting

This function consists of costing inventory transactions recorded in the Materials Planning and Control Subsystem, reporting these transactions, and then passing them on for use in the work-in-process, general ledger, and budget accounting functions. An account of inventory transactions (e.g. - additions and depletions of stock) occurring in the Materials Planning and Control Subsystem passes daily to the Financial Control Subsystem where it is used as imput to inventory accounting operations. Information from the Inventory Masterfile is used as input to general ledger and work-in-process accounting operations. Costed transactions are reported by means of:

(1) Transaction Register (daily and weekly) - Lists inventory transactions by part number.

(2) Inventory Trial Balance Report (monthly) - Lists costed inventory balances by part number.

(3) Account Distribution Report (monthly) - Lists costed inventory transactions by number of the account to which it is charged. Specifically, most transactions are charged to either the work-in-process or the cost of goods sold account.

A physical count of inventory items is carried out on a continuing basis. The number of times the stock of a particular item is counted annually is determined statistically on the basis of the frequency of demand and dollar value of transactions for that item. The physical count of an item is compared with its inventory book balance and reconciled through use of the daily transaction register as mentioned above. The weekly transaction register for the past week is used where possible to resolve any discrep-

ancies noted. Any necessary adjustments are input to the Materials Planning and Control Subsystem where they are used to update the Inventory Masterfile.

Payroll Accounting

Payroll operations are of two general types: weekly non-exempt, including salaried office and factory hourly employees; and semimonthly exempt (i.e. - exempt from recording time spent against project numbers, departments, etc.). These operations are quite similar except for differences in the use of time cards.

Inputs to the payroll accounting function include the following:

(1) Employee Masterfile.

(2) Pay rate revisions.

(3) Attendance (time) data.

(4) Bond Applications.

(5) Stock deduction authorizations and cancellations.

(6) Insurance data.

The Employee Masterfile is updated as necessary to reflect any changes such as pay rate adjustments, changes in voluntary deductions, etc. Then, the necessary calculations are carried out and employee records updated to reflect vacation and sick time accured, tax deductions, and voluntary deductions for items such as:

(1) Employee and dependent medical insurance.

(2) Community chest.

(3) Credit Union.

(4) U. S. Savings Bonds

(5) Company stock.

Outputs from this operation include payroll checks and journal, a deduction register, a bond issue report, an accural-balance-eligibility register, and for non-exempt employees, wage distribution and seniority reports listing employees both by department number and by labor grade. This operation also produces periodically a review sheet for each employee due for performance review. Two other reports produced are a quarterly stock purchase report and annual W-2 forms. Payroll operations also yield attendance card data used for reconciliation purposes in labor reporting and payroll accounting transactions which are input to the general ledger and budget function.

Labor Reporting

The labor reporting function includes: (1) recording both actual and standard labor charges against sales projects, work orders, accounts, departments, groups, and employees; (2) producing various hard copy reports showing these labor charge distributions; and (3) supplying various entries to the other financial control functions.

The factory labor is broadly divided into two classifications, direct and indirect. Engineering effort is classified as indirect labor and is included with factory indirect labor in the burden rates. Sales and administrative efforts are not included in the burden rates. Factory indirect labor is divided into several accounts in order to assist the individual foreman in budgeting his expenses. All factory time, other than supervision, is reported on labor tickets which are either blank cards (indirect labor) or prepunched cards issued in the Production Scheduling and Dispatching Subsystem.

Inputs to the labor reporting function are labor ticket data, attend-

ance data supplied by the payroll accounting function, standard departmental pay rate data, and a list of accounts and account titles. The labor ticket data is matched with corresponding attendance data, and any discrepancies are reconciled. Labor costs are extended using the payroll and department standard pay rates. The following hard copy reports are generated:

(1) Employee Summary Report (weekly) - Lists employees by department, employee number, and labor type, and reports each individual's productivity rating. This information is given to the employee and serves as a supplement to periodic reviews.

(2) Labor Distribution Report (weekly and monthly) - Lists by account number charged and by department, all direct labor costs applied to inventoried parts and stock.

(3) Departmental Labor Summary (weekly) - Separate sheet for each department lists work performed, netted charges transferred in and out of department, and production variances both in hours and by dollar amount. This report is used by department supervisors in preparing their budgets.

(4) Group Labor Summary (weekly) - Combines, on a group level, the functions of the employee and departmental labor summaries.

(5) Departmental Production Report (weekly) - Lists for each operation the ratio, on each type of operation performed, of standard hours to production hours for work done in the past week. This report is used by department foremen as a guide in judging employee efficiency and by industrial engineers as a basis for determining the accuracy of the standard hours rates.

In addition to the reports generated, labor transactions are produced for

use in the general ledger and budget accounting function.

Work-in-Process Accounting

This function establishes and maintains an accurate accounting of all material, labor, and burden charges against assembly operations and against fabricating and special work orders. The latter category of work orders comprises those issued for such activities as advertising, printing, building, and machine maintenance, engineering projects, and any type of special activity for which separate reporting of charges is desired.

Inputs to the work-in-process accounting function include the work-in-process file, information about scrap generated in manufacturing, labor cost information from the labor reporting function, and material expenses and work order release data from the inventory accounting function. Material, labor and burden costs are accumulated against assembly operations within departments, and the Work-in-Process Masterfile is updated to reflect cost accumulations, new work order issues, and closing of orders. Weekly and monthly reports are produced which show the material, labor and burden accumulated against both open and newly closed fabricating and special work orders. The same data is also given by department for each assembly operation. Both actual and standard costs are given for fabricating and assembly operations, and variances are calculated and reported. In the case of special work orders, both actual and estimated (or authorized) expenses are indicated. Exception reports are issued indicating over-expended work orders and completed work orders showing excessive variances. The work-in-process accounting system also prepares work order expense transactions for use in the general ledger and budget accounting function.

Receivables and Payables Accounting

Computerization of the receivables accounting function was found to be not economically justifiable due to the minimal need for account aging. Rather, receivables accounting is carried on by means of a "ledgerless" system, that is, invoices produced in the Sales Order Processing Subsystem constitute the receivables file. When a payment is received, an entry is made in the cashbook, the corresponding invoice is moved from the open file to the paid file, and a transaction debiting accounts receivable and crediting sales is generated in a form suitable for input to the computerized general ledger and budget accounting function.

The payables accounting function's purpose is to develop and update as necessary an accurate record of all capital items. Whenever new fixed assets are acquired, or significant changes are made to those already owned, these transactions enter the fixed asset accounting function. The fixed asset file is updated monthly to reflect new acquisitions, changes, and accumulated asset depreciation. Hard copy reports are generated to show asset additions, depreciation, and retirements and sales. Also, these transactions are placed in a form suitable for use in the general ledger and budget accounting function.

General Ledger and Budget Accounting

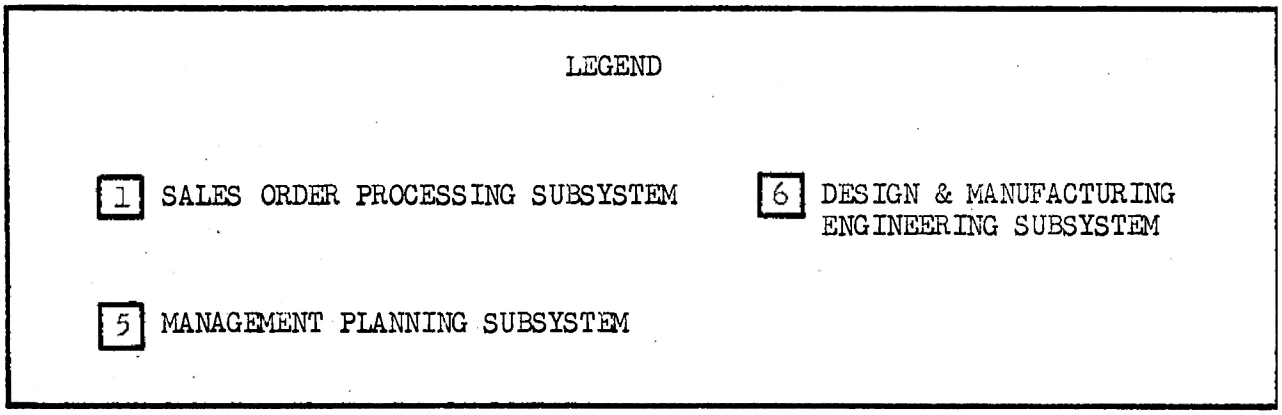
This function consists of two broad areas, one of which comprises maintaining the General Ledger Masterfile and producing company financial statements. The other area includes the recording of the department budgets, accumulating expenditures against them, and reporting performance. Inputs to this function include accumulated transactions from all of the financial

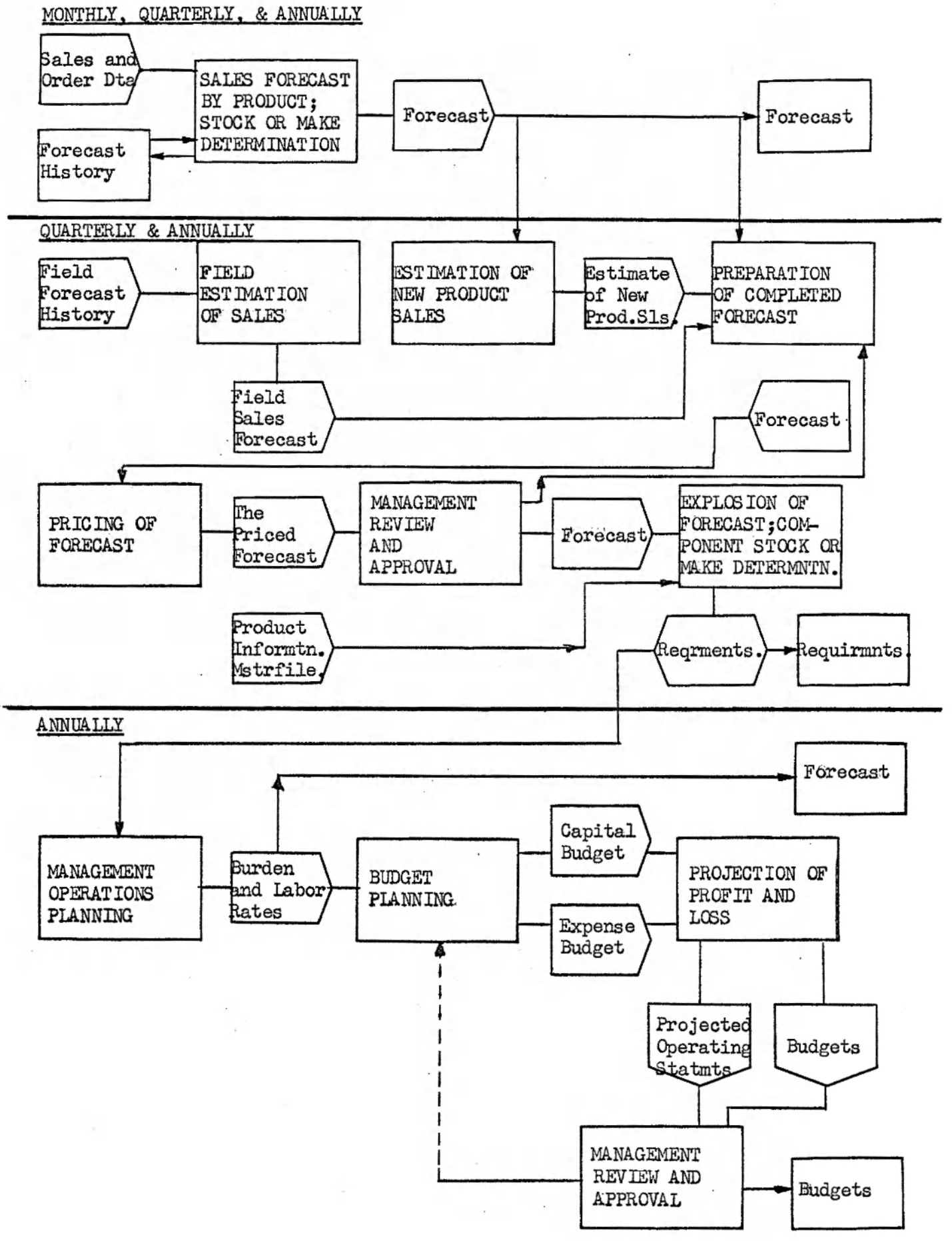
control functions described previously plus a few small, isolated journal entries which are relatively insignificant, such as postage used, supplies requisitioned, and telephone expenses.

The general ledger and department budget files are updated monthly. Along with posting of accumulated transactions from the several sources already described, the general ledger update also includes posting of several constant entries such as: (1) expense accruals, (2) cafeteria expense, (3) building occupancy, (4) employee service, and (5) data processing, which are all based on estimates. The monthly general ledger operation also includes developing several entries based on manipulations of input data; examples of these internally developed entries include: (1) factory burden allocation, (2) engineering burden allocation, and (3) amortization of variances. Those general ledger entries representing variable expenses are posted to departmental budgets. Hard copy reports produced by the monthly general ledger and budget accounting operations include a trial balance, a balance sheet, a profit and loss statement, operating statements, and departmental budget reports.

EXPLANATION OF PLATE VI

The data flow in the Management Planning Subsystem.




MONTHLY, QUARTERLY, & ANNUALLY
Sales and Order Dta
SALES FORECAST BY PRODUCT; STOCK OR MAKE DETERMINATION
Forecast
Forecast
Forecast History
QUARTERLY & ANNUALLY
Field Forecast History
FIELD ESTIMATION OF SALES
ESTIMATION OF NEW PRODUCT SALES
Estimate of New Prod.Sls.
PREPARATION OF COMPLETED FORECAST
Field Sales Forecast
Forecast
PRICING OF FORECAST
The Priced Forecast
MANAGEMENT REVIEW AND APPROVAL
Forecast
EXPLOSION OF FORECAST;COMPONENT STOCK OR MAKE DETERMNTN.
Product Informtn. Mstrfile
Reqrments.
Requirmnts.
ANNUALLY
Forecast
MANAGEMENT OPERATIONS PLANNING
Burden and Labor Rates
BUDGET PLANNING
Capital Budget
Expense Budget
PROJECTION OF PROFIT AND LOSS
Projected Operating Statmts
Budgets
MANAGEMENT REVIEW AND APPROVAL
Budgets

MANAGEMENT PLANNING SUBSYSTEM

The most important function in the integrated information processing and control system being described is Management Planning. Every system must have a master plan to keep it running smoothly and to prevent sudden stops and starts. This master plan is formulated by the Management Planning Subsystem where management develops and maintains a master plan which comprises long-range goals, thus, providing a framework for making short-range decisions. Tools used in plan development include sales statistics, annual and periodic sales forecasts, operating budgets, and financial statements of current and past operations. (See Plate VI).

Periodic Sales Forecasting

Every month, a computerized forecast of the sales of the entire product-line is performed. The inputs to this operation are sales statistics recorded in the Sales Order Processing Subsystem and historical data from past forecasting operations. For each finished product, the historical data includes three forecasts of the past period's sales. Each of these forecasts is produced by a different exponential smoothing formula. The three formulas are individually tailored to forecast accurately in particular sales environments. That is, one formula is designed for situations where sales exhibit a linear trend; another formula forecasts for accelerating sales and the third works best when sales are more or less stabilized.

Also included in the forecast history are data which indicate for past periods the average differences between the sales forecasts produced by each formula and the demands actually experienced. These data are combined

with calculated data indicating the differences between the three input forecasts and current sales experience to provide a determination of which forecasting formula has been most closely predicting actual sales volume.

Forecasts of sales for each product for the next month are prepared for using each of the three forecasting formulas. For each product, the forecast produced by the formula which has been most closely predicting actual experience is chosen as the best forecast for the ensuing period. This forecast is used in the Materials Planning and Control Subsystem for establishing such inventory control values as order quantities, order points, and weekly usages for each finished product.

Determination of Product Stocking Practices

The computerized forecasting technique described above includes a set of decision rules designed to determine for each product whether or not its customer applications and usage rates warrant providing finished goods inventory to cover future sales. This determination results in stocking each product fully, partially, or not at all. In this manner, a balance is maintained between short delivery schedules and relatively long flow times on the one hand, and possible product or application obsolescence on the other, thus preventing unprofitable overstocking while at the same time maintaining the desired level of on-time deliveries.

Quarterly and Annual Sales Forecasting

Quarterly and annual sales forecasts are initially prepared in the same manner as are the monthly forecasts described above -- that is, by computer. Thereafter, however, the best judgement of the marketing and product planning groups, as well as management, are brought to bear on the

basic forecast produced by computer.

In preparation for field estimation of sales, a special computer operation processes sales history data recorded in the Sales Order Processing Subsystem and produces field sales report sheets. Each sheet contains: a listing of the actual sales by calendar quarter in the present year and in the past two years; a record of the forecasts made by the respective field office for those periods; and information about current open orders for the product in the factory. Field sales report sheets are distributed to the cognizant branch sales offices where new estimates of sales are prepared, along with explanations concerning those cases where a significant change in sales is anticipated. New applications of product-line items and proposed new products are reported separately in a format similar to that of the field sales report sheet. Field sales estimates, along with new product sales estimates produced by the product planning organization, are used to adjust the quarterly or annual forecast being prepared.

After the newly prepared forecast has been adjusted as necessary, it is priced by family in a fully automatic computer operation. The priced forecast is then submitted to management for review and approval.

After the introduction of any necessary changes, the approved forecast is exploded against the Product Information Masterfile to determine the labor, material, and equipment required for its manufacture. These requirements are used in the Materials Planning and Control Subsystem for the establishment of inventory control values (weekly usages, reorder points, and order quantities) for each component and raw material used in manufacturing finished products. In addition, the data obtained in this forecast explosion are also used to determine the extent of requirements for subcontracting supplemental manufacturing capacities.

Preparation of Annual Expense and Annual Capital Budget

Management personnel from all departments work together to establish for the following year the wage rates for each job classification and the burden rate for each work center. Using the labor requirements obtained from the explosion of the annual forecast, in combination with the established wage rates, departmental and work center supervisors then prepare budgets of variable operating expenses for the coming year. Budgets of variable operating expenses from all areas of the company are combined with a fixed expense budget produced in the Financial Control Subsystem to construct an over-all operating expense budget for the company.

As in the case of the operating expense budget, preparation of the capital budget begins on the department and work center level. In the manufacturing departments, the primary consideration in estimating capital expenditures is whether or not sufficient productive capacity is available to manufacture the volume of products indicated by the annual sales forecast. An estimate of additional equipment requirements is made by comparing the amount of equipment available with the amount of equipment indicated, in the explosion of the annual forecast, as necessary for manufacturing the forecast. Budgeting of capital expenditures by factory management is also influenced by such factors as the planned introduction of new manufacturing methods and processes, and the anticipated performance by the company of jobs previously subcontracted. The departmental budgets are combined with such general budgetary items as funds for the expansion of plant facilities to produce an over-all capital expense budget for the company.

Projected Financial Position and Budget Approval

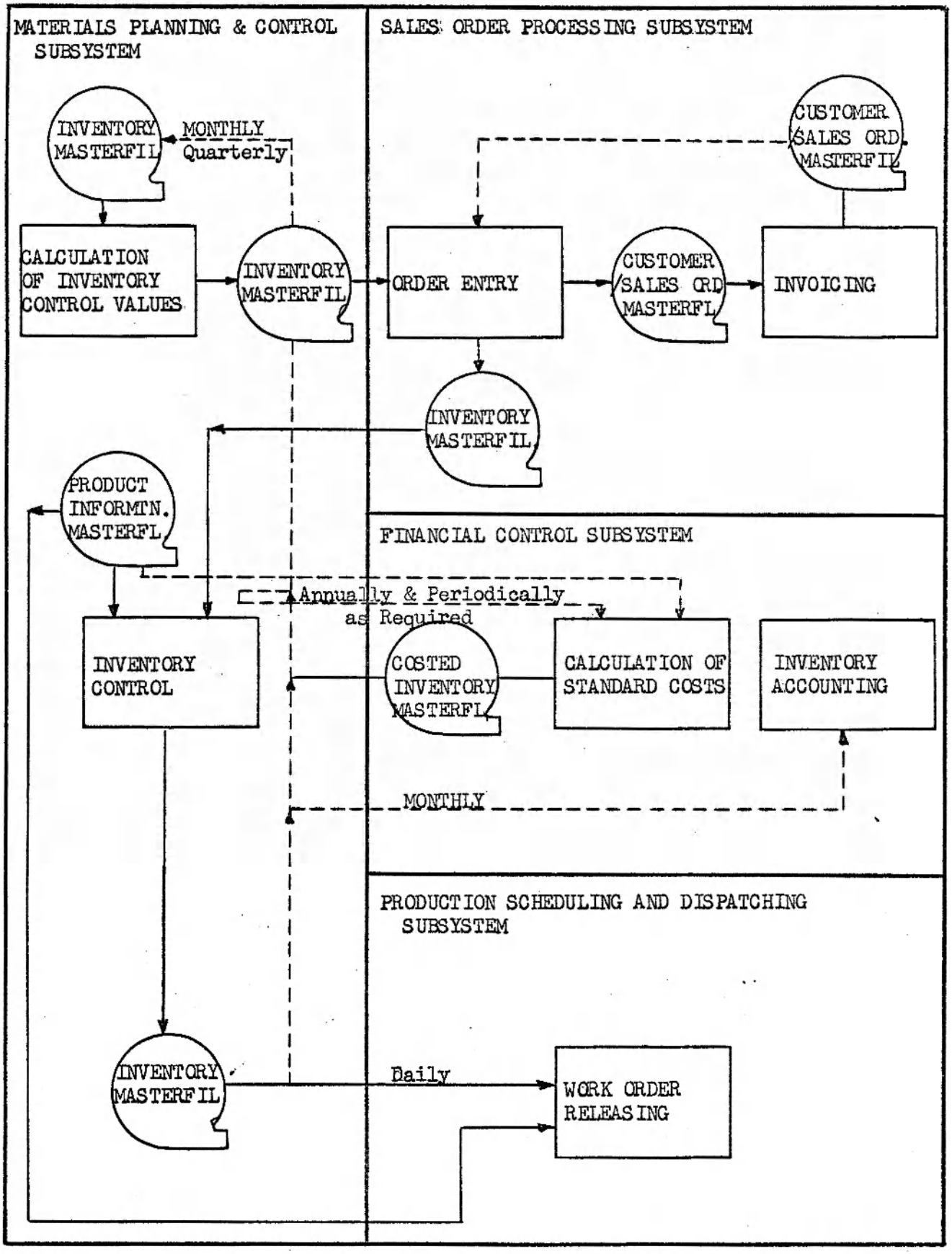
Information derived from the priced annual sales forecast is combined with budget information to produce projected operating statements which are submitted to top management for review and approval. Once any necessary changes have been made to bring the anticipated financial position of the company into line with the goals of divisional and corporate management, the budgets are accepted. Thus, the budgetary control basis for the division as well as for all departments and work centers is established.

The total integrated management control system, including all of the major and minor subsystems, is flow-charted in detail in the appendix. As can be seen, this chart combines all of the subsystems that have been discussed previously into one coherent, integrated network, showing the entire system interrelationship.

EXPLANATION OF PLATE VII

The integrating effect of masterfiles on the various major subsystems.

PLATE VII


MATERIALS PLANNING & CONTROL SUBSYSTEM
SALES ORDER PROCESSING SUBSYSTEM
INVENTORY MASTERFIL
MONTHLY Quarterly
CUSTOMER SALES ORD MASTERFIL
CALCULATION OF INVENTORY CONTROL VALUES
INVENTORY MASTERFIL
ORDER ENTRY
CUSTOMER SALES ORD MASTERFL
INVOICING
INVENTORY MASTERFIL
PRODUCT INFORMTN. MASTERFL
FINANCIAL CONTROL SUBSYSTEM
Annually & Periodically as Required
INVENTORY CONTROL
COSTED INVENTORY MASTERFL
CALCULATION OF STANDARD COSTS
INVENTORY ACCOUNTING
MONTHLY
PRODUCTION SCHEDULING AND DISPATCHING SUBSYSTEM
INVENTORY MASTERFIL
Daily
WORK ORDER RELEASING

THE MASTERFILE CONCEPT

It was indicated in a previous discussion that the key to the effective integration of all parts of the total system is centralization of vital information in magnetic tape files (18, pp. 20-64). It is the purpose of the following discussion to illustrate how this masterfile concept has been applied (See Plate VIII).

Four Various Masterfiles

Basic information about company operations is contained in five magnetic tape masterfiles. One of these, the Inventory Masterfile, is described below in more detail. The other four masterfiles are: (1) the Customer/Sales Order Masterfile, (2) the Product Information Masterfile, (3) the Employee Masterfile, and (4) the Work-in-Process Masterfile.

The Customer/Sales Order Masterfile describes each customer in terms of such items as customer code number, name, credit status, and address, and provides a complete enumeration of all open sales orders. Sales order information includes an account of items on order, requested and promised delivery dates, destinations of goods, and relevant tax and insurance information.

The Masterfile on Product Information provides complete information about each component and product-line item, including identifying information and the details of its manufacture, including required bill of materials, operations, setup, tooling and equipment.

The Employee Masterfile contains complete information about each employee organized under the categories of personnel and payroll. Included are pay rate, vacation, earnings, and taxes to date; termination

information; deductions authorized; balances of deductions made but not yet paid to various agencies; insurance data; and sick pay.

The Work-in-Process Masterfile comprehensively describes the status of all jobs currently in the factory. For each work order, there are a number of separate information items including work order and stock numbers, labor and burden value added at standard cost, and inventory account numbers to which completed work is charged.

Inventory Masterfile

One of the most important elements in the information processing system is the Inventory Masterfile. This file contains approximately one hundred different information items for each article of inventory; the data is categorized as follows: Standard inventory data (identification numbers, inventory control values, flow and process times, price, discounts, etc.); customer requirements (reservations against inventory); inventory balance data, and open factory orders.

The Inventory Masterfile is an interlocking element in a majority of the primary subsystems already described. Plate VII shows how this and other magnetic tape masterfiles serve to tie together the Sales Order Processing, Materials Planning and Control, Production Scheduling and Dispatching, and Financial Control Subsystems. The following discussion describes the operations indicated in the plate.

Daily Operations

The order entry operation in the Sales Processing Subsystem is performed twice daily. It involves: (1) entering new sales orders in the Customer/Sales Order Masterfile; (2) acknowledging sales orders just entered

and those for which confirming assembly schedule dates have been established; (3) issuing shipping orders; (4) updating the Inventory Masterfile to reflect assembly schedule confirmations and finished goods stock receipts as well as requests for made-to-order-items, reservations against stocks to fill orders, and commitments for shipping orders issued. The updated Inventory Masterfile is used as input to operations in the Materials Planning and Control Subsystem.

Performed once a day, the inventory control operation in the Materials Planning and Control Subsystem consists of: (1) updating the Inventory Masterfile to reflect shipping transactions recorded in the invoicing operation at the Sales Order Processing Subsystem and stock withdrawals against previously issued requisitions for components and materials; (2) updating the Inventory Masterfile to reflect data regarding newly-established fabrication and assembly schedules; (3) analyzing the balances indicated in the Inventory Masterfile to determine what stock and make orders must be issued and then issuing these orders; (4) exploding orders against the Production Information Masterfile to determine manufacturing requirements; and (5) making reservations against stocks of required components and raw materials.

After completion of the daily inventory control operation, the Inventory and Product Information Masterfiles are used an input to the Production Scheduling and Dispatching Subsystem. This operation involves producing the work orders, requisitions, and labor and move tickets required to initiate production jobs scheduled to begin two days hence. Also, the Inventory Masterfile is updated to reflect the commitments against stocks set up by the requisitions issued. The Inventory Masterfile is then cycled back for use in the next day's order entry operations.

Monthly, Quarterly, and Annual Operations

Once each month, the Inventory Masterfile is used as input to an inventory accounting operation in the Financial Control Subsystem. This operation involves costing of the past month's inventory transactions for use in inventory reporting and in work-in-process and general ledger accounting operations. Also, at the same time, inventory control values (weekly usages, order quantities, reorder points, etc.) for finished goods are calculated in the Materials Planning and Control Subsystem on the basis of the sales forecast generated in the Management Planning Subsystem. These values are superimposed on the Inventory Masterfile and are used in inventory control operations throughout the ensuing period. A similar procedure is performed quarterly to establish inventory control values for components and raw materials.

During the final month of each year, unit standard costs are calculated for all material, labor and burden going into the production of each finished goods item. This operation, a function of the Financial Control Subsystem, is fully computerized and includes updating the Inventory Masterfile to reflect the newly-calculated standard costs. These costs are used throughout the following year for inventory accounting purposes and for determining variances. Standard costs are also calculated periodically as necessary for competitive purposes.

SUMMARY AND CONCLUSIONS

Total Systems - Mid-Point or Terminus?

With the design of the system completed, the final question one must ask is: Will the system pay off? What are the benefits to be gained from it? How can we measure the increases in business performance, if any, and what are they? So far as return on investment is concerned, the total systems concept has the potential to provide both short-term and long-range dividends. But it is unprofitable, if not impossible, to invest solely for short term benefits. The dividends of organizational as well as systems integration are paid daily and are accumulative; the longer the investment and the more invested, the greater the return (within limits of course). In contrast to normal investments, the payoff begins almost as soon as the investment is made.

From the broad point of view, just so long as the integration is practical and feasible, the more you integrate the more effective will be the data processing functions of a business. Simplifying and bringing together functions of a business may not necessarily call for capital investment in traditional or new electronic computing equipment.

In a small company, integration may still require only the reorganization of the administrative process and the simplification of paperwork procedures. Common language tapes or even punched cards may not be needed. (9, pp. 392-433). Large-scale communications systems linking factories and sales offices from coast to coast with a central headquarters may be entirely unnecessary. Nevertheless, the principles of integration will be called upon to provide small businesses with the substantial improvement in operations, and the consequent savings in time and personnel,

needed to keep them competitive with medium-sized and large organizations (15, pp. 25-27).

In the wide range of middle-sized companies, the total systems concept may involve simply the addition of a tape-producing typewriter or intermediate size calculators. Or, in a large retail department store, point-of-sale tape-producing registers and a punch-tag setup may provide the impetus for even broader applications.

Among large corporations and the real giants of industry, total systems may call for a variety of medium-and large-sized computers, special purpose machines, and large numbers of building-block units linked by common language media. Here, also, will be found the tie-up of modern network communications with modern integrated data processing. This latter category of business is therefore applicable to the type of management information system that has been detailed in this report.

It should also be noted that automation does not provide the decision-making function essential to management. No machine yet conceived can totally run a business without human intervention. What one can hope for, though, in data processing is the development of techniques and equipment which will permit an ever-increasing proportion of the routine tasks performed to be integrated and automated; to be put together into combined functions which can be funneled to the human minds of management for decision and action.

Benefits to be Derived from Business Automation

To summarize the benefits to be gained from the application of digital computers to the total integrated management system, we have (22, pp. 137-140; 25, pp. 7-13):

(1) Speed - The ability to produce the information faster, the benefit of speed, is an often overemphasized factor, but again it is an important one in certain instances. The over-all survey of data processing practices quickly indicates those records upon which management functions depend, and the schedule and periodicity involved.

(2) Accuracy - By eliminating much of the manual routine copying of information, integration and computerization abolishes much of the opportunity for human error. However, management should provide standards by which accuracy can be equated to its real function and value.

(3) Reduced Costs- As has already been discussed, total systems, properly engineered, installed, and operated, can cut processing costs in many instances. The savings are principally the result of making one recording (i.e. - masterfiles) do the job of many, reducing the personnel time involved, and being able to spread the fixed cost further by producing more and better reports and records. The interrelationship between improved performance of the business and reduced costs will be discussed in greater detail later in this report.

(4) Flexibility - It is comparatively easy to expand or contract the system to meet temporary needs or growth without large capital investments; various elements within the total system itself can be enlarged or contracted without affecting such other factors as input, output, calculation, and conversion. Moreover, integration makes it possible to use data in ways which previously involved painstaking manual and machine methods requiring much time and labor.

(5) Improved Reporting - Reports are needed that are slanted toward specific problem areas, to phases of operations demanding a quick and positive opinion, in addition to the regular reports covering the everyday topics of concern.

(6) Improved Communications - Being able to link the sources of information directly with the system which processes it for management's use is one of the major benefits of the total integrated system. In addition to being able to tie in directly with telephone and telegraph systems using punched tape, many companies are combining their data processing operations with private communication systems linking various parts of the company.

(7) Greatly Improved Management Control - Under integration, an executive has a better opportunity to learn of the problems perplexing his opposite numbers and to get his views before his colleagues. Integrated data processing systems cross artificial department and division barriers. As a result, the management of a company is more closely united under such a total system than under one in which there is no integration.

Measures of System Performance

In order to place the performance of any control system in proper perspective, it is necessary to provide a yardstick by which to measure the load being placed on that system (12, pp. 53-58). A control system exhibiting apparently outstanding performance may not appear so remarkable in the light of data indicating that very little is being controlled.

When considering a business control system, one parameter which is very expressive of the amount of activity being controlled is sales volume.

EXPLANATION OF GRAPH I

This is a graph of the sales volume as a percentage of some base year versus time in years; this is perhaps the basic parameter to consider when measuring the other indicators of performance.

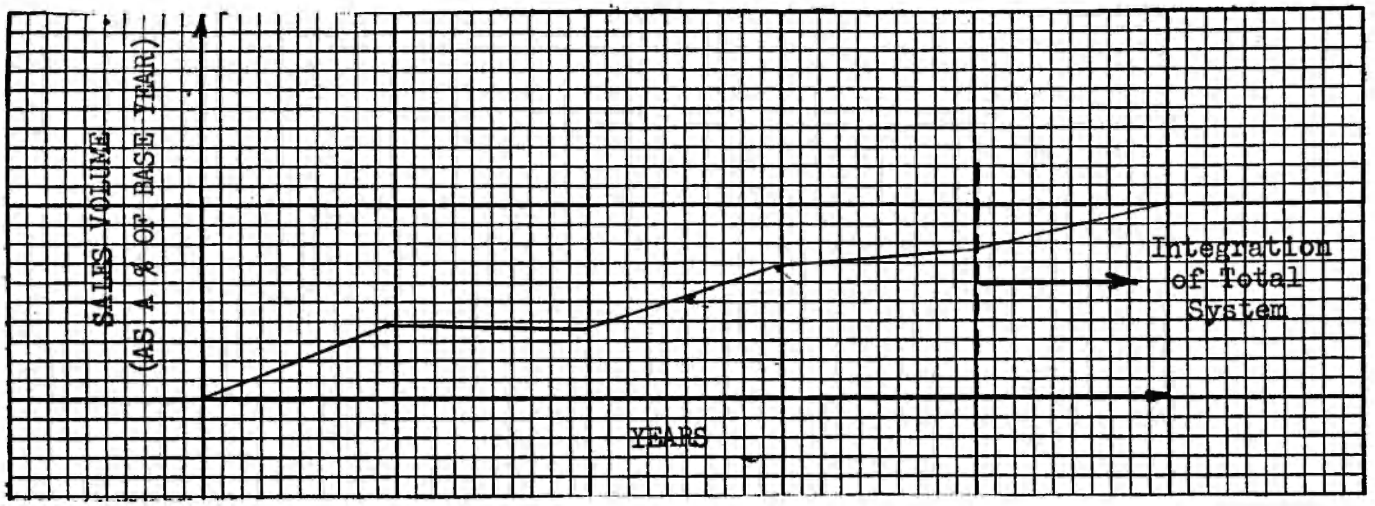
EXPLANATION OF GRAPH II

This is a graph of on-schedule deliveries as a percentage of total number of deliveries made during a given period versus time in years; note the anticipated increase of the measure of performance after the integration of the total system.

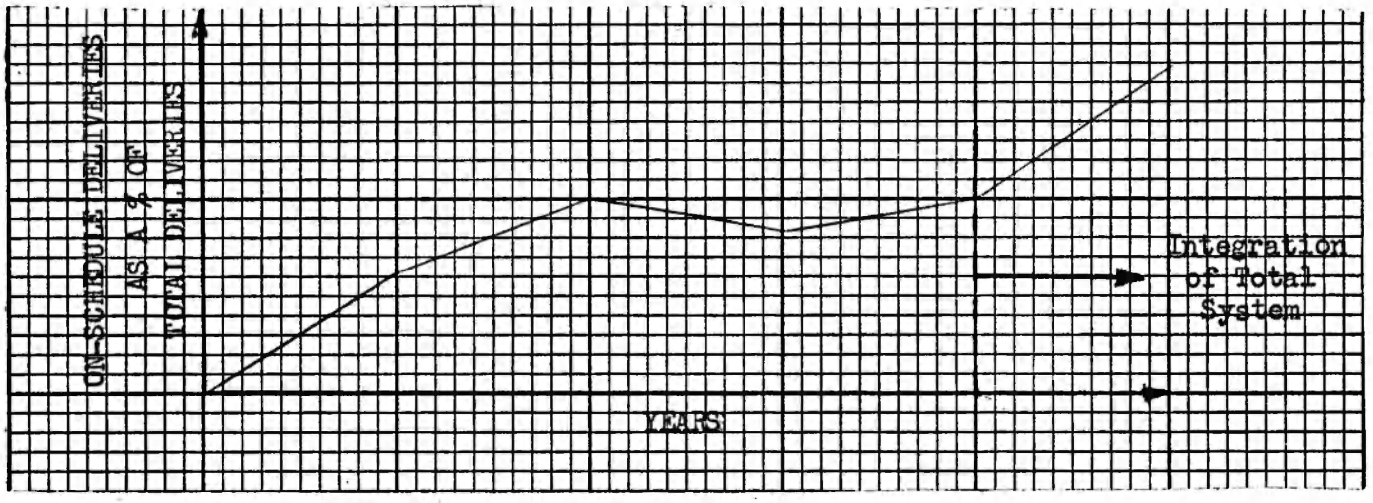
EXPLANATION OF GRAPH III

This is a graph of the sales to inventory ratio versus time in years; note the anticipated increase in this ratio after the integration of the total system.

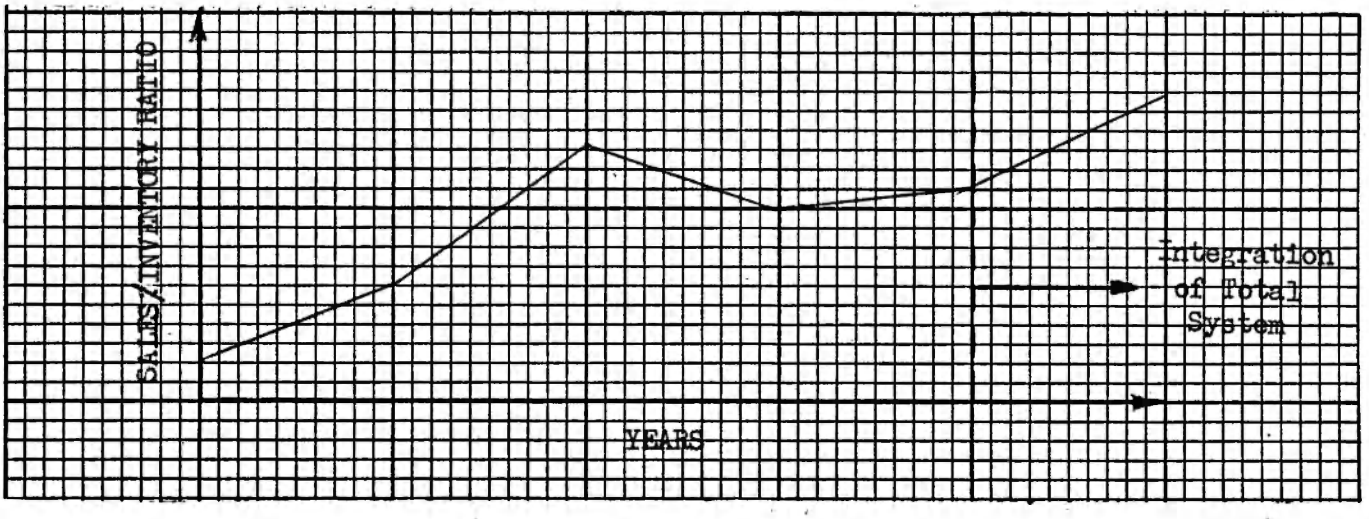
GRAPH I



GRAPH II



GRAPH III



Obviously, when more sales are being made; more orders are being processed, more raw materials and components are being stocked, more products are being manufactured, more employee records are being maintained, more accounting transactions are being recorded, and in an over-all sense, more data must be monitored for control purposes. Therefore, if a business is expanding in sales volume as shown in Graph I, and the total integrated management system is at least as efficient and reliable as the previous system, then we have one realistic indicator of its success.

Another measure of system performance is the percentage of on schedule deliveries that a company maintains. If the percentage of total on schedule deliveries increases as shown in Graph II, especially if the sales volume is likewise increasing, then it is evident that the total systems concept has contributed successfully in another area also.

A third measure is the sales/inventory ratio, a measure of the annual turnover rate of average inventory. It would be expected to increase as shown in Graph III.

In order to maintain and expand its market, a business must set competitive prices while at the same time maximizing profits. Neither of these activities are possible unless accurate information is available concerning the cost of each material and each manufacturing operation which goes into making a product. A good measure of a company's knowledge of its product costs is its ability to set accurate standard costs for accounting purposes. If the differences between anticipated and actual costs of manufacturing products are great, this knowledge is obviously inadequate. Therefore, for good system performance, as shown in Graph IV, the variances as a percent of production at standard cost should decrease, and further should become increasingly stable.

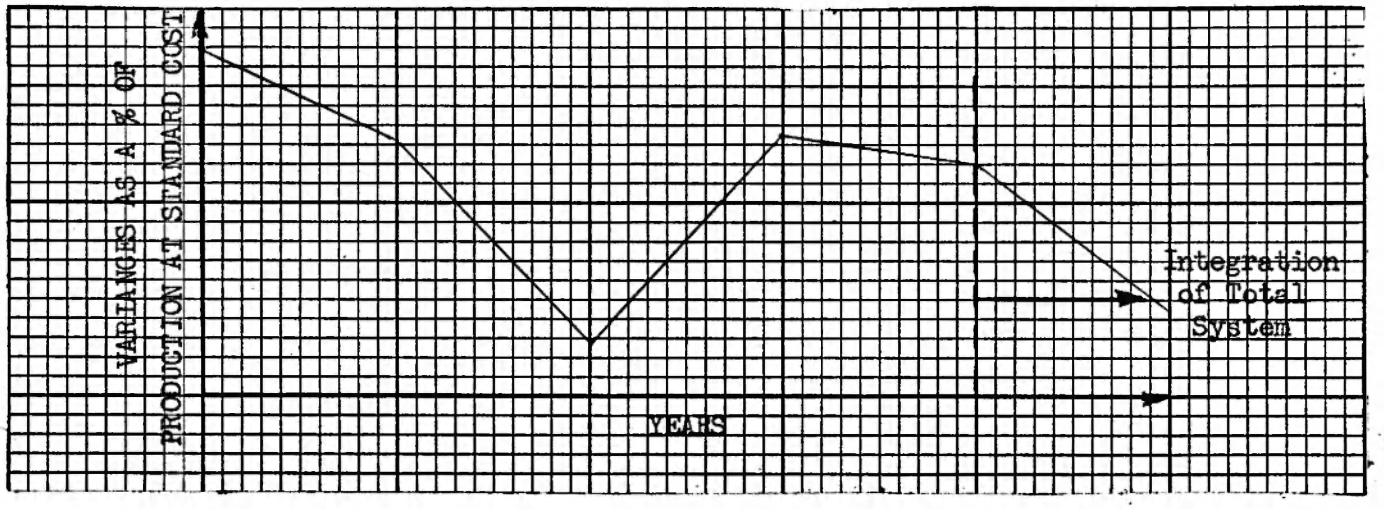
EXPLANATION OF GRAPH IV

This is a graph of the variances between the anticipated and actual costs of production; note the anticipated decrease after the integration of the total system.

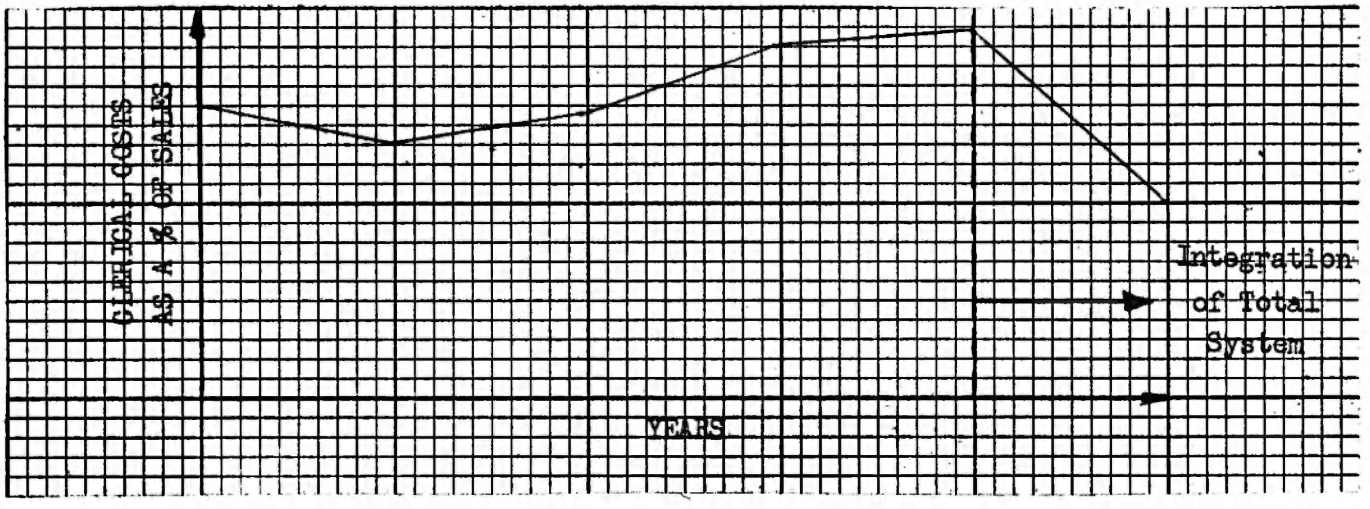
EXPLANATION OF GRAPH V

This is a graph of the clerical costs as a percentage of the sales volume; note the anticipated decrease after the integration of the total system.

GRAPH IV



GRAPH V



Likewise for improved system performance, paperwork efficiency should increase. In the total integrated management system illustrated in this report, basic information has been centralized into masterfiles; and reports are made only when performance indicators being monitored move outside the limits of a preset range of acceptable values. Centralization of basic information in masterfiles has eliminated duplication of effort, duplication of pieces of data, and in many cases has obviated entirely the necessity of maintaining certain files. Exception reporting has cut to a minimum the number of reports containing non-useful information. Although much more data is processed, the outputs of the processing operations are proportionally much smaller than before, and many times more useful.

A final measure of system performance would be the percentage of sales spent for clerical purposes. As shown in Graph V, this ratio should decrease if the installation of a data processing facility is to be economically feasible.

Conclusions

In short, regardless of the size or type of business, the considered application of the total integrated system's concept will furnish management with an efficiency and effectiveness heretofore unapproached. Industry has in its grasp not only the concept and format, but the equipment - rudimentary as it may be when judged in the light of what is yet to come - and an ample supply of proved applications in every major industry and business field to support the validity of the judgement that integration is not only remedial in relation to present problems, but it provides a completely adaptable program for the future.

ACKNOWLEDGEMENTS

My sincere thanks go to my major professor, Professor J. J. Smaltz, Department of Industrial Engineering, for his instruction during the preparation of this report, and for his counsel in innumerable matters not particularly related. I am also indebted to the many fine industrial firms (listed in the footnote on page 7 of this report) who opened their files to me and graciously expended their time to answer my questions.

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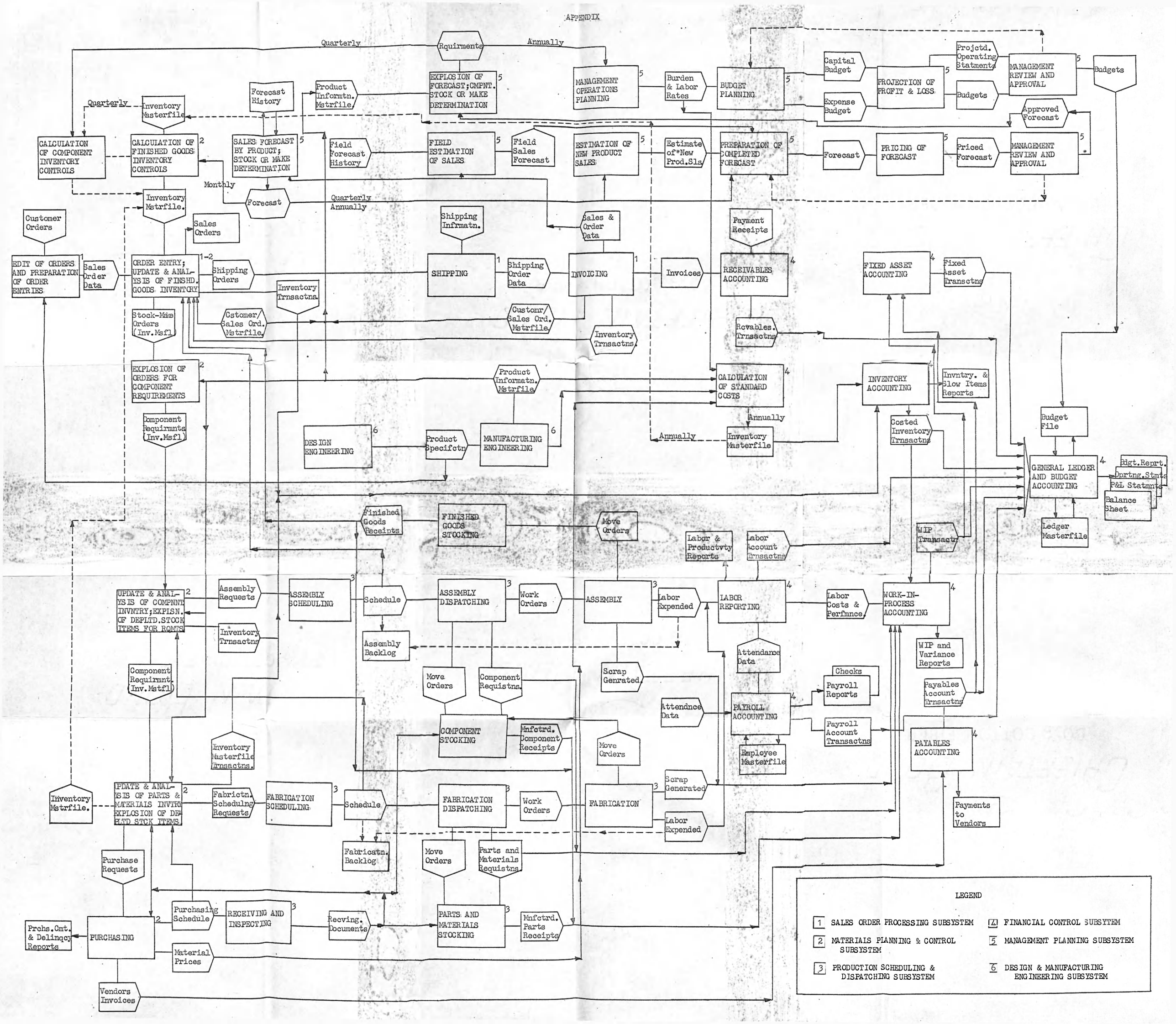
APPENDIX

APPENDIX

Detailed data flow of all the major and minor sub-systems in the total integrated management control system.

APPENDIX


Quarterly
Rquirments
Annually
EXPLOSION OF FORECAST;CMPNT. STOCK OR MAKE DETERMINATION
MANAGEMENT OPERATIONS PLANNING
Burden & Labor Rates
BUDGET PLANNING
Capital Budget
Expense Budget
PROJECTION OF PROFIT & LOSS
Projctd. Operating Statments
Budgets
MANAGEMENT REVIEW AND APPROVAL
Budgets
Approved Forecast
Quarterly
Inventory Masterfile
Forecast History
Product Informtn. Mstrfile
CALCULATION OF COMPONENT INVENTORY CONTROLS
CALCULATION OF FINISHED GOODS INVENTORY CONTROLS
SALES FORECAST BY PRODUCT; STOCK OR MAKE DETERMINATION
Field Forecast History
FIELD ESTIMATION OF SALES
Field Sales Forecast
ESTIMATION OF NEW PRODUCT SALES
Estimate of New Prod.Sls
PREPARATION OF COMPLETED FORECAST
Forecast
PRICING OF FORECAST
Priced Forecast
MANAGEMENT REVIEW AND APPROVAL
Monthly
Forecast
Quarterly
Annually
Inventory Mstrfile.
Customer Orders
Sales Orders
Shipping Infrmatn.
Sales & Order Data
Payment Receipts
EDIT OF ORDERS AND PREPARATION OF ORDER ENTRIES
Sales Order Data
ORDER ENTRY; UPDATE & ANALYSIS OF FINSHD. GOODS INVENTORY
Shipping Orders
Inventory Trnsactns.
SHIPPING
Shipping Order Data
INVOICING
Invoices
RECEIVABLES ACCOUNTING
FIXED ASSET ACCOUNTING
Fixed Asset Transctns
Stock-Make Orders (Inv.Msfl)
Cstomer Sales Ord. Mstrfile.
Customr/ Sales Ord. Mstrfile
Inventory Trnsactns
Rcvables. Trnsactns
EXPLOSION OF ORDERS FOR COMPONENT REQUIREMENTS
Product Informatn. Mstrfile
CALCULATION OF STANDARD COSTS
INVENTORY ACCOUNTING
Invntry. & Slow Items Reports
Component Requirmnts (Inv.Msfl)
DESIGN ENGINEERING
Product Specifctn
MANUFACTURING ENGINEERING
Annually
Inventory Masterfile
Costed Inventory Trnsactns
Budget File
GENERAL LEDGER AND BUDGET ACCOUNTING
Bdgt.Reprt.
Oprtng.Stmts
P&L Statmnts
Balance Sheet
Ledger Masterfile
Finished Goods Receipts
FINISHED GOODS STOCKING
Move Orders
Labor & Productvty Reports
Labor Account Trnsactns
WIP Transactn
UPDATE & ANALYSIS OF COMPNNT INVNTRY;EXPLSN. OF DEPLTD.STOCK ITEMS FOR RQMTS
Assembly Requests
ASSEMBLY SCHEDULING
Schedule
ASSEMBLY DISPATCHING
Work Orders
ASSEMBLY
Labor Expended
LABOR REPORTING
Labor Costs & Perfmnce.
WORK-IN-PROCESS ACCOUNTING
Inventory Trnsactns
Assembly Backlog
Attendance Data
WIP and Variance Reports
Component Requirmnt. Inv.Mstfl
Move Orders
Component Requistns.
Scrap Genrated.
Checks
Payroll Reports
Payables Account Trnsactns
Attendnce Data
PAYROLL ACCOUNTING
Payroll Account Transactns
COMPONENT STOCKING
Mnfctrd. Component Receipts
Inventory Masterfile Trnsactns.
Move Orders
Employee Masterfile
PAYABLES ACCOUNTING
Inventory Mstrfile.
UPDATE & ANALYSIS OF PARTS & MATERIALS INVTRY EXPLOSION OF DEPLTD STCK ITEMS
Fabrictn. Scheduling Requests
FABRICATION SCHEDULING
Schedule
FABRICATION DISPATCHING
Work Orders
FABRICATION
Scrap Generated
Labor Expended
Payments to Vendors
Fabricatn. Backlog
Move Orders
Parts and Materials Requistns.
Purchase Requests
Purchasing Schedule
RECEIVING AND INSPECTING
Recving. Documents
PARTS AND MATERIALS STOCKING
Mnfctrd. Parts Receipts
Prchs.Cmt. & Delinqcy Reports
PURCHASING
Material Prices
Vendors Invoices
LEGEND
1 SALES ORDER PROCESSING SUBSYSTEM
2 MATERIALS PLANNING & CONTROL SUBSYSTEM
3 PRODUCTION SCHEDULING & DISPATCHING SUBSYSTEM
4 FINANCIAL CONTROL SUBSYTEM
5 MANAGEMENT PLANNING SUBSYSTEM
6 DESIGN & MANUFACTURING ENGINEERING SUBSYSTEM

THE APPLICATION OF DIGITAL COMPUTERS TO THE TOTAL INTEGRATED MANAGEMENT SYSTEM'S CONCEPT

by

STEPHEN CLARKE REDDING

B.M.E., Clarkson College of Technology, 1963.

ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1965

In order for a company to reap the full benefits of automated business data processing, the power of the electronic computer must be harnessed in the framework of a well-designed effective system. One can define the total integrated management system's concept as the ability to control operations, set policy, and base forecasting upon data which have been systematically developed, not through a mere integration of clerical tasks, but through an integration of overall company functions (i.e. - inventory control, production control, and sales forecasting) which has the end result of producing integrated information.

The key to the effective integration of the many separate parts of the total integrated management system is centralization of key information. Basic information about the business is contained in magnetic tape master-files which form the backbone of the entire information processing system. The total system would obviously contain a number of subsystems. The first subsystem is the Design and Manufacturing Engineering Subsystem. Design Engineering prepares complete product specifications, as well as individual product bills of materials and drawings. Based on this data, Manufacturing Engineering prepares specifications describing the production of each item in terms of manufacturing departments and centers concerned, tooling and equipment required, and operations to be performed with the appropriate labor standards included.

The primary functions of the Sales Order Processing Subsystem comprises entering orders into the system, shipping, and invoicing orders which can be supplied from stock, informing Materials Planning and Control of orders which require manufacture, and compiling order backlog and shipping statistics for Management Planning.

The Materials Planning and Control Subsystem maintains inventories of manufactured items and raw materials at levels high enough to meet delivery schedules while at the same time preventing the unnecessary expenses of obsolescence and excessive carrying costs resulting from overstocking practices.

The Production Scheduling and Dispatching Subsystem includes both assembly and fabrication operations. These production areas are supported by scheduling, dispatching, and stocking functions. The materials receiving function is also included in this subsystem.

The Financial Control Subsystem monitors all company activities, determines their effects on the financial position of the company, and produces reports concerning these effects for management's use. All of the accounting functions for many other areas, calculation of standard costs, labor analysis, and general ledger and budget accounting are included also.

The master plan, which keeps all the subsystems running efficiently, is formulated by the Management Planning Subsystem, where management develops and maintains a master plan which comprises long-range goals, thus providing a framework for short-range decisions. Tools used in plan development include sales statistics, periodic sales forecasts, operating budgets, and financial statements.

Concluding, regardless of the size of the business, the considered application of the total integrated management system's concept will furnish management with an efficiency and effectiveness heretofore unapproached.