CHAPTER SIX

MANUFACTURING PLANNING AND SCHEDULING

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MANUFACTURING PLANNING AND SCHEDULING

OBJECTIVE

In achieving the objectives of a production program, a substantial body of resources must be effectively applied to the defined task. The purpose of manufacturing planning and scheduling is the identification of these resources and their integration into a structure that provides the capability to achieve production objectives. The material in this chapter identifies the actions which should be taken by the program manager and the system contractor(s) to develop that structure. The issue of manufacturing risk assessment and its application to the planning process is described. Risk assessment, one of the program manager's significant manufacturing tasks during development — is an element which is required to be addressed in the milestone review process. The primary manufacturing planning and scheduling challenge to the program manager involves measuring the qualitative and quantitative manufacturing resources required for production.

After reviewing this chapter, the Program Manager should:

- Have a good understanding of the elements involved in manufacturing planning and scheduling.
- Be able to assess the quality, depth and type of analysis performed by a contractor in developing the manufacturing plan and schedule.
- Understand the need for and value of the contract manufacturing plan and schedule.
- Understand the importance of schedule integration based upon a valid master phasing schedule.
- Have a basic understanding of some of the types of manufacturing planning and control systems used by contractors today, and what they are designed to accomplish.

INTRODUCTION

Based upon the product manufacturing demands, a business structure for the program can be developed. This structure should define the specific elements of the prime contractor organization that will be involved in the program and the numbers and types of subcontractors required. The decision regarding subcontractors should be made from the standpoint of contractor capability as well as capacity. Within the context of the defined business structure, there should be an identification of the specific resources required. Personnel should be identified in terms of both quantity and specific skill types required, time-phased over the planning horizon. Manufacturing facilities and equipment which will be required at the prime and subcontractor locations should also be identified. In DOD programs, consideration should be given to the use of government furnished facilities and equipment. Under Federal Acquisition Regulation (FAR 45.302-1), providing government facilities is discouraged.

While the system cost is not normally an element of the manufacturing plan, the cost of manufacturing a product can be significantly impacted by the specific methods selected to accomplish the manufacturing tasks. Key guidelines are:

1. Assure that development contracts include requirements for contractor planning and scheduling for production.
2. Challenge assumptions concerning the availability of manufacturing resources.
3. Explicitly consider the risks inherent in the proposed approach and initiate actions to reduce the risk or provide fall-back positions.
4. Require contractor preparation of a manufacturing plan to assure that proper consideration has been given to

the resource needs for production.

5. Evaluate the plan.

FEASIBILITY AND CAPABILITY ANALYSIS

The issues of manufacturing feasibility and capability are addressed in the initial phases of the product development process. The evaluation of manufacturing feasibility and capability are directed toward analysis of the compatibility of the demands of the manufacturing task and the manufacturing facility and equipment required to accomplish it. The capability of a contractor (manufacturing source) to successfully execute the manufacturing effort depends upon that contractor having:

- An understanding of the manufacturing task,
- Adequate qualitative production skills,
- Sufficient personnel (on hand or available),
- Sufficient facility floor space,
- Equipment in satisfactory condition,
- Adequate, operable test equipment,
- Assured, capable suppliers,
- Management capability, and
- A plan to coordinate all resources.

In the initial phases of product development, the Program Manager should ensure that a manufacturing feasibility assessment is accomplished. The feasibility estimate determines the likelihood that a system design concept can be produced using existing manufacturing technology while simultaneously meeting quality, production rate and cost requirements.

Feasibility is a bounded issue. It is bounded by existing manufacturing technology. There is a presumption that the state of current manufacturing technology relative to the system concept can be defined. There is also a presumption that the system concept will have sufficient definition to determine the technology demands embedded in it. Having determined the state of technology and the system demands, questions such as those which follow should be raised. What is the likelihood that the manufacturing task can be accomplished given your knowledge of the design and given your knowledge of the production environment in existence today? Based upon the feasibility assessment, the PMO should develop a manufacturing risk evaluation to quantify the statement of manufacturing feasibility. What is the risk level? Normally, risk is expressed in terms of high, medium and low. A major result of the feasibility evaluation is the identification of manufacturing technology needs. The purpose of this identification is to determine which planned or on going manufacturing technology programs are required to achieve production phase objectives. Priority can then be given to these programs to ensure that necessary capabilities can be put on line in the factory prior to the production phase.

The feasibility analysis also provides a basis for manufacturing planning because its accomplishment involves the evaluation of:

1. Producibility,

2. Critical manufacturing processes and special tooling developments,

3. Test and demonstration requirements for new materials and processes,

4. Alternate design approaches,

5. Anticipated manufacturing risks and potential cost and schedule impacts.

MANUFACTURING RESOURCE ANALYSIS

Manufacturing management, as defined in DOD Directive 5000.34, is "The effective use of resources to produce on schedule the required number of end items that meet specified quality, performance and cost." A few comments can be made about this definition to serve as a basis for consideration of manufacturing planning. The first significant word is "effective." The question is: "When measured against what baseline?" How does something that has to be defined on a specific program in terms of relative or absolute cost compare to programs within similar resource constraints?

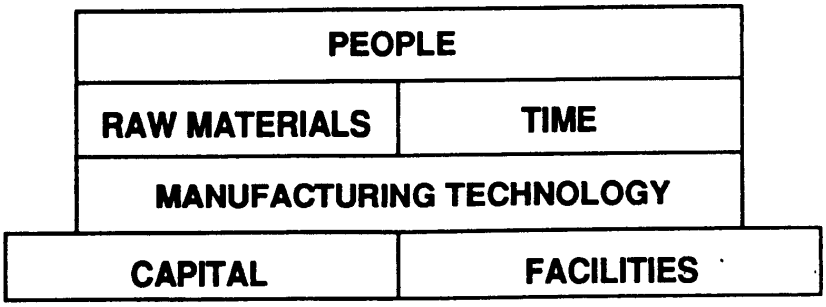

Figure 6-1 Manufacturing Resources

The classic manufacturing resources required are illustrated in Figure 6-1.

1. Capital. Capital represents the monetary assets which are available to the contractor. Capital can be used to finance on going work, for investment to improve capacity or capability, to broaden the market base, or for any of the number of competing uses within the contractor's organization.

2. Facilities. Facilities are the real property in the factory - the environment in which the products are built. The term includes the industrial equipment, machine tools, and shop aids to manufacturing.

3. Manufacturing Technology. Manufacturing technology is that set of efforts undertaken to improve the manufacturing processes, techniques or equipment required to support current and projected requirements. This area involves advancements in the way things are done in the factory, including the processes that are available to take raw material, enter it into a productive process, and transform it into something useful that meets DOD needs.

4. Raw Materials. Raw materials are the basic materials used in the manufacturing process. The focus of the government and contract effort should be on the most efficient utilization of the required raw materials.

5. Time. Time is a resource available to all contractors. It provides a constraint on the contractor since performance and delivery commitments are related to specific dates.

6. People. People include those managing the program, design engineers, manufacturing engineers, and (prob-

ably the most important) factory operations — the direct and indirect labor personnel.

DEMAND CAPACITY ANALYSIS

In developing a manufacturing plan, expected demands have to be analyzed in terms of equivalent resource requirements. Demand capacity analyses involve “exploding” units of output into equivalent units of input and processing capability required to produce these outputs. The purpose is to define the amounts and types of materials, equipment, and personnel skills that will be required to meet the contract requirements.

Some resources remain relatively fixed, whereas others are variable. Machines, floor space, tools, and equipment — fixed capital assets — remain relatively constant from one planning period to the next; but personnel staffing may vary.

The development of an effective manufacturing plan is dependent upon the ability of the contractors involved to accomplish a rather detailed translation of the product’s physical and functional characteristics into a set of manufacturing processes. The program office should evaluate the contractor’s performance in accomplishing the detailed definition of process demand to ensure (a) that a complete definition is available, including process precision requirements, and (b) the information is provided to the personnel responsible for identifying and providing the manufacturing resources.

MANUFACTURING RISK ASSESSMENT

Manufacturing risk assessment is a supporting tool for the contractor and program office decision-making process. It seeks to estimate the probabilities of success or failure associated with the manufacturing alternatives available. These risk assessments may reflect alternative manufacturing approaches to a given design or may be part of the evaluation of design alternatives, each of which has an associated manufacturing approach.

Assessing Risk

Manufacturing processes and materials may be divided into three broad groups:

1. State-of-the-practice

2. State-of-the-art

3. Experimental.

State-of-the-practice implies that the material or process is in general use in industry, is well understood, and has a long usage record. These processes and materials generally represent low-risk approaches.

State-of-the-art implies that a material or process has had some factory usage, but was recently developed and is available from only one or a limited number of sources. These types of processes often provide the potential for cost or time savings but may introduce risk if they have not been used in the particular application or by the producer.

Experimental processes or materials have been demonstrated in the laboratory, but not in the factory environment. These processes and materials often hold great promise in terms of reduced cost, improved material properties, and better performance. Their use should be demonstrated in the factory environment prior to use in a manufacturing program.

Risk Identification

As the design evolves, the manufacturing implications of various design options should be evaluated as part of the ongoing review process, as shown in Figure 6-2. The appropriate manufacturing concepts should be identified by the manufacturing engineers so that the risk levels associated with those approaches can be evaluated.

This is a critical procedure if the selected system design alternative requires the use of an experimental material or process. If it does, or if a state-of-the-art material or process is to be used, two actions should be taken:

1. Establish a plan to prove out the material or process prior to initiation of manufacturing, and

2. Identify a fall-back approach if the material or process cannot be used successfully in manufacturing.

Tracking contractor progress in identifying and resolving manufacturing risk can be accomplished through the combination of a government design review process and the production readiness review. When there is a reasonably high level of manufacturing risk, the Program Manager should consider the advisability of having the contractor provide status at each of the scheduled program reviews. Also, the Program Manager should have the members of his team track risk and its resolution. The status report could be made a part of the internal reporting system.

DEVELOPING THE MANUFACTURING PLAN

The statement of work and the product design are the elements on which a program manufacturing plan is based. The manufacturing plan defines the required sequence of operations in engineering, purchasing, manufacturing, and product assurance prior to delivery. The plan contains the tasks to be performed by the contractor and the subcontractors, as appropriate, and the organizations delegated responsibility for carrying out these tasks.

One of the most complex operations in developing the manufacturing plan is estimating the resource requirements. Manufacturing planning, tooling, fabrication and assembly, installation, testing and product assurance labor-hour costs must be developed by applying valid estimating techniques. The final step is to convert these labor hour values into specific skill requirements. Equipment and other facility requirements must also be determined and cost estimates developed.

Estimates of manufacturing resource requirements are used in conjunction with the work statement to develop a time-phased action plan. This plan displays the time flow of the manufacturing elements such as tooling, receipt of purchased parts and materials, fabrication, assembly, test, product assurance, and delivery.

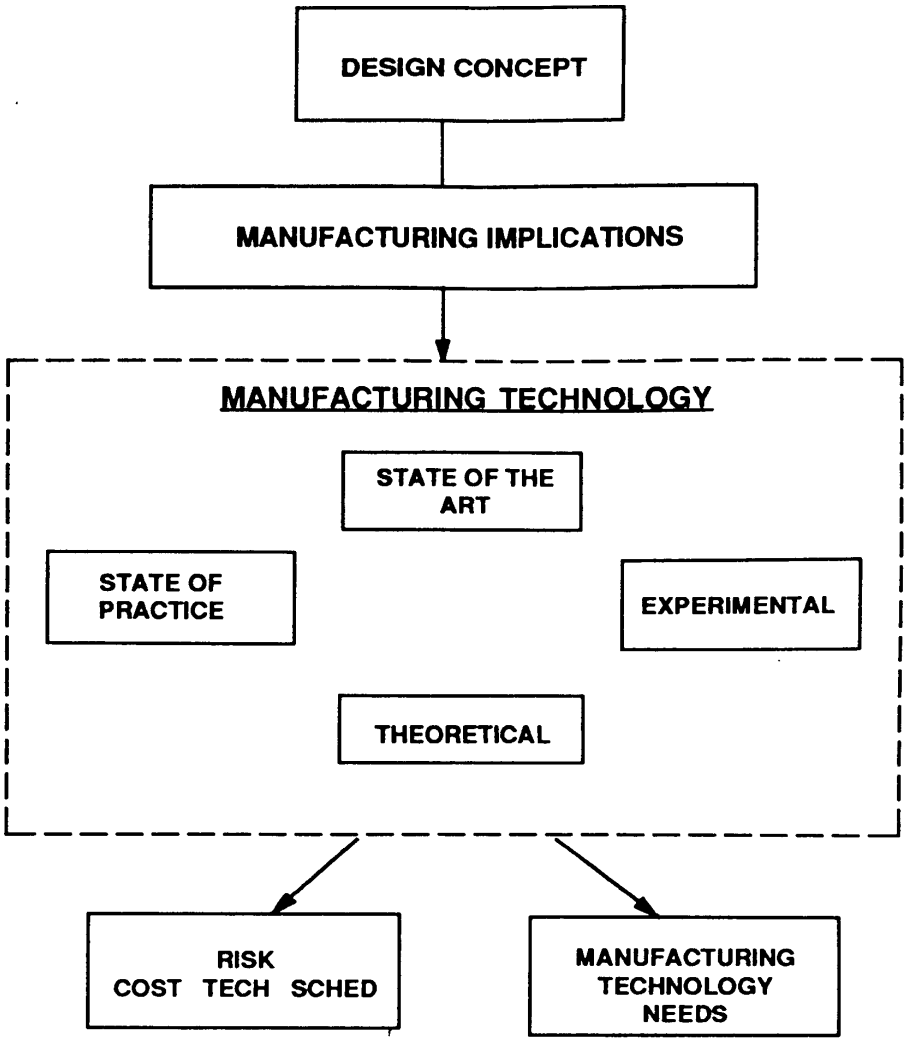

Figure 6-2 Manufacturing Risk Assessment

The longest cumulative flow prior to a manufacturing control point determines the time at which design definition must be available from the engineering function. These flows are converted to manufacturing demand dates which are coordinated between engineering and manufacturing operations. The intent of the total process is to ensure on-time product delivery.

Figure 6-3 shows the concept involved. Prior to ordering the necessary parts or raw materials, a preliminary design definition is required. This preliminary design definition should provide sufficient detail to obtain the necessary material required for in- house or subcontractor fabrication. Final design for a part is required prior to

initiation of part fabrication.

This particular example in Figure 6-3 presumes the use of an assembly tool. The tool design, fabrication and check out times are shown. Detailed design definition of the assembly is required in order to properly design the tool. The need dates identified for the various preliminary and final designs are communicated to develop the engineering release schedule for the various parts and assemblies comprising the system. Where there are inconsistencies between the demand dates and the release schedule, replanning of either the release schedule or the manufacturing schedule must be accomplished.

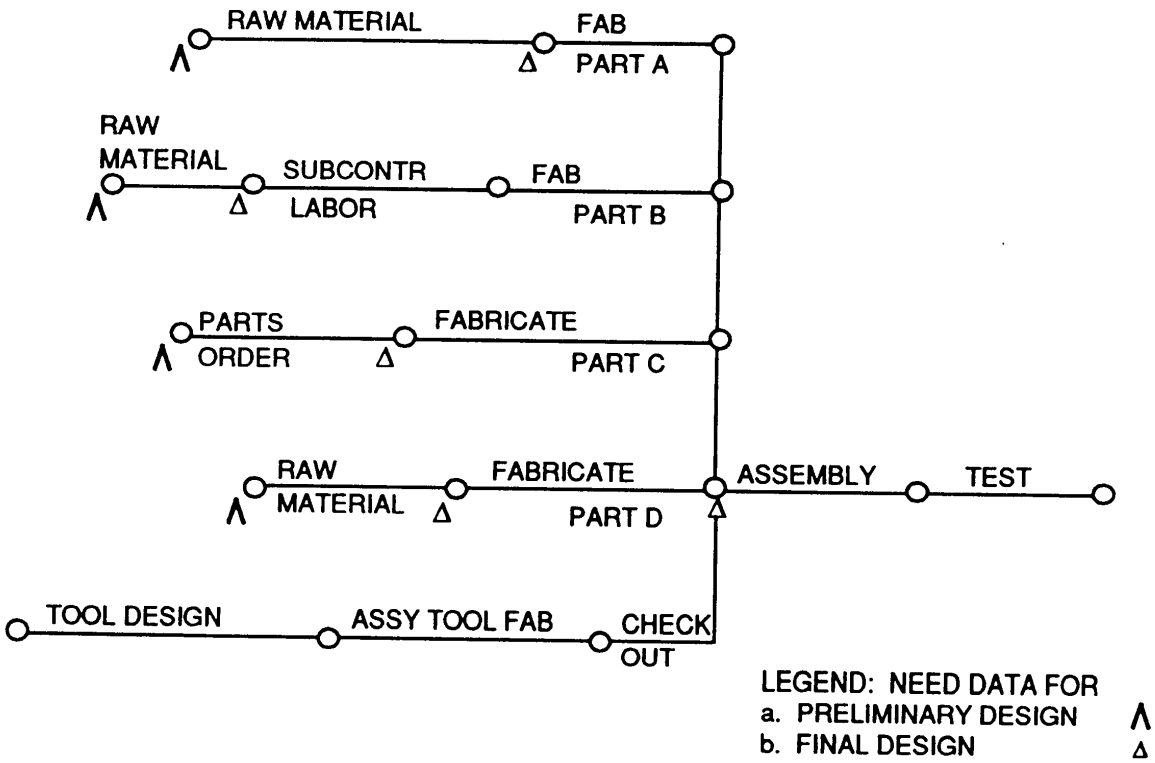

Figure 6-3 Extract from Manufacturing Plan

Scheduling

One of the primary objectives of the contractor during the Production Phase is to produce and deliver a specified number of units of product to the user on the planned dates. In order to meet this objective, the contractor must schedule all of the steps in the process, from design to delivery, in a logical and economical pattern. The manufacturing plan and the schedule must be integrated since scheduling represents the ultimate application of time to the tasks to be performed. The plan emphasizes how and what to build. It determines when the resources are expended and must consider all active requirements. Scheduling ensures that resources are available when needed, no resources are overloaded or overexpended during any of the manufacturing tasks, the most efficient application of resources is made, and customer delivery dates are satisfied.

The planning strategy must be communicated to scheduling, with all the supporting information on work

package size selection, content, personnel loading, work center level loading, facilities occupancy determinations, timing of actual material needs, process options in the event that tools and equipment are unavailable or overloaded, and the many other considerations in the manufacturing plan. Since scheduling may be a function of several organizations or elements, this may be a formidable problem area.

A second problem area includes the need to accomplish the planned actions within the total resources available, without any discontinuities in the orderly and efficient performance of work. When discontinuities arise, scheduling often is compromised. Soon the carefully conceived manufacturing plan does not reflect the shop practice and the work is guided by a series of "work around" plans.

Information affecting scheduling must be available. It must be processed, sorted, and stored. Each contractor will have its own unique information system. The PMO must be familiar with that system and its ability to recall quickly and accurately all those pieces of information impacting the execution of the manufacturing plan.

A wide variety of schedules may be used by a contractor, some produced by the schedulers themselves. Some schedules cover the entire manufacturing effort and affect everyone. Others contain information of interest only to the group that produces them. To keep the many schedules from conflicting with each other, even though they may have been produced independently, a system of top-down scheduling is used. This means that a subordinate schedule must conform with the constraints of the parent schedule. A carefully disciplined one-way system keeps the more detailed but smaller scope subordinate schedules in harmony with the rest.

The material in this section describes some of the typical schedules used in manufacturing defense systems or equipment and their interrelationships.

Master Phasing Schedules

The master phasing schedule establishes the basic relationship between engineering release of the production design, parts and material procurement, fabrication, assembly, installation, test product assurance and delivery of the product. It summarizes the entire program in order to ensure compatibility of all subsequent planning and scheduling. The master phasing schedule is developed to reflect both the program requirements and contractor commitments. Completion milestone dates are normally displayed pictorially in a master-phasing chart, which visually depicts milestones for each major phase and planning element that must be completed. Figure 6-4 lists the major events for which relationships are required in a typical defense system production program.

The master phasing schedule provides the basic schedule framework within which detailed schedule planning is accomplished. The master phasing schedule is used to develop the first unit flow chart, master schedules, and overall schedule direction for the various functional organizations.

First-Unit Flow Chart

The first-unit flow chart is developed to define the schedules for the first unit of a new program or a model change. The first unit flow chart is developed by utilizing the schedule milestones found on the master phasing schedule and the assembly sequence, estimated labor hours, and most desirable crew size for each assembly or installation operation. The flow time for each of the assemblies is determined by utilizing the estimated labor hours, the most desirable crew size, and the number of shifts to be used. (This information is often estimated from past projects of similar nature and size.) Figure 6-5 is illustrative of a first-unit flow chart.

With the overall sequence of the major operations defined, all of the simultaneous activities and operations must be scheduled for completion to meet subsequent events which are dependent upon them. Correspondingly, start times for all the activities and operations being carried on simultaneously are determined in turn by individually working back through their required flow times. Their individual flow times will dictate the scheduling of their starting dates.

In this manner, the entire schedule can be displayed on one chart for the first production unit. All organizations can determine at a glance when their responsibilities start, how long they have to carry them out,

and when they must be completed.

Master Schedules

Master schedules are developed in a manner similar to the first unit flow chart except that they show all the production components or units in sequence over a period of time instead of just the first unit. Master schedules are so called because they are the major source for controlling overall manufacturing operations. They are the basis for coordinating all supporting elements of the program from space and facilities requirements to tooling and equipment, vendor activity, labor, raw material preparation, detail parts fabrication, assembly and installation operations, functional testing, and finally delivery to the customer. Figure 6-6 shows a master schedule for an electronics system showing span times for specific units from procurement, production, to delivery on dock.

EVENTS	SCHEDULE
PROGRAM MILESTONES PROGRAM GO-AHEAD LONG-LEAD GO-AHEAD MANUFACTURING DECISION START DESIGN LAYOUTS ENGINEERING DRAWING RELEASE CONTRACT DELIVERY SCHEDULES	(SHOW APPROPRIATE START AND COMPLETION DATES BY MONTHS OR WEEKS IN THIS SECTION OF THE SCHEDULE)
ASSOCIATE CONTRACTORS SUBSYSTEMS ON-DOCK	
FABRICATION, ASSEMBLY & CHECKOUT SCHEDULES & EVENTS	
OPERATIONS SCHEDULING ISSUE ASSEMBLY PLAN ISSUE FINAL TOOLING PLAN ISSUE MASTER SCHEDULE	
PURCHASING/MAJOR SUBCONTRACTS MAKE-OR-BUY PLAN PURCHASE ORDER AWARDS MAJOR SYSTEM AWARDS PROCURE LONG-LEAD MATERIAL PRRs FOR CRITICAL MAJOR SUBCONTRACTS	
QUALIFICATION TESTING COMPONENTS SUBSYSTEMS SYSTEMS	
MANUFACTURING & ENGINEERING TECHNOLOGY DEVELOPMENT PLAN SUBCONTRACT DATA PACKAGES MANUFACTURING TOOLING POLICY MANUFACTURING OR PURCHASING PLAN PRODUCIBILITY STUDIES IDENTIFY RATE TOOLING	
TOOLING FABRICATE MASTER TOOLS FABRICATE DETAIL TOOLING FABRICATE ASSEMBLY TOOLING DESIGN TOOLING DESIGN INTERFACE TOOLING IN SUPPORT OF SUBCONTRACTORS FABRICATE MANUFACTURING TOOLING	
FACILITIES MANUFACTURING STATION PLAN LAYOUTS FOR FACILITIES FACILITY CONTRACTS EXTENSIONS DESIGN, CONTRACT, PREPARE & OCCUPY MANUFACTURING FACILITIES SET UP ASSEMBLY AREAS FOR MANUFACTURING	
MANPOWER DEVELOP TRAINING PLAN ACQUIRE PERSONNEL TRAIN PERSONNEL	
MANAGEMENT SYSTEMS ISSUE MATERIAL REQUIREMENTS SYSTEM ISSUE MATERIAL PROCUREMENT & INVENTORY SYSTEM ISSUE PRODUCTION CONTROL SYSTEM ISSUE WORK MEASUREMENT SYSTEM	

Figure 6-4 Master-Phasing Chart for a Typical Defense System Production Program (Simplified)

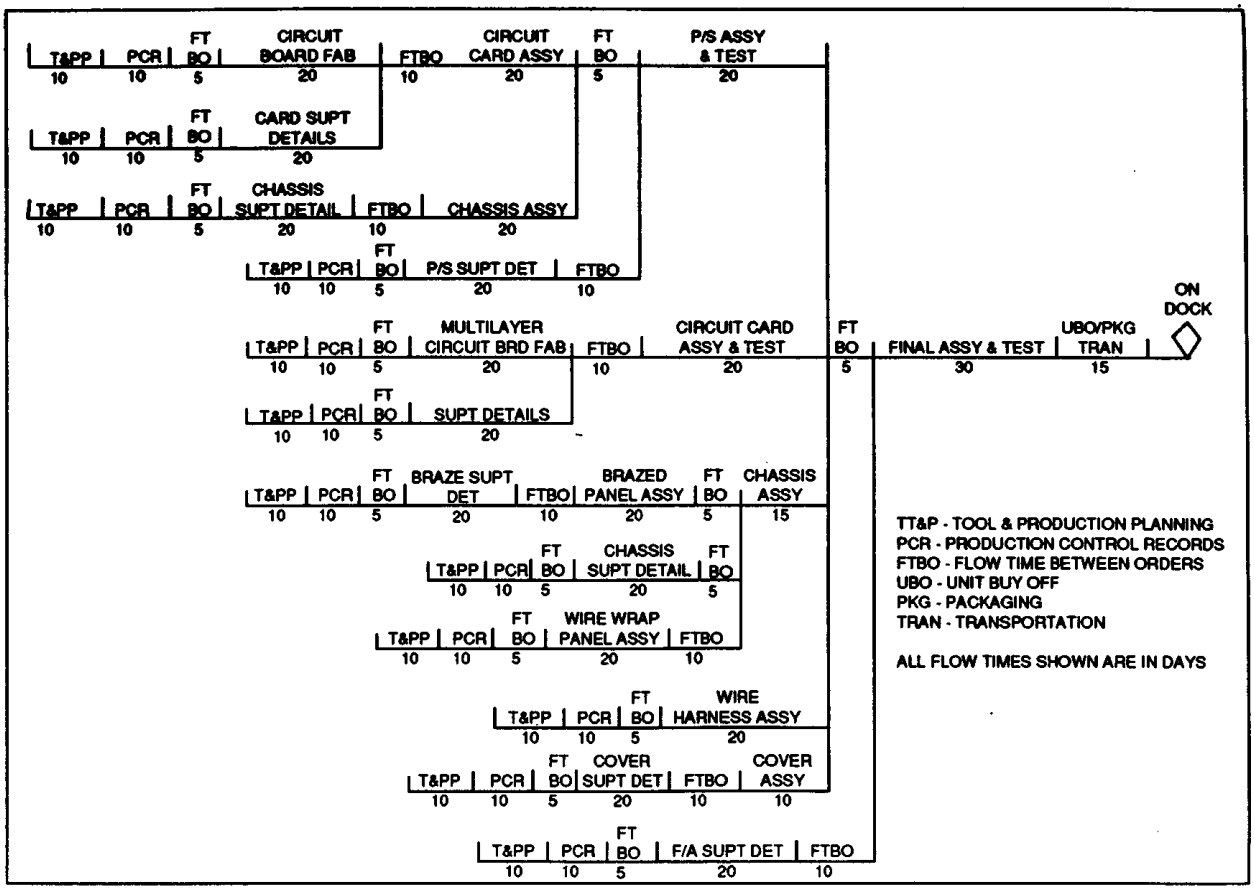

Figure 6-5 Example of First Unit Flow Chart for a Symbol Generation

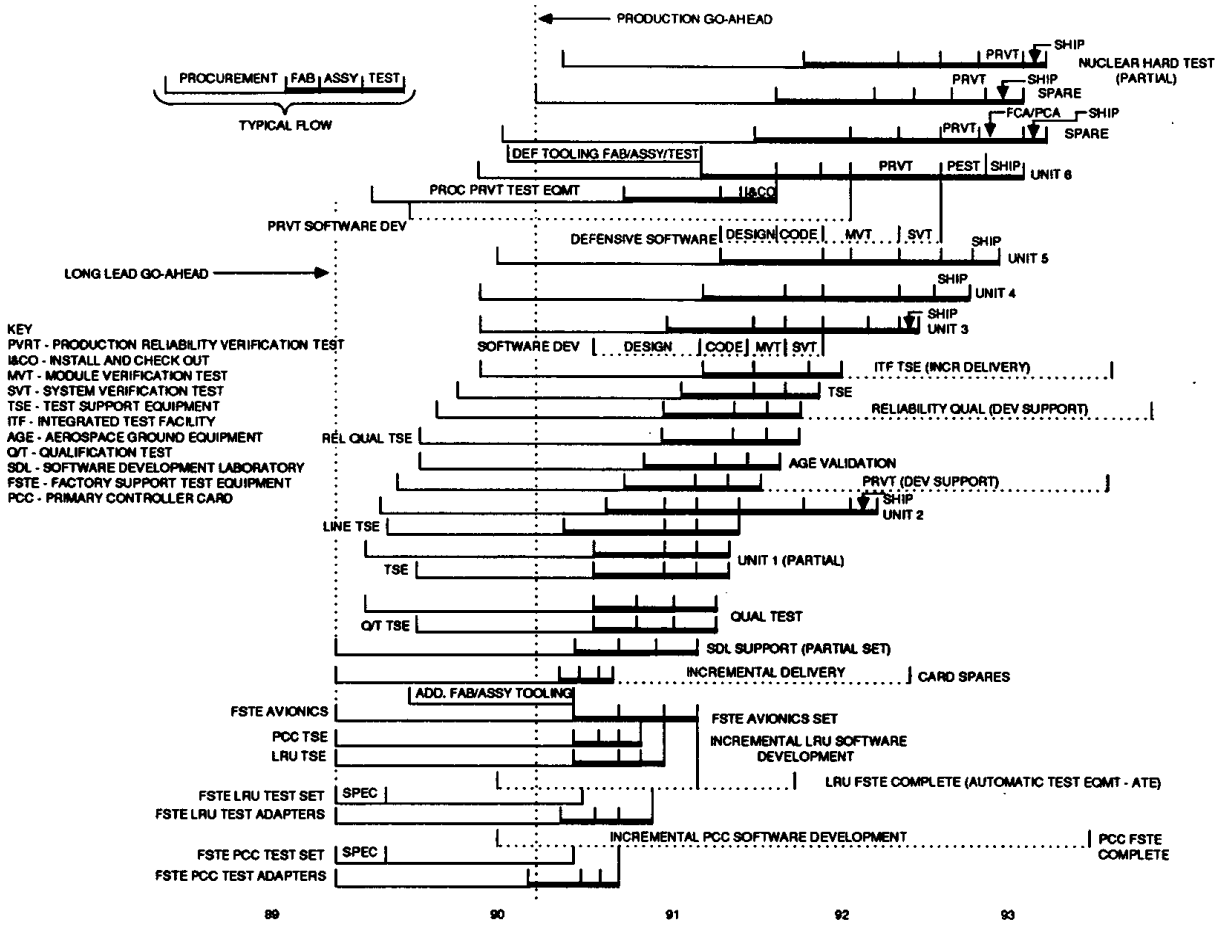

Figure 6-6 Master Schedule for an Electronics LRU

Several different criteria and data are utilized to develop master schedules:

A. <u>Shipping Schedule</u>

The order in which the company has planned to meet the delivery commitments is shown to the point of completion of final assembly in the factory. This establishes the basic cycle rate as follows:

Delivery rate : 10 units per month
Average work days per month : 21 days
Basic cycle rate: <u>Work days per month</u> = <u>21</u>
Delivery rate 21: 10 = 2.1
Thus, the basic cycle rate is one unit every two work days.

B. <u>First-Unit Labor Hours</u>

The first-unit labor hours are those estimated to complete the first unit of production.

C. Crew Loads

The crew load represents the total number of assembly personnel that can operate concurrently on a specific unit in a particular production area.

Scheduling And Factory Loading

The goal of the scheduling effort is to optimize all of the manufacturing resources from program go-ahead through delivery of the product.

In general, the process involves analysis of the complete manufacturing operations down to detailed factory operations. The master schedule, discussed earlier, defines the framework of the starting and completion dates of the major manufacturing tasks to be accomplished in a defined period. The scheduling effort involves filling in this framework with the detailed manufacturing schedules of all components involved in the product. The first step taken in this effort is to integrate all of the details for producing each major assembly and section into an overall time table in units of days or weeks. The second level schedule shows the logical, practical sequence which ensures a smooth flow of work. It provides the schedule for completion of engineering, tooling, procurement, fabrication, assembly and check-out.

The third (next lower) level schedule, evolved from the master schedule, determines the day (or hour) each component is to be completed. This schedule is concerned with tooling, detail parts, subassemblies, and component fabrication.

The fourth level schedule is the most detailed. It includes the daily production activities of all the factory shops. Individual jobs are analyzed and sequenced and standards are applied to factory loading of materials, machines, and labor. Figure 6-7 shows the concept of the hierarchy of manufacturing schedules. These are integrated with other functional schedules as shown in Figure 6-8.

The initial effort in the production phase of a program often involves maximum personnel loadings to meet the schedule. The latter phases strive for optimum crew loading through refinement of the operating plan and supporting activities to achieve cost reduction. The objective of the manufacturing analysis during the Full Scale Development Phase is to determine these optimum loadings, but normally the design changes which occur during initial production require revisions to the original concept. The contractor should have specific goals for each operating function, i.e., the facilities, material, and personnel required to perform the work. In order to achieve the manufacturing goals, the contractor should have a cost data collection and status reporting system to evaluate performance relative to the goals, determine performance trends, and make necessary adjustments.

There must be latitude available in all of the schedules. It follows, then, that the resulting schedules do not, indeed cannot, reflect the most streamlined and efficient way of doing the work, and the most cost-effective planning possible. Maximum effort is needed to carry out the work according to the lowest level manufacturing schedules so that the higher level schedule structure is satisfied. Otherwise, a major scheduling revision will be required that may impact other programs in the contractor facility along with the one in trouble.

The scheduling integration issues raised are applicable to all programs. While the manufacturing planning and scheduling techniques used to build defense systems — aircraft, ordnance, and space systems, — will vary, the program manager must be aware of the existence of this important aspect of manufacturing management in developing the manufacturing plan.

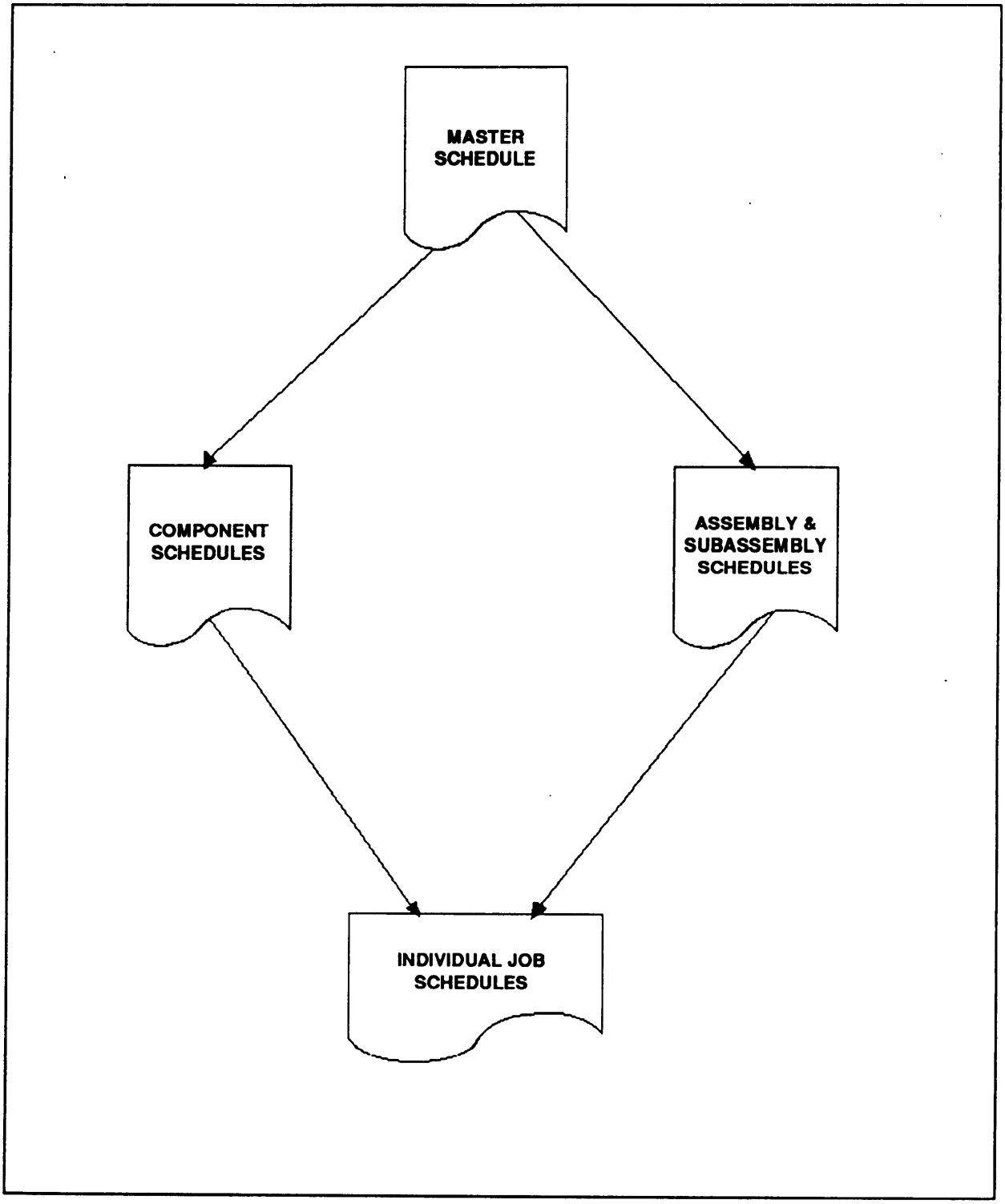

Figure 6-7 Hierarchy of Schedules

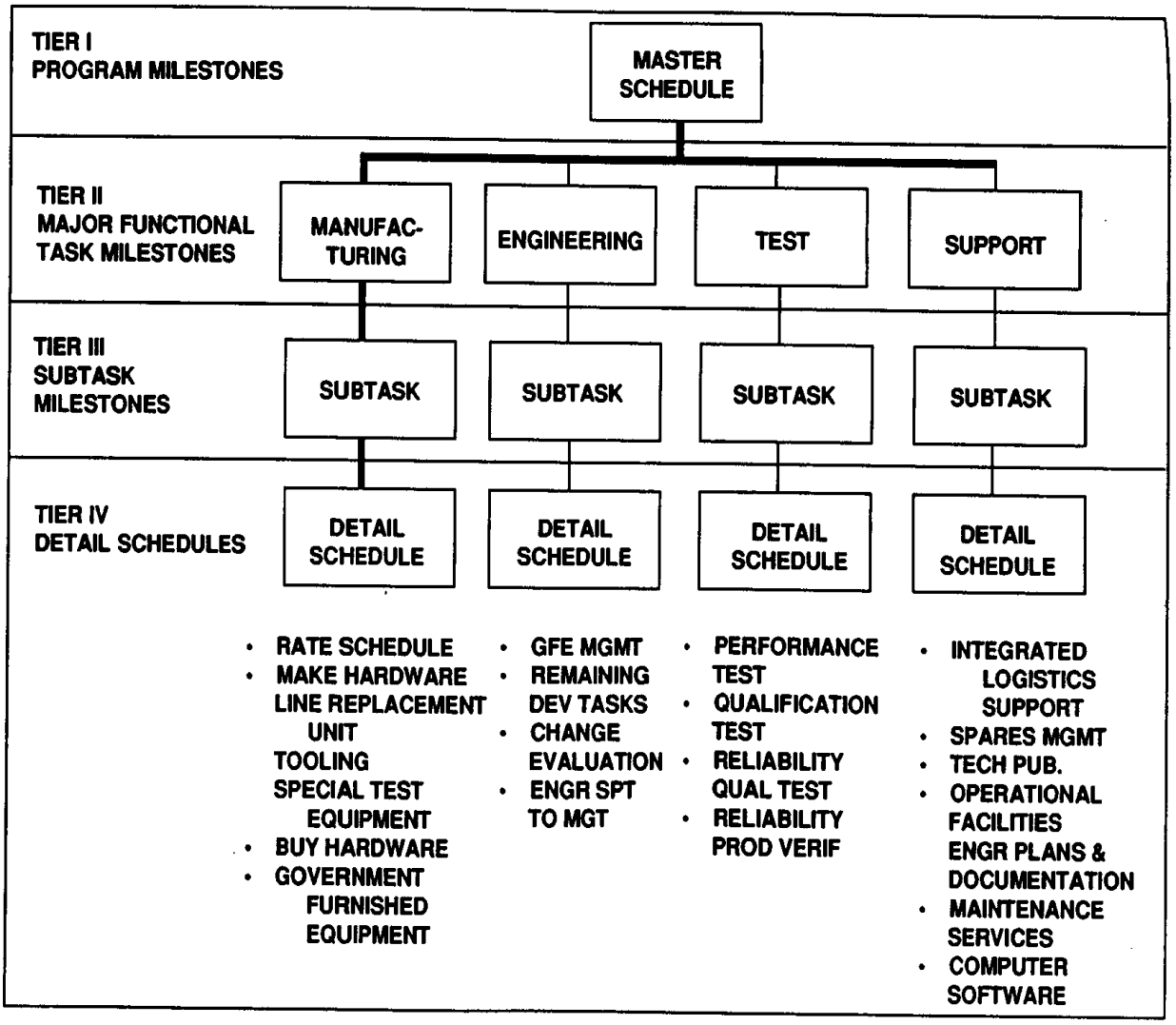

Figure 6-8 Typical Hierarchy of Schedules

Inventory Control

Manufacturing management is concerned with the integration of people, materials, equipment, machine tools, and manufacturing processes in the production of the end item. This requires determination of material requirements and components to support the manufacturing rate and determination of manufacturing lot quantities. These decisions can be treated as inventory control functions. The traditional approach to inventory control appears to concentrate on three areas: stockroom housekeeping, accuracy of inventory records, and surveillance of inventory variances. These are certainly important areas, but they do not address the central function of inventory control, i.e., maintaining minimum investment in material consistent with operational requirements.

Types of Inventory

There are two basic types of material inventories. These are:

1. In-process or Pipeline Stock. The size of the work-in process inventory is necessarily a function of process time and demand rates.

2. Stock Inventories. Stock inventories are inventories carried between stages in a manufacturing-distribution process.

Manufacturing inventories are "decouplers" or "insulators." Stock inventories insulate a manufacturing process from the inherent variability of the processing stages in the manufacturing cycle. These inventories also provide protection against potential line stoppages.

Many companies use inventories to decouple successive stages of production. They view it as uneconomical to schedule parts through some systems due to the unbalanced nature of operation times in processes performed at the various machine stations and the tool changes required for each operation. The use of inventories to disengage successive stages allows each stage to operate more efficiently; the operation of a particular stage is not compromised by the demands of preceding and succeeding stages. Although inventories provide production benefits, they represent an investment that involves capital costs that needs to be balanced against the benefits obtained. Batch processing is a term often used to describe this type of manufacturing system. Batch size should reflect the most economical order quantity for the process, thus minimizing total cost of setup and processing.

Just-In-Time

The just-in-time (JIT) manufacturing control philosophy has evolved from Japanese manufacturing techniques. In essence, Japanese manufacturers have rejected approaches utilizing complex management programs and controls, computers and information processing, and with mathematical modeling. The Japanese way is to simplify the problem. Japanese systems consists of simple procedures and techniques that do not require a particular cultural environment for implementation.

As pointed our by Schonberger in his book Japanese Manufacturing Techniques, the Japanese control system consists of two types of procedures and techniques. The two types pertain to productivity and to quality. The aspect of the Japanese system pertaining to productivity is known as just-in-time, but there are a host of other Japanese quality improvement concepts and procedures. Total quality management (TQM) covers this set of procedures and techniques. TQM encompasses some of the just-in-time techniques and improves productivity by avoiding waste.

In Japan, the workers and line manager are the focal points of implementing just-in-time procedures and techniques. There is much less emphasis on staff specialists than in the United States. While there is a growing awareness of the just-in-time philosophy, there has only been small progress made in implementing JIT in the United States. This will continue to be true as long as upper management is uninformed about the power and payoffs associated with JIT.

Just-in-time is a misunderstood philosophy in the United States. There are many erroneous perceptions of what it is. JIT is not:

- An inventory program.
- An effort than involves suppliers only.
- A cultural phenomenon.
- A materials project.

- A program that displaces MRP.

- A panacea for poor management.

Rather, JIT is an enterprise-wide operating control philosophy that has as its basic objective the elimination of waste. Under JIT, waste is considered anything other than the minimum amount of equipment, materials, parts, space, and worker's time that is absolutely essential to add value to a product. JIT strives to identify activities that do not add value and eliminate them. JIT can be used by any manufacturer interested in eliminating waste and simplifying the workload.

The companies in the U.S. that have implemented JIT have realized spectacular results as indicated in Table 6-1.

Reductions	Automotive Supplier	Printer	Fashion Goods	Mechanical Equipment	Electric Components	Range
Manufacturing lead time	89	89	92	83	85	83-92
Inventory						
Raw	35	70	70	73	50	35-73
WIP	89	82	85	70	85	70-89
Finished goods	61	71	70	0	100	0-100
Changeover time	75	75	91	75	94	75-94
Labor						
Direct	19	50		5	0	0-50
Indirect	60	50	29	21	38	21-60
Exempt	?	?	22	?	?	?-22
Space	53	N/A	39	?	80 (Est.)	39-80
Cost of quality	50	63	61	33	26	26-63
Purchased material (Net)	?	7	11	6	N/A	6-11
Additional capacity	N/A	36	42	N/A	0	0-42

(Coopers & Lybrand)

Table 6-1 Estimated Percent Improvement for Different Industries as Result of JIT Implementation

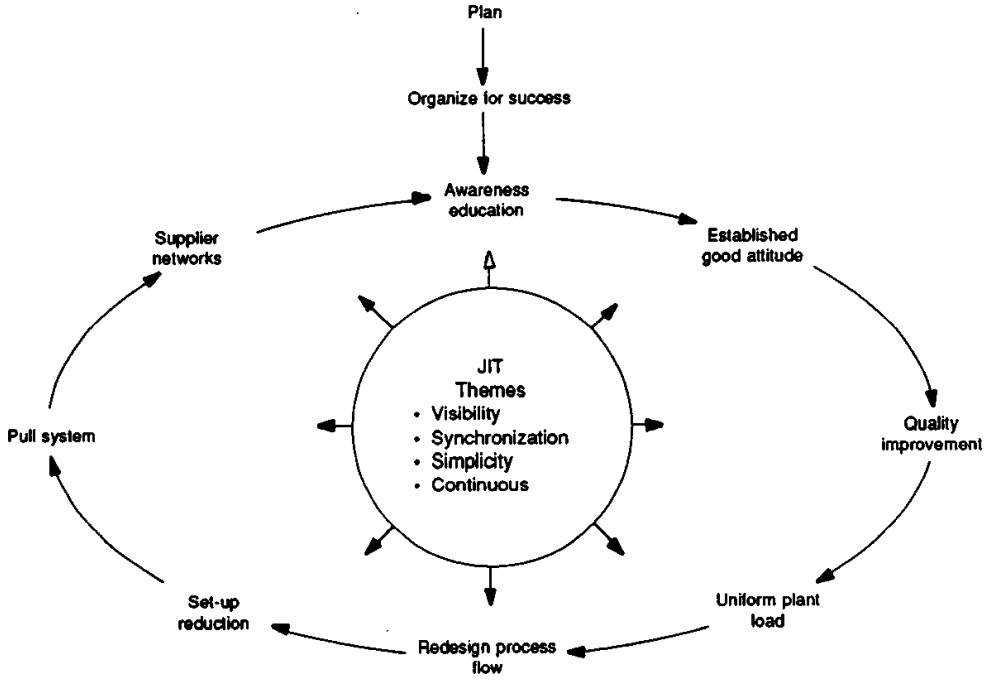

Figure 6-9 Proposed Steps in a JIT Manufacturing Program

William A. Wheeler III of Coopers and Lybrand has identified 10 distinct steps that should be considered in any comprehensive JIT manufacturing program. See Figure 6-9

A summation of the steps that can be taken by a manufacturing company follows.

1. Invest time in learning JIT control techniques.

2. Organize for success, i.e., establish a productivity control organization to identify and implement operational improvements.

3. Ensure all employees gain awareness of JIT and become educated in JIT technologies.

4. Establish an attitude that each person has a responsibility for his/her equipment and tools.

5. Continuously control and reduce variances to improve manufacture and quality of product.

6. Whenever possible, manufacture end items to meet demand and not to stock.

7. Redesign the process flow to eliminate operations that don't add value.

8. Eliminate set-ups or changeovers, where possible by dedicating equipment to product groups.

9. Select a few critical parts and institute a pull system prior to call completion.

10. Get the supply continuum involved in delivering only when needed.

Implementing JIT techniques is not just an inventory program of only for suppliers. If conceived properly, it can be a strategic tool for greater market participation.

Lead Time Evaluation

It is necessary for the contractor and the PMO to maintain continuing visibility of material, parts, and processing lead times.

There are several definitions of "lead times." Clarification of the most commonly used terms is provided in Figure 6-10. An initial estimate of the time required to procure the necessary components and to manufacture the item is defined as the "contract lead time." This lead time can be divided into its two primary components: manufacturing lead time and material lead time. Manufacturing lead time can be further sub-divided into inspection (also called dock time), fabrication, assembly and check-out. Material lead time can be defined in several ways. This is especially relevant when material or component lead times are experiencing large changes. There are three primary material/component lead times considered in this section; (1) First End Item Lead Time; (2) Material or Component Production Lead Time; and (3) Total Material and Component Lead Time. The time required to deliver the first end item (first end article lead time) may exceed the contract lead time when material and component lead times are extremely long.

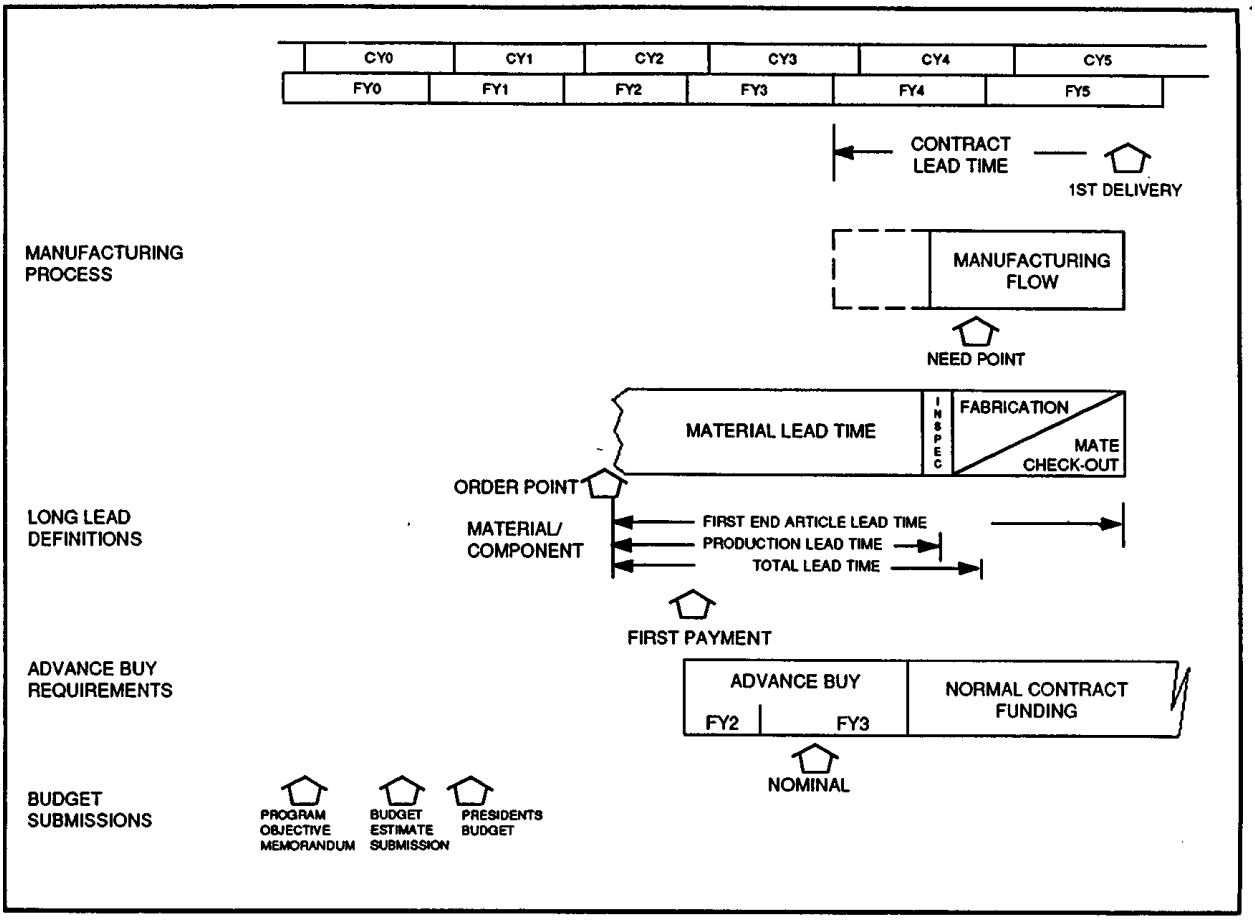

Figure 6-10 Lead Times

Determinants Of Lead Time

The lead time for a particular material or component is not static. It varies with a number of economic or other type conditions. Some of the elements which affect lead times are:

- Number of industrial sources
- Industrial source workload,
- Raw material availability,
- Raw material costs,
- Overall industry demand,
- Technology level of parts and materials,
- Cost of money,

- Escalation due to inflation, and

- De-escalation due to technology.

Lead Time Analysis

Defense systems typically exhibit lead time volatility. In the discussions of scheduling it is noted that the start date for contractor activity is normally based on a set back from the required completion date. The setback is dictated by the operation flow times and the material and component lead times. When the lead time is in error, two possible problems exist. If the lead time estimate is excessive, the funds requirement will be established unnecessarily early. This may lead to an overstatement of the lead-time funding requirement and could result in funds being drawn unnecessarily from other areas of need. If the lead time estimate is understated, specific contractor activities could experience a start date that will not support the required delivery date without the expenditure of premium effort, resulting in higher than necessary program cost or even potential schedule slippage.

The impact of lead time variations on a particular program can be minimized. The set of actions to achieve this, shown in Figure 6-11, can also have beneficial effect on the need for and magnitude of the long lead material requirements discussed below.

- **ENCOURAGE DESIGN STABILITY**
- **INVESTIGATE ADVANCE PROCUREMENT FUNDING POSSIBILITIES**
- **CONSIDER USE OF MULTIYEAR PROCUREMENT**
- **CONSIDER USE OF OFF-THE-SHELF SUBSYSTEMS**
- **ENSURE COMPLIANCE WITH DEFENSE PRIORITIES SYSTEM RATED ORDERS**
- **EVALUATE SPECIFICATION NEEDS. CONSIDER SUBSTITUTIONS FOR COMPONENTS AND MATERIALS IDENTIFIED AS LONG-LEAD-TIME ITEMS**
- **CONSIDER COMBINED PROCUREMENT OF END ITEMS, SPARES, AND REPAIR PARTS**

Figure 6-11 Actions to Minimize Impact of Lead Time Variations

Existing Regulations For Advance Buy

The primary regulation governing advance buys is DODD 7200.4, dated 30 October 1969. Interpretation of this regulation requires that three criteria be met in the justification of advance buys:

1) component lead time significantly longer than average component lead time,

2) component requirement independent of end items, and

3) component fully funded. The latter two criteria often present obstacles to efficient management of weapon systems procurement. The reality of today's defense marketplace suggests that a timely response to military needs in periods of long lead times requires that some subcomponent production decisions be made prior to end article manufacturing decisions.

In determining the amount of advance buy funding required, the program manager should task the

contractors to identify their needs in their budgetary and planning estimates. Where the lead time is a potential problem, the PMO should assure that the program planning documents include a long lead material contract and that sufficient funds have been identified in the Five-Year Defense Program.

Given the volatility of costs and lead times for defense system components, the PMO should carefully evaluate the contractor's estimate of the long lead requirement. The basis for both the time span and the cost should be clearly supported. Where the long lead tasks include elements such as tool design or manufacturing engineering, these should be carefully reviewed to ensure that they are not a part of the development activity or included in a previous contract.

For those items which represent risk to the program, the PMO may establish a program of continuing information interchange with other DOD programs which use those materials and components. These contacts will provide data which can be used to evaluate or corroborate the lead time data being acquired from the contractor. In addition, it may be advisable for the Program Manager to establish a specific program procedure for maintaining continuing visibility of lead time variation. Other potential actions which can minimize program risk include use of dual sources and alternate materials and increased contractor inventories of these items.

Personnel Planning

In developing a personnel plan, the contractor needs to consider the number of personnel needed, the specific skills of the personnel, the phasing of the requirements, and the ability of the organization to add personnel. The ability to meet the personnel demands should be a function of the labor pool available within the contractor's organization and the ability of the local area to provide the quantity and types of people required.

There also needs to be a clearly defined profile of the required workforce and a plan for the acquisition and training of new personnel. While on-the-job training (OJT) may be an effective mechanism for providing the required knowledge, its effectiveness is limited. Where the skills involved are relatively complex, there should be some form of formal training provided.

The PMO should review the adequacy of the planned personnel loadings to ensure that adequate numbers of people of the required skills are made available. When a large personnel increase is planned, the sources of those personnel should be determined and evidence of their potential availability should be provided by the contractor.

Facility Planning

The facility includes the plant and productive equipment which is to be made available to accomplish the production task. In developing the facility plan, both the quantitative and qualitative demands of the product must be considered. The qualitative analysis determines the types of processes which will be required. The contractor then has the option of utilizing currently existing facilities, acquiring new facilities, requesting government-furnished facilities (must be requested in the proposal) or subcontracting a portion of the effort. The quantitative analysis will determine the size of the processing departments within the facility. This analysis should consider the number of units to be delivered, and the rate of delivery. The information collected in the analysis will provide a measure of the number of work stations and the floor space required.

After determination of the facility requirements, the next concern is plant layout and workflow planning. In most cases, the layout is constrained by the existing facility; however, it may be possible to revise the layout for a new program.

The planning for material flow within a manufacturing facility is of major importance. Some studies have indicated that, in the job shop environment (which is representative of much of the defense industry) parts are in transit, or waiting at work stations, as much as 95% of the time. In developing the flow pattern, the objective is to establish a pattern that allows constant progress from raw materials and purchased parts (or components) to the completed product.

In facility planning, the contractor should make a sufficient in-depth analysis of the demands on the

facility to determine the most cost effective approach to production. This analysis should focus on the demands for services, and such things as power requirements, clean rooms, overhead clearance, as well as special requirements for handling explosives and other hazardous materials. The results of such an analysis and the plan to meet the demands on the facility are required data in some contracts. The requirement for such an analysis should be considered for inclusion in any contract where facility planning may have a major impact on program success.

MANUFACTURING PLAN PREPARED BY THE CONTRACTOR

Purpose

The purpose of the manufacturing plan prepared by the contractor for a specific program is to portray the method of employing facilities, machines and tooling, and the personnel resources of the contractor and selected subcontractors. The plan should reflect all time-phased actions which are required to produce, test and deliver acceptable systems on schedule and at minimum cost. The general structure of the plan should include, as a minimum, a description of the manufacturing organization, the make or buy plan, resources and manufacturing capability, and manufacturing planning data.

Manufacturing Organization

This section of the plan should address the contractor's organizational structure, i.e., the people responsible for the manufacturing task. It should include an organizational chart(s), identification of key individuals, and descriptions of the functional responsibilities of the key individuals. The government review of this section of the plan will focus on assuring that responsibilities are clearly defined and that all required tasks are assigned to the appropriate organizations. During the execution of the production phase of the program, this document should identify the points of contact for information and action.

Make Or Buy

This section of the plan should describe the distribution of effort between the prime and subcontractor. Of specific interest during the evaluation of the plan is the impact of the in-plant loadings on the prime contractor's overhead rates. This is of great importance in the case of a facility which is involved with many programs, because the overhead rate to be applied to the program of interest can be greatly affected by the level of activity of the other programs planned for the facility. Specific attention should be given to the contractor's rationale for specific make or buy decisions because there may be differences between overall contractor goals in structuring make or buy decisions and the goal which a Program Manager considers appropriate for his/her specific program.

Resources And Manufacturing Capability

This section of the plan should describe the resources to be applied to the manufacturing task. The facilities to be used should be described in detail, and the division of the government-furnished and contractor-furnished resources should be described, including the relationship to any Industrial Modernization Incentive Programs (IMIP) which are planned. If any improvement or rehabilitization of government-owned facilities is required, these should be described and justified.

The layout of the facilities to be utilized should be described along with the work flows through the facility. Where there are other programs in the facility, the integration of the work flow should be described. The key issue is to assure that there is a reasonable expectation that sufficient equipment and personnel exist in a form that will allow a manufacturing flow reflecting minimum cost and reasonable probability of schedule attainment.

The specific skills of the personnel required should be described in terms of time-phased requirements. Where personnel are not currently on-board, the contractor should describe how the required quantities and types of personnel will be acquired. The personnel requirements need to be analyzed in relation to the other programs within the facility and the local personnel market.

The contractor should describe the materials and components which will be utilized on the program. Where new materials or components which are in short supply are to be utilized, they should be justified. The relationship of material and component selection should be discussed in terms of the producibility studies which

have been accomplished (or are planned). The contractor should provide a manufacturing breakdown - one that shows the relationship between manufacturing methods and materials, tooling concepts, and facilities. Also, the manufacturing risks on the program should be assessed.

The manufacturing breakdown should be supplemented with a discussion of the plan for tooling, including special tooling and special test equipment (as defined in the FAR). The contractor should describe the overall tooling concept and approach including the planning, design, fabrication, and control of tooling and test equipment. The mix of limited life (often described as “soft”) and durable (often referred to as “hard”) tooling should be described along with the rationale. The government interest in the tooling and test equipment is motivated by the cost and by the potential for cost reduction through investment in tooling or test equipment capability.

Where a requirement exists for surge or mobilization, the production plan should describe the facilities and other resources required and the method of accomplishing the required increase in manufacturing output.

Manufacturing Planning Data

This section of the plan should provide the detailed delivery schedules for the total program even though the specific contract may be for only a portion of the program. The schedule shows the lead times required for the major and critical elements of the program and the time phasing of the major milestones involved with attaining the schedule. Detailed schedule requirements for activities having potential impact on the end item delivery schedule such as engineering release, material procurement, tool fabrication, facility acquisition or improvement and government-furnished property should be provided. The Program Manager should carefully analyze the details of the schedule to determine its attainability, the inherent risk, and the potential to use the Defense Materials System/Defense Priorities System. One of the more visible indicators of the program during the production phase is delivery performance. An unrealistic initial schedule can force a program into such things as high cost priority efforts to attain schedule and acceptance of equipment through waivers and deviations.

The success of the contractor in meeting the defined schedule can be affected by the quality of the manufacturing control system utilized. This control system should be described in the manufacturing plan so that the PMO can assess its adequacy for detailed shop release, manufacturing performance evaluation, and corrective action.

It is often beneficial to have the contractor include in the manufacturing plan a chart that portrays the details of the process of manufacture and assembly. These are often developed in formats such as tree charts or “goes-into” charts.

The productivity of the industrial organization can have a significant impact on the effectiveness and efficiency of the manufacturing activity. Where possible, the manufacturing plan should describe the measures planned to improve organizational productivity. These measures may be directed toward improvements in the effective utilization of personnel, equipment, or materials. Where these measures are described, the impact of their successful introduction on the overall manufacturing effort should be defined.

Value Of The Manufacturing Plan

The contractor’s development of a formal manufacturing plan contributes value to the program from two standpoints. A primary benefit accrues from the fact that the contractor has to crystallize the manufacturing planning to a point where it can be described in the detail required. A well constructed plan is the basis for the successful accomplishment of the manufacturing effort. The secondary benefit is the visibility the plan provides to the PMO personnel. It can serve as a basis for a structured review of the contractor’s approach, the expected cost of the production phase of the program, and an assessment of risk.

Planning For Spares

Spare parts production places an additional demand upon manufacturing resources. Determining the quantity of resources required must be based upon supporting both the deliverable system hardware and the required spares. Spares planning arises from two standpoints. The first is planning for those spare parts which must be produced concurrently in the weapon system production quantities. The second involves planning for the

continuing availability of the spare parts during deployment. This requires establishing a way to acquire the needed spares on a competitive basis. Competition can be based on a performance specification or an acquisition data package with unlimited rights. If the latter approach is taken, it is necessary that the PM take action during the development phase to obtain a contractor commitment to deliver a full acquisition data package with unlimited rights.

ECONOMICAL PRODUCTION RATES

One of the major issues to be addressed in the development of the manufacturing plan is the determination of the rate of production. Recently, OSD emphasis has been placed on determining and using more economical production rates for system development programs. An economical production rate is one which makes effective and efficient utilization of existing manufacturing plant and facilities. Generally speaking, the higher the rate, the lower the unit production cost.

Economical production rates can be analyzed by plotting unit cost versus quantity. The maximum economical rate occurs just before the existing or planned plant capacity, (including tooling or test equipment) is exceeded; i.e., further increase in quantity incurs an increase in unit cost due to the inability to amortize further facilitization and rate tooling costs. The minimum economical rate occurs at the knee of the unit cost/quantity curve while still effectively utilizing existing manufacturing facilities or where further reduction in quantity causes an increase in unit cost with an unacceptable return on investment.

An economical rate for many commodities is one at which the facility is operating nominally on a one-shift basis; however, programs can be structured to accommodate different bases (such as a two-shift operation). The availability of personnel in requisite numbers and skill levels, the existence of other plant loading (such as other systems produced at the same facility), and the capability of the industrial base including suppliers and vendors are other factors to be considered.

Planning for economical production rates (EPRs) must begin early enough in a program to influence contractor decisions. As early as the concept demonstration and validation phase, decisions on production quantities and production funds availability influence the EPR. During the production and deployment phase, the production rate should be maintained at the predetermined EPR in order to make the most efficient use of available industrial resources.

The production cost changes resulting from a change in production rate may be estimated either through direct discussion with the manufacturer, or through a modeling technique, or both. There are several models that can be used to predict the effect of a production rate change on unit cost. Unfortunately, many models require data that are very difficult to obtain, such as contractor variable and fixed costs.

The economical production and procurement rates represent goals. In practice, contractors usually produce, and program management offices usually procure, below the optimum rates. The prevalent reason for procuring (producing) a defense system below the EPR is affordability. Other reasons include keeping a “warm” production base, and not having an identified requirement for a follow-on defense system.

MANUFACTURING PLANNING AND CONTROL SYSTEMS

The program manager must understand the type and extent of computerization utilized by the contractor in the management of the day-to-day manufacturing planning and control activities. Most DOD prime contractors and their subcontractors have implemented or are in process of implementing Material Requirements Planning (MRP), Manufacturing Resource planning (MRP II) or JIT systems purchased from hardware/software vendors. Some contractors have developed and implemented equivalent systems because of real or perceived weaknesses in commercially available systems.

Whatever the situation might be, the program manager should acquire an understanding of such systems. There are vast differences between MRP and MRP II, for example, and the program manager must recognize that

the effectiveness of such systems is limited, i.e., they are not "cure-alls." Most important, the program manager should recognize that valuable information relative to program status can be obtained from such a system if the system has been properly planned for, implemented, and utilized.

The following is intended as a brief overview of MRP and MRP II which should provide a basic understanding of what each is, what each can provide, and requirements for successful implementation of such systems.

Material Requirements Planning

Material Requirement Planning (MRP) is a computer-based priority planning technique based on the theory of independent versus dependent demand. It is a time-phased explosion of the master production schedule utilizing bill-of-material and inventory status data to calculate the answers to these questions:

- What parts do we need to make or buy?
- How many of these parts do we need?
- When must these parts be available?

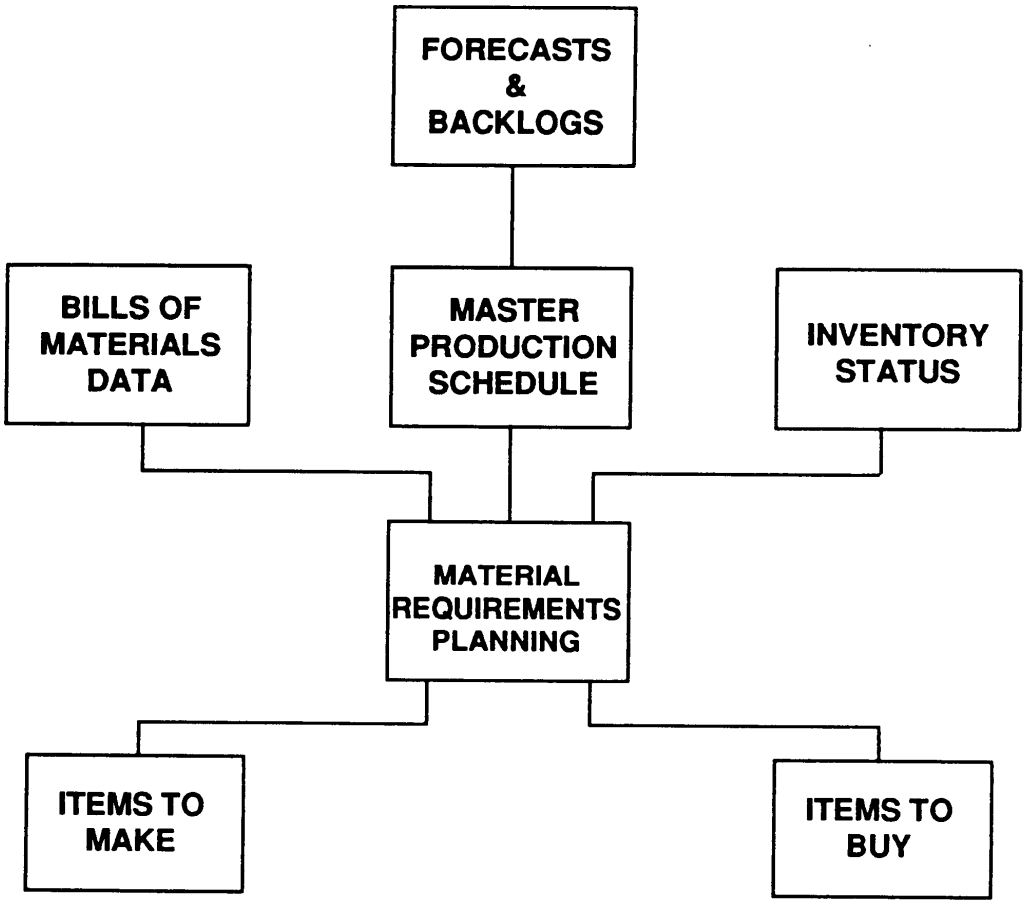

Figure 6-12 Materials Requirements Planning Information Flow

Figure 6-12 indicates the limited information flow associated with an MRP system.

When properly planned for, implemented, and utilized MRP can reduce inventory because the contractor should only make or buy what is needed. It can help improve on-time delivery of end products because, as a priority planning technique, MRP identifies which parts are needed to make or buy, and when the parts must be available to support the Master Production Schedule. MRP can also improve manpower and equipment utilization because, by knowing what parts are needed, how many and when, it is possible to better plan and control the use of resources.

The Master Production Schedule is crucial to the effectiveness of MRP. If the Master Production Schedule does not accurately reflect the product, quantities, and required need dates that satisfy contractual requirements, MRP will generate invalid priorities for manufacturing and purchasing. Inventory records and bills-of-material must be highly accurate for MRP to generate valid priorities.

Even with a Master Production Schedule that identifies the correct mix of end products required, as well as the correct quantities and timing of availability for those products, MRP may be ineffective in today's dynamic manufacturing environment. MRP assumes that there is infinite capacity available to accomplish the Master Production schedule. MRP provides no built-in feedback mechanism that reports back on the actual status of planned activities throughout the manufacturing and related functions. Today's dynamic manufacturing environment generates information from many functional areas that needs to be gathered, stored, and formatted for easy access by a large number of users. MRP must be interfaced with many other data processes to be effective such as:

- Customer demand activity
- Production plans
- Production schedules and their execution
- Purchasing management
- Inventory management
- Product cost reporting
- Support of and financial applications of accounts receivable, accounts payable, general ledger, and payroll.

The more that MRP is interfaced to other data sources, the more it evolves into Manufacturing Resources Planning (MRP II).

Manufacturing Resources Planning

Today, the effective manager recognizes the interdependent nature of functions, the need for interactive management information systems, the need for accurate, timely data reporting and storage for user-friendly access, and the need to share common data in order to enhance day-to-day management decision-making.

Current needs to go beyond managing just inventory, purchasing, and production. Planning needs in all areas of the company must be integrated into a plan which provides feedback to keep the "company game plan" up-to-date and which answers "what-if" questions through computerized simulation. MRP II systems provide the answers when properly planned for, implemented, and utilized.

The magnitude of the integration associated with an MRP II system is shown in Figure 6-13. MRP II represents a significant cultural change in that a company can utilize such a system to help run its business.

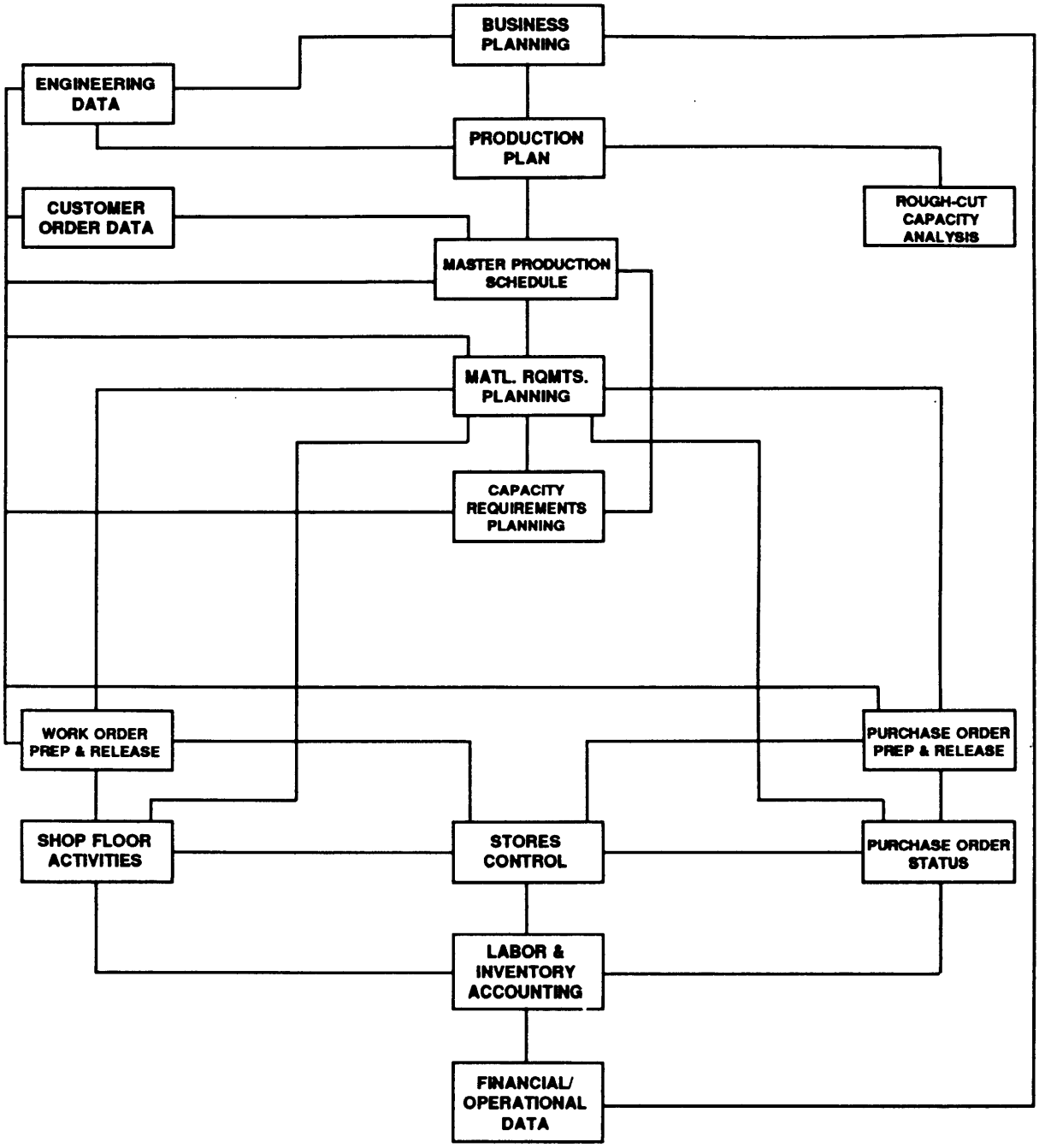

Figure 6-13 Manufacturing Resources Planning II Information Flow

The program manager should be sufficiently knowledgeable about an MRP II system to ensure that the following critical requirements are met:

- Top management understanding, commitment and involvement
- Teamwork — a company-wide system
- Common engineering and product data definition
- User education and training
- Realistic production plans
- Valid master production schedule
- Capacity planning, including simulation, as well as timely and accurate feedback regarding the status of plans
- Accurate bill-of-material, routing and inventory data
- Shop activity reporting
- Product costing reports by production run, along with variances and inventory evaluation
- Accurate maintenance of company records and the taking of corrective actions to keep plans on target

MRP II systems are normally of a modular design that facilitates implementation of a few modules at a time. There is a vast difference in the complexity of MRP versus MRP II. MRP is a group of modules which can be viewed as the foundation upon which an MRP II system can be built. Until such time that capacity planning including simulation, and shop floor and purchasing feedback are in place, as well as the modules normally associated with MRP, the program manager may view the Master Production Schedule as a contractor "wish-list."

With proper understanding, commitment, and involvement of top management; the proper selection and implementation of hardware and software; adequate user education; training and discipline, an MRP II system can be very helpful to the program manager. If any of the above are missing on a program, the MRP II system as well as the program will be in trouble.

MRP-MRP II Problems From The DOD And DCAA Perspective

In April, 1987, the Defense Contract Audit Agency (DCAA) identified 10 common "deficiencies" in MRP-MRP II systems. The DCAA indicated that the deficiencies "make these systems unreliable for government contracting and in violation of Cost Accounting Standards and other regulatory requirements."

?2MRP-MRP II systems and respond with plans to address the deficiencies which were identified in the letter. The perceived deficiencies, along with other relevant background information, are documented in the "DOD Position Paper On Contractors' Material Requirements Planning Systems - a memorandum from Deputy Assistant Secretary of Procurement, a memorandum from the Assistant Director of DCAA, and a DCAA pro forma letter to contractors."

As a result of the DCAA audits and information exchanges with defense contractors and MRP-MRP II vendors, and because of concerns expressed by the Congress, the Office of the Assistant Secretary of Defense issued "Policy guidance on contractors MRP systems", December, 1987. It identified 10 key elements that contractors must demonstrate as part of their MRP-MRP II systems in order for these systems to be acceptable for government contracting purposes. The "Final Policy Guidance on Contractors' MRP Systems" was published in the Federal Contracts Report, dated December 14, 1987.

An Approach To MRP-MRP II System Assessment

Quite a bit of publicity has been directed at MRP-MRP II and equivalent systems. Most of this publicity tends to lead the uninitiated to negative conclusions about MRP-MRP II in the government contracting environment.

Most of the perceived problems with MRP-MRP II are really only symptoms of the real problems. Symptoms which, when properly analyzed and studied, would lead us to a proper diagnosis of the real problems - the lack of up-front understanding of what it takes (or will take in the future) to operate a business from a total system standpoint and a lack of education and training about MRP-MRP II concepts and the inherent disciplines required to effectively implement such systems.

Every company needs to do a thorough "top down" analysis of how it is doing business (the "as-is" environment) and how it will be doing business in the next 3 to 10 years (the "to-be" environment) before implementing MRP II. As part of the analysis, each company needs to address, among other things, the adequacy of the current and planned material management and accounting system to ensure that it is in compliance with external regulations and standards as well as internal policies and procedures. If the "top down" analysis uncovers areas of non-compliance or other deficiencies in a current or future-planned system, the deficiencies can be remedied in an effective, well-planned manner and all parties can become aware of the existing problems.

Unfortunately, many major defense contractors have MRP II or some equivalent system in place or are in-process of installing such a system without a thorough "top down" analysis to assist and guide them from a systems standpoint.

Each program manager must understand the need to assess the effectiveness of contractor MRP-MRP II or an equivalent system. Just because a contractor has such a "state of the art" system in place does not assure that the program is under control and operating effectively. The contractor's attention to management of information that is in, or is an output from, such a system will ultimately determine the effectiveness of the system.

Today, hardware and software vendors can provide most of the functions required in the defense contracting environment. However, there will almost always be a need to either tailor some of a vendor's product to make it fit the contractor's business environment or, to tailor the way the contractor is doing business to fit the vendor's product. It is important to understand what and how much tailoring was done and how it impacts the ability of the government to obtain information needed to monitor contractor performance.

The program manager must view the interface or interaction between the system and the people who must understand and utilize the information provided by the system as a critical element to be analyzed as part of any assessment of an MRP-MRP II system.