PRODUCTIVITY IMPROVEMENT SYSTEMS FOR MANUFACTURING

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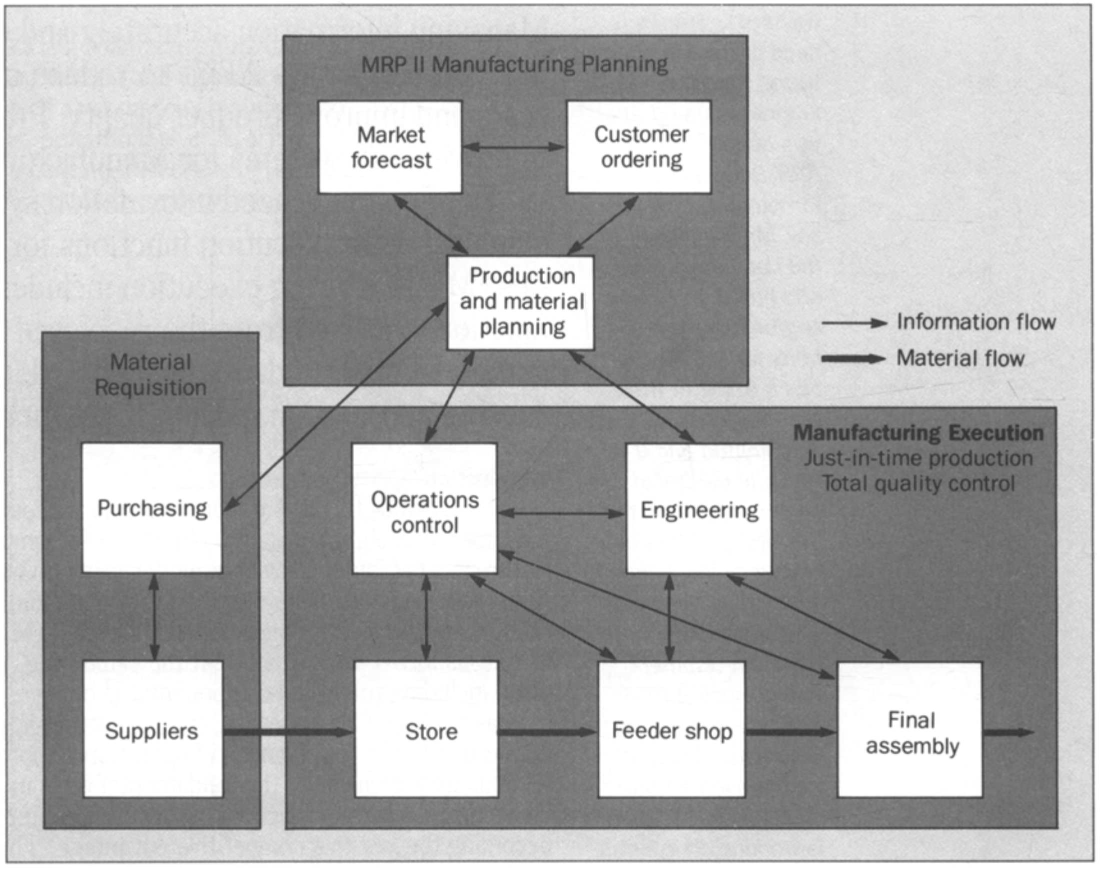
Managing information accurately and efficiently is a key function that allows AT&T to reduce manufacturing costs and improve product quality. Productivity Improvement Systems for Manufacturing (PRISM) is a family of computerized information systems supporting manufacturing execution functions for AT&T's factories. Manufacturing execution includes all factory functions involved from the receipt of materials to the making of final products, including deriving the engineering information guiding these functions.

Introduction

Manufacturing is experiencing a rapid evolution in philosophy, fundamental techniques, and technology. To compete worldwide, manufacturers must invest heavily in modernizing manufacturing plants. Approaches such as *just-in-time* (JIT) production, *total quality control* (TQC), and *manufacturing resources planning* (MRP II) are being tested in various forms and degrees. At the same time, physical automation, often including robot-like components, is being used to meet the increasingly tight cost, quality, and production-speed objectives dictated by the marketplace. Advances in operational approach and automation technology are changing the fundamental ways in which management views manufacturing. Once viewed as cost centers, factories are becoming the key to a competitive advantage. The penalty for not modernizing may ultimately lead to failure in the marketplace.

It is evident that simplifying the underlying operational processes and associated information management is the key to controlling manufacturing resources and guiding them to peak performance. In the modern manufacturing environment, timely and accurate information is invaluable in the competitive arena, enabling a company to produce higher quality products faster and at lower costs. *PRISM* (Productivity Improvement Systems for Manufacturing) has been designed and developed to support AT&T in meeting this challenge. PRISM is being planned and implemented through the combined efforts of AT&T Bell Laboratories, the AT&T Engineering Research Center, the AT&T Operations Systems Technical Center, and various AT&T factories.

Figure 1. Manufacturing operations overview. Representative flows of information and materials are shown. Information flows are the plan and the information needed to manufacture the product, while material flows signify the actual movement of material during the production process.

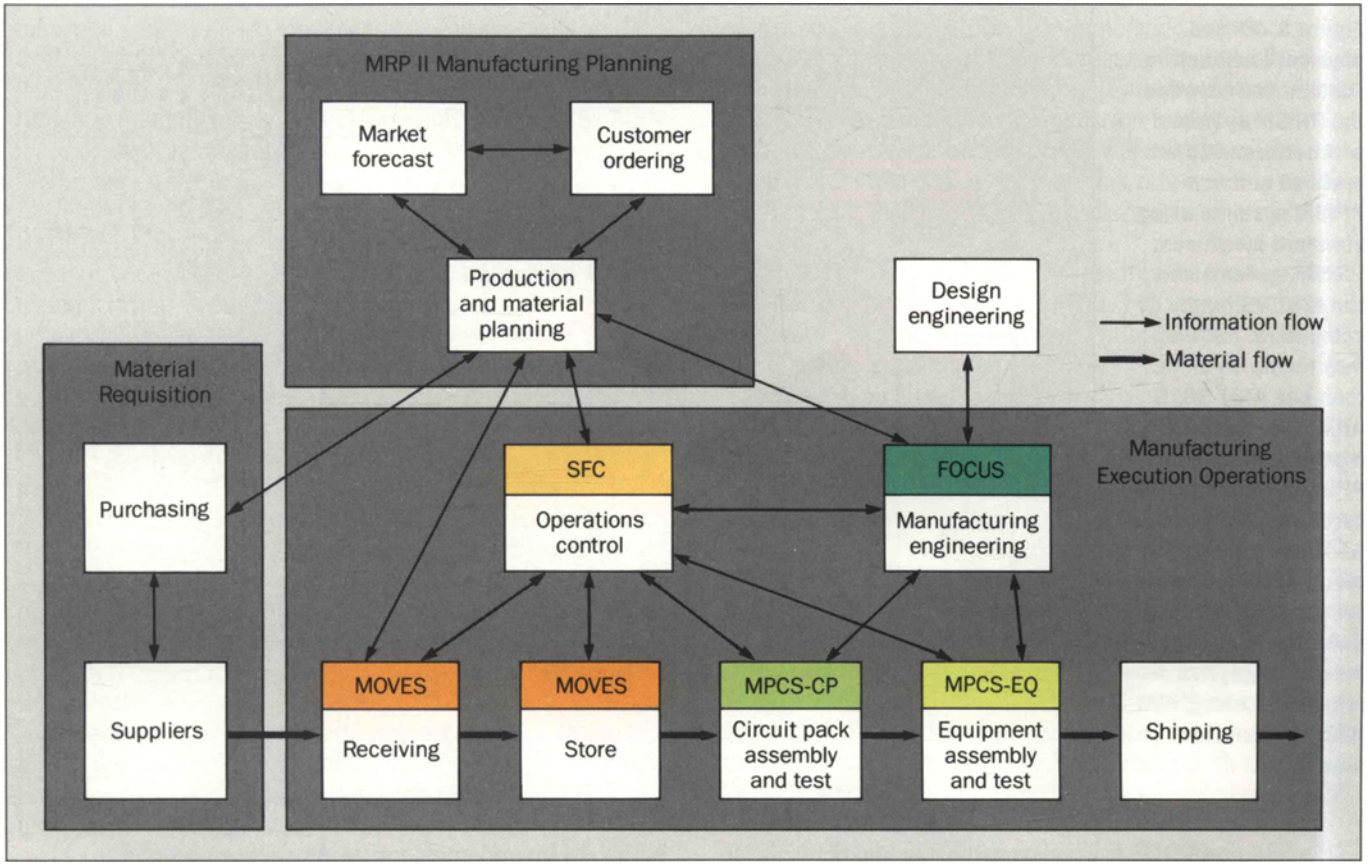


PRISM is a family of computerized information systems supporting manufacturing execution functions for AT&T's factories. PRISM assists in moving materials from suppliers onto the production floor and transforming these materials into final products through the appropriate engineering information. The following sections describe how PRISM supports these functions from end to end and each of the PRISM systems in detail. The final section addresses future directions for the development and use of PRISM.

PRISM Overview

Figure 1 summarizes manufacturing functions. PRISM focuses on the areas of operations that turn manufacturing plans into products. It has four main systems:

1. *MOVES*—Material Operations and Velocity System
2. *SFC*—Shop Floor Control System
3. *MPCS-CP*—Manufacturing Process Control System for Circuit Packs



4. *MPCS-EQ*—Manufacturing Process Control System for Equipment.

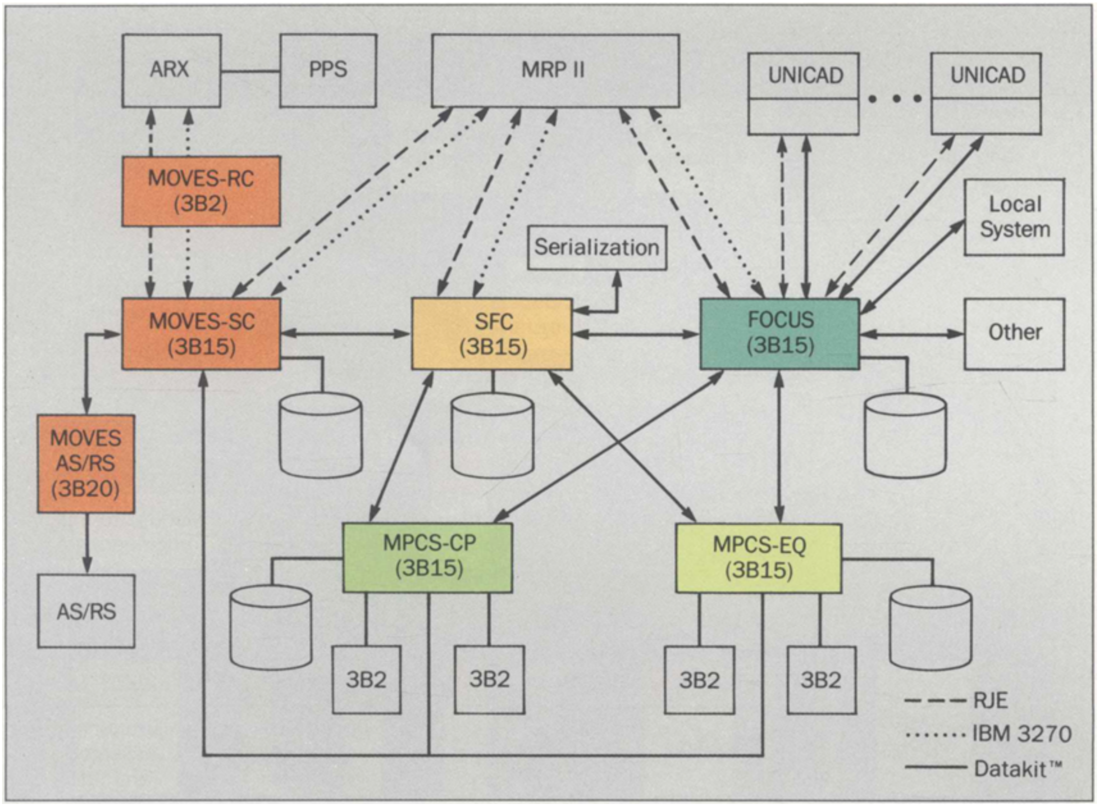
Figure 2. PRISM focuses on those areas of operations that turn manufacturing plans into products.

Figure 2 shows the functions that PRISM supports in more detail. The following is a brief overview of these functions, highlighting the role of each PRISM system.

Based on requests from the manufacturing planning function of the factory, suppliers deliver raw materials and subassemblies to the receiving area of the factory, which forwards them either directly to the production area or to the various manual and automated storerooms. This function is supported by the MOVES system of PRISM, which receives the plan for materials acquisition from the Manufacturing Planning systems and supports its implementation. MOVES also provides needed information to corporate accounting and purchasing systems.

In parallel, the plan for production is sent to the

Figure 3. PRISM physical architecture. Data moves between the PRISM systems and between PRISM systems and non-PRISM systems using standard interfaces. PRISM systems use the AT&T 3B family of computers. FOCUS may reside on more than one AT&T 3B15. ARX = Accounting receiving executive; PPS = Planning procurement systems; AS/RS = Automated storage and retrieval system; UNICAD = universal computer-aided design; RJE = remote job entry; IBM 3270 = terminal emulation.



SFC system of PRISM, which coordinates and controls all manufacturing execution inter-shop activities.

SFC sends the appropriate information to the relevant Circuit Pack Assembly and Test Shops, which execute the plan by processing the material made available to them from the storerooms. The MPCS-CP system helps these shops to get and use the needed information.[1]

Following the same plan from SFC, the Equipment Assembly and Test Shops assemble the circuit packs into final products, supported by the MPCS-EQ system of PRISM.

A necessary input for the manufacturing execution processes (for both circuit pack and equipment assembly) is the design and engineering information needed to assemble and test each type of circuit pack and each version of the final product to meet the customers' specifications. This function is supported by the FOCUS system of PRISM, formerly two separate systems, MDS and SPECS. (MDS stands for manufacturing data system; SPECS stands for synchronized production engineering control system.)

MDS supported design information transfer functions from the design environment and SPECS, as a member of the PRISM family, supported manufacturing engineering functions using the design information in the factory. Because it is important to get design information into the factory and get manufacturing feedback into design, we have made these into one system, thereby improving the manufacturing design of AT&T products, reducing manufacturing costs, and improving product quality. (For additional information on FOCUS, see the article by Burling et al.[2] in this issue.)

The PRISM systems are new and evolving rapidly. PRISM was first used to mechanize the acquisition and management of the specific information needed for each manufacturing execution function. This was done by integrating PRISM's own systems and by coordinating with other information systems supporting the factory, most notably the manufacturing planning and the manufacturing design systems.

Eventually, PRISM should be able to provide information to users to guide and support full JIT/TQC manufacturing execution operations. Some PRISM features are now available; others are under development. When this evolution is complete, the information provided by SFC to MOVES, MPCS-CP, and MPCS-EQ will be sufficient to *sequence* the operations that the systems support more precisely and efficiently than is possible today. This precise sequencing closely coordinates the work in feeder and consuming shops so that material flows in a synchronized manner through the shops, reducing the amount of inventory held in each shop and more fully using the shops' production resources.

Proprietary algorithms are the technical backbone of this complex function. At the same time, MPCS-EQ, MPCS-CP, and MOVES will also use different proprietary algorithms to support what is referred to in JIT literature as *pull* of material—that is, the ability of the consuming shop to stop the production in a feeder shop by not removing material from the feeder shop's output buffer. The feeder shop ceases production once its physical or logical output buffer is full. This method, also referred to as *electronic kanban,* prevents the production of unnecessary inventory thereby lowering overall product costs.

With both detailed sequencing and a pull discipline, each feeder shop produces exactly what is needed by the consuming shop at the right time and the velocity of materials through production increases dramatically. An important final point is that in a serious production disruption, such as an outage in a production facility or a shortage in needed material, SFC will *resequence* the production activities temporarily, so that other orders of the same priority get filled while the disruption is being resolved.

These two key PRISM features, sequencing and pull, will be the cornerstone for JIT/TQC manufacturing execution operations, integrated with the MRP-II-based manufacturing planning operations.

PRISM Architecture

PRISM is a loosely coupled, distributed family of systems built on UNIX® System V using the C and C++ programming languages. (See Figure 3.) Each distinct system resides on one or more AT&T 3B computers. Data moves between the PRISM systems and between PRISM systems and non-PRISM systems using standard interfaces. The PRISM family is interconnected via a Datakit™ local area network, and can connect with local systems through Datakit or through gateways into the local factory networks. It provides a terminal-to-host switch and host-to-host communications. Communications with corporate-level IBM systems is by RJE (remote job entry) and IBM 3270 terminal emulation.

PRISM is a database-centered system. Many PRISM transactions involve interactions with various databases containing design and operations information. Each PRISM system has its own database that it manages, while at the same time, interchanging information with other systems, primarily through file transfers across the network.

PRISM is being designed to allow for incremental deployment and evolution. This includes accommodating local differences, including interfaces to locally developed systems, and supporting physical variations such as different factory networks.

As PRISM and industry standards evolve, PRISM will move toward support of these standards, including support of:

- The SQL query language for database access (SQL stands for structured query language).
- ISO and MAP application interfaces built on the UNIX System V transport layer interface (ISO stands for International Standards Organization; MAP stands for manufacturing automation protocol).
- SCSI disks, which provide more disk capacity and allow for mirrored and multi-ported disks (SCSI stands for small computer system interface).
- A global data dictionary system that will provide a unified, global view of the PRISM information resource and easy access to that resource for user programming.

This approach provides an open architecture with a database management system and a network- and processor-independent structure that readily accommodates change and local factory variations.

MOVES

MOVES supports the execution of materials operations in the receiving dock and raw materials storeroom areas of AT&T factories. MOVES *receiving* (MOVES-RC) provides support for receiving dock operations and the subsequent routing of material through the factory. MOVES *stores control* (MOVES-SC) supports the raw materials storeroom operations, and interfaces to MRP II planning systems. MOVES-RC and MOVES-SC are standalone systems, communicating through an on-line interface.

MOVES-RC is designed to speed up the flow of material through the dock area. When material arrives at the dock, dock operators use MOVES-RC to determine whether the material should be received and where to route it. Information for the corporate *accounting receiving executive* and *planning procurement systems* (ARX/PPS) is communicated in real-time by MOVES-RC. All material in the receiving area is identified and tracked using serial numbers.

The primary functions in a storeroom include storeroom receipt and stocking of material, selection of parts for delivery to production areas, inventory management, and communication of storeroom transactions to the MRP II system. MOVES-SC provides terminal interfaces for operators doing these functions and automates the communications with the MRP II system. MOVES-SC is designed around a highly modular *core* storeroom capability that provides overall storeroom coordination and is capable of supporting a variety of physically different storeroom arrangements. MOVES-SC will interact with the automated storage and retrieval systems (AS/RS).

MOVES Logical Architecture. Figure 4 shows the MOVES logical architecture.

MOVES-RC. The system consists of two logical subsystems. The first, *factory receiving*, allows data about received material to be recorded, compared with what is expected by the factory, and transmitted to ARX/PPS. The second subsystem, *dock routing and tracking*, determines the path received material is to take between dock receipt and final delivery, keeping track of its location and status along the way.

When material is received at the dock, information must be collected to ensure that the material may be received into the factory. Information about expected materials is forwarded to MOVES-RC by ARX/PPS. The information recorded at the time of receipt is compared with what is expected. If there is a discrepancy, such as incorrect quantity, incorrect item, or early arrival, the material is held until the problem is resolved. Otherwise, the materials are received into the factory.

MOVES-RC determines the path received material takes through the receiving area using the information provided by the accounting and purchasing systems and that recorded during the receiving process. Material may be routed to zones within the dock area, such as inspection, before being delivered to its final destination. Final destinations include storerooms, shop floor areas, and nonstock areas, such as the office building. MOVES-RC tracks the location and status of all material as it moves through the receiving area. Material is tracked beyond the dock area, until its delivery location is reported. If the material is received into a storeroom, MOVES-RC sends the store-

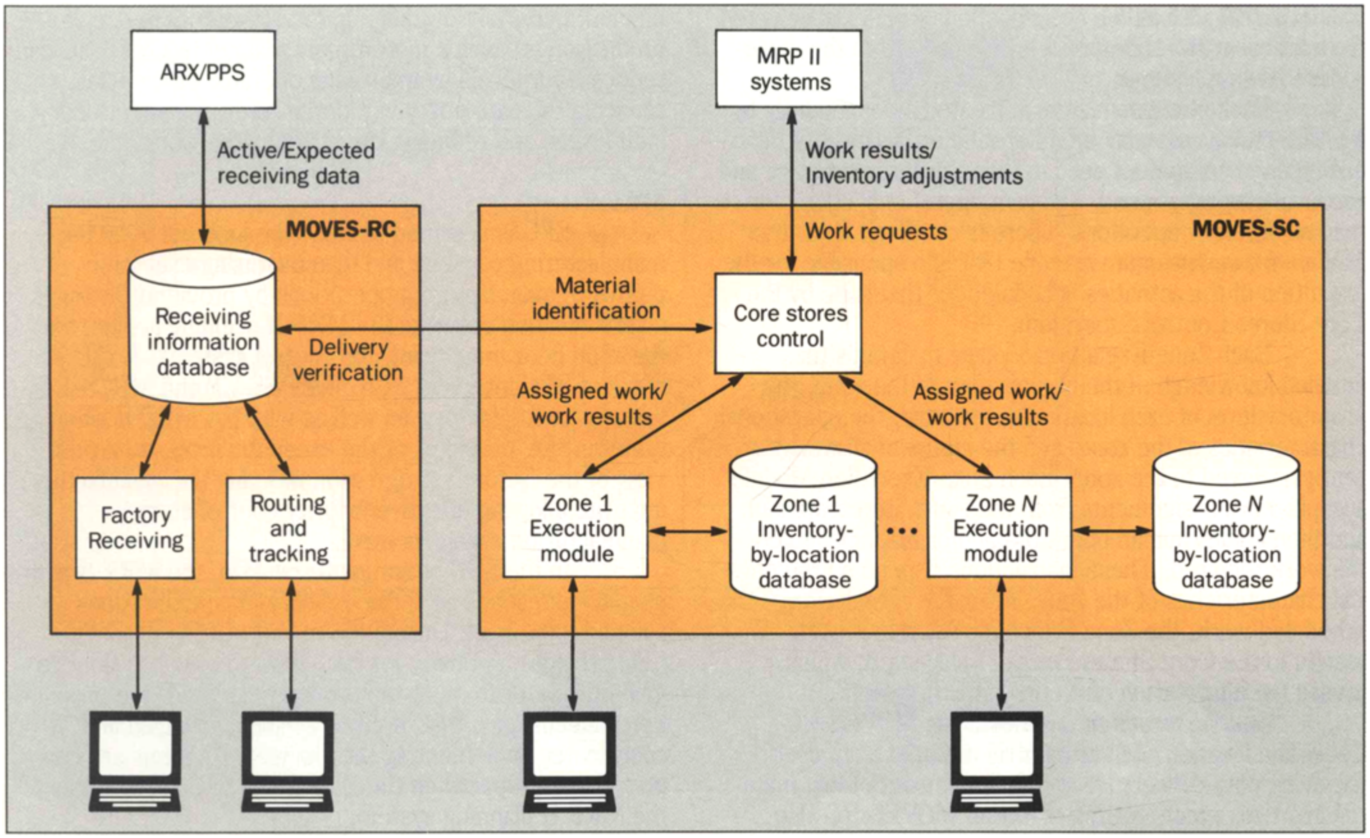


Figure 4. MOVES logical architecture. Operators may tie into PRISM using terminals or portable radio frequency terminals.

room the system data needed for storeroom receipt, reducing the amount of data entry required.

MOVES-SC. This system is also divided into two logical subsystems: *Core Stores Control*, and a set of *Storeroom Zone Execution Modules*. Core stores control is responsible for interfacing to the MRP II systems, and for coordinating the activities of the entire storeroom. Each Storeroom Zone Execution Module is responsible for coordinating the activity in its particular storeroom zone.

Core Stores Control is responsible for coordinating the activities of the storeroom as a whole. It is responsible for the interfaces to MRP II systems, to MOVES-RC, and to MOVES-AS/RS. Core Stores Control tracks the inventory level of each item across all zones of the storeroom. After receiving work requests from the MRP II systems, Core Stores Control assigns work to the different zones of the storeroom based on the inventory level and work backlog in each zone. The work assigned includes stocking, selecting, and counting. Core Stores Control is also responsible for accepting material into the storeroom and assigning it to be stocked in a particular zone based on the zone inventory levels. Core Stores Control coordinates the movement of material from one zone to another, as well as the accumulation of material selected from different zones before it is delivered from the storeroom to a shop.

Each storeroom zone is treated independently by MOVES-SC. Zones may be differentiated because of different types of equipment used in them, different storage and retrieval strategies used, different operational characteristics, or different operators. There is one Zone Execution Module for each storeroom zone that is responsible for the execution of the activities scheduled for that zone by the Core Stores Control Subsystem.

Each Zone Execution Module maintains the detailed knowledge of the organization of the zone, the inventory level of each location in the zone, the operational characteristics of the zone, and the status of all work currently assigned to the zone. Each Zone Execution Module accepts work assignments from the Core Stores Control, and then guides human operators and/or machines to do the work required. These instructions depend on the physical characteristics of the zone. After the completion of the scheduled work, the Zone Execution Module reports the results to the Core Stores Control Subsystem, which passes the information on to the MRP II system.

Benefits: MOVES-RC and MOVES-SC. MOVES-RC tracks the location and status of all material from dock receiving until delivery, reducing the amount of lost material and time spent locating material. MOVES-RC also allows material to be received even if the accounting and purchasing systems are temporarily unavailable. Material moves through the dock faster because its location and status are known at all times.

With MOVES-SC, accurate tracking of inventory levels reduces the amount of safety stock needed to provide an acceptable service level. Operations support improves the accuracy of the work done by the storeroom. The delivery of the appropriate material and quantities reduces disruptions on the shop floor. Because of improved inventory control, the amount of material in the storeroom and staging areas is reduced, thereby freeing floor space. MOVES-SC's work scheduling algorithms allow a more efficient material flow, helping the storeroom to supply the production areas in a more timely manner. MOVES-SC can reduce labor levels by improving operator efficiencies, reducing the data-entry workforce, reducing supervisory staff levels, and reducing the staging area workforce.

SFC

SFC is designed to close the loop between the manufacturing planning and manufacturing execution phases of manufacturing operations by providing two-way communication between the MRP II planning system and the shop floor monitoring and control systems. A single, resident SFC interacts with all MPCS-CP and MPCS-EQ systems in the factory, as well as with the MRP II planning system. SFC provides, at the execution level, an overall view of the factory's progress in meeting the manufacturing plan, allowing effective priority control and manufacturing change control.

In the SFC operational scenario, the MRP II planning system sends SFC the orders and configurations planned to be built. During the manufacturing process, SFC provides a priority for each item to the shop floor to guide the work to meet the production plan. If the production plan changes, SFC notifies all shops involved and coordinates implementing the changes. As items are completed (or scrapped) on the shop floor, SFC reports this to the MRP II planning system.

SFC relies on the MPCS systems for tracking items on the shop floor and for direct support of the manufacturing process, such as direct control of machines. SFC provides to the MPCS systems the orders and configurations to be built, and blocks of serial numbers that MPCS assigns to those items for tracking purposes. SFC's global view prevents serial number duplication in different parts of the factory.

SFC Logical Architecture. SFC has a four-part logical subsystem with four major types of data to perform these functions: (1) orders and configurations data; (2) work-in-process data; (3) operation, routing, and time data; and (4) shop floor description data. (See Figure 5.)

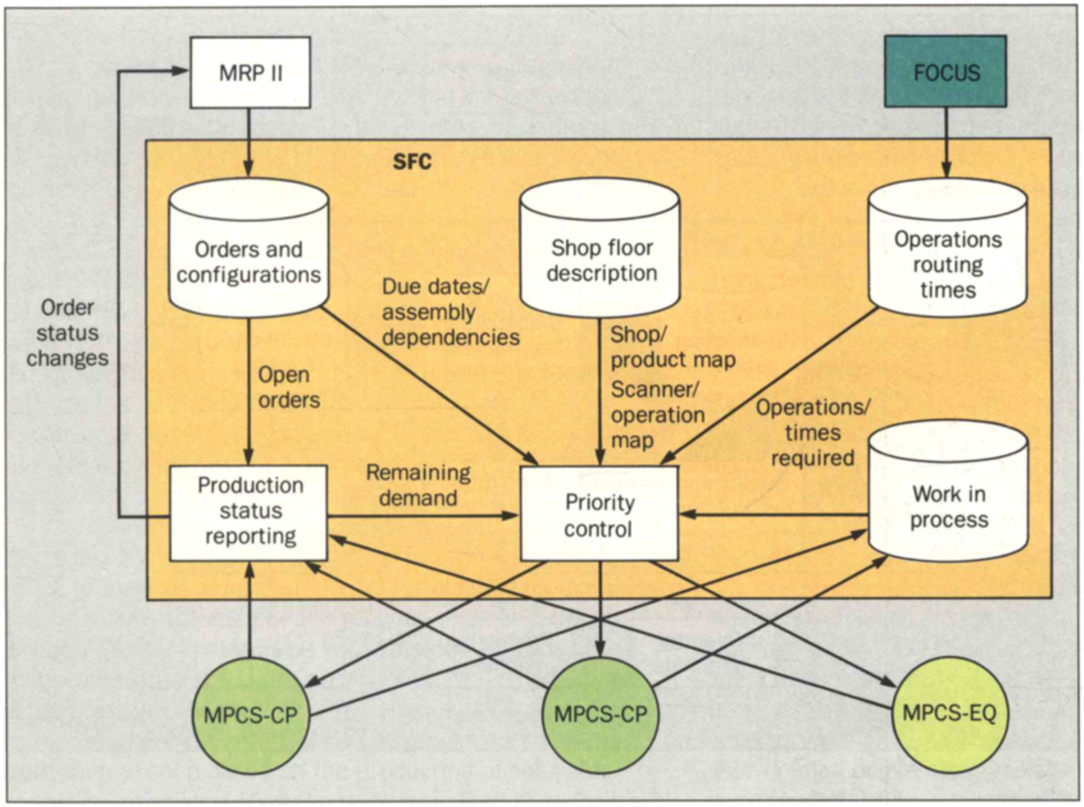


Figure 5. SFC overview. SFC sends the appropriate portions of the manufacturing plan to each PRISM system, tracks implementation, and coordinates production shop activities.

SFC data requirements. The first two types of SFC data are relatively volatile. They represent what is planned for manufacture, and what is currently being manufactured. Orders and configurations from MRP II consist of quantities required and descriptions of products, along with due dates for them. The work-in-process (WIP) data from MPCS are very volatile, and are updated as often as is feasible, for example, every hour. The WIP data show the current location of every item being manufactured in all MPCS shops, to the level of specificity that the number of MPCS scanners provides.

The remaining two types of SFC data are relatively stable. The operation, routing, and time data supplied by FOCUS describe what steps each type of product requires in its manufacture and how long each step will take. The shop floor description data have several purposes. For example, in order to build *sequences* for shops, SFC must be able to map shops to products. As a second example, to interpret WIP, SFC must be able to map its operations to MPCS scanners.

Production status reporting subsystem. Production Status Reporting requires only a knowledge of the orders and configurations, together with reports from the MPCS systems on items completed and scrapped. This function can operate in a dynamic or a static mode. In the dynamic mode, MPCS reports an item type only, SFC assigns the

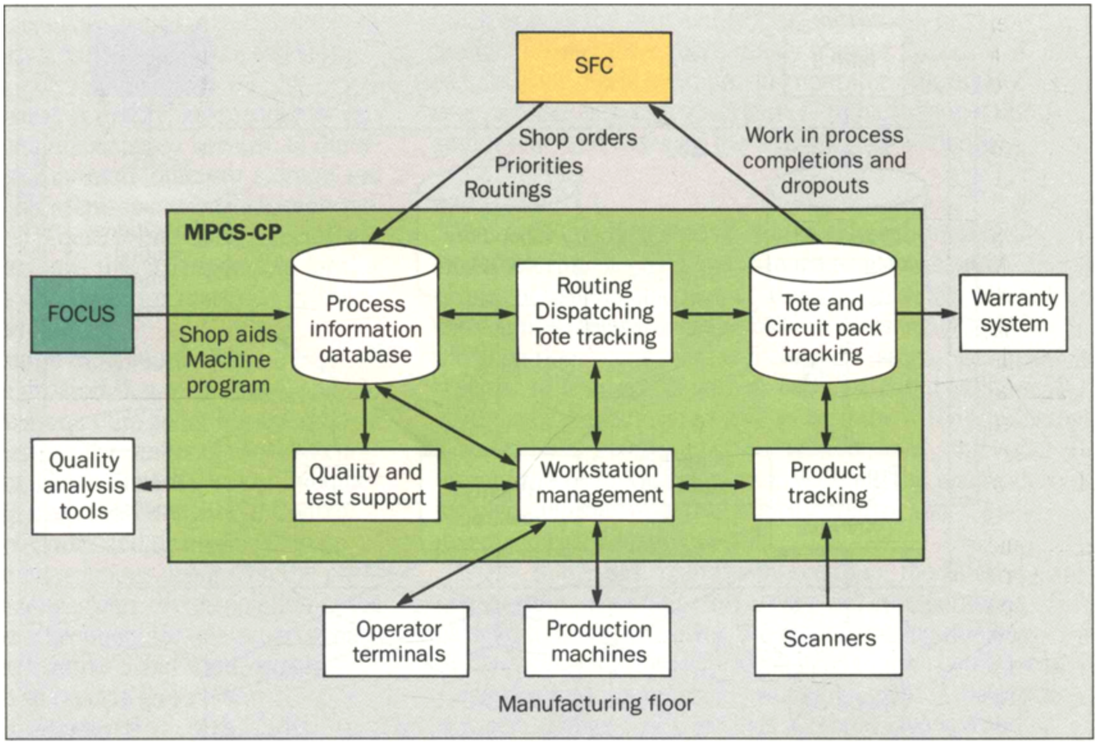


Figure 6. MPCS-CP overview. MPCS-CP sends the appropriate engineering information and assigns work to each shop area, tracks shop progress, controls the flow of material, and supports test and repair operations, as well as supporting the hands-on management of shop workstations.

item to the open order for this item type with the earliest due date, and SFC reports a change in the status of this order to MRP II. This mode is useful when making a large volume of orders for the same type of product. In the static mode, MPCS ties each item to an order number and reports this to SFC, which passes it on to MRP II. This mode is used for customized products.

Priority control subsystem. Priority Control requires all four types of SFC data, plus the output of the Production Status Reporting Subsystem. The priority of an item depends on the current demand for the item, when it is due, its progress through the shop floor, the remaining work time for completion, and its dependencies on other items and their status. SFC calculates the priority and sends this information to the appropriate MPCS terminal for display. Shop floor personnel use this priority information to determine which job to work on next.

In the *priority sequencing scheme* described above, SFC *sequences* the final products in the final assembly shop. The sequences for other shops follow from the *final assembly sequence*. The final assembly sequence implies a certain sequence of subassemblies output from the shops that feed the final assembly shop. In turn, via backward scheduling using the manufacturing time interval through each shop, one constructs the order in which the products should start in these shops. (An algorithm more advanced than backward scheduling may be used. For example, one may also attempt to balance the load over time offered to the various machines.) The same logic then sequences items upstream through the factory and may even apply to the storeroom selecting of material.

Manufacturing change control subsystem. Engineering change requests originate in FOCUS and are passed to SFC. SFC allows the change to be effective on a specified future date. SFC uses the shop description data to identify the affected shop, and sends notice of the change to that shop. If the identification of the item is different after the change, SFC updates its orders and configurations data and the MRP II planning system.

The MRP II planning system originates customer order changes. SFC uses its view of completed items from the Production Status Reporting Subsystem together with WIP data to determine what items belonging to the customer order are still in process, and determines which shop they are in. SFC then notifies those shops of the change, and updates its order and configuration data.

Benefits: SFC. Making completion data available electronically to the MRP II system improves the accuracy of the process of ordering material for planned production. This improves throughput and reduces work-in-process inventory factory-wide. The WIP between shops is reduced because the shops are working based on a coordinated priority scheme.

Via priority control, SFC directs material flow from shop to shop based on the production of shippable products, in contrast to the local optimization of each individual shop. This enhanced shop coordination shortens the overall manufacturing interval.

The system's responsiveness to manufacturing order changes ensures that the right products, in the right quantities are produced on time, which in turn improves customer satisfaction.

MPCS-CP

MPCS-CP is a shop-floor monitoring and control system supporting circuit pack manufacturing. MPCS-CP supports both in-line and flexible manufacturing of circuit packs.

MPCS-CP collects production data from laser scanners, terminals, and machines at assembly and test operations on a manufacturing line. These data, and the subsequent information MPCS-CP provides, allow product to be tracked and effectively moved through the factory, and provide measures of in-process inventory, production status, and product quality.

MPCS-CP Logical Architecture. MPCS-CP consists of four logical subsystems: (1) Product Tracking; (2) Workstation Management; (3) Routing, Dispatching, and Tote Tracking; and (4) Quality and Test Support. (See Figure 6.) These subsystems receive textual and graphical shop aids and machine programs from FOCUS and receive shop orders, priorities, routings, workstation configurations, and operation mappings from SFC. These subsystems collect production data from laser scanners, terminals, and machines at assembly and test operations on the manufacturing line. They also provide data to and receive data from process and product databases, and provide data to quality analysis tools and warranty systems.

Product tracking. The Product Tracking Subsystem supports individual circuit pack and circuit pack panel tracking, as well as flow control. On the same production line, circuit packs can travel together in a tote (group), can travel fixed together as panels, and can travel as individual circuit packs. MPCS-CP uses laser scanners positioned at user-defined points along the line to read the serial number encoded on the bar code label affixed to each circuit pack and panel. This scanning process is used to chart the progress of the circuit packs through production and to determine work in process.

Flow control is for managing the movement of circuit packs and panels down the line, subject to different constraints. The different types of flow control include: sequence validation, stopwork and rework control, finished goods control, and pay point control. A product data archive is used to maintain information about the product after it has completed manufacture and has been shipped off the end of the line. This information can be retrieved if the product ever returns to the line after it has completed manufacture.

Workstation management. The Workstation Management Subsystem aids workstation operators in processing circuit packs more efficiently and with increased quality. This is accomplished by the large variety of information that is passed to and from operators through MPCS-CP workstation terminals. From terminals, the workstation operators who process the circuit packs have access to such information as shop aids and machine programs made available by the FOCUS-MPCS interface. The workstation operators also have access to the Quality and Test Support Subsystem, which facilitates the exchange of test, inspection, diagnosis, and repair information between the operators and MPCS-CP.

Through information exchange with the Routing, Dispatching, and Tote Tracking Subsystem, dispatch operators access lists of workstations that are available to receive work, lists of work that is ready to move to the next operation, and other information necessary to support the dispatching of product from one workstation to another. The Workstation Management Subsystem also supports other users, such as production line supervisors, engineers, and MPCS-CP system administrators.

Routing, dispatching, and tote tracking. The Routing, Dispatching, and Tote Tracking Subsystem supports semi-automatic dispatching, with possible future extensions to automatic dispatching. An interface to material transport systems is also provided. Under both forms of dispatching, a *pull* method of production is supported. In pull manufacturing, a product is not moved to a workstation performing the next operation until that workstation is ready for more work.

Routings from the process information database are used to support the dispatching process. By exchanging information with the Workstation Management Subsystem, semi-automatic dispatching provides the dispatch operator with the necessary information to determine which product can be moved to the next operation on its routing, and which workstation to move it to. This subsystem also records, in the tote tracking database, the tote location and status of totes carrying product down the manufacturing line.

Quality and test support. The Quality and Test Support Subsystem, through the Workstation Management Subsystem, collects data from and distributes data to circuit pack test, inspection, diagnosis, and repair operations. These data are collected manually from terminal and scanner data entry and automatically through direct interaction with test and inspection machines. These data are distributed through terminals to diagnostic and repair operators to aid in the diagnosis and repair processes. This subsystem also uses the collected data to monitor test and inspection repair loops, provide periodic and on-demand test and inspection reports, and drive external quality analysis tools.

Benefits: MPCS-CP. MPCS-CP helps move product through the factory while helping identify manufacturing bottlenecks and problem areas. Specifically, MPCS-CP:
- Provides real-time visibility of in-process inventory and production result
- Assists shop personnel in moving product quickly and efficiently through the factory
- Assists shop operators through the collection and distribution of manufacturing data as well as through the use of on-line shop aids and machine program loading
- Helps identify trends in manufacturing processes before they become problems.

The net result is a decrease in work-in-process inventory, direct labor and equipment costs, and an increase in the rate of production and product quality.

MPCS-EQ

MPCS-EQ is a shop floor monitoring and control system for equipment assembly. It is targeted to support manufacturing complex, optioned products according to a JIT/TQC operational philosophy, by providing product tracking information, dispatching support, change notices, quality data, and manufacturing aids to shop personnel. In supporting equipment assembly, MPCS-EQ can work with SFC, which provides it with *build sequences* for equipment shops, to pull material from storerooms and the circuit pack area.

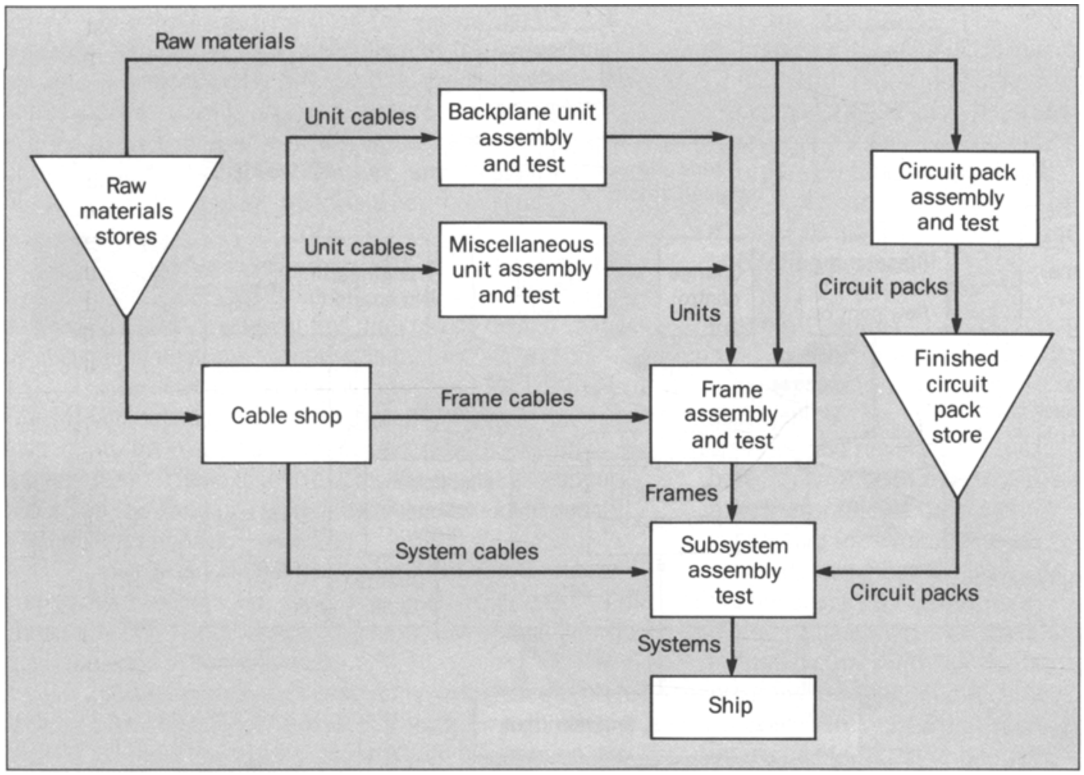


Figure 7. Equipment assembly process for circuit packs with subassemblies.

Highly-optioned equipment products are configured for specific customer applications, and are typically built in stages by putting together several levels of subassemblies in different shops. (See Figure 7.) For example, a 5ESS™ switching system contains several modules, each of which contains several frames and interframe cables. Each frame contains several units and intraframe cables and is populated with circuit packs. Units, frames, cables, and circuit packs come in many varieties.

To avoid the build-up of costly inventories on the shop floor, and to minimize the manufacturing interval, work in all the shops must be closely coordinated, so that the correct combination of materials reaches each shop just in time to make the higher level assembly that requires them. MPCS-EQ provides the real-time visibility within and across shops that is a prerequisite for close coordination, and the capability to pull materials between shops and stores as they are needed.

MPCS-EQ is designed to provide maximum flexibility by allowing users to define which types of subassemblies to track, the location of the tracking points, and the types of quality data collected. It allows users to add customized applications and generate customized reports by providing ready access to its databases.

MPCS-EQ Logical Architecture. Figure 8 shows the MPCS-EQ logical architecture. MPCS-EQ contains three major logical databases: customer orders, tracking, and quality. The customer order database contains the ordered

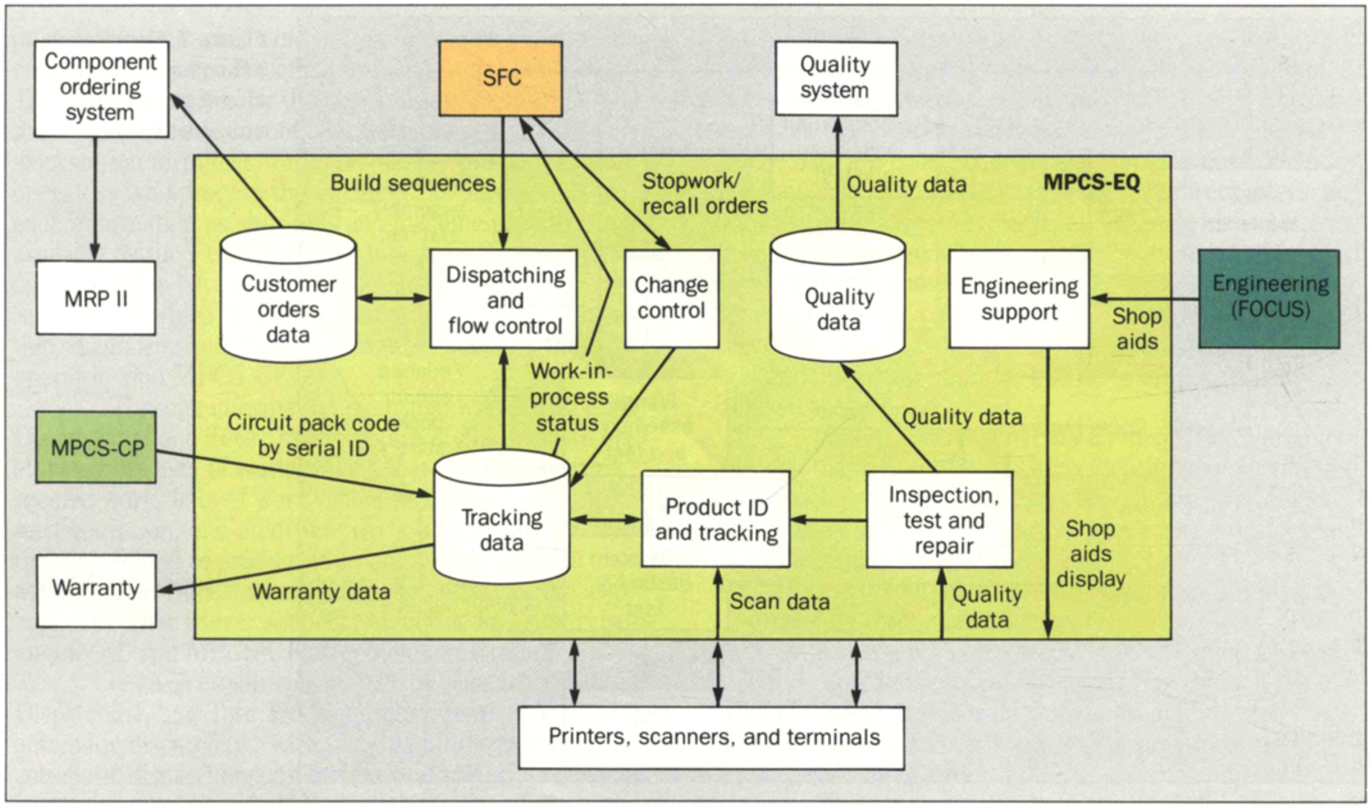


Figure 8. MPCS-EQ overview. MPCS-EQ is similar to MPCS-CP except that it supports the equipment assembly area, and provides the addition of a finer ability to schedule detailed operations for the final assembly shops.

configurations expressed in terms of the types of subassemblies to be built, the options exercised on each, and how lower level subassemblies are to be combined into higher levels. Taken together with the final assembly schedule (FAS) from Manufacturing Planning, this represents the demand for the equipment area. The tracking database contains the current location and history for each tracked item. Quality-related data for tracked items, such as process checking results, inspection results, and test diagnostics are stored in the quality database.

Product identification and tracking subsystem. Items that are tracked by MPCS-EQ are identified by the serial numbers on their bar-code labels, which are scanned as the items progress through the assembly operations. On-line reports provide the shops with the current status of work in process. MPCS-EQ tracks the assembly of such items into higher level assemblies, so that the location of all physically attached subassemblies is known by scanning a single label. By keeping track of when tracked subassemblies are assigned to customer orders, received from Manufacturing Planning systems via SFC, MPCS-EQ can report the progress toward completing manufacture of the ordered systems.

Dispatching and flow control subsystem. MPCS-EQ supports dispatching jobs in the shop by displaying build sequences generated by SFC, and by reporting the availability of raw materials and manufactured subassemblies needed to build an item. MPCS-EQ supports JIT procedures by electronically transmitting and tracking the status of *pull orders* for moving materials between shops and storerooms.

Change control subsystem. MPCS-EQ compares change orders received from SFC against the tracking database, so that tracked items affected by design changes or changes in customer orders can be located.

Inspection, test, and repair subsystem. MPCS-EQ provides flexible quality data collection to associate inspection, process checking, or test results with any tracked item. These data are available on-line to support repairs in the shop or can be downloaded to local quality systems for analysis.

Engineering support subsystem. MPCS-EQ stores, and displays on demand, shop aids, such as an index to the current issue of engineering drawings and textual information contained in the drawings.

System interfaces. As part of an integrated systems architecture, MPCS-EQ supports interfaces with other PRISM systems and local manufacturing information systems. Users interact with MPCS-EQ through bar-code scanners, terminals, and printers located throughout the equipment area. MPCS-EQ provides a user programming interface by permitting access to its databases.

Benefits: MPCS-EQ. MPCS-EQ provides better control of equipment shops by increasing visibility of the manufacturing process, improving communications among the various shifts and shops, and instilling discipline in shop operations. It offers the following major benefits:

- Reduced WIP and shortened manufacturing interval by providing timely and accurate tracking information, checking material availability, and issuing *pull orders*. This allows AT&T to be more responsive to customers.
- Improved product quality by transmitting order and engineering changes to the shop floor and by supporting process checking, inspection, test diagnosis, and repair operations.
- Improved shipping performance by providing the shop floor with reports that show which items required for a customer order have been completed. This helps to focus the shops' efforts toward shipping customers' orders on time.
- Reduced direct and indirect labor costs by automating many of the data collection and reporting functions done by shop personnel.

PRISM's Evolution

PRISM focused initially on the materials, engineering, and assembly and test operations of AT&T's large assembly, wiring, and test factories. Through operations analyses and resulting process simplifications, significant benefits have been realized. In addition to enhancing the manufacturing functions already supported by PRISM and supporting the evolution to JIT/TQC operations, other areas of manufacturing have also been identified as potential beneficiaries of future operations systems support. These include more extensive support of product quality assurance, preventive and corrective maintenance, product warranty tracking, and packing and shipping of finished goods. There are further plans to support component and intermediate factories that produce products such as integrated circuits and subassemblies.

In addition to supporting the manufacturing execution environment within each factory, the concurrent improvement of coordination between individual factories, to better integrate all of AT&T's manufacturing capability, is an absolute necessity. Closer ties between AT&T's component factories, and vendor partnerships with outside suppliers of the materials used by AT&T's final assembly factories will result in still shorter end-to-end order intervals and better responsiveness to customer needs.

Similarly, integrating other business functions and operations support systems, in areas such as product distribution, customer order management, billing, and customer service will further enhance the process. This is a decisive step toward a fully computer-integrated end-to-end business.

The goal of the PRISM projects is to continue to enhance our ability to deliver the highest quality products to a growing, global customer base, at low cost, and in a timely fashion, meeting and exceeding customer expectations of AT&T.

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Biographies (continued)

Engineering Research Center of AT&T Technologies in Princeton, New Jersey. Mr. Hsu joined the company in 1970 and is responsible for manufacturing information systems that increase the efficiency and quality of manufacturing operations. He has an M.S.E.E. from the University of Missouri. ***L. Gary Raymer*** *is a member of the technical staff in the Manufacturing Systems Engineering department at Bell Laboratories in Holmdel. Mr. Raymer joined AT&T in 1979 and is working on the FOCUS system. He received a B.S. and M.S. in electrical engineering from Rice University.* ***Bernard E. Snyder*** *is head of the Manufacturing Systems Planning department of Bell Laboratories in Holmdel. Mr. Snyder joined the company in 1964 and is responsible for longer-term planning of the overall PRISM product family and integrated information systems planning with specific AT&T factories. He has a B.S. in electrical engineering from Virginia Polytechnic Institute and an M.S. in electrical engineering from Rutgers—The State University.*

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