DEFENSE SYSTEMS MANAGEMENT COLLEGE

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DEFENSE MANUFACTURING MANAGEMENT
GUIDE FOR PROGRAM MANAGERS

APRIL 1989

THIRD EDITION

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DEFENSE SYSTEMS MANAGEMENT COLLEGE
FORT BELVOIR, VIRGINIA

This guide was prepared by the Modern Technologies Corporation, Dayton, Ohio, under the direction of Mr. Thomas M. McCann under Contract No. MDA 903-88-C-0105. The contract was supervised by the Defense Systems Management College, Fort Belvoir, Virginia. The views and opinions expressed herein are those of the authors and should not be construed as an official Department of Defense position or policy unless so designated by other official documentation.

Whenever in this publication, "man", or "men", or their related pronouns appear, either as words or parts of words (other than obvious reference to named male individuals), they have been used for literary purposes and are meant in their generic sense.

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PREFACE TO THE THIRD EDITION

When the Defense Systems Management College (DSMC) published the first editions of this guide (then called a "handbook"), it promised to release new editions whenever there were sufficient changes in policies, procedures, and practices to make it appropriate to do so. Now it is appropriate to release the third edition.

Although the text has been revised, the basic objective of the guide has changed very little. The guide has become one of a family of educational guides published by the college and written from a Department of Defense (DOD) perspective; i.e., non-service peculiar. These guides are intended primarily for use in the courses at the DSMC and, secondarily, as desk references for program and project management personnel. This guide is intended to assist both the Government and industry personnel in executing their management responsibilities relative to the manufacture of defense systems.

The current family of technical guides, in addition to this document, includes the following:

- Integrated Logistics Support Guide
  First Edition: May 1986
- Systems Engineering Management Guide
  Second Edition: Dec 1986
- Test and Evaluation Management Guide
  First Edition: Mar 1988
- Mission Critical Computer Resources Management Guide
  First Edition: Sep 1988
- Risk Management Guide
  First Edition: Mar 1989

This guide is designed to provide the user with an understanding of, and a basic working familiarity with, the newest and most effective manufacturing management methods used in defense systems acquisition programs today. It is intended that the guide be particularly useful in preparing for and executing the production phase of a defense system program. The guide includes a discussion of DOD policies, directives, methodologies, and practices -- along with a list of acronyms and a glossary of terms -- applicable to the management of the manufacturing efforts of defense contractors.

The basic activities associated with producing defense systems and associated equipment, the current critical issues affecting manufacturing management, the common causes (and cures, when known) of manufacturing problems, and lessons learned on past programs have been placed in focus. Manufacturing management considerations during the development, as well as the production phase of a program, have been addressed. Further, the guide has related the manufacturing function to the fielding of defense systems and subsequent logistics support activities.

The DSMC has accepted the long-range responsibility for keeping this guide up to date. Therefore, anyone having comments and recommendations relating to the overall text, or the coverage of a specific aspect of manufacturing management, is encouraged to use one of the tear sheets located at the end of the guide -- or a letter, if no tear sheet is available. Mail it to the Director, Technical Management Department, Defense Systems Management College, Fort Belvoir, Virginia 22060-5426. Your comments and recommendations will be given serious consideration during preparation of the next edition.

David D. Acker
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Co-Project Manager

Defense Systems Management College
Fort Belvoir, Virginia
1 April 1989

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CHAPTER ONE

OVERVIEW OF DOD MANUFACTURING MANAGEMENT

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OVERVIEW OF DOD MANUFACTURING MANAGEMENT

OBJECTIVE

Manufacturing (production) is the conversion of raw materials into products and/or components thereof, through a series of manufacturing procedures and processes. It includes such major functions as manufacturing planning and scheduling; manufacturing engineering; fabrication and assembly; installation and checkout; demonstration and testing; product assurance; and determination of resource requirements.

Manufacturing management is the technique of planning, organizing, directing, controlling and integrating the use of people, money, materials, equipment, and facilities to accomplish the manufacturing task economically. A manufacturing management system is composed essentially of three phases: planning, analysis, and control.

1. During the planning phase, consideration must be given to such factors as material acquisition, an adequate work force, the engineering design, and provisions for sub-contractor support. Production feasibility and producibility of the engineering design are critical factors that must be considered early in a program. This consideration must include planning, new processes, facilities, tools and test equipment, and cost control during design.

2. During the analysis phase, answers must be provided to such questions as: Is the manufacturing process working? Is it efficient? Is manufacturing being accomplished by the most economical method? Is the manufacturing plan being followed and are the established goals being met? (During system design and development, these questions need to be projected into the future manufacturing effort to identify required preparatory actions and to assess risks.)

3. During the control phase, the manufacturing effort must be monitored to ensure that the manufacturing management function is performing within the constraints and limits that have been established.

Throughout all these phases, an essential element is the role of the manufacturing manager and the organizational environment under which he operates. The focus of this chapter is on the organizational structures within DOD and the nature of the assignment of responsibility for manufacturing management tasks within that structure. There is also consideration of the nature of the relationship between the program manager and the industry counterpart organizations. The successful completion of a program requires that an effective working relationship be established, with mutual understanding of the responsibilities of each.

INTRODUCTION

The objectives of DOD manufacturing management are:

1. To ensure that proper manufacturing planning has been accomplished early in a program so that the manufacturing effort will be performed smoothly.

2. To ensure that the system design will lead to efficient and economical quantity manufacture.

3. To assess the status of the program at any point during the production phase to determine if schedule, costs, and quality standards are being met.

4. To conduct assessments and reviews of the manufacturing effort required to meet decision points at each phase of a defense systems acquisition program.

One of the basic thrusts within DOD is to increase management focus on manufacturing and total quality management during early defense system (weapon) program phases. There are significant costs associated with the manufacturing effort. These costs, to a great degree, are inherent in the design. As a design evolves, certain costs become essentially fixed. Given the objective of minimizing cost and the existence of projections that indicate limited dollars available for future manufacturing effort, it will be necessary to identify costs at the point when they are being fixed. This situation provides the need for early assessment.

ORGANIZATIONAL STRUCTURE

The Undersecretary of Defense for Acquisition has the direct responsibility for DOD manufacturing management policy and guidance in the acquisition of defense systems. The head of each DOD component (Military Departments and Defense Agencies), in turn, is responsible for developing and implementing procedures within the components. Figure 1-1 depicts the variation of the command structures for defense system acquisition within the components.

DOD Directive 5000.1, Major and Non-Major Defense Acquisition Programs, establishes the approval cycle and procedures for weapon system acquisition. The directive applies to the staff of the Secretary of Defense, the Military Departments, the Organization of the Joint Chiefs of Staff, the Unified and Specified Commands, Defense Agencies, including The Strategic Defense Initiative Organization, and DOD Field Activities or Components.

The Directive establishes the Undersecretary of Defense for Acquisition as the Defense Acquisition Executive (DAE). The DAE is charged with assuring that the manufacture of each weapon system is performed so as to produce the most efficient, cost-effective, and highest quality end item possible. He does this through his role as the Chairman of the Defense Acquisition Board (DAB). The DAB (vice-chaired by the recently created Vice Chairman of the Joint Chiefs of Staff who assures that requirements are met) provides approval, policy guidance and issues resolution as the weapon system moves through the acquisition cycle from: Milestone O - Program Initiation/Mission-Need Decision; Milestone I - Concept Demonstration/Validation Decision; Milestone II - Full-Scale Development Decision; Milestone III - Full Rate Production Decision; Milestone IV - Logistics Readiness and Support Review; and Milestone V - Major Upgrade or System Replacement Decision. (See Chapter 3 for discussion of the acquisition process.) The Undersecretaries of the Army and Navy and the Assistant Secretary for Acquisition for the Air Force serve as Service Acquisition Executives (SAE) for their respective components. The individual SAEs manage the established acquisition structure and process within their component, consistent with DOD guidance; report breaches to the program baselines; and establish policy for managing component programs.

Authority for acquisition management is assigned in a three tier management structure recommended by the President's Blue Ribbon Commission on Defense Management (better known as the Packard Commission). Within this structure, program managers report to Program Executive Officers (PEOs) who report to the SAE, as shown in Figure 1-2. In responding to this requirement (from the Goldwater-Nichols Department of Defense Reorganization Act), each of the Services has structured acquisition policy and program execution organizations somewhat differently.

The Army has a single command, the Army Materiel Command (AMC) that accomplishes all the research, development, acquisition and logistics support functions. Within AMC, the Chief of Staff for Production provides manufacturing management guidance to the Major Subordinate Commands (MSCs). The MSCs such as Aviation Systems Command, Missile Command, Tank-Automotive Command or Test and Evaluation Command manage the specific research, development, acquisition, test and support for each assigned weapon system within their respective program management office.

The Navy's principal subordinate Systems Commands (SYSCOMs), i.e., Naval Sea Systems, Naval Air Systems, Space and Naval Warfare, Naval Mine Warfare, Naval Supply Systems, and Naval Facilities Engineering are responsible for providing material support for the operating needs of the Navy and for certain Marine Corps needs. The SYSCOMs report directly to the Chief of Naval Operations. The program offices within the SYSCOMs are responsible for the manufacturing management functions for the defense systems under development. However, guidance on transitioning from development to production comes from the Assistant Secretary of the Navy for Ship Building and Logistics.

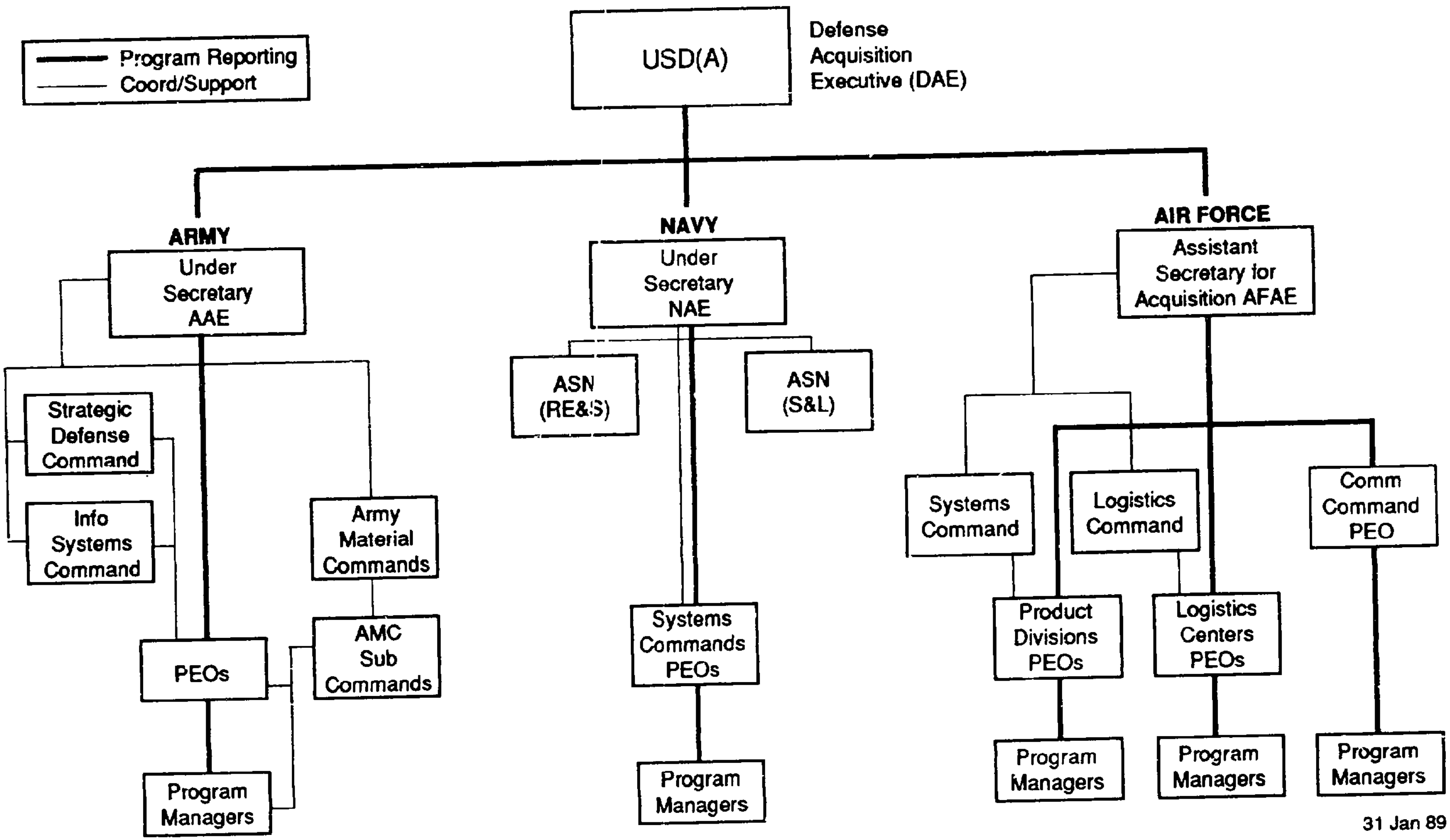

Figure 1-1 Program Manager's Reporting Chain

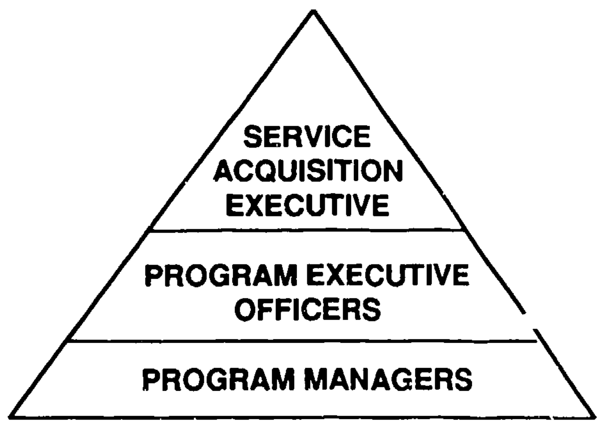

Figure 1-2 Acquisition Management Structure

Responsibility for manufacturing policy within the Air Force is held by the Director of Contracting and Manufacturing Policy within the Office for the Assistant Secretary of Acquisition. The Air Force has two major commands concerned with the defense systems acquisition process, the Air Force Systems Command (AFSC) and the Air Force Logistics Command (AFLC). AFSC, through the Deputy Chief of Staff/Product Assurance and Acquisition Logistics, is responsible for the manufacturing function. AFLC, through the Deputy Chief of Staff/Contracting and Manufacturing is responsible for the manufacturing function after the program management responsibility is transferred from AFSC to AFLC.

OSD AND DOD COMPONENT RESPONSIBILITIES

As stated previously, DOD Directive 5000.1, Major and Non-Major Defense Acquisition Programs, gives the Undersecretary of Defense for Acquisition, as the DAE, the responsibility to establish manufacturing policy and direction. Policy emphasis is placed on long range planning and effective requirements which allow for smooth transition from development to production. The guidance includes such areas as production planning, transition to production, concurrent engineering, total quality management, could cost, and manufacturing technology. The DAE passes this policy through the respective SAEs, who are the senior acquisition executives within the DOD component having cognizance and management responsibility over defense systems. The manufacturing policy is assessed by the components' PEO and is provided to the program managers. The PEOs are the officials responsible for administering a defined number of acquisitions and reporting program status to the SAE. The concept behind this approach is that the acquisition system will be characterized by short, direct lines of communications; less staff interaction; and streamlined procedures. Overall the program manager, who is the individual responsible for executing the program, will experience fewer layers of management oversight (no more than one management tier between the PM and the SAE), and will be able to receive the guidance he requires in a timely fashion.

In addition, OSD chartered in the summer of 1988 a Defense Manufacturing Board (DMB) similar to the Defense Science Board. This group of senior personnel from government, defense and non-defense industry, labor and academia will provide analysis and advice to OSD on manufacturing issues and will aid in evaluating the effectiveness of new policies and initiatives. The Board will also develop approaches to apply innovative technology throughout the manufacturing industry; improve quality in manufacturing processes, primarily through the concept of Total Quality Management; and increase the use of concurrent engineering -

designing the product and its manufacturing processes at the same time. The initial term of the DMB is two years. At that time, a decision will be made as to the Board's future.

DOD Directive 4245.6, Defense Production Management, establishes policy and assigns responsibility for manufacturing management within the DOD components for the acquisition of major defense systems. This direction is practical for programs of all magnitudes and is supplemented with more detail by the respective DOD components.

Major programs in each Service begin following SECDEF or Deputy SECDEF acceptance of the mission need statement (MNS). The justification contains an analysis that has taken into consideration the existing technology base. Manufacturing management is considered at each decision point throughout the system life cycle. A manufacturing feasibility assessment is made by the responsible DOD component during the development of the component/OSD decision leading to the concept demonstration/validation phase. The producibility of the design approach and production risks are reviewed prior to the full-scale development phase. Toward the end of the full-scale development phase, a final Production Readiness Review is performed to determine whether the program is ready to enter the production and deployment phase.

GOVERNMENT PROGRAM MANAGER RESPONSIBILITIES

The government program manager (PM) needs to be concerned with manufacturing management early in the process of defense system acquisition. The design producibility, the manufacturing processes, the tooling to be developed, and production testing and demonstrations identified during preliminary design should be evaluated to determine the overall manufacturing risk, as well as cost and schedule impacts. Manufacturing risk is one of the important factors in making the decision to proceed with the concept demonstration/validation phase and later with the full-scale development phase.

No later than the concept demonstration/validation phase, a producibility analysis should be made to aid in the identification of risks, the development of preliminary cost and schedule estimates, and the identification of issues that must be resolved prior to the Milestone II decision. Preparation for Production Readiness Reviews should begin in the concept demonstration/validation phase. The Program Management Office (PMO) should establish and provide criteria to the contractor as early as possible. A successful Milestone II requires a plan for transitioning from development to production. Milestone III requires verification of the product producibility and production schedule capabilities.

The PM should work closely with the contractor counterpart to ensure that all manufacturing objectives will be met. The PM should insist on aggressive producibility actions, comprehensive production planning and scheduling, and efficient manufacturing methods. Sufficient funds should be budgeted for use during the full-scale development phase to accomplish these tasks. Producibility engineering and planning (PEP) and initial production facilities (IPF) definition efforts should start during product design to avoid incurring significant cost and delays in starting the manufacturing effort.

The, PM through the manufacturing team in the PMO, should monitor progress against the manufacturing plan. The PMO team should have a good technical understanding of the product so that technical problems can be resolved and design modifications can be evaluated effectively. The PM, of course, must be aware of each contract and engineering change during the program, and the impact of that change on the overall program.

RELATIONSHIP BETWEEN GOVERNMENT AND CONTRACTOR PROGRAM MANAGERS

Interaction between contractor manufacturing executives and the government PM is required during program planning when program schedules and budgets are being established. This relationship should continue throughout the life cycle of the program. Such interaction usually results in the development of better schedule and cost planning. Also, it increases the validity of information used by the contractor(s) for work force, technology and capital expenditure planning.

Interaction is required in the review of work in process and the contractor methods and procedures. This assists both government and contractor managers in their understanding of the manufacturing proposals and in the expeditious resolution of manufacturing problems. This interaction is an absolute necessity, and in some cases the PM will find that interaction between the government and contractor manufacturing personnel can serve as a forcing function for the top contractor design personnel to communicate and coordinate program decisions with their own manufacturing personnel. A management tool like Award Fee can increase visibility into the interaction aspects of the producibility program.

When budgeting for manufacturing, interaction will enable the government PMO to determine the significant cost impacts experienced by the contractor. Interaction increases the government PMO's understanding of the contractor's manufacturing operations and manufacturing pricing methodology, as well as the factors that can impact manufacturing operations.

GOVERNMENT PROGRAM MANAGEMENT OFFICE PERSONNEL SELECTION

Personnel selected to perform the manufacturing management task in a government PMO should be production-oriented and should understand fully the importance of continuing assessment of the manufacturing effort. Knowledge of the following is important for government personnel to have or to develop when they are assigned the manufacturing management responsibility:

Manufacturing processes and their management.

Engineering operations.

The technical performance requirements of the defense system/product (as specified in the contract).

The DOD planning, programming, and budgeting cycle.

Manufacturing planning and scheduling.

The relationship of manufacturing management to acquisition strategy.

Configuration management and its relationship to the manufacturing effort.

Total quality management.

Depot maintenance or repair facility operations. How to control/reduce costs.

Productivity improvement.

TOTAL QUALITY MANAGEMENT AND COULD COST

The goals of Total Quality Management (TQM) and Could Cost are to improve the quality and lower the cost of system acquisitions. These require the commitment of the entire acquisition community. Attention must be focused on integrating the acquisition processes, reducing non-value- added work, and improving contractor performance.

There are many acquisition streamlining and quality initiatives which contribute to the TQM/Could Cost goals. By combining these initiatives with innovative thinking, a corporate strategy can be formulated that will achieve the goal of quality/cost improvements in DOD acquisitions.

The TQM/Could Cost philosophy can be integrated into the acquisition process through ongoing initiatives, encouraging future innovations which improve quality and reduce cost, and assuring that TQM/Could Cost tools and techniques are addressed in the planning and execution of acquisition programs.

Applying the TQM/Could Cost philosophy in the acquisition process will require a "cultural" change within DOD. To effect that change, a TQM Master Plan has been developed which concentrates on one fundamental objective: the continuous improvement of DOD products and services. To meet this objective there will also have to be full DOD and contractor participation and commitment. Some of the primary challenges in implementation of this concept are:

1. Foster an awareness of and commitment to the philosophy in the DOD acquisition community.

2. Work closely with industry to identify and remove barriers to quality/cost improvement and to develop acquisition incentives that encourage contractor performance improvements.

3. Identify, describe and develop tools and techniques that have a positive impact on quality and cost; integrate them into functional processes.

4. Integrate this philosophy into acquisition programs.

5. Assess the effectiveness of TQM and Could Cost implementation by evaluating functional and program performance improvements.

REFERENCE DOCUMENTS

Numerous reference documents impact the manufacturing management function throughout the acquisition process. These documents originate from many sources and range across academic disciplines, functional activities, and job specialties.

The following is a reference list of DOD Directives (D), Instructions (I) Manuals (M), Pamphlets (P) Military Standards (MS), and other documents. The documents listed contain DOD policy guidance applicable to the manufacturing management function. They are listed as sources of DOD manufacturing management information.

REFERENCE LIST

	Number	Title
(D)	2000.9	International Coproduction Projects and Agreements
(I)	2010.4	U.S. Participation in Certain NATO Groups Relating To Research, Development, Production and Logistics Support of Military Equipment
(D)	2010.6	Standardization and Interoperability of Weapons Systems and Equipment Within the North Atlantic Treaty Organization
(I)	3235.1	Test and Evaluation of System Reliability, Availability and Maintainability
(D)	4005	Defense Acquisition Research
(D)	4005.1	Industrial Preparedness Production Planning
(D)	4005.16	Diminishing Manufacturing Sources and Material Shortages
(I)	4005.3	Industrial Preparedness Planning
(M)	4005.3-M	Industrial Preparedness Planning Manual
(H)	4105.59H	DOD Directory of Contract Administration Services
(I)	4120.20	Development and Use of Non-Government Specification and Standards
(D)	4120.3	Defense Standardization and Specification Program
(I)	4120.19	DOD Parts Control Program
(I)	4140.41	Government-Owned Materiel Assets Utilized as GFM for Major Acquisition Programs
(D)	4155.1	Quality Program
(I)	4155.20	Contractor Assessment Program
(D)	4160.22	Recovery and Utilization of Precious Metals
(I)	4200.15	Manufacturing Technology Program
(D)	4120.8	DOD Bill of Materials
(D)	4245.3	Design to Cost
(D)	4245.6	Defense Production Management
(D)	4245.7	Transition from Development to Production
(M)	4245.7-M	Transition from Development to Production Manual
(D)	4245.8	DOD Value Engineering Program
(H)	4245.8	DOD Value Engineering Program
(D)	4245.9	Competitive Acquisitions
(D)	4275.5	Acquisition and Management of Industrial Resources
(I)	4210.4	Studies on the Availability of Materials
(I)	4400.1	Priorities and Allocations
(D)	5000.1	Major and Non Major System Acquisitions
(I)	5000.2	Defense Acquisition Program Procedures
(D)	5000.3	Test and Evaluation
(D)	5000.29	Management of Computer Resources in Major Defense Systems
(I)	5000.38	Production Readiness Reviews
(D)	5000.39	Acquisition and Management of Integrated Logistic Support for Systems and Equipments
(D)	5000.40	Reliability and Maintainability
(D)	5000.43	Acquisition Streamlining
(D)	5000.44	Industrial Modernization Initiatives Program
(D)	5000.45	Baselining of Selected Major Systems
(D)	5000.49	Defense Acquisition Board
(I)	5010.12	Management of Technical Data
(D)	5010.19	Configuration Management
(D)	5010.20	Work Breakdown Structures for Defense Material Items
(M)	5025.1-M	DOD Directives System Procedures Manual
(D)	5220.22	DOD Industrial Security Program
(I)	7000.2	Performance Measurement for Selected Acquisitions
(I)	7000.3	Selected Acquisition Reports
(I)	7000.10	Contractor Cost Performance, Funds Status, and Cost/Schedule Status Reports

(I) 7000.11	Contractor Cost Data Reporting (CCDR)
(I) 7045.7	The Planning, Programming, and Budgeting System
(I) 7220.31	Unit Cost Reports
(MS) 109B	Quality Assurance Terms and Definitions
(MS) 470	Maintainability Program Requirements (for Systems and Equipments)
(MS) 480	Configuration Control - Engineering Changes, Deviations and Waivers
(MS) 481A	Configuration Control - Engineering Changes (Short Form)
(MS) 482A	Configuration Status Accounting Data Elements
(MS) 490	Specification Practices
(MS) 499A	Engineering Management
(MS) 785B	Reliability Program for Systems and Equipment Development and Production
(MS) 881A	Work Breakdown Structures for Defense Material Items
(MS) 1521A	Technical Reviews and Audits for Systems, Equipments and Computer Programs
(MS) 1523A	Production Management
(MS) 1567A	Work Measurement
DOD-STD-100C	Engineering Drafting Practices
MIL-I-45208A	Inspection System Requirements
MIL-Q-9858A	Quality Program Requirements
(DCAA) P 7641.47	Cost/Schedule Control Systems Criteria Joint Implementation Guide

CHAPTER TWO

THE INDUSTRIAL BASE

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THE INDUSTRIAL BASE

OBJECTIVE

Success in developing and producing defense systems relies heavily on the technological and industrial capability of the defense industry. In managing development and production programs, the program manager needs to specifically assess and understand the capabilities of the industrial base to support the program. The material which follows describes the structure and problems of the industrial base and the avenues available to the program manager to achieve the necessary and available support from that base. Key guidelines to follow are:

1. Determine the capability of the base to supply the types and quantities of material required.

2. Provide industry motivation to compensate for any shortcomings in capability or capacity.

3. Make use of the Defense Priorities and Defense Materials Systems.

4. Assure continuing ability to meet production surge and continuing support demands of the operating forces.

INTRODUCTION

The industrial base is composed of prime contractors, together with tiers of subcontractors, with the plant and equipment and skilled workers necessary to develop and produce the hardware required to fulfill the nation's defense program.

The mission of the Department of Defense is to provide for the common defense of the country. This requires a political and military infrastructure which can provide worldwide influence. The heart of the United States deterrent power is an inventory of military equipment and human resources. The lifeblood of this capability is the United States' industrial base. The "industrial base" combines the manufacturing processes with the managerial talent which establishes a strong economy and industrial sector to produce weapon systems required to provide for the defense of the country.

The U.S. Congress has been focusing attention on the defense industrial base for a number of years. One of the definitive descriptions of the base was a report by the House Armed Services Committee (HASC) on December 31, 1980, titled, "The Ailing Defense Industrial Base: Unready for Crisis." This report described a serious decline in the nation's defense industrial capability. The report cited an alarming erosion of crucial industrial elements, coupled with a mushrooming dependence on foreign sources for critical materials.

A number of problems have degraded the ability of the industrial base to respond to near-term readiness, surge and mobilization requirements in a timely manner. The same problems have resulted in a deterioration of the subcontractor and vendor base which has diminished the likelihood of competition and contributed to the emergence of production bottlenecks.

Our society is changing at an ever-increasing pace due to advances in technology and economic stimulation by foreign competition. America has historically been a leader in technology innovation, application, and productivity. This has provided us the competitive edge necessary to secure a large market share. A substantial loss in commercial market share in recent years has been largely due to United States' failure to acknowledge and prepare for the increasing capabilities of our worldwide competitors.

The market for defense systems and equipment has been relatively shielded, but is now being affected by the increasing reliance on foreign manufacturers for various products that U.S. manufacturers can no longer produce with comparable quality at competitive prices.

Current economic conditions and the uncertain future being projected are compelling reasons for a change in attitude. American industry is awakening to the challenge of foreign competition, but finds itself in a mind-set that is very difficult to change. The industrial revolution and the post-World War II prosperity gave everyone a false sense of security. A sustained demand for American products, supported by a lack of competition in the international markets, induced complacency regarding quality and led to the pursuit of short - term objectives for larger profit margins.

In many cases industry has disregarded the impact of quality technology due to perceived excessive cost. Manufacturers are now being required to radically modify many of the ingrained concepts and adopt new principles based on the new concept that quality cannot be inspected into the end item.

During the past decade, we have witnessed a substantial loss of manufacturing capability as many companies and practically entire industry segments have closed shop. Failure to improve quality, while striving to reduce costs and improve the declining profit margins caused by foreign competition, has often been cited as the problem. Many companies have been driven out of the market due to their inability to recognize their shortcomings and implement fundamental changes throughout their organization. This process has, through the years, caused a significant erosion of our industrial base.

The ability of our military forces to meet our national security objectives is, in large measure, a function of the strength and vitality of U.S. industry. If we characterize the condition of U.S. industry as a percent of the national product, it appears to be expanding. For example, factory capacity is increasing, capital investments are up, and unemployment is at its lowest level in seven years. However, these statistics are misleading because they do not reflect the true status of key defense industries. The DOD is dependent on many highly specialized industries; therefore, we must focus on specific industry segments when we assess the industrial base in relation to national interests.

The DOD has been surveying some industries known to be facing difficulties. We do not know the full extent of the implications of a failure of these highly specialized industries on our ability to preserve the peace or mobilize for war; but we do know that the DOD cannot solve industry's problems. Ultimately, industry's behavior will determine not only its own health, but also the national economy, and the future of the work force. However, DOD cannot be complacent about the national security implications of a declining industrial base. We must, therefore, use the leverage of the DOD procurement budget to help modernize our factories, increase productivity and quality, and provide incentives that will promote technological and manufacturing leadership essential to national security.

INDUSTRIAL BASE ASSESSMENT

The Congress and DOD have both been active recently in defining the status of the industrial base and developing potential solutions.

Senate Activity

On July 23, 1987, the Senate Subcommittee on Defense Industry and Technology of the Committee on Armed Services conducted a hearing on the manufacturing capabilities of key second-tier defense industries. The information presented to the Senate included statements about the health of the optics, bearing and machine tool industries, and a statement from the Defense Advanced Research Projects Agency (DARPA). The subcommittee members received in-depth testimony on the technology base, the industrial base and on the impact of the changes to DOD's acquisition process. The conclusions arrived at by the committee members were that the technology and industrial base were deteriorating; but, more importantly, the root cause of this condition appeared to be in the second and third-tier defense manufacturers. Within the optics industry, foreign manufacturers provide 75% of the optics used by DOD and American manufacturers. The crux of the problem seems to be in the nature of competition between American and foreign manufacturers, which will be discussed later. The recommendations provided to the Senate by the optics industry include the following: require DOD to purchase all precision optical components from domestic sources; provide government support to an industry-wide apprenticeship training program; and provide congressional and DOD funding support for a program aimed at making the U.S. optical manufacturer more competitive in the world market.

It is readily apparent that the bearing industry plays an important role in all aspects of the country's defense. Current studies indicate that the domestic industry cannot meet mobilization requirements. The import picture for 1986 shows that the U.S. imported 64% of ball bearings, 40% of tapered roller bearings and 17% of other roller bearings. The Anti-Friction Bearing Manufacturers' Association supports an import quota program and DOD has ruled that all its contractors must buy only American-made ball bearings.

The machine tool industry's capability to support a mobilization is not any better that the previous examples. Since 1986 imports have met 49% of the domestic machine tool demand; 25% of the domestic machine tool capacity has been forced from the business or moved off-shore. The National Machine Tool Builders' Association (NMTBA) which supports a continuation of the 1987 Defense Appropriations Act states that, "Fiscal Year 1987 funds cannot be used to purchase, for use in DOD facilities, 23 Federal supply classes of defense-sensitive machine tools from sources other than the United States and Canada." The NMTBA is also a strong supporter for increased use of the IMIP and MANTECH programs.

A DARPA representative's testimony summarized the nature of the competition by concentrating on the Japanese approach to conducting business. First, they use many techniques to achieve rapid commercialization of new technologies facilitated by the Ministry of International Trade and Industry (MITI). The MITI establishes strategic direction, sets up joint ventures, and provides financing and protection in the domestic marketplace. Second, the nature of the Japanese manufacturing enterprise is also important. The Japanese invest heavily in manufacturing research; make extensive use of just-in-time inventory control procedures which reduce work-in-process costs; and maximize the output of the human resource by attracting the best engineers, providing extensive training to the workers and rotating the job assignments for all categories of workers. Finally the Japanese fully subscribe to the "total quality concept". The Japanese belief that quality is designed in, not inspected in, permeates all aspects of business from R&D, design, vendor purchase, and fabrication finally to test. This approach provide the utmost flexibility for conducting business in the world market.

The result of this hearing was the introduction of a bill, SS1892, to strengthen the industrial base. S1892 acknowledges the importance of the industrial base for the defense of the nation: to develop technologically superior defense material rapidly and to produce such material efficiently in cost-effective quantities during peacetime and to expand production capacity rapidly to meet the demands of a national emergency. The bill provides for the maintenance and improvement of the industrial base. It gives management responsibilities to the Undersecretary of Defense for Acquisition to encourage investment in emerging technologies, modernizing production facilities fostering the dedicated participation of private U.S. sources, and discouraging unfair practices by foreign sources.

<u>House Activities</u>

The House conducted several hearings before the Subcommittee on Economic Stabilization of the Committee on Banking, Finance and Urban Affairs during the months of July and September 1987, to develop the new Industrial Base Initiative. The hearings focused on the entire cross-section of industrial base issues including: condition of the defense production and mobilization capability; and the defense supply system for such parts as gears and aircraft parts; finally the hearings centered around DOD's industrial base initiative, which will be discussed later. The hearings concluded that there is a growing dependency on foreign sources for key components and materials required for the manufacture of weapon systems; the dependence threatens the capability of industry to respond to defense production needs in a timely manner; vendors could only sustain a military operation for a few months; the U.S. industrial capability must be strengthened and preserved; and a potential conflict's outcome could depend upon our ability to produce faster than the enemy. The result of the hearings was a bill, H.R.4037, which was to amend the Defense Production Act of 1950. H.R.4037 is designed to revitalize the defense industrial base of the United States. The Act gives the President the authority to: limit the purchase of parts for all existing and new weapons systems to domestic sources; designate critical industries for assistance in facilities modernization; develop domestic capability for material, services or skills; and use loan guarantees, price guarantees or direct loans all in support of the industrial base.

DOD POLICY INITIATIVES

A major portion of the testimony to the House of Representatives from the Assistant Secretary of Defense for Production and Logistics is expanded in a document titled, "Bolstering Defense Industrial Competitiveness," dated July 1988. In the document, the Undersecretary of Defense for Acquisition reported to the Secretary of Defense on a plan to preserve the industrial base and lay the ground-work for any mobilization activity. The underpinnings to this approach are that DOD plays an important role in the marketplace with spending that represents approximately 21% of the manufacturing gross national product and so has the leverage to accomplish the plan. The more pressing portion of the plan, which has been accomplished, includes the establishment of a Deputy Undersecretary of Defense for Production Base and International Technology and a Defense Manufacturing Board (DMB). Initially the Undersecretary will function as the focal point or advocate for the production base; assess the impact of foreign dependency; determine which industry segments should be supported by DOD strategic planning; and develop a DOD technical educational scholarship program. The DMB is chartered to develop a better relationship with industry; recommend enhancements to the Industrial Modernization Incentives Program; and study methods to integrate the manufacture of commercial and military product lines.

Additionally, on 23 March 1987, Mr. E. J. Healey, the Assistant Deputy Minister (Materiel) Department of National Defense Canada, and Mr. R.B. Costello, Assistant Secretary of Defense for Acquisition and Logistics, U.S. Department of Defense, signed the charter for the North American Defense Industrial Base Organization (NADIBO). The Organization officially recognizes the defense industrial base relationship which has existed between the two countries for more than 50 years. The Organization is designed to: promote the U.S. and Canadian Industrial Preparedness Programs; foster cooperation and coordinated Industrial Preparedness Programs; coordinate defense materiel acquisition responsibilities, promote data exchange between countries to improve industrial responsiveness and the effectiveness of the production base analysis; provide guidance with the goal to develop executable programs; and develop policy recommendations.

INDUSTRIAL BASE IMPACTS

The impact of crucial industrial base elements on program success is apparent when one examines lead times, the supplier base, productivity, and industrial preparedness planning. This chapter will not cover each of these subjects in detail; however, the major points presented here should give the reader an understanding of the magnitude of the problem and some of the new initiatives within the DOD to deal with them.

Lead Times

Lead times for defense material and components tend to be volatile. There are various reasons for this situation, such as: imbalances between capacity and demand; competition from commercial suppliers; raw materials not available.

Lead times are severely impacted by capacity limitations. As orders increase beyond existing capacity, the contractor has the option to increase capacity or to add new orders to backlog. For a contractor with a reasonably steady demand and no capacity expansion, increasing backlog increases in lead time. When these lead time increases are communicated to customers, their response to the lead time is to issue orders immediately to ensure material availability. With constant capacity, these new orders must also be added to backlog, which must then be reflected in increased lead time. As this self-fueling process, often called the lead time capacity syndrome, continues, a relatively small increase in demand can result in extremely large increases in lead times. The area of component and material lead time is extremely critical to meeting program schedules and defining long lead and advanced buy requirements. The program office should maintain continuing visibility of the current status of and the forecast changes in lead times.

Supplier Base Reduction

Numerous causes have been linked with the reduction in the defense supplier base. The primary reasons include economic conditions, material shortages, foreign competition, and government regulations. The impact on defense systems programs is fewer companies in the market place, some loss of competition (with all that entails) and a possible increase in lead times. The implications in periods of surge or mobilization are obvious, as numerous defense systems place demands on too few suppliers.

It is of paramount importance that sufficient production capacity exists within the industrial base to produce defense systems according to planned peacetime schedules with sufficient capacity to expand to meet increased requirements or accelerated schedules due to a wartime situation.

Although defense hardware is usually thought of as being produced by only a few large prime contractors, the entire industrial base encompasses a large number of subcontractors and suppliers that may be engaged entirely, or to some extent in government work. The large prime contractors generally have sufficient capacity to meet normal requirements and surplus capacity for wartime surge demand. Crucial to meeting wartime demand are the many tiers of subcontractors. This is especially critical since the DOD depends almost entirely on the private sector for the materials necessary to support wartime operations.

Of the many thousand companies that comprise the defense industrial base, the majority (over 70 percent) are classified as being subcontractors and lower tier suppliers. More than half of all the dollars expended for defense materiel acquisition go to this segment of the industry. This underlying sector of the industrial base has deteriorated drastically since the Vietnam War resulting in bottlenecks for many parts and supplies. Thousands of suppliers dropped out of the defense business entirely, and others are reluctant to expand in fear of future curtailments in defense expenditures. During the defense build up of the 1980's many of these firms returned to the defense base and were joined by many new entries. The emphasis on competition provided motivation for many new suppliers to enter the base. A number of these new and returning firms are questioning the desirability of remaining in the base for a number of reasons. Many small firms find the requirements imposed by the DOD make business unprofitable.

The program manager should regularly evaluate the total industrial structure supporting the program for indications of potential capacity or capability problems. The fact that this very critical portion of the industrial base is deteriorating is a concern of the Department of Defense. DOD Directive 4005.16, "Diminishing Manufacturing Sources and Material Shortages," is a result of this concern and assigns responsibilities within each DOD component for action to be taken when essential manufacturing sources are endangered. Contractual provisions that would serve to alleviate problems that may be encountered by subcontractors should be used whenever possible.

CAPACITY AND INVESTMENT DECISIONS

Capacity can be defined as the maximum rate of productive or conversion capability of an organization's operations. Capacity is normally constrained by physical facilities, available productive equipment, tooling and/or test equipment. The portion of this capacity actually utilized is determined by the demand on the plant for current and known future workload. Firms engaged in the defense industry must be particularly aware of a need for excess capacity because its customer's (military) demands tend to be somewhat unstable over time.

Operational and investment decisions, made by the contractor, which could increase capacity are influenced by return on investment or profit in relation to the risk perceived and the potential return from other opportunities. Since the early 1970's there have been indications that a majority of industrial facilities used to produce weapon systems and materiel have been growing older, and new investment has not been keeping pace with equipment obsolescence or the advances in manufacturing technology which could lead to higher productivity and lower costs. This has led to an industrial bottleneck where certain limited suppliers are taxed to capacity with competing military and civilian orders. Lead times for the items produced at these facilities tend to be extremely volatile and subject to the demand lead time syndrome described above.

Firms engaged in defense related business tend to look for relatively short pay-off periods for investment, thus reducing the risk of financial losses if the long term business outlook proves unfavorable. There is an indication that defense industries are maintaining their profitability by limiting their investments in equipment. In doing so, they continue to use equipment that is aging faster economically than that used in many commercial industries. This practice is likely to result in increasingly labor intensive operations and higher prices for DOD goods. This problem is discussed in more detail later in this chapter.

The availability of capital together with its cost, exerts a great influence on the defense firm's decision for increased investment. Generally, lending institutions perceive defense contractors as less attractive risks than their commercial counterparts. Whenever capital is scarce, less desirable credit risks have a difficult time in securing outside financing; therefore, defense contractors find it hard to raise money if a capital shortage develops. If they can secure needed financing, it will generally be at a higher rate than that charged to commercially oriented firms.

A DOD Investment Policy Study Group (IPSG) formed in 1976 found that "necessity" (that is, to produce the product to stay in the business), competition, rates of return, cash flow, and perceived risk were the major determinants of investment in defense business. Of these, risk in relation to return and cash flow seemed to be the major factors with respect to the analysis of individual investment projects.

There are several measures that may be taken by the government to encourage needed investment by defense contractors. Among these are multiyear contracting, industrial modernization incentives which are discussed elsewhere in this Guide.

MOBILIZATION CAPABILITY

A factor that is unique to defense plant and equipment requirements is the excess capacity that must be established and maintained in order to provide mobilization capability. The defense industry's ability to rapidly expand its manufacturing operations is an essential part of the overall defense posture.

The following factors should be considered to improve planning for mobilization:

- Planning should be highly selective. Products that would be required and could be supplied should be identified.

- Critical parts and essential manufacturing machinery, rather than just end items must be effectively planned. Planning must be done for the long lead items, the parts for which there are only a few suppliers, or the particular machinery that is already in use on three shifts.

- Critical labor categories must be examined since this could be a large potential problem. Planning must include other demands on this labor, including military reserve requirements.

- More research and development work needs to be sponsored to find substitutes for the many critical materials on which we are presently foreign dependent. Advances in manufacturing technology could aid in alleviating this problem.

- Purchases should be funded of all items which would significantly affect mobilization capability but would not significantly reduce peacetime defense production. An example would be buying long lead time parts one or two years in advance.

Most of the defense industry prime contractors have some excess plant capacity to gear up in the event of mobilization or surge, but the lower tiers, the parts suppliers and subcontractors, represent the bottlenecks in mobilization capability. In developing these plans it is important to remember that different primes may depend on the same subs for "surge."

PRODUCTIVITY

Productivity enhancement is important to both industry and DOD management. In industry, productivity growth leads to lower costs and provides an opportunity for lower priced products and/or higher profits. It also makes possible increased benefits for employees. In DOD, productivity growth helps to ensure that defense system programs will meet cost and schedule targets, thus providing more resources for other defense needs. The productivity of any industrial firm is a measure of how well the resources in that firm are brought together and used to accomplish a set of results. Productivity isn't just an increase in the volume of shipments, although this is one element. Traditionally, productivity has been defined as the acceptable output per labor hour. Using this definition, we would quickly discover that in a firm with many employees and little automation, productivity depends principally upon human achievement. On the other hand, in a firm where automation predominates, the human contributions to productivity play a lesser role.

Fred G. Steingraber has written a fine summary of how the definition of productivity has changed over the years. This is the way he sees it:

"The definition of productivity has changed considerably over the past fifty years. Back in the 40's and 50's the measurement of productivity focused on output, or the production of as much as possible. In the 60's and 70's quantity was no longer as important as efficiency, or production at the lowest possible cost. Now in the 80's, given the constraints imposed by scarcities, regulations, changes in job skill and cost mix, and greater international competition, the productivity emphasis is on effectiveness. Corporations are increasingly liable for the quality of their products and the services they offer. [Corporations] are considered social entities, not just economic entities. And, as social entities, [they] are held accountable for attitudes toward issues ranging from the environment to the quality of life in the work place and ultimately to the quality of the product delivered. As a result, the definition of productivity as output over input is useless unless we realize that output now includes in addition to product such factors as quality, service, and safety, while the input is government, unions, people, money, technology, information, motivation . . . ."

Productivity is more than output over input. It is the relationship of the quantity and quality of products, goods, and services produced to the quantity of resources (personnel, capital facilities, machine tools and equipment, materials and information) required to produce them.

To determine productivity one must ask: First, was the desired result achieved? (the effectiveness question). And, second, what was the quantity of resources consumed to achieve it? (the efficiency question). Effectiveness relates to performance; efficiency, to resource utilization. How well resources are brought together and utilized is indicated by comparing the magnitude/volume of results, usually called the output (effectiveness) with the magnitude/volume of the resources consumed, usually called the input (efficiency). This ratio becomes an index of the definition and a measurement of productivity.

Factors That Influence Productivity

The factors that influence productivity growth are the work force, management, capital investment, and technology.

Work Force

The members of the work force represent an integral part of the productivity picture. This is portrayed in Figure 2-1. Referring to this figure, you can see that each of the three categories -- work force, process, and product -- is composed of subordinate elements, any one of which can impact productivity growth. Productivity growth occurs when the cumulative effect of the interdependent elements is improved.

The quality of the work force affects productivity. As the quality increases or decreases, the productivity increases or decreases. There has been a decline in the quality of the work force in the United States during the past few years. This decline can be attributed to a rise in the proportion of young and inexperienced workers in the work force and the decrease in the average work effort. Also, the lack of motivation of many young workers has had an adverse effect on productivity.

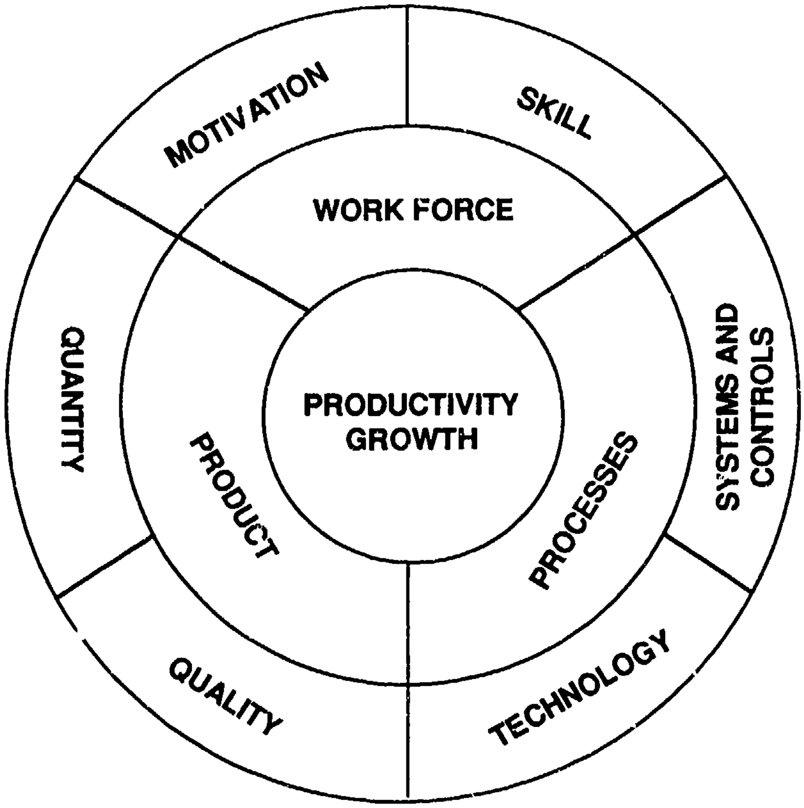


Figure 2-1 Productivity Results from Effective Interaction of the Work Force, the Processes, and the Product

In the Summer, 1981, issue of Productivity newsletter, it was indicated that people -- the work force -- are the most essential ingredient in any productivity improvement program. The publisher of the newsletter, Norman Bodek, reporting on the results of his survey, stated that the most effective way to bolster productivity is through employee participation programs. Better communications ranks second, followed by improved labor management relations, increased training, improved quality, increased automation, productivity incentive plans, cost reduction programs, and increased research and development.

Management

One of the keys to productivity enhancement within any organization is management. The attitudes, actions, and personal examples of management pervade the organization and affect directly the attitudes, actions and motivation of the work force. It is from management that the workers generally take their cues. Accordingly, astute managers must convey clearly the importance they place on productivity, and their desire to enhance productivity throughout the organization. Unfortunately, actions that management takes to improve productivity in one organization may not work out well when applied to another. Therefore, it is important for managers to assess the situation within their organization before taking specific actions to enhance productivity.

Capital Investment

Capital investment is necessary if productivity is to be enhanced. Productivity is influenced by the dollars industrial firms are able to set aside for investment in new technology, equipment, and facilities. If the United States is looking for a way to improve productivity, it needs to stimulate capital spending.

Tom Wolfe, contemporary author and social critic, believes that the greatest source of productivity loss in the United States in the 1970's was in the short term orientation of industrial managers. Managers who occupy their positions for short periods of time, either because of job rotation or turnover, are not prone to make long term investment decisions or substantial capital investments. Further, industrial firms have problems in executing long range and consistent company strategies when management changes frequently. Finally, there seems to be a trend away from engineering backgrounds among chief executive officers in the defense industry. Perhaps some of our problems today are the result of the muted voices of engineering and manufacturing executives when key policy decisions are made.

Wolfe bemoans the rise of self-centeredness in our social fabric. Unfortunately, the lack of commitment he has observed in our social fabric has also begun to appear in our industrial fabric. The stockholders in our industrial firms are demanding higher short term earnings. Industrial growth calls for capital investment which reduces short term profits. The management of industrial firms in the United States must make long term commitments to research and development (see Figure 2-2), automating the factory, and corporate growth if productivity is to be enhanced.

New Technology

"Economic growth, technological innovation . . . these are the components of progress. These are the engines that drive our country forward," says Herbert E. Meyer, an editor of Fortune. The enhancement of productivity is not only affected by the results of research and development, but by application and acceptance of new technology. According to Frank Batten, past president of the New York Stock Exchange," Productivity growth [results from] the application of new technology to the production of goods and services."

A well-managed industrial firm is one in which there is an effective integration of the work force and advanced technology. The genesis of such an organization is an implementation plan that includes education of the work force for factory automation, early identification of new manufacturing processes that will lend themselves to automation, manpower/work load forecasting that takes into account factory automation, and a mechanism for worker feedback.

The Challenge

Productivity enhancement is especially important in the defense systems acquisition business. It is only through enhanced productivity that we can continue to afford defense (weapon) systems in sufficient quantities to deter or counter any foreign threat to our way of life. In the United States we have reached the point at which it has become difficult to sustain the rate of productivity growth we attained in the past. Continuing technological innovation and increased capital investment will help, but they cannot enhance productivity without a work force in tune with the need. The ability, attitude, and action of the people in the work force will have a pronounced effect on the future growth of productivity in this country.

CRITICAL MATERIALS AND COMPONENTS

There is a growing dependence in the defense industry on materials and products from foreign countries. The dependence ranges from relying entirely on imported minerals to using electronic components in our weapons systems that are manufactured abroad.

Strategic and Critical Materials Stockpiling

The Strategic and Critical Materials Stockpiling Act requires that a national defense inventory of strategic and critical materials be acquired and retained to preclude dependence on foreign supply sources in times of national emergency.

The growth of high technology has altered the various military threat environments faced by deployed forces. Fundamentally, threat environments, weapon systems, the domestic industrial base, and materials used in defense have been in a constant state of change over the past 40 years; the rate of change is increasing. International industrial interdependency has added to the complexity. A national defense stockpile needed 40 years ago when the domestic industrial base was in an expansion mode is different than a stockpile needed today with the base in a diminishing mode.

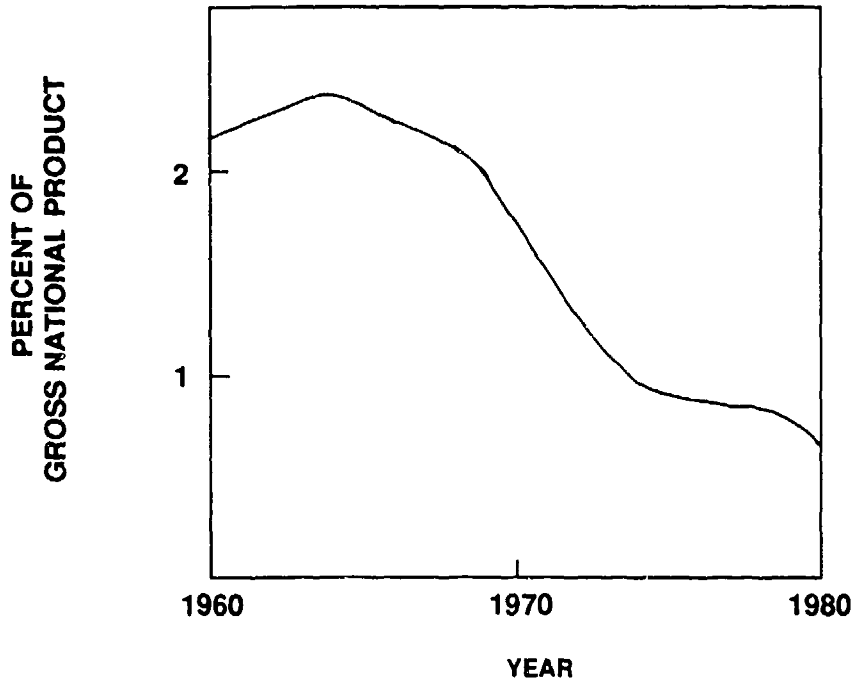


Figure 2-2 Industrial Spending in U.S. for Research and Development

The range of defense industrial need for a national defense stockpile during national emergencies is also different. During World War II and the Korean conflict, the concept of a stockpile was to provide a secure source of industrial raw materials for suppliers to process, so fabricators and subcontractors could provide parts and components needed to manufacture weapon systems and to maintain basic essential industries. Although his concept is still important, the United States is moving away from a basic materials intensive society. Whereas the stockpile was an insurance foundation of fundamental raw materials upon which the industrial base could rely, today's need is increasingly focused on selective applications throughout the various tiers of manufacturing to make up for lost capacities in order to support surge of the weapon and equipment production lines which will exist at the time of national emergency.

The critical materials stockpile is not at established goals. Of the 62 family groups and individual materials that are to be stockpiled, about 60 percent do not meet the goals. The U.S. defense industry has becomedependent on foreign sources for materials and components. Japan has taken almost half of the U.S. market for the computer memory chip, and Japan is posing a serious threat to the U.S. semiconductor industry.

Program management offices should perform a study early in the program to identify critical material problems due to uncertain availability or foreign dependency. Contractors should be encouraged to establish material management programs that cover availability, conservation, reclamation, substitution, and the minimal use of critical materials. Increased emphasis should be placed on efforts to improve existing manufacturing processes and introduce new manufacturing technologies that would make more efficient use of critical materials. Defense systems designs that economize on critical materials should be encouraged with incentive awards to contractors.

DOD POLICY ON THE DEFENSE INDUSTRIAL BASE

As stated in the beginning of this chapter, the Department of Defense is responsible for assuring that sufficient industrial capacity exists to meet potential wartime needs for the military services. Executive Order 11490 assigns responsibility to the Department of Defense, in conjunction with industry and other government agencies, for conducting industrial preparedness planning. The Defense Department has issued a number of directives and instructions stating the policy that will be followed and setting forth guidelines and implementing procedures. Pertinent to this purpose are the following:

1. DODD 4005.1, "DOD Industrial Preparedness Production Planning," (a) establishes policy and assigns responsibilities for planning of industrial resources for peacetime, surge and mobilization production of essential military material, (b) issued pursuant to the emergency preparedness responsibilities assigned to the SECDEF under Section 401 of Executive Order 11490 and the production readiness functions as defined in Defense Mobilization Order 11, Maintenance of the Mobilization Base.

2. DODI 4005.3, "Industrial Preparedness Planning." This instruction authorizes: (a) publication of a single DOD Industrial Preparedness Program Planning Manual (DOD 4005.3-M); (b) policy and guidance to identify and prioritize an Industrial Preparedness Planning List (IPPL); (c) preparation of a Production Base Analysis (PBA) report on the existing industrial base; (d) integration of industrial preparedness planning for both surge and mobilization into the production management of defense systems by the responsible program/project and item managers.

3. DODD 4005.16, "Diminishing Manufacturing Sources and Material Shortages." Establishes policies and assigns responsibilities within each DOD component to assure timely action is initiated when essential end item production capabilities are endangered by the loss or impending loss of manufacturing sources or by material shortages.

Other references that deal with industrial preparedness planning are:

1. Executive Order 11490, Assigning Emergency Preparedness Functions to Federal Departments and Agencies, 11 June 1976.

2. Defense Mobilization Order 11 (DMO-II), Maintenance of the Mobilization Base, 1 July 1980.

3. DODD 4275.5, Acquisition and Management of Industrial Resources, 8 October 1980.

4. DODD 5000.1, Major and Non Major Defense Acquisition Programs.

5. DODI 5000.2, Defense Acquisition Program Procedures.

6. DODD 4151.1, Use of Contractor and Government Resources for Maintenance of Material, 20 June 1970.

7. Federal Acquisition Regulation.

8. DODD 4245.1, Defense Production Management.

9. DODI 4400.1, Priorities and Allocations - Delegation of DO and DX Priorities and Allocations Authorities, Rescheduling of Deliveries and Continuance of Related Manuals, 16 November 1971.

10. DODI 4210.4, Studies on the Availability of Materials, 6 October 1971.

11. DOD Manual 4005.3-M, Industrial Preparedness Planning Manual.

The objectives below have been established to improve industrial base capability and responsiveness:

1. Develop an industrial base capability to produce and deliver the five-year peacetime procurement program efficiently, effectively and as quickly as possible.

2. Develop an industrial base capability which will provide surge responsiveness.

3. Develop an industrial base capability which will permit accelerating the attainment of programmed sustainability for selected critical systems or items.

4. Increase industrial preparedness planning funding levels and integrate industrial preparedness resource requirements into the Planning, Programming and Budgeting System (PPBS).

Basic Concept

Mobilization involves preparing for war or other emergencies through assembling and organizing national resources; and the process by which the Military Services, or part of them, are brought to a state of readiness for war or other national emergency. This includes activating all or part of the Reserve components, as well as assembling and organizing personnel, supplies, and material.

The industrial preparedness program is a coordinated system of plans, actions and measures for the transformation of the industrial base, both government-owned and civilian-owned, from its peacetime activity to the emergency program necessary to support the national military objectives. It includes industrial preparedness measures such as modernization, expansion and preservation of industrial facilities. Industrial preparedness focuses on two major areas of industrial base capability, mobilization and surge. Mobilization involves preparing for war or other emergencies through assembling or organizing national resources to focus those resources on bringing the Armed Forces to the required state of readiness and providing the resources to sustain Armed Forces operations. Surge is the accelerated production, maintenance and repair of selected items, and the expansion of logistics support services to meet contingencies short of a declared national emergency utilizing existing facilities and equipment. Only existing peacetime program priorities will be assumed available to obtain materials, components and other industrial resources necessary to support accelerated program requirements.

The foundation of mobilization preparedness planning is the realistic determination of the total production requirements necessary to support the approved forces post-mobilization day (M-day). Surge, on the other hand, is not planned on a given scenario but on the ability to accelerate production of needed items to satisfy various contingencies, using peacetime priorities and allocations authorities and existing facilities and equipment.

D to P Concept

Mobilization planning is based on the "D to P" concept. This is a logistics planning concept by which the gross material readiness requirement in support of approved forces at planned wartime rates (for conflicts of indefinite duration) will be satisfied by a balanced mix of assets on hand on D-day (the day on which operations commence) and assets to be gained from post D-day production through P-day when the planned rate of production deliveries to the users equals the wartime rate of expenditure. The expansion of production occurs through a mobilization effort (initiated at M-day). D-day and M-day may or may not occur simultaneously. The demands for consumption are established based upon the operational scenario. These demands are translated by the Joint Chiefs of Staff into a Composite Commander in Chief's Critical Items/Weapon Systems List (CINC's List) and furnished to the DOD components for consideration in developing the service Critical Item List (CIL). The CIL is used to develop the Industrial Preparedness Planning List (IPPL). This list shows the weapons systems and components selected by the military departments and the Defense Logistics Agency for industrial preparedness planning. Once items on the IPPL are specified, any of a number of methods may be used for planning including:

1. Preparation of Industrial Preparedness Production Planning Schedule (DD Form 1519).

2. Data Item Description (DID) for Industrial Preparedness Planning (this is especially appropriate for new acquisitions).

3. Direct Industrial Base Planning (without Armed Services Production Planning Officer (ASPPO) involvement).

4. Special Studies.

These approaches are described in detail in the Industrial Preparedness Planning Program Manual, DOD 4005.3-M.

Surge Capabilities

During 1983, a simulation of industrial responsiveness was accomplished under the auspices of the American Defense Preparedness Association and the National Security Industrial Association. The simulation, requested by the Deputy Secretary of Defense, had as its objective the development of a set of recommendations for potential government and industry actions, which would, if instituted, provide a capability to increase production of critical end items (surge) in a national security emergency situation short of full mobilization. At the completion of the simulation, the following conclusions were reached.

1. Production capacity for significantly expanded output can be made available at the prime level at a reasonable cost subject to these conditions:

a. Findings may be transitory as a function of economic developments.

b. A number of second and third tier suppliers could become choke points.

c. Continued comfortable reliance on offshore capability for low cost labor processing, some unique products and coproduction could lead to major disruptions.

d. Commercial production develops and supports capability for expanded military output.

e. Critical materials, if not stockpiled and supplied as required, could become production stoppers.

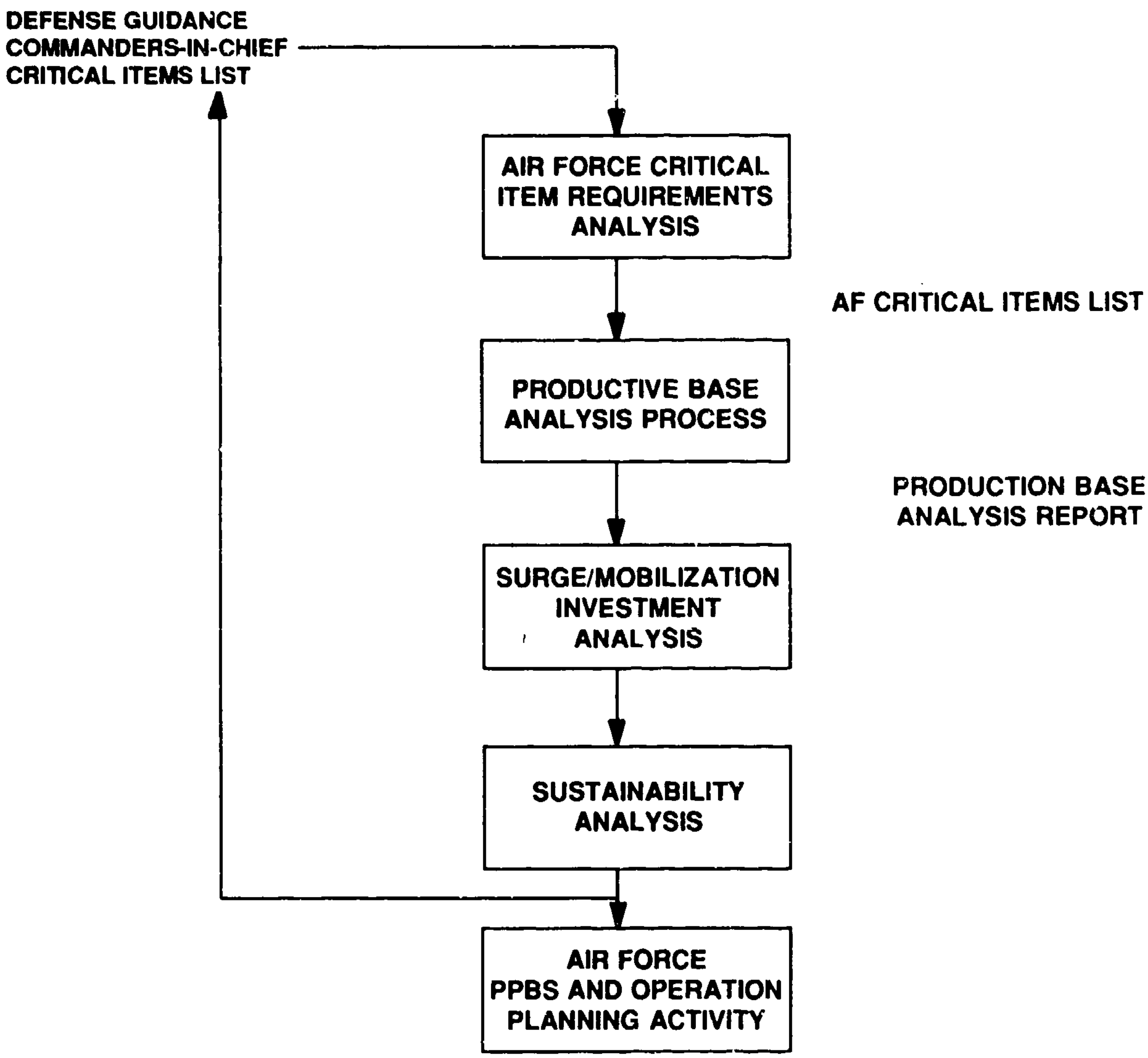
2. The major output drivers are the basic availability of production capacity, i.e., production and test equipment, manpower, material, energy, etc. at the prime and subtier level. Waivers and deviations contribute to accelerated production and, in specific instances, perpetuate major bottlenecks if not granted.

3. Preparatory funding, assumed for the simulation, is a real need to build subcontractor capability and to support increased demand for subcontractor and prime working capital.

Additional specific problems in reaching surge objectives were identified in a year-long study by about 60 aerospace companies. The study determined that shortfalls in the U.S. aeronautical space industry hamper airframe and engine manufacturers' ability to surge production to meet emergency requirements and could seriously hurt U.S. defense capabilities. The study showed that while there is some surge capability among airframe and engine producers, production at surge levels cannot be sustained for more than a few months at best.

THE INDUSTRIAL BASE PLANNING PROCESS

The process is really twofold; first, the program manager is required to plan for surge and mobilization, which will be discussed later. The Military Services, along with DLA, are required to assess the capabilities base to meet surge and mobilization requirements and determine where essential military items can be obtained to satisfy surge and mobilization requirements. To accomplish the planning the services are required to develop an annual Production Base Analysis (PBA). The combined PBA of the services measures industry's capability to meet defense requirements and assesses the condition of the industrial base. The PBA evaluates current and planned plant capacity and the potential competing demands between military and commercial requirements during emergencies. During this annual process the Secretary of Defense provides the services with "Defense Guidance", which outlines the latest scenario upon which to plan for an industrial base program. Also, each year the Commanders of the Unified and Specified Commands provide a single list of critical weapon systems and components or critical items list (CINC's CIL) to the industrial base planners. The services then develop their own list of critical weapon systems which is analyzed to determine which components, spares and production capacity are required to support the CINC's CIL. As an example the Air Force's data flow is outlined in Figure 2-3. The process quantifies production for surge and mobilization; identifies IPMs; provides feedback to the operation planners; and develops peacetime investment options for the PPBS and an emergency budget.



Source: Draft AF Industrial Base Program Planning Manual, 19 July 1988

Figure 2-3 Air Force Data Flow for Production Base Analysis

Industrial Preparedness Measures

The analysis of industrial capability provides the basis for estimating the ability of the production base to meet specified production requirements as well as the facility's maximum capabilities to provide a certain item or items. They also suggest what types of actions could be taken to enhance a firm's ability to respond to demand for needed products. These actions are called Industrial Preparedness Measures (IPMs). These IPMs may include such actions as:

1. Modernizing or expanding facilities.

2. Developing improved production techniques.

3. Awarding "pilot line" contracts.

4. Establishing or maintaining stand-by production lines.

5. Maintaining a warm production base.

6. Acquiring and maintaining plant equipment packages with all the necessary special tools, dies, fixtures and special test equipment.

7. Establishing and maintaining multiple production sources.

8. Prestocking raw materials, semifinished materials, components and assemblies.

9. Multiyear contracting.

10. Establishing programs to increase the retention of personnel with key technical skills.

11. Exercising guarantee authority of the FAR and Defense Production Act.

12. Recommending design changes or waivers.

13. Underwriting the establishment/maintenance of U.S. production sources for critical defense material when no current U.S. source exists.

14. Conducting special studies.

One of the more significant recent DOD initiatives to improve industrial preparedness involves the integration of planning responsibilities for current systems into the program management and procurement functions of the services. This change will require program managers and procurement officers to consider industrial preparedness from system development through production/deployment and will be part of the DAB approval process. Planning for critical systems, equipment, and components may be funded as a separate line item in procurement contracts (including appropriate Data Item Descriptions).

The program manager is required to include mobilization capability in acquisition planning. This requirement was included in the Defense Programming and Planning Guidance and in the Planning and Programming Guidance Memorandum for FY 1982. DOD Directive 4005.1, Instruction 4005.3, and Manual 4005.3-M emphasize this responsibility.

The responsibility for IPP has recently been added to the program manager's charter. The PM must:

1. Provide contractors with information concerning required mobilization capabilities.

2. Plan for funds for the creation of any required surge or mobilization capacity.

3. Evaluate the contractor's mobilization plans.

The provisions for attaining the required mobilization levels should be described in the production plan with specific attention to the issues identified in 1983 Industrial Responsiveness Simulation. Also, the impact of the requirement on facility needs should be described. As a program nears completion of the production phase, IPP requirements should again be considered as part of the decision process involved in the disposition of the special tooling and special test equipment.

GRADUATED MOBILIZATION RESPONSE

The latest thinking from OSD is in the area of Graduated Mobilization Response (GMR), as a technique to better fit-up industrial base planning to potential hostile acts on the part of an aggressor. In January

1988, GMR was defined as, "An interagency coordinating system and process for integrating ambiguous and specific warnings with appropriate resource action to: mitigate the impact of, improve responsiveness to, and/or recover from a national security emergency or other crisis." The GMR system provides a framework for mobilization planning across a range of conditions from peacetime to total mobilization. The concept is a system which triggers the response of the industrial base in much the same manner that the DEFCON system triggers the military service and National Security Command in event of an emergency. GMR allows for reaction to all aspects of emergencies from acts of aggression on the part of a belligerent to a natural disaster. GMR has three stages which are further defined into seven levels as shown in Figure 2-4. An important aspect of this system is the increasing control exercised by senior officials.

purposes. First, the systems help ensure that national programs are maintained on schedule by providing priority treatment for the purchase of products and materials by government agencies, contractors, subcontractors and their suppliers. This is accomplished by directing the flow of materials and products to the nation's military, atomic energy, space, and domestic energy production or construction programs. These programs are referred to as "claimant agency" programs. e mobilized should the need arise.

The Defense Priorities System and the Defense Materials System provide the means for exercising the priority and allocation authorities of the President for the purpose of promoting the national defense. They also provide a system which can be promptly expanded to direct the industrial economy of the country to meet the exigencies of war, or

GMR STAGE 3	GMR STAGE 2	GMR STAGE 1
PLANNING AND PREPARATION	CRISIS MANAGEMENT	NATIONAL EMERGENCY/WAR
level 6	5 4 3	2 1
deliberate planning and investment	crisis planning, preparations, and actions	mobilization of the economy
	(pattern of threat to US id'ed)	(direct challenge to US security)
independent actions and info exchange	progressively more coord and NSC direction	NSC or other centralized control

Figure 2-4 Graduated Mobilization Response

DEFENSE PRIORITIES SYSTEM AND DEFENSE MATERIALS SYSTEM

Description

The Defense Priorities System (DPS) and the Defense Materials System (DMS), promulgated under authority of the Defense Production Act of 1950 (DPA) as amended, are designed to accomplish two main other programs designated by law and a Presidential finding as being essential to national security and to maximize domestic energy supplies.

Defense Production Act and Associated Executive Orders

Under Title 1 of the Defense Production Act of 1950, as amended, the President is authorized to establish priorities in the performance of contracts or orders for the purpose of assuring contract performance. He is also authorized, under the same authority, to allocate materials and facilities for the purpose of promoting the national defense. The term "national defense" is defined in the Defense Production Act as ". . . Programs for military and atomic energy production or construction, military assistance to any foreign nation, stockpiling, space, and directly related activity."

Executive Order 11912. Executive Order 11912 delegates to the administrator of General Services authority to use the priorities and allocations authority of the DPA to maximize domestic energy supplies.

Executive Order 12148. Executive Order 12148 delegates to the Federal Emergency Management Agency, General Services Administration (FEMA/GSA) overall authority for the supervision and coordination of the emergency planning activities of the Federal Departments and Agencies. It also makes FEMA responsible for assessments of the nation's industrial capability to support military and essential civilian emergency requirements.

In accordance with this Executive Order, specific authority for the various functions of Title 1 of the DPA has been redelegated as follows:

1. The Secretary of Energy with respect to petroleum, gas, solid fuel and electric power;

2. The Secretary of Agriculture with respect to food and the domestic distribution of farm equipment and commercial fertilizer;

3. The commissioner of the Interstate Commerce Commission with respect to certain limited, domestic transportation functions; and

4. The Secretary of Commerce with respect to all other materials and facilities.

Implementation of functions under Title 1 of the DPA has been assigned by the Secretary of Commerce to the Domestic and International Business Administration (DIBA). The administration of these powers with respect to industrial production and allocations of designated materials is accomplished through a series of regulations and orders called the Defense Materials System and the Defense Priorities System.

Rated Orders Under Defense Priorities System

The rules relating to the status, placement, acceptance, and treatment of priority rated contracts and orders are contained in Defense Priorities System Reg. 1. There are two types of priority ratings: DO ratings and DX ratings. A complete priority rating consists of either one or the other of these ratings symbols and the appropriate program identification symbol (e.g., DO-A1 or DX-A3).

All DO ratings have equal preferential status and take priority over all unrated orders. The program identification symbol which is part of the rating does not affect the preferential status of the rating, that is, the rating DO-A1 has the same preferential status as the rating DO-E2. All DX rated orders have equal preferential status and take priority over all DO rated orders and unrated orders.

Between rated orders of equal preferential status, priority is given to the order which was received on the earlier date. If there is a conflict between orders of equal preferential status received on the same date, preference must be given to the order which has the earliest required delivery date.

Assignment of Priorities to Rated Contracts

The Defense Priorities System and the Defense Materials System require that any contractor or supplier who receives a DO or DX rated contract or order must use the assigned priority rating in obtaining products, materials, or services needed to complete production, construction and research and development projects for such programs. Properly identified rated orders are called "mandatory acceptance orders" because they must be accepted and given preferential delivery over nonrated orders.

Priorities are assigned to prime contracts by Claimant Agencies. The Department of Defense initiates the use of ratings by assigning them to prime contracts or purchase orders for defense related items. The prime contractors to whom the priority ratings are assigned must place these rating symbols on the subcontracts and purchase orders which they place to complete their rated contracts. Subcontractors and suppliers who accept priority rated orders from their customers must use the ratings they receive to obtain products, components, and materials to fill such rated orders.

Requirements, Set-Asides and Allotments

Requirements for controlled materials are submitted to the Federal Emergency Management Agency, General Services Administration (FEMA/GSA) on a quarterly basis by the Claimant Agencies (DOD, ERDA, DIBA and DOE). The FEMA/GSA uses the requirements submissions to make program determinations as to the amount of controlled materials needed for each Claimant Agency program. For these determinations the FEMA allots appropriate quantities of each of the controlled materials to the Claimant Agencies. The allotments constitute an authorization to the Claimant Agencies to use the specified quantities of controlled materials in the accomplishment of approved programs. The Department of Defense makes allotments of appropriate quantities to the several military departments and subclaimant agencies.

Allotments are issued to Claimant Agencies in terms of the following breakdown of controlled materials:

1. Carbon steel (including wrought iron).

2. Alloy steel (except stainless steel).

3. Stainless steel.

4. Copper and copper-base alloy brass mill products.

5. Copper wire mill products.

6. Copper and copper-base alloy foundry products and powder.

7. Aluminum.

8. Nickel alloys.

The "set-aside" is one of the techniques developed under DMS/DPS to assure the availability of an adequate supply of resources for the fulfillment of authorized programmed requirements. Producers are required to reserve space on their order books for the acceptance of ACM orders in the case of controlled materials and rated orders for other materials or products, up to a specified percentage of their production. The reserve percentage on the order books is held open only during specified lead times after which ACM orders or rated orders may be rejected. However, DX orders must be accepted irrespective of lead time and whether or not the reserve percentage has been reached.

Requests for Special Assistance

Usually, mandatory acceptance orders are accepted and the products and materials called for thereunder are provided to meet the required delivery dates. There are, however, occasions when the regular procedures provided by DPS and DMS are not sufficiently effective in enabling contractors to fulfill rated contracts on schedule.

When a contractor finds that the delivery promised by a supplier will not support the contract delivery schedule, or if he is unable to obtain acceptance of orders for products or materials required to perform the contract, he shall request assistance from the appropriate Claimant Agency, generally through the procuring organization, often through the program office.

Request for assistance must establish that:

1. There is an urgent need for the products, materials or services covered by the mandatory acceptance order.

2. The contractor has exercised reasonable effort to resolve the problem through employment of his own resources.

3. The request for assistance is timely.

4. The request is not seeking to: (a) Force the solution of purely technical problems, (b) Press for price advantage, (c) Force the resolution of contractual problems, (d) Force unnecessary acceleration of delivery dates, (e) Secure performance beyond the reasonable capability of the supplier, (f) Force acceptance of superior terms and conditions of sale.

Each level of the contractual chain is expected to employ its full resources in attempting to resolve the problem before passing the assistance request to the next higher level. If the Claimant Agency to whom the request may be sent is unable to overcome the difficulty, the request is forwarded to the Office of Industrial Mobilization (OIM) in the Department of Commerce for appropriate action.

OIM officials will attempt to expedite the deliveries, correct any bottleneck, or have the order accepted, by negotiating directly with the supplier or perhaps by locating other sources of supply. OIM provides special assistance in such cases using either formal or informal administrative methods.

A directive issued by OIM takes precedence over all mandatory acceptance orders depending on the terms of the directive. For this reason it is a particularly useful formal tool in eliminating bottlenecks and expediting orders. A contractor must accept and comply with each directive issued. Directives usually require a contractor to take some specific action as defined in the directive itself. Directives take precedence over all rated orders both (DO and DX) as well as over unrated orders. Directives, unlike priority ratings, are not extendible to the lower tiers in the production chain.

CHAPTER THREE

PRODUCT DEVELOPMENT

CONTENTS

CONTENTS (CONT)

OBJECTIVES

This chapter of the guide establishes a model of the process by which products are developed and produced for use. A generic development process is described to serve as a basis: (1) for integrating the specific manufacturing management activities and issues discussed in the Guide, and (2) to obviate the need for major revision of the text which could result from changes in the DOD development process. This generic process is compared with the current DOD process (as it has been modified during the DOD Acquisition Improvement Program) to establish a correspondence between the DOD phasing and terminology and the Guide material.

INTRODUCTION

A large variety of products (defense systems and equipment) are developed and produced for the DOD. The process by which these products are developed and produced contains basic similarities from one product to the next. The generic process (Figure 3-1), which we will explore here, is applicable to commercial as well as DOD products.

Identification of Need/Opportunity

The process starts with the definition of the need for a product or the identification of an exploitable technological opportunity. Each of these possibilities needs to be examined separately. In the commercial arena, companies are continually evaluating their markets to determine market segments which are not being served with an appropriate product and which could be profitably served by a new product or a modification of an existing product. DOD, in a similar vein, continuously reviews the operational missions assigned to its forces to determine areas which are not adequately served by the available weapons. In the commercial as well as the military environment, needs which are identified are structured in terms of the "market place" -- consumer needs or military operational performance. These functional descriptions thus serve as the basis for initiation of a product development.

In a similar vein, both DOD and the commercial business entities are continually performing or sponsoring research efforts. Often these efforts uncover technologies which, if exploited, could yield a significant advantage. In this case, the "market" is evaluated to determine in what form the technology should be developed in order to yield maximum advantage. This analysis also produces a functional description of the performance of the eventual product or weapon system and can serve to initiate the product development process.

Candidate Concepts to Satisfy Need

After the need or opportunity has been defined, the second phase of the process involves search for and selection of candidate concepts to meet the need or apply the exploitable technology. This phase is somewhat unconstrained in the sense that limits of cost, technology and time may be ignored during the process of defining candidates. The basic thrust is to allow creativity and innovation to flourish, hopefully yielding optimal solutions to the defined problems. Within the commercial environment, the initial definition of the problem may be constrained in terms of the eventual cost to the consumer of the product to be developed. This constraint may result from the decision to exploit a particular selling price range within the competitive marketplace and, as such, the candidates must have a reasonable likelihood of being produced at a cost compatible with the defined selling price.

Development of Budgets and Schedules

As the process of budget and schedule development begins, some of the constraints of the "real world" are applied to the candidate concepts. Within commercial entities, as well as the DOD, there are limited resources which may be applied to development and production of products. One constraint which impacts DOD, as well as the commercial entity, is the issue of affordability. The basic question is whether the capability of the product is sufficiently valuable such that the potential cost can be justified within the limited resources forecast to be available. In the commercial sector, this would involve estimating the ability of the product to compete effectively for the target consumer's

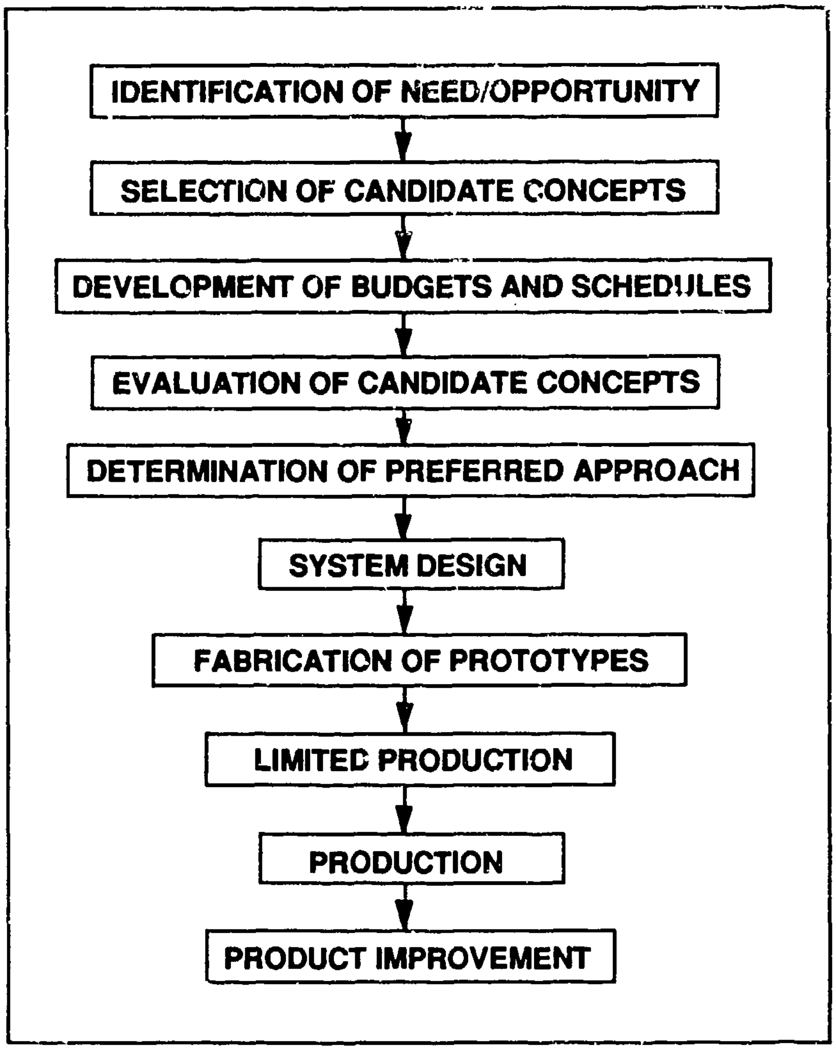


Figure 3-1 The Generic Product Development Process

budget. In the military environment, the focus is on the ability of the product to justify the necessary level of allocation of DOD budgetary resources. The budget development process causes the candidate concepts to compete among themselves for resources, as well as to compete with other development programs under consideration by the organization. The final apportionment of resources by the organization reflects such issues as the magnitude of the need or opportunity, the expected benefits to be derived from the development program, the level of resources required and the perceived likelihood of success. These initial budgets and schedules are normally firm for the early exploratory phases of the process but reflect estimates or targets for the later phases.

Evaluation of Candidate Concepts

During the portion of the process involving the evaluation of candidate concepts, decisions are made which have profound impact on the nature of the product or system which results from the development process. These decisions are embedded in the set of criteria which are used for evaluation of the candidate concepts. The inclusion of a measure such as cost to produce at this early phase can weight the development cycle toward products whose costs are within, or at least near, the "affordable" zone. Conversely, excluding or minimizing such a measure would tend to allow for development of a product or system whose cost may later prove to be prohibitive. This argument applies equally well to such other measures as performance, supportability or reliability.

The evaluation of candidate concepts can include actual fabrication of prototype hardware or physical models. It may also be limited to paper analyses or fabrication of portions of the eventual product or system. The critical issue to be addressed during this time period is the assurance that the technology embedded in the product is sufficiently well understood so that the product performance objectives can be attained within acceptable risk limits. The issue of the degree of acceptable risk is unique to the organization and may vary over time within individual organizations. It is necessary to develop estimates of the level to which each candidate solution will satisfy the established measures of effectiveness. These estimates can then serve as a basis for the decision to commit additional resources to one or more of the candidates which reflect preferred approaches.

Determination of Preferred Approach

The determination of the preferred approach utilizes the results of the evaluation of the candidates against the measures of effectiveness, in conjunction with the near term financial constraints, to define the nature of the next element of the development process. Unless one of the candidate solutions has been shown to be both technically far superior and attainable at low risk, it is beneficial to carry more than one candidate into a more explicit design. The decision maker needs to balance the higher probability of ultimate development success attendant to multiple alternatives with the cost involved with detailed design and test of the alternatives. The eventual choice normally reflects a compromise between these two factors.

System Design

When the preferred alternatives have been identified, detailed design of the extended product or system is initiated. The term "extended product design" includes design of the product in terms of its interaction with the manufacturing system from which it will be produced, the use environment it will face and other products or systems with which it must interface, as well as the details of the product itself. In the commercial arena, the emphasis on use environment has been strongly reinforced through increased product liability litigation and legal and regulatory actions such as recalls. In the military environment, there is increasing emphasis on assuring that systems can be effectively operated and maintained by the users of the equipment. The extended product design needs also to focus on the support of the product or system throughout its expected life. Repair concepts and maintenance service systems must be specifically defined for those products which are not consumables. The product or system itself must be completely defined so that prototype units can be constructed. Again during this effort there are competing cost pressures. The designers seek to attain the target performance capability within a defined budget. There is also emphasis on managing the design so as to control the cost to produce the product and the user's cost to support it. These latter costs can be controlled but the control normally requires additional design iterations, thus increasing the cost of generating the design.

System survivability is the ability of a system to withstand or survive the external effects of a hostile environment and continue to perform the mission for which it is designed. Survivability considerations such as temperature extremes, shock, vibration, humidity, etc., are routinely considered during system design. However, the special areas of nuclear and nonnuclear survivability are not usually emphasized as much as the more conventional environmental factors mentioned above. These two special areas, particularly nuclear survivability, must be placed on equal footing during design with the other environmental factors for systems having these survivability requirements.

Fabrication of Prototypes

When the design is defined, prototypes are fabricated. There are two primary purposes for prototype fabrication. They are:

1. To demonstrate through test that the product has the features and capabilities required, and

2. To validate that the product can be built within the cost and time constraints.

When we look at the first of these objectives, it is important to note that many of the required attributes may be usage oriented, that is they speak to the utility of the product in its end use environment. The degree to which the product satisfies these required attributes (such as availability and reliability) will reflect the attention given to these attributes during the design phase and the degree to which realistic testing of these attributes in the prototypes can be accomplished.

The second objective for prototype fabrication can be achieved by actually building the prototypes in the manufacturing shops and recording the time and cost required. This approach is not available for most cases. Often, the design is not sufficiently stable to support the development of specific manufacturing instructions. It is also possible that the investment in production tooling is not justified until it is determined that the product should go into quantity production. As a result of these or other compelling reasons, the fabrication is often done by selected personnel, in special fabrication areas in accordance with media different from those used for quantity production. Thus, the validation of a manufacturing approach is often a projection of controlled experience into the actual shop environment.

The physical and functional testing of the prototype provides the basis for an informed decision to start quantity production. By testing the product against the defined performance objectives, a profile of the utility and value of the product is developed. Often the testing addresses two separate, but related issues:

1. How well does the product meet its defined performance objectives?

2. How well does it satisfy the current need of the ultimate user?

If both of these questions are satisfactorily answered and the product can be produced within the defined time and cost constraints, the product is released for quantity production.

Production

The release for production normally involves a significant financial commitment for the developer. The manufacturing system must be adapted to the new product and often a significant amount of production tooling must be built and put in place. These efforts are often hindered by a need to incorporate some level of change to the design reflecting either shortcomings identified in test or recognized opportunities for improvement. Limited production involves establishing a base line design, a plan for change introduction and the organization of the manufacturing resources required to execute the design. The primary resources which must be acquired and applied are personnel, capital and capital equipment, technology and materials. One of the critical challenges in this phase is the control of the manufacturing process. It is of paramount importance to ensure that: (a) the design capabilities are not degraded in the as-built product, and (b) the cost to execute the design remains within target.

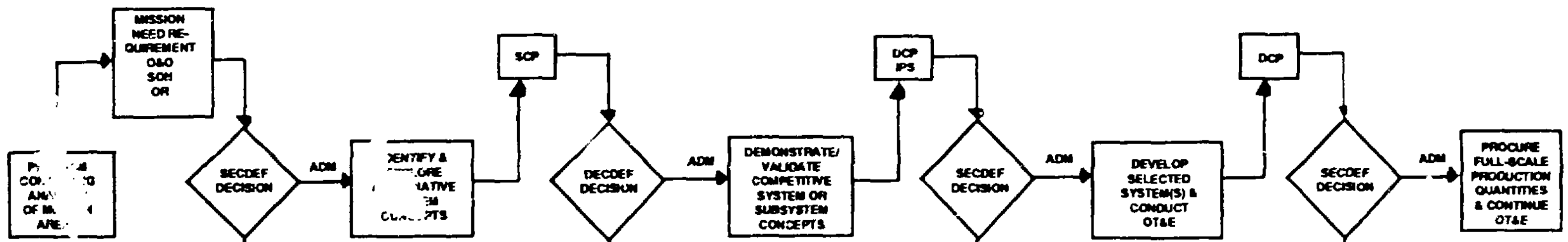
Product Improvement

As production of the system continues and feedback is received from the users, there is often a series of product improvements which are defined and executed. When the product is competitive with similar products, these improvements are often driven by the action of competitors. The challenge in this phase of the cycle is to integrate these changes into the production system with minimum disruption and cost. The changes introduced reflect both improvements in the ability of the product to meet the original design objective and extensions of capability to meet increased or broadened performance objectives.

MANUFACTURING MANAGEMENT FOR MAJOR DOD ACQUISITION PROGRAMS

Introduction

The model of manufacturing management in system acquisition describes the major manufacturing tasks (activities) which are typical for major hardware development and production programs within the Department of Defense. The tasks are described within the context of the acquisition process described in DOD Directive 5000.1, Major System Acquisition. The chart, included as Figure 3-2, lists the manufacturing tasks which are to be accomplished, as a minimum, in each phase of the acquisition process. Each of the tasks listed on the chart is described in overview fashion in the supporting text. The text also provides references to the Defense Manufacturing Management Guide for Program Managers where additional discussion of these topics may be found.



	CONCEPT EXPLORATION/DEFINITION	CONCEPT DEMONSTRATION/VALIDATION	FULL-SCALE DEVELOPMENT	PRODUCTION & DEPLOYMENT
THE PHASE OBJECTIVES ARE THE MAJOR TASKS WHICH ARE ACCOMPLISHED WITHIN EACH PHASE OF THE SYSTEM ACQUISITION PROCESS. THESE OBJECTIVES ARE SUPPORTED BY ACTIVITIES IN EACH OF THE FUNCTIONAL AREAS INVOLVED IN THE PROGRAM MANAGEMENT EFFORT.	PHASE OBJECTIVES • ASSIGN PROGRAM MANAGER; ORGANIZE/STAFF PROGRAM OFFICE • DEVELOP TAILORED ACQUISITION STRATEGY AND PROGRAM PLANS THAT MINIMIZE TIME TO DEPLOY, e.g., - SEPARATE ALTERNATIVES IN HIGH-RISK AREAS - PROTOTYPING OF CRITICAL COMPONENTS - COMBINING OR OMITTING PHASES - CONTINUITY OF CONTRACTOR EFFORTS AND PARALLEL GOVERNMENT DECISION MAKING • SELECT SYSTEM CONCEPTS FOR DEMONSTRATION/VALIDATION: - IDENTIFY ALL REASONABLE SYSTEM ALTERNATIVES - NARROW OPTIONS TO MANAGEABLE/AFFORDABLE NUMBER - MAINTAIN COMPETITIVE CONTRACT ENVIRONMENT - BALANCE ANALYTICAL AND EXPERIMENTAL EFFORTS	PHASE OBJECTIVES • REDUCE RISKS TO A POINT WHICH IS ACCEPTABLE FOR FULL-SCALE ENGINEERING DEVELOPMENT • SELECT BEST DEVELOPMENT - COST, SCHEDULE, PERFORMANCE, AND SUPPORTABILITY TRADE-OFFS - TECHNICAL RISKS AND PRODUCIBILITY - NATO AND INTERSERVICE STANDARDIZATION AND INTEROPERABILITY • ACHIEVE READINESS FOR NEXT PHASE - SYSTEM DEVELOPMENT SPECIFICATIONS - DETAILED PLANS; COST PROPOSALS	PHASE OBJECTIVES • COMPLETE DEVELOPMENT OF SELECTED SYSTEM • INITIATE LIMITED PRODUCTION FOR OT&E AND LONG-LEAD-TIME PROCUREMENT ITEMS • ACHIEVE READINESS FOR PRODUCTION - FAVORABLE OT&E FINDINGS - FIRM PRODUCTION SPECIFICATIONS - DESIGN-TO-COST AND LIFE CYCLE COSTS VALIDATED - PRODUCTION READINESS REVIEW - FIRM PRODUCTION COST PROPOSAL - LOGISTICS PLANNING • REFINE PLANS FOR INTERNATIONAL COOPERATIONS AND LOGISTICS SUPPORT	PHASE OBJECTIVES • ACHIEVE PRODUCTION OF AUTHORIZED QUANTITIES ON SCHEDULE AND WITHIN BUDGET • ACHIEVE READINESS FOR SYSTEM DEPLOYMENT • EXPAND AND REFINE PLANS FOR INTERNATIONAL COOPERATION; REFINE/IMPLEMENT PLANS FOR HOST NATION LOGISTICS SUPPORT • ACHIEVE HIGH LEVEL OF OPERATIONAL READINESS FOR DEPLOYED SYSTEM - PERSONNEL ASSIGNMENT - TRAINING - MAINTENANCE - SUPPLY/SPARES SUPPORT - OVERHAUL, ALTERATIONS, AND REPAIR
THE MANUFACTURING CONCERNS INVOLVE THE PRIMARY TASKS WHICH SHOULD BE ACCOMPLISHED BY THE PMC IN SUPPORT OF THE OVERALL PROGRAM MANAGEMENT EFFORT. THEY REPRESENT A SEQUENTIAL SERIES OF TASKS WHICH ARE DIRECTED TOWARD A COST-EFFECTIVE EXECUTION OF THE PRODUCTION OF THE REQUIRED QUANTITY OF SYSTEMS FOR OPERATIONAL DEPLOYMENT.	MANUFACTURING CONCERNS • EVALUATE PRODUCTION FEASIBILITY • ASSESS PRODUCTION RISK • IDENTIFY MANUFACTURING TECHNOLOGY NEEDS • ESTIMATE MANUFACTURING COST • DEVELOP MANUFACTURING STRATEGY • IDENTIFY DEFICIENCIES IN U.S. INDUSTRIAL BASE • DETERMINE AVAILABILITY OF CRITICAL MATERIALS • DEVELOP CONTRACT REQUIREMENTS OF FACILITIES FOR VALIDATION AND DEMONSTRATION PHASE	MANUFACTURING CONCERNS • PLAN FOR USE OF STANDARD COMPONENTS AND SUB-SYSTEMS • ASSESS POTENTIAL PRODUCIBILITY OF COMPETITIVE DESIGNS • ACCOMPLISH PRODUCTION RISK RESOLUTION • EVALUATE PRODUCIBILITY CRITERIA • PLAN FOR ACHIEVING PRODUCIBILITY • ASSESS PRODUCTION FEASIBILITY • COMPLETE MANUFACTURING TECHNOLOGY INDUSTRIAL MODERNIZATION IMPROVEMENTS • PLAN FOR USE OF COMPETITION IN PRODUCTION • DEVELOP INITIAL MANUFACTURING PLAN • EVALUATE LONG-LEAD PROCUREMENT REQUIREMENTS	MANUFACTURING CONCERNS • EVALUATE PRODUCIBILITY OF DESIGN • DEFINE REQUIRED MANUFACTURING RESOURCES • DEVELOP DETAILED PRODUCTION DESIGN • DEFINE AND PROOF MANUFACTURING PROCESSES AND EQUIPMENT • ACCOMPLISH PRODUCIBILITY ENGINEERING AND PRODUCTION PLANNING • DEVELOP PRODUCTION WORK BREAKDOWN STRUCTURE • DEVELOP MANUFACTURING COST ESTIMATES • COMPLETE MANUFACTURING PLAN • ACCOMPLISH PRODUCTION READINESS REVIEW • DEVELOP CONTRACT REQUIREMENTS FOR PRODUCTION PHASE	MANUFACTURING CONCERNS • COMPLETE INITIAL PRODUCTION FACILITIES • EXECUTE MANUFACTURING PROGRAM • INTEGRATE SPARES PRODUCTION • MAINTAIN PRODUCTION SURVEILLANCE • PROVIDE AND SUPPORT RFP • ACCOMPLISH VALUE ENGINEERING • ACCOMPLISH SECOND SOURCING/COMPONENT BREAKOUT • COMPLETE INDUSTRIAL PREPAREDNESS PLANNING • PLAN FOR THE ACCOMPLISH SYSTEM TRANSITION

Figure 3-2 Manufacturing Management For Major DoD Acquisition Programs

The intent of the model is to provide an introductory overview of the manufacturing management tasks which should be accomplished to ensure a successful acquisition program. The development of the manufacturing system necessary to build the defense system is a complex task which may rival the complexity of the defense system design process. If it is to be successfully accomplished, proper action is required from the earliest phases of the acquisition process.

The manufacturing activities described within this model reflect those actions typical of a major DOD hardware acquisition program. Where the primary emphasis of the acquisition is on software, firmware or subsystems, there may be substantial difference between the model and the actual activity. For these types of acquisitions the model may be viewed as a general guide to the kinds of activities which should be considered. These considerations must be tempered with the realities of the acquisition program and the differing end objectives of the program. There may also be differences where the objective of the development process is an electronic system. This type of system, while requiring similar types of activities as mechanical systems, often involves earlier fabrication of the models and prototypes which can be subjected to test. In this event, the other supporting activities described in the model may occur at earlier points than are described in the model.

The manufacturing management effort is a subset of the total program management planning and execution. Consequently, the plan for accomplishment of the manufacturing activities should be embedded in the program management planning documents early in the development cycle. In developing the manufacturing management approach, it is critical to note that the activities for all phases should be defined relatively early. This early definition is necessary since activities appropriate for later phases often need to appear as statements of intent or planning guidance in the program documentation or contracts developed in earlier phases. It is therefore suggested that the total model be reviewed when developing plans or contractual requirements for a specific phase. This will allow the manufacturing manager to consider the potential impact of future activities and establish a base line for the types of activities which should have been accomplished in earlier phases. Where these preceding events have not occurred, the manufacturing manager can determine if the activities described for the phase of interest need to be modified to account for accomplishments to date.

The model is developed from the perspective of the DOD manufacturing manager. It focuses on the responsibilities of the personnel involved within the program management office for achieving a capability to successfully enter and complete the production phase. While many of the activities described in the model reflect actions to be taken by the prime and subcontractors, the model is not meant to be a total description of the contract responsibilities. Since many of the actions required to achieve the manufacturing management objectives are accomplished through contract actions, the last section of this model provides a brief discussion of the support required from manufacturing management personnel during the solicitation and award process.

MANUFACTURING CONCERNS DURING THE CONCEPT EXPLORATION/DEFINITION PHASE

Evaluate Production Feasibility

The program manager should ensure that a manufacturing feasibility assessment is accomplished in the initial phases of product development. 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.

The feasibility analysis involves the evaluation of:

1. Producibility of the potential design concepts.

2. Critical manufacturing processes and special tooling development which will be required.

3. Test and demonstration required for new materials.

4. Alternate design approaches within the individual concepts.

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

The feasibility assessment is accomplished to bound the manufacturing risks incurred in selecting a particular design, fabrication concept and material as the basis for moving into the concept demonstration and validation phase. Without this type of assessment, the program manager may find that later phases of the program cannot be accomplished within the defined thresholds as a result of incompatibilities between the system design and the manufacturing technology available to execute it.

Guide References: 6-1, 8-1

Assess Production Risks

Based upon the feasibility assessm' ', the program management office : uld develop a manufacturing risk evalua ,n to quantify the statement of manufacturing feasibility. Manufacturing risk assessment is a supporting tool for the contractor and pro;; office decision making process. It see',s to estimate the probabilities of success or failure associated with the manufacturing alte'' atives available. These risk assessments m' eflect alternative manufacturing approacht to a given design or may be part of the eva',ation of design alternatives, each of which ha; an associated manufacturing approach. It s' ould also consider the sensitivity of the fea,, 'ty estimates to the assumptions which , re made on those areas of the design ior wl ,h specific design data were not available.

The quantified risk levels can then serve as the basis for the developr ,, of specific risk resolution approaches for ' e later phases of the acquisition cycle and can provide guidance to the budget estim,tio, process. In programs where manuf'acturing risk has not been add, ssed during development phases, , ere have been problems during the production pha , involving high cost, extensive de,ign chang, s, unplanned material a ,d process changes a d difficulties in deliv ring hardware which conform to the cont, ac' requiremer ts on time.

Guide Refere, ,: 6-3

Identify Man, f 'uring Technology Needs

The evaluation of manufacturing capability is base, on the analys : of the compatibility of the demands of the manufacturing task
and the manufacturing facility and equipment required to accomplish it. Part of the result of the manufacturing feasibility evaluation is the identification of manufacturing technology needs. The needs are identified so that the kinds of manufacturing capabilities that will be required can be put on line in the factory prior to the production phase. When manufacturing technology development programs involve some risk, the program manager should consider requiring the design contractor to identify (o, develop) fall-back positions for each of 'he risk areas and/or demonstrate the rec ired capability in the laboratory or in pilot production.

Guide References: 4-3, 8-5

Estimate Manufacturing Cost

At the level of system definition typically available during the concept exploration phase, detailed manufacturing cost estimates cannot be developed. There is a need, however, to develop estimates of the level of resource expenditu,es that will be required to develc an' produc , the various system alternatives. These estimates will be used as part o, the evaluation c' affordabi 'ty and in establishing initial program thres' olds. In most cases, the e 'es will be developed through the use atistically ed cost estimating rel io, ,ps (CE or by comparison of the proposed yste, ns ith similar systems whose costs a e known. The cost estimates will be used for evaluating and selecting system concepts for entry into the concept demonstration and validation phase.

Guide References: 9-5

Develop Manufacturing Strategy

Program production strategy is a subset of the overall acquisition strategy. Specif, decisions need to be made concerning the level of competition which is to be attained during the productic, phase. If the program will be dual sourced, the early pla,,ning must take into account the strategy required to assure availability of capability and data and data rights for dual sourcing. New manufacturing technologies, if required by the system concept, will require specific plans for development, proof and transition of the technology to the eventual producer. This effort will necessitate close coordination with the Service manufacturing technology organization to assure compatibility of the technology development schedule with the system development schedule. Many studies have shown that competition makes a major contribution to reducing weapon system cost. If competition is to be effective, it must result from the application of a clearly defined strategy to ensure that an environment of true competition can be established and maintained.

Guide References: Chapter 4

<u>Identify Deficiencies in U.S. Industrial Base</u>

The manufacture of the system concepts under evaluation will require a particular mix of type and quantity of manufacturing capabilities. The various system concepts need to be evaluated to define the demand that they will create for specific materials and manufacturing processes. These demands need to be compared with the current and forecast ability of the defense industrial base to insure that the required capabilities will be available. Where deficiencies are identified, the management strategy should be modified to adapt the system design to the forecast capability, or action should be initiated to motivate industry to create the capability required. If neither of these actions is feasible, the development or adaptation of government-owned facilities may have to be pursued.

This identification must also consider the capabilities of the subcontractors. Chapter 2 provides information indicating that there is a deteriorating capability of the subcontractor base to support the planned levels of production from both a quality and quantity standpoint.

Guide References: 2-2

<u>Determine Availability of Critical Materials</u>

A number of materials are classified as strategic by the U.S. Government for industrial and defense purposes. For many of these materials the United States is heavily dependent upon imports. Defense system performance may be dependent upon the use of one or more of these materials. In some cases the future availability of these materials is dependent upon factors beyond the control of the program manager or the U.S. Government. In the evaluation of the alternate system concepts, needs for these critical materials should be identified and system acquisition planning should specifically consider the risk of their nonavailability. This may include measures such as the use of alternate materials (which may offer lower performance but have reasonably assured availability) or specific forward planning to obtain the required materials. This forward planning may include establishing a track of the availability and market for the required materials. If difficulties are forecast in obtaining the materials from the open market, it may be possible to place an advance buy or to obtain them from government stockpiles.

Guide References: 2-9

<u>Develop Contract Requirements for Concept Demonstration and Validation Phase</u>

The program effort during the concept demonstration and validation phase will be dictated by the specific requirements which are established and included in the contract(s). Manufacturing involvement during the demonstration and validation phase is primarily directed toward the resolution of the identified manufacturing risks, the assessment of system producibility and the development of initial production plans. Specific statement of work language and data item requirements need to be established to clearly identify the specific tasks which the contractor is to accomplish. Broad general statements which establish objectives for the manufacturing management function in the early phases of the program will not normally result in cost-effective, producible designs.

Guide References: 3-21, Chapter 10

<u>MANUFACTURING CONCERNS DURING THE CONCEPT DEMONSTRATION/ VALIDATION PHASE</u>

<u>Resolve Production Risk</u>

Production risk resolution involves demonstrating the attainability of the levels of manufacturing capability required. During this phase, it is not necessary that all the details of the production processes be demonstrated. The areas that represent advances beyond the current capability should be demonstrated in environments which are somewhat representative of the production floor. The focus is on determining that there is a reasonable expectation that the manufacturing materials and processes which will be required can be obtained or fabricated in sufficient quantity and quality to meet the production phase requirements. Deferring risk resolution to a later phase incurs a concern that the design will have to go into production relying on the processes or materials which have relatively unpredictable processing time and cost. There is the possibility that compromising efforts to meet quality, cost, and schedule goals may adversely affect technical performance of the end item.

Guide References: 4-5, 6-3

Complete Manufacturing Technology Developments

For those technologies identified during the concept exploration phase as requiring development, laboratory demonstrations should be accomplished. As with the system development program, the manufacturing technology development often represents a phased approach to definition and demonstration. The technology developer should demonstrate that the required process or material capability is attainable under laboratory or controlled conditions and also describe the procedure by which the technology can be extended into the manufacturing shop environment. Since it is normally anticipated that critical processes will be demonstrated in the production environment during the full-scale development (FSD) phase, it is important that the laboratory (or controlled production) process capability be demonstrated during this phase. Failure to do so may increase the risk, during FSD, that the material or process may be found not to be a viable approach for meeting the weapon system design requirements.

Guide References: 8-5

Develop Initial Manufacturing Plan

The purpose of the manufacturing plan is to portray a method of employing the facilities, tooling, and personnel resources of the contractor and subcontractors. It should reflect all the time phased actions which are required to produce, test and deliver acceptable systems on schedule and at minimum cost. During the Concept Demonstration and Validation (DEMVAL) Phase the prime contractor(s) should be tasked to prepare an initial draft of the manufacturing plan. This plan should reflect the degree of system definition attained during concept DEMVAL, identify the fabrication methods planned within the facilities, and estimate personnel resources forecast to be available during the production phase. The plan will also reflect the programmatic decisions concerning the degree and type of competition in the production phase and the needs for long lead procurement or limited production. Where it is anticipated that significant facilities modification or construction will be required, this effort should be described within the manufacturing plan. An initial description of the time phased schedule for both the Full-Scale Development and the Production and Deployment Phase tasks necessary to successfully produce the required quantity of systems should also be described. If it is determined that the learning curve will be applicable for scheduling and cost estimation, the elected slope(s) and base points (first unit, standard) should be estimated. The program office should carefully evaluate this schedule for reasonableness and attainability within the scope of the planned yearly program budgets.

Guide References: 6-2, 6-4

Assess Potential Producibility of Competitive Designs

Producibility is a measure of the relative ease of producing a product or system. It is also an engineering function directed toward generating a design which is compatible with the manufacturing capability of the defense industrial base. Each competing design needs to be evaluated from a producibility standpoint. The producibility effort must take into account the quantity of units or systems to be produced and the rate at which they will be manufactured, since quantity and rate determine the magnitude of the potential manufacturing efficiencies to be gained or problems to be avoided. Producibility evaluations will serve as a basis for estimating the likely manufacturing cost and assessing the level of manufacturing risk of the system. Results of these assessments will support the development of specific contractual provisions for the full-scale development phase. Specific requirements may be identified based upon the inherent level of producibility, the specific system designs, and the susceptibility of each to manufacturing cost reduction through an aggressive producibility program.

In assessing producibility of the various design concepts, it is important to define the types of production technology required and to contrast it quantitatively and qualitatively with the existing and forecast capability of the defense industry. There is a direct correlation between producibility and cost, which needs to be a part of the comparative analysis of the competing system designs. Ignoring the issue of producibility can lock the acquisition program into design solutions which can only be accomplished at unnecessarily high levels of production cost or design changes which can entail substantial technical, cost and schedule risk.

Guide References: 2-2, 6-2, 7-3

<u>Evaluate Producibility Criteria</u>

A part of the contract for the Concept DEM/VAL phase should require that the contractor develop producibility criteria to guide the design effort. The criteria should reflect a blending of general criteria (such as minimum parts count) and specific criteria applicable to the type of equipment being developed. The effectiveness of the producibility program will be controlled by the extent to which the design engineers understand and apply these criteria. Success also depends heavily on the definition of a clear complete criteria list and its communication to the design function.

Guide References: 7-10

<u>Plan for Achieving Producibility</u>

Achieving producible designs requires creating a plan that will permit the integration of producibility analysis into the mainstream design effort. As a result of the contract requirements, a plan should be created by the contractor which describes how these issues will be addressed within the organization which will create and test the design. Although many of the detailed tasks in achieving the producibility objective may not be accomplished until the Full-Scale Development Phase, the plan should describe specifically what activities will be accomplished in each phase, the responsible organization, and the management controls that will be established to ensure successful accomplishment. The PMO review should focus on the realism, completeness and clarity of the planning accomplished by the contractor. Formal submission of the plan may be required by the contract or the plan may be reviewed at the contractor facility.

Guide References: 7-10

<u>Assess Production Feasibility</u>

Production feasibility is the likelihood that a system design concept can be produced using existing production technology while simultaneously meeting quality, production rate and cost requirements. As a follow-on to the feasibility assessment accomplished during the concept exploration phase, the program office should use the increasingly more complete description of the system to update the assessment. This may be done within the program office or by the prime contractor(s). As the system design concept and manufacturing approach are validated and design decisions are made, the amount of flexibility on the choice of production technologies decreases. It is important for the program manager to ensure that design decisions reflect currently available production technology. Consideration of feasibility must occur in a bounded environment. The primary bounds are the existing state of production technology, the cost targets established for the system, and the production rate and schedule requirements.

Feasibility assessment is useful in supporting decisions concerning which of the competing system designs should be carried into FSD. It is also used to determine which of the manufacturing processes should be proofed during FSD and the nature of the proofing required. The process of weapon system design is dynamic and the search for the-best solution often involves changes to the design concept which can impact the manufacturing processes to be used. Failure to assess feasibility at a number of points during the acquisition process can result in accepting changes to the design which are incompatible with the capability of the industrial base.

Guide References: 5-4, 6-1, 8-1

<u>Plan for Use of Competition in Production</u>

If the program manufacturing strategy (see above) includes the use of competitors in the Production Phase, specific plans for achieving the defined level of competition must be established during the Concept Demonstration and Validation (DEMVAL) Phase. The Concept DEMVAL contracts establish whether there will be a competitive production phase and ensure that provisions are included so that the government receives the necessary technical data and rights to its use. During the Concept DEMVAL phase, the planning effort should focus on identifying the potential limits on competition which result from the various design solutions and on means for reducing their impact. Decisions should be made relative to the timing of the introduction of competition and the basis on which the competition will be held. If parts of the system are planned for later government breakout for competition, this should be clearly described in the contract to ensure that contractor plans are based on the same presumptions as the government plans. This can prevent later misunderstanding and friction during the execution of the production phase effort.

Guide References: 4-1, 4-8

Evaluate Long Lead Procurement Requirements

For many defense systems the time span between release of production funds and the required first delivery is less than the required lead times for some of the materials or subsystems. In developing the full-scale development (FSD) phase plans and the data for the Decision Coordinating Paper/Integrated Program Summary, the requirements for long lead materials or subsystems, both contractor and government furnished, should be identified. The funds required for these long lead items should be identified during the budget process. Determining the specific requirements for long lead funding is made difficult by the volatile nature of lead times for many defense materials. Where possible the analysis should be based on expected availability and lead times which are forecast to be in existence at the time of production start.

Guide References: 6-15, 11-11

Determine Need for Limited Production

Low rate initial production is a term describing a low rate of output at the beginning of the manufacturing program to reduce the government's exposure to large retrofit programs and resulting costs while still providing adequate numbers of hard tooled production items for final development and operational test prior to a full production decision. This approach can be used to minimize the risk of committing the necessary resources for the production phase by allowing for test and tryout of the manufacturing equipment prior to full production release. It also may provide test items which are fully representative of the production configuration. The difficulty in using a limited production approach is the need to invest in manufacturing tooling and test equipment earlier in the acquisition cycle. This may cause budgetary problems. There is also a risk that development and operational test results may indicate a need for design changes that will obsolete the tooling and test equipment.

Guide References: 4-5, 6-7, 11-12

Develop Initial Manufacturing Cost Estimate

One of the major elements of the life cycle cost of any defense system is the investment cost to produce the quantity required for deployment. The improved definition of system design and manufacturing planning should provide a basis on which the manufacturing costs can be estimated with greater precision than was available for the estimate accomplished during the Concept Exploration phase. The earlier estimate, in most cases, is based heavily on statistical and parametric estimating approaches. As the design definition increases, the contractor and the PMO should be able to replace these statistical estimates with estimates based upon specific design characteristics and features and a knowledge of the manufacturing system in which they will be fabricated. At this point in the development cycle we should not expect to have the specific design definition needed to develop a detailed estimate based upon manufacturing labor standards; however, it should be possible to utilize a higher order estimating standard such as hours-per-circuit-board (by type) or cost of castings based upon number of castings and total weight. If a design-to-production unit cost requirement is included in the contract, the reasonableness and attainability of the contractor's apportionment of the unit production cost goal should be assessed to prevent the program from being based on unattainable goals which will later cause unavoidable cost growth.

Guide References: 9-5, 9-17

Develop Production Readiness Review Plan

One of the major PMO program office tasks during the FSD Phase is completion of the Production Readiness Review (PRR). It is critical that the specific requirements for contractor planning and support to the PRR be included in the FSD contract. There is also a need to ensure that the necessary government evaluation skills are available during FSD. These needs can only be met if the major readiness issues are identified during the DEMVAL phase and the methods for evaluating readiness are clearly defined. The readiness issues must cover both the defense system design and the production planning required. Since many of these issues are normally evaluated as part of the continuing process of design and program reviews, the planning for PRR should clearly describe how the outputs and analyses of these reviews can be applied to the PRR task.

Guide References: 6-1, 12-3

Develop Contract Requirements for Full Scale Development Phase

The FSD Phase will involve the definition of the full detailed design for the weapon system, the logistics support structure and the manufacturing system. Specific statement of work language needs to be developed to cover those manufacturing areas which have been determined to be necessary during FSD. Typical areas to be considered for inclusion are:

1. Manufacturing management systems

2. Work measurement

3. Production planning

4. Producibility engineering and planning (PEP)

5. Production readiness reviews (PRR)

6. Reporting systems

7. Manufacturing data (including production plan)

8. Make or buy

9. Technical data

10. Long lead authorization

If valid requirements exist for contractor actions during FSD, they must be included in the contract. If it is necessary to include them later by contract modification, the cost will almost always be greater and the efforts will start later than the optimal start time. These optimal start times are developed by analysis of the required set-back times required to allow completion of the necessary activity prior to the need date dictated by the program schedule.

Guide References: 3-21, Chapter 10

MANUFACTURING CONCERNS DURING THE FULL-SCALE DEVELOPMENT PHASE

Define and Proof Manufacturing Processes and Equipment

Among the critical elements to be defined during FSD phase are the manufacturing processes which will be utilized to build the defense system. The sequence of manufacturing processes begins with the receipt of the raw material, where special handling and storage may be required. Additional processes requirements may include such items as cleaning, heat treatment, clean room controls, controlled testing and special handling (i.e., personal grounding requirements for electronic components). Identification of all processes must be a part of the design documentation. Where the selected processes contribute manufacturing risk to the program, the processes should be proofed during FSD. The purpose of proofing is to ensure that the process can produce repeatably conforming hardware within the cost and time constraints of the production phase. It is important that the proofing be accomplished in an environment that simulates actual production conditions. These conditions include the physical facilities, personnel and manufacturing documentation. It may also be necessary for the contractor to establish training and certification programs for the shop personnel to ensure that the process capabilities can be attained on a recurring basis.

Guide References: 4-5, 8-5, 8-12

Complete Manufacturing Plan

At the end of the FSD, all of the information necessary to plan the detailed manufacturing operations for the system should be available. This information should be described in a manufacturing plan covering the issues of manufacturing organization, make or buy planning, subcontract management, resources and manufacturing capability, and the detailed fabrication and assembly planning. The plan should also describe the types of Government Furnished Property (GFP) required and the specific need dates for it. The contractor management control systems, including those for configuration management, the control of subcontractors and manufacturing performance evaluation should be described in sufficient detail for the program management office to determine their expected utility. The plan developed should also include consideration of the potential requirements for industrial preparedness planning, including surge capability during the production phase and the post production phase requirements for support to employment of the system in combat situations. The development of this formal manufacturing plan contributes value to the program from two standpoints. The 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. The secondary benefit is the usability the plan provides to the program management office personnel. It serves as a basis for a structured review of the contractor approach, the expected cost of the production phase effort, and a fuller assessment of manufacturing risk. Where such a plan is not developed during the FSD Phase there is often unnecessarily high cost and schedule turbulence at the front end of the production phase.

Guide References: 4-1, 6-4, 6-20

Execute Producibility Engineering and Production Planning

Producibility, as noted above, is a measure of the relative ease of producing a product or system. Alternate manufacturing methods, materials, resources, and processes must be a consideration of the detailed design if the economics of manufacturing and assembly are to be considered. Producibility studies and analysis of the alternatives are conducted by the contractor with consideration of the impact on cost, schedule and technical performance. Early production planning based on design and schedule requirements is essential if production delivery schedules are to be fulfilled. Production planning must include identification of potential problems with an assessment of the capability required to produce the item and industry's current capability to manufacture the system as designed. Potential production problems that require further resolution by study or development must be identified and action for resolution initiated. The producibility engineering and planning effort also results in the definition and design of the special tooling and test equipment required to execute the production phase effort, as well as the preparation and release of the manufacturing data required for the start of manufacture.

Guide References: 4-3, 7-6, 11-10

Evaluate Producibility of Design

There are a number of factors to be considered in ensuring the producibility of a design:

1. Liberal tolerances (dimensions, mechanical, electrical).

2. Use of materials that provide optimum machinability, formability and weldability.

3. Shapes and forms designed for castings, stampings, extrusions, etc., that provide maximum economy.

4. Inspection and test requirements that are the minimum needed to assure desired quality and maximum usage of available and standard inspection equipment.

5. Assembly by efficient, economical methods and procedures.

6. Minimized requirements for complex or expensive manufacturing tooling or special skills.

There should be evidence that the contractor has accomplished producibility analyses of various options for the manufacturing task. The FSD phase results in the system design for entering production. As the design evolves during FSD, its producibility should be subjected to regular review (probably as part of the normal design review process.)

Guide References: 7-3, 7-10

Define Required Manufacturing Resources

One of the most important elements of any production design is the definition of the manufacturing processes. No matter how good a design may be, it is useless if system or product cannot be built. Although impossibility of production is unusual, the capability to produce the design may be limited or the costs to produce it may be excessive. It is therefore essential that availability of manufacturing resources be a consideration during the design review process. Manufacturing engineers should be a part of each design team to assure adequate consideration of availability of required manufacturing resources.

Manufacturing resources should not be limited to manufacturing methods but should include materials, capital, manufacturing technology, facilities, qualified labor, and the management structure to effectively integrate them. The successful completion of the production phase will depend upon the efficient application of the full spectrum of these resources to the task of fabricating and delivering the defense system design.

Guide References: 6-20, 8-1

Develop Detailed Production Design

Prior to release of drawings to manufacturing the detailed design drawings, bills of material and, product and process specifications must be completed. Further, it is essential that design reviews be conducted to assure that the contractor is complying with the design requirements and meeting the cost/design goals. The final design definition is the result of the performance requirements, the outcomes of the testing accomplished, producibility studies and other design influences. The production phase effort requires that the design be specified to a very low level of detail so that the required processes and resources can be identified and obtained.

Guide References: 11-14

Develop Production Work Breakdown Structure

The planning, execution and control of the production phase activities require that the work be divided into manageable tasks that are compatible with the existing manufacturing and performance measurement systems. Often, the work breakdown structure (WBS) used during the development phases will not be appropriate for the production phase. Consequently, the contractor should, as a basis for production planning, identify the WBS which is to be used. While this WBS may differ from the FSD structure, the two should be such that production phase costs can be related to the development WBS. This is critical for those programs which have utilized a design-to-unit production cost management approach during development.

Guide References: 9-17, 13-13

Develop Manufacturing Cost Estimates

As the definition of the system design and the manufacturing approach are completed during the FSD phase, the information necessary for more precise estimates of production phase manufacturing cost becomes available. During the FSD phase, the initial manufacturing cost estimate should be updated on a regular basis to reflect the increasing degree of detail available. These estimates should be based upon application of detailed manufacturing standards to the operations to be performed and adjusted, as necessary, by realization factors and/or learning curves to develop the time phased manufacturing cost. If the contractor(s) does not have a system for development and application of labor standards, strong consideration should be given to including a contract requirement, such as MIL-STD-1567A, Work Measurement, in the FSD phase contract. If there is to be an Industrial Modernization Incentives program accomplished, the manufacturing cost estimate should be structured to reflect the expected benefits of this program.

Guide References: 9-5, 9-7, 9-9

Accomplish Production Readiness Reviews

The objective of a PRR is to verify that the production design planning and associated preparations for a system have progressed to the point where a production commitment can be made without incurring unacceptable risks of breaching thresholds of schedule, performance, cost, or other established criteria (DODI 5000.38). PRRs should be conducted by the program manager, as a time-phased effort that will span FSD and encompass the developer/producer and major subsystem suppliers. The PRR examines the developer's design from the standpoint of completeness and producibility. It examines the producer's production planning documentation, existing and planned facilities, tooling and test equipment, manufacturing methods and controls, material and manpower resources, production engineering, quality control and assurance provisions, production management organization, and controls over major subcontractors. The result of the PRR supports the program manager's affirmative decision at the production decision point, that the system is ready for efficient and economical rate production.

Guide References: 11-6, 12-3

Develop Contract Requirements for Production Phase

Specific requirements must be identified for inclusion in the statement of work for the production phase. The particular requirements reflect the areas that have been determined to be of importance, given the acquisition strategy of the program. Typical areas to be considered for inclusion are:

1. Manufacturing management systems
2. Work measurement
3. Manufacturing data (including manufacturing plan updates)
4. Initial production facilities
5. Production and material control systems
6. Manufacturing reporting systems (especially line of balance)
7. Control of subcontractors and vendors
8. Make or Buy program
9. Government Furnished Property
10. System audit
11. Technical data
12. Competition

Production phase incentives may be included to motivate contractors to improve performance and control costs. The benefits attainable through use of multiyear contracting should also be explored.

Guide References: 3-21, 4-9, Chapter 10

MANUFACTURING CONCERNS DURING THE PRODUCTION AND DEPLOYMENT PHASE

Execute Manufacturing Program

The primary function of the production phase is to complete the manufacture of the defense system within the established time and cost constraints. Normally, the production rate is structured to start slowly and build to a defined steady state rate. Much of the same type of evaluation of contractor planning for initiation of the production phase (generally through the PRR) needs to be focused on the contractor planning to increase to the defined rate. The program manager also needs to focus attention on the levels of engineering change activity. An excessive number of engineering changes can disrupt the structure of the manufacturing planning and result in high manufacturing costs. Also, attention needs to be given to ensuring that acceptance criteria for the product or system are clearly specified and that there is minimum use of waivers, deviations and Material Review Board actions during the acceptance process. The program office manufacturing personnel should participate in the Physical Configuration Audit (PCA) when the "as built" item is compared with the technical documentation. Upon satisfactory completion of the PCA, the primary acceptance criteria will be the physical and test requirements listed in the technical documentation. The completion of the production phase normally involves a series of contract actions which will need to be planned and completed to fill the system acquisition objective. For each of these contracts, a decision will need to be made on the contract type, the incentive structure, if any, the level of government control and the desired program visibility.

Guide References: 5-3, 10-1, 13-5

Complete Initial Production Facilities

The Initial Production Facilities (IPF) include the special tooling, special test equipment and plant rearrangement cost necessary to accomplish cost-effective manufacturing. The design of the IPF should have been accomplished as part of the Producibility Engineering and Planning (PEP) accomplished during full-scale development. The PEP output includes a description and design of the required facilities and is based upon the production plan developed during FSD. Changes to that facility definition and design may be required if the production plan has been obsoleted by program changes or test problems. The timing of the IPF may pace the initiation of the production units if the manufacturing approaches are tooling dependent.

Failure to initiate and complete IPF in a timely manner generally results in greatly increased direct labor unit cost for the early units, delayed completion of early units and delays in the start of progress along the expected program learning curve. The increase in early unit cost results from the fact that the investment in special tooling and special test equipment is justified on the basis of unit cost reductions. There may also be unforeseen additional cost for the revision of the manufacturing process documentation developed during PEP since the documentation was developed on the presumption that the IPF would be in place.

Although claims of large unit cost reductions may be made, the average unit cost over the total production quantity will be higher when FSD tasks are incomplete. A well developed production plan will be more economical in terms of total program cost or average unit cost even though it may follow a higher value learning curve. The number of change proposals will also be less for a well planned program.

Guide References: 4-5, 6-20, 11-10

Integrate Spares Production

As the system is deployed and enters training and operational use, there is a continuing requirement, on many systems, for spare and repair parts. To the extent possible, the manufacture of these parts should be integrated with the basic system production to take advantage of the lower costs associated with larger fabrication lots within the facility. The spares items to be produced can also impact the cost estimate where learning curve analysis is used at lower levels of the system hardware since the spares quantities can increase the number of units built above that shown on the end item schedule. Failure to consider the capacity needs for spares can result in diminished capability to support the fielded system, thus reducing its availability, or a drain on production parts as they are diverted to support of the deployed systems.

A second source for spare parts may be desired to ensure future delivery or for enhanced competition. The production phase is an opportune time to solicit second source bids and identify possible spare parts suppliers. The data package is complete and quantity requirements for quantity buys may be sufficient for a supplier to tool up for the parts.

Guide References: 3-20, 6-21

Maintain Production Surveillance

One of the primary program management tasks during this phase is to establish and maintain a system for accomplishing surveillance over the progress of the contractor performing the manufacturing tasks. Generally, the program manager will want to ensure that information is available to measure contractor effectiveness from time, cost and technical achievement standpoints. The program manager must also choose between a formally structured and contractually specified management control system or a currently existing contractor system. When problems occur during the production phase, the management control system should provide timely information to the program manager in a format that will support decision making and action processes.

Guide References: 6-22, 10-1, 13-16

Implement Product Improvement

The Follow-On Operational Test and Evaluation (FOT&E) and the initial user feedback on the system often identify areas where improvements can be made to the system to allow it to better meet the constantly changing operational environment. The challenges for the program manager involve the decisions on which of these improvements to make, and the method of incorporating them on the production line. To minimize production cost,the number of engineering changes should be kept to a minimum, but operational requirements often militate in favor of change. A program may also involve preplanned product improvement. If this acquisition strategy applies, when and how to incorporate such improvements must be resolved early in the program.

Guide References: 3-24

Provide and Support Government Furnished Property (GFP)

Where a decision has been made to provide use to the contractor, the program manager must ensure that the property, conforming to the technical description, is delivered to the contractor in accordance with the agreed-to schedule. The primary motivations for providing government property to contractors are to reduce cost and increase standardization within the logistics system. The trade-off for these benefits is the acceptance by the government of some of the responsibility for contract performance. When GFP is involved, the contract clause provides that if the GFP is late or defective there may be an adjustment to the contract schedule, or price, or both. It is, therefore, incumbent upon the program office to ensure that an effective management control system is established to; a) validate contractor need dates, b) budget for the GFP, and c) acquire the GFP and deliver it to the contractor on time.

Guide References: 4-5

Accomplish Value Engineering

Value engineering (VE) is an organized effort directed at analyzing the function of a product or system for the purpose of achieving the function at the lowest overall cost. During the production phase, the value engineering effort amounts to a reappraisal of the design from both a functional and cost standpoint. There are two ways to include value engineering in the production phase contract: by a Value Engineering Incentive Clause or by a Value Engineering Program Clause. The VE Incentive Clause provides the contractor with the opportunity to submit Value Engineering Change Proposals (VECPs) and to share in the savings accrued from approved VECPs. The VE program clause requires the contractor to establish a VE program within his facility to identify potential applications of VE and prepare VECPs.

VE has the potential to significantly reduce acquisition and support costs for those elements of the product or system to which it is applied. In addition to including the appropriate contract language, the success of a VE program is critically dependent upon the level of program office support which is provided. This support can be provided in two ways. First, the decision makers in the program office can encourage the identification and submission of VECPs. Second, the personnel evaluating VECPs can approach the task with an open mind.

Guide References: 7-16

Accomplish Second Sourcing/Component Breakout

As noted above, competition has been shown in a number of studies to have a beneficial effect in reducing program cost. The plan for introducing competition during the production phase can involve either the establishment of a second source or the breakout of selected components of the system for direct government (preferably competitive) procurement. Accomplishing government objectives in these two areas requires that the data and data rights are obtained from the developing contractor. These rights should have been obtained during the development phases with data delivery late in FSD or early in the production phase. Since the introduction of new sources will involve contractors who may not have the benefit of the development experience, a careful plan for technology transfer must be established. Many times, successful manufacture of a product or system is dependent upon processing factors not disclosed in the technical data package.

Guide References: 4-6, 4-8

Complete Industrial Preparedness Planning

The Industrial Preparedness Planning (IPP) program focuses on establishing the capability to support increased levels of usage of equipment resulting from combat operations. The primary emphasis during the production phase is the evaluation of the ability of the contractor base to surge production to meet higher levels of consumption. As the production phase is nearing completion, action needs to be taken to determine if any of the subsystems or components of the defense system will be critical to support of wartime operations. If so, the mobilization requirements for the items must be identified, contractor plans for accomplishing the mobilization must be established, and the capability to execute the mobilization must be created or retained from the production phase equipment.

Guide References: 2-13, 3-20

Plan for and Accomplish System Transition

As the system acquisition process is completed with the attainment of the acquisition program objectives, the responsibility for the product or system acquisition functions: procurement, engineering, finance, and logistics is dispersed through the respective Service organizational structure. The effort focused on the program management approach is no longer needed. The program manager must ensure that documentation of the system is complete, and the support requirement is properly defined and structured.

Guide References: 3-18

POST PRODUCTION SUPPORT AND PROGRAM TRANSITION

The term "transition" is analogous to many terms used throughout the Services to describe the attainment of the acquisition program objectives and the dispersion of product/system acquisition functions -- procurement, engineering, production finance, logistics, facilities -- in whole or in part throughout the respective Services, organization structures. A sample of such terms include "transition planning," "program transition," and "turnover management."

Program management documents and master schedules must include transition considerations. While the mechanics involved in transition will vary among the Services, the end result is the availability of the system for use by the operating forces in consonance with DOD objectives.

Emphasis in weapon system acquisition has been on early production and delivery and the establishment of support capability to coincide with initial fielding of the system. This has often forced provisioning to be accomplished in a very short time. While some success has been achieved in having spare parts on hand, it has virtually eliminated our ability to establish competitive sources or assure fair and reasonable pricing of these spare parts. If the Services are to support weapon systems as they are delivered into the inventory, and obtain spare parts at fair and reasonable prices, some radical changes in the weapon system acquisition process will be required.

Interface Questions

With considerable resources now invested in the product/system, many interface questions become extremely crucial. Are organizational force and equipment tables, allocation of units, and field support plans compatible with the production planning? Have the production rates been established for support program requirements, support and test equipment, spares support, storage and transportation, and training? Have test and demonstration requirements been established and a methodology developed for incorporating user changes in documentation for release to production? Are plans formulated for updating specifications and drawings to reflect the production design and for obtaining suitable technical documentation packages necessary for considerations such as competitive procurement and component breakout?

As noted above, a host of program transition considerations confront the program manager in the production and deployment phase. While relatively dormant earlier in a program, these considerations suddenly become critical at the very height of the production process. Has a risk analysis identified potential production plan and rate deficiencies? Is the producibility plan adequate for full and follow-on production? Are the various facilities, tooling, industrial capacity and related schedule plans current? Have Foreign Military Sales (FMS) and other Service requirements as well as related production processes, rates and quantities been validated, documented and kept current?

As the focus shifts from the program manager to the internal Service interface, those seeds sown early-on in the product development process will mature and, if done properly, will ensure program integrity to the system user.

Changing Production Capability

The program manager should be aware of changing production capability as the transition from production to spare parts provisioning will severely reduce his opportunities for future spares procurement if production facilities are changed to accommodate a new product line, material needs change or new tooling for special purpose machines is installed. If extended production runs did not provide a spare parts inventory, the cost of parts produced at a later date can be significantly higher than the original procurement. Conditions which drive up spare parts prices include:

a) Smaller order quantity requirements.

b) Orders for earlier configuration units which require special documentation.

c) Parts require special purpose tooling.

d) Unique or scarce material requirements.

e) Lack of production capability due to a number of factors: Out of business, discontinued facilities, lack of available production capacity, etc.

f) Special handling, packaging and shipping requirements.

End Item Production Endangered

DOD Directive 4005-16 establishes policies and assigns responsibilities to assure that timely action is initiated when essential end item production capabilities are endangered by the loss or impending loss of manufacturing sources, by material shortages, or that have been reduced to a single source with inadequate production capabilities. DOD components have a responsibility to coordinate with operational activities within other government agencies on the identification of critical items and possible solutions, when faced with a material shortage or manufacturing phaseout.

Implementing Procedures

In accordance with DOD Directive 4005.16, each DOD component shall develop implementing procedures by the initiation of prompt and timely actions to assure the availability of critical materials and manufacturing capabilities to support current and planned defense requirements. Component responsibility includes:

1. Establishing and maintaining a single organizational focal point to monitor all material shortage and diminishing source situations.

2. Developing plans and simplified coordination mechanisms to deal with existing and potential diminishing manufacturing sources and material shortages, including interaction with government activities.

3. Taking rapid remedial action when faced with a material shortage or manufacturer phaseout.

4. Initiating actions to reduce reliance on sole source manufacturers and suppliers through the development of additional sources or coordination of substitute items with equipment users.

5. Maintaining close contact with industrial/scientific and engineering organizations and industry through a system of follow-ups to discern future trends.

6. Using engineering, standardization and technical organizations to assure that the most current standard or preferred parts are used in systems design and development.

7. Reviewing the efforts of other government departments in the area of material shortages and production phaseouts. Using output from their system where possible and ensuring that a compatible data interchange method is established.

8. Developing compatible management techniques through coordination with other DOD components and ensuring that adequate information and controls for material shortage and diminishing source situations.

9. Ensuring that diminishing manufacturing sources and material shortages are recognized in the DAB proceedings.

10. Developing a technique where feasible to identify "end item application" for those critical or weapon system essential items affected by shortage/phaseout conditions.

11. Seeking manufacturer's and supplier's commitments to provide maximum advance notice prior to phasing out production or supply of material.

12. Advising using Military Departments and other users of date(s) beyond which support will no longer be provided for item(s). The DOD components are responsible for notifying International Logistics (IL) customers.

While the mechanics involved in transition will vary among the Services, the end result is the availability of the system for use by the operating forces in consonance with DOD objectives. Transitioning the system to the operational forces, and developing as well as monitoring and controlling transition milestones become especially important in the production phase of the system acquisition process.

Support for Out-of-Production Systems

Support for out-of-production systems should provide an organized approach and methodology for attaining competition and fair and reasonable prices for spare parts no longer in production.

For out-of-production systems, the weapon system program manager should consider the value to DOD of establishing post production support agreements for those systems. This can ensure that costs for required spares do not reflect source constraint circumstances leading to unreasonable prices. Procedures also need to be established to qualify additional manufacturing sources to provide competition on specific parts. These procedures should be consistent across the procuring agencies and should allow for qualification across general groups of items built using the same manufacturing process.

High Value Spare Parts Breakout Program

For items which represent recurring spare parts requirements and substantial annual buy value, aggressive action to develop alternative sources of supply is required. These sources ensure continuing part availability and competitive sources for these parts. The process of establishing competitive sources for these parts starts early in the production phase and continues as long as they are in the supply system.

During the provisioning process, decisions are made in consonance with the Maintenance Concept, including what spare parts will be specified, and what spare parts new to the inventory must be identified and purchased to meet initial support requirements. After identification of the spare parts required to support the Maintenance Concept, decisions also must be made as to how they will be procured in terms of competitive posture. The intent of the High Value Spare Parts Breakout Program is to identify those high dollar spare parts which offer the greatest potential savings through competitive procurement or "breakout." High Dollar Value Replenishment Spare Parts can be defined as spare parts included in those items ranked in descending order of annual buy value (computed by multiplying the unit price times the annual buy quantity) which represent at least eighty percent (80%) of all dollars expected to be spent in the 12-month period when measured in descending order from the highest annual buy value item.

Usually, the developing contractor is asked (required by the contract) to provide the contractor technical documentation as a basis for government decision on the method of purchase. Each item is screened by the government and the item is assigned an Acquisition Method Code (AMC) and AMC Suffix Code in accordance with DOD FAR Supplement 6. The AMC will determine how the item will be purchased unless changed by subsequent review. The suffix code explains the basis for assignment of the AMC. During the life of the part or item, regular screening intervals (often three years) are established. At each screening, the item management organization reviews the forecast buy and the item to determine if action could be and should be taken to develop competitive sources for the item.

CAO Involvement

Significant improvements can be attained by greater involvement of the Contract Administration Offices (CAOs) in the spare parts acquisition process. This involvement should include review of prime contractor vendor competition, source identification for direct purchase, limited rights assertions and price reasonableness of prime and subcontracted spare parts. This effort should be implemented through use of support and interface agreement consummated between the CAOs and the involved buying activities. The increased CAO involvement will add to the spare parts acquisition program the knowledge and access that results from the continuing relationship between the CAO and the prime contractor. Specific management attention must be directed to the identification and quantification of price pyramiding on spare parts. Removing situations in which prime contractors and upper tier subcontractors add cost to an item without adding value can make a significant contribution to achieving fair and reasonable prices for spare parts. This can be achieved by breaking these parts out for direct purchase from the actual manufacturer (or possibly for open competition).

Life of Type Buy

When all other alternatives have been exhausted for an item no longer to be produced, life of type buy, a one-time procurement may be necessary. Procurement quantity, according to DOD Directive 4005.16, will be based upon demand and/or engineering estimates of mortality, sufficient to support the applicable equipment until phased out of the system.

Post production support will, by focusing organizational resources on improving the process by which spare parts are acquired, assure a more efficient and responsive logistics support program, as well as normalize the price paid for each part.

MANUFACTURING CONCERNS RELATED TO CONTRACTING SUPPORT

The model presumes that each phase of the acquisition process will be accomplished through a separate contract action. This will not be true for all programs since the program manager has the flexibility to develop acquisition plans which may combine phases within single contracts or delete specific phases based upon the strategy developed for the individual acquisition program. Irrespective of the particular acquisition strategy, almost every program will have at least one contract action associated with it and the vast majority of programs will have a number of contract actions. The significance of these actions lies in the fact that the implementation of the manufacturing management goals of the program is accomplished primarily by the contractor, and program success depends upon establishing clear contract provisions for each contract let during the system acquisition. This section provides a brief discussion of the typical activities which would be required from the manufacturing management group in support of the contracting effort.

Figure 3-3 provides a graphic representation of some of the major events to be supported during a contracting action. The approval of a program through the Acquisition Decision Memorandum (ADM) or other similar documentation, combined with availability of budget funds, provides the basis for a solicitation document, usually a Request for Proposal (RFP) to industry The manufacturing management function provides to the contracting officer the detailed requirements for the manufacturing tasks to be accomplished during the period of contract performance. This could include statement of work language, data items or contract special provisions required to achieve the manufacturing management objective defined for that period of performance. The development of these requirements should reflect the types of activities described in the model for the particular acquisition phase(s) covered by the contract, as well as other requirements which reflect areas unique to the specific program.

For each of the requirements included in the RFP, evaluation criteria need to be established. These criteria should focus on those elements of the proposal which could affect system effectiveness, the contractor's ability to produce the system or the government's ability to support it. The developed criteria are needed to describe the minimum performance or compliance acceptable to enable a contractor to meet the requirements of the RFP. These criteria are then used as a basis for the evaluation of the individual contractor proposals. In performing the proposal evaluation, the evaluator needs

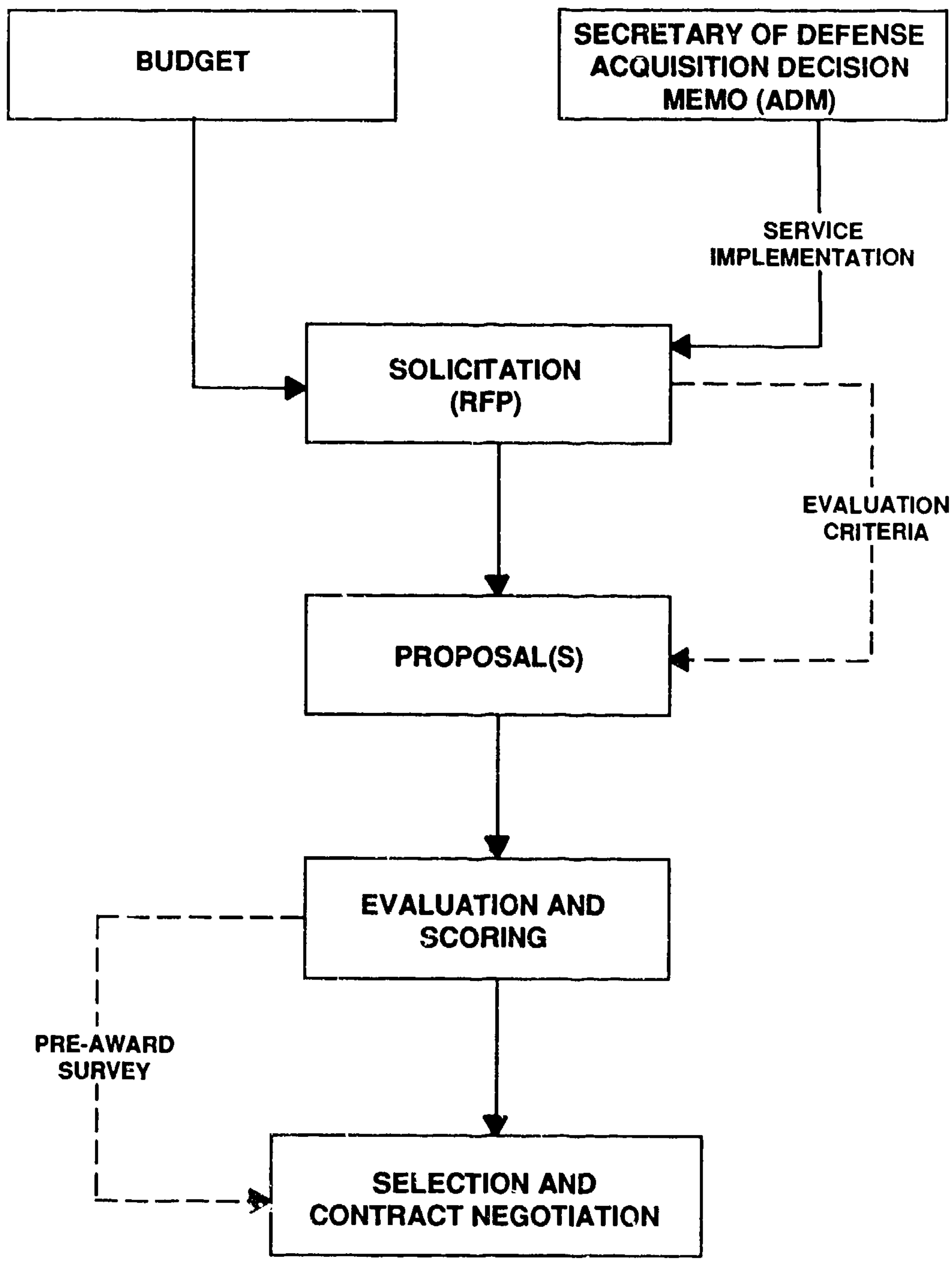


Figure 3-3 Contracting Support

to know the requirement as stated in the solicitation, and what is considered to be the minimum acceptable response. For each area, generally, the evaluator must provide an evaluation of the contractor's proposal, in particular whether it meets or exceeds the minimum requirement; a narrative discussion of the evaluation; and an assessment of the risks attendant to the contractor's proposed approach.

The individual evaluations are then combined according to the individual scoring and weighting system for the particular contract action to develop relative measures of the proposals received. It is important to note that proposals are measured against the standard -- not against each other. The technical evaluations are combined with the evaluation of the cost proposals to determine that proposal which is most advantageous to the government. As an adjunct to the proposal evaluation and analysis effort, a preaward survey of those offerors being considered for award is normally accomplished. This preaward survey is accomplished by the Contract Administration Office (CAO) which has cognizance over the individual offerors' facilities based upon request by the acquisition office (and often with personnel augmentation from the program office). The purpose of the preaward survey is to determine that the offerors have the physical, financial and managerial capability to accomplish the effort described in the proposal.

The support to the contracting process is directed toward ensuring that all required manufacturing management requirements are: a) included in the solicitation, b) appropriately addressed in the proposal, c) capable of being accomplished by the proposing contractor, and d) included in the contract as awarded. The specific support activity tends often to be more extensive and intense than the discussion above may imply, especially when there are a relatively large number of offerors for a complex system. It is essential that care be exercised throughout the process to ensure that the resulting contract includes those requirements necessary to establish a firm basis for successful manufacture of the ultimate system design.

Review of an individual contractor's proposal, especially with an unsuccessful contractor, can be expected following announcement of award. In these reviews, the information provided should be factual and specific as to the proposal content and program requirements or standards. Although government evaluation factors should be available for review, scores for competing proposals are not to be disclosed as they serve no useful purpose in helping the contractor to identify critical program needs and possible proposal inadequacies.

PREPLANNED PRODUCT IMPROVEMENT

Preplanned Product Improvement (P3I) ... sometimes written, PPPI ... is an acquisition strategy which programs resources to accomplish an orderly and cost-effective phased growth of a system's capability, utility and operational readiness. P3I is directed toward the objectives of:

Shortening the acquisition and deployment time for a new system or an incremental capability;

Reducing overall acquisition and operational support costs, extending useful life of equipment, reducing technical, cost and schedule risk;

Accomplishing orderly growth from initial to mature system reliability; and

Reducing logistics and support problems entailed with new material introductions.

New System Application

P3I is normally applied to a system early in the program _ when it can be a factor in concept selection. P3I is subsequently carried forward in a program by including flexibility in the basic system design to accommodate future evolutionary improvements.

The P3I approach is a useful acquisition concept for new programs under the following circumstances:

There is a long term military requirement to be satisfied,

The threat or need is projected to change as a function of time requiring a change in the response, Required technical performance or system capability is expected to increase with time,

There is a need to field the system in the near term with less than its full capability, and

The sponsoring service is willing to pay higher initial costs to obtain growth potential for future exploitation.

DOD policy being promulgated as a result of the DOD Acquisition Improvement Program (AIP) initiated in 1981 requires the program manager to include P3I as an element of the program acquisition strategy, and to pursue P3I when it is clearly established that its application will reduce risk, acquisition time, and/or overall cost. P3I will not be used to artificially extend the development effort or correct deficiencies encountered in attaining initially specified system performance.

As the design of a new system evolves under a P3I approach, the basic design of the system will anticipate any preplanned product improvements which are identified in the military requirement documents and subsequently contained in the acquisition strategy and confirmed at milestone decisions. Provisions will include structure, space, weight, moment, power, air conditioning, and other accommodations to facilitate production incorporation and retrofit and minimize operational disruptions.

P3I is approached as a design change mechanism for incrementally phased introduction of additional system capabilities at specifically defined points. Each evolutionary materiel change should meet a corresponding aspect of the threat or exploit a technological advantage.

As stated above, P3I is not used to correct deficiencies encountered in the basic development. In particular, P3I is not a test and fix technique to achieve the reliability, availability, and maintainability (RAM) specified for initial operation; however, P3I is used to achieve a planned growth in the RAM level. Resources to accomplish P3I will be made visible during the PPBS cycle and placed in the Five-Year Defense Plan, (FYDP) Program Objectives Memorandum/Budget Estimate Submission (POM/BES) and Extended Planning Annex (EPA). Once P3I becomes a part of the acquisition strategy, failure to fund it will be considered a major change in program.

P3I is to be used where there are legitimate technical and schedule risk impediments to proceeding with a full capability system, but is not to be used as a ruse to initiate an underfunded and unaffordable program. Such programs are destined to become deficient in performance or to suffer early cancellation.

<u>Product Improvement</u>

For on going systems, i.e., those already in FSD or beyond, product improvements should be considered for incorporation only when production incorporation is not more costly than a new design, retrofit costs are reasonable, and equipment downtime is not excessive. Product improvements, rather than new product designs, should be considered under the following circumstances:

O There is change in the threat requiring increased capability or utility which is technically feasible to obtain,

O There is technological breakthrough in advanced development which will present an opportunity for significant advancement in system military worth,

O When improvement in design will provide a cost-effective means for meeting otherwise unattainable readiness requirements,

O When the system is modular or adaptive to accept upgrading,

O When there is sufficient capacity for growth in the design in the form of structural, space, weight, and power provisions so that needed engineering changes can be made without prohibitive modification costs in production or retrofit, and

O The system service life is compatible with the changes entailed.

When a product improvement is made to a weapon system, it should represent a cost-effective approach to achieving the new level of operational capability required.

CHAPTER FOUR

MANUFACTURING STRATEGY

MANUFACTURING STRATEGY

OBJECTIVE

This chapter describes the program manufacturing strategy development within the context of acquisition strategy development. A number of manufacturing strategy alternatives will be presented to aid the PM in the strategy development and definition process. In addition, specific elements of the alternative strategies are described to establish the basis for application and their conditions for use.

INTRODUCTION

Manufacturing strategy development is a key element of acquisition strategy development. As shown in Figure 4-1, the same could be said of engineering, contracting, or logistics strategy. Integrated within the program management approach, these four disciplines are primarily responsible for achieving program goals for cost, schedule, and operational effectiveness and suitability.

Strategy and the strategic planning process should involve three major features, rational decision making, a single defined goal, and optimization. Unfortunately, these features are not typical of the planning activities in many Program Management Offices (PMOs). More often the planning and the resulting strategy results from negotiation, consensus building and adaptation to decisions and constraints imposed by Congress, DOD or Service Headquarters. The time pressures inherent in the acquisition process can also contribute to a significant reduction in the emphasis on and resources committed to developing a rational strategy.

Strategy is fundamentally a long term issue. It focuses on the clear definition of the details of the program objectives and the development of an integrated approach to achieve those objectives. Measurable goals and milestones are vital for success in executing the strategy. These goals and milestones must be supported by action plans which include the underlying assumptions, allocation of responsibility, time and resource requirements and risks.

ELEMENTS OF MANUFACTURING STRATEGY

A manufacturing strategy is a detailed plan for assuring timely and cost effective production of an item which meets all operational effectiveness and suitability requirements. To be effective the strategy must be developed in consonance with program engineering, contracting, and logistics strategies, considering current and projected constraints, risks, and opportunities in the industrial-technological base. Key elements of consideration are identified in Figure 4-2.

Manufacturing strategy development must begin during the earliest stages of system development. Acquisition decisions such as system design approach and production rate are intimately intertwined with manufacturing strategy. Manufacturing strategy will affect design and production rate decisions. Design and production rate decisions will affect manufacturing strategy.

While only the most general definition of manufacturing strategy may be possible during the early stages of system development, this general definition will provide a foundation for early acquisition decisions and for later, more detailed, strategy definition. The manufacturing strategy must be flexible enough to identify and adapt to changes in the product and the manufacturing environment. Changing constraints, risks, and opportunities can affect even mature system production.

Clear manufacturing strategy development will affect government and contractor actions. Both government and contractor management will be motivated to adopt options that minimize the effect of manufacturing constraints and risks and pursue beneficial manufacturing opportunities.

Figure 4-3 lists the major elements of the manufacturing strategy for a particular program. For each element in the strategy, decisions must be made relatively early in the acquisition process to ensure that the required actions are taken in a timely manner. Tradeoffs are made, often within the context of the development of the program acquisition

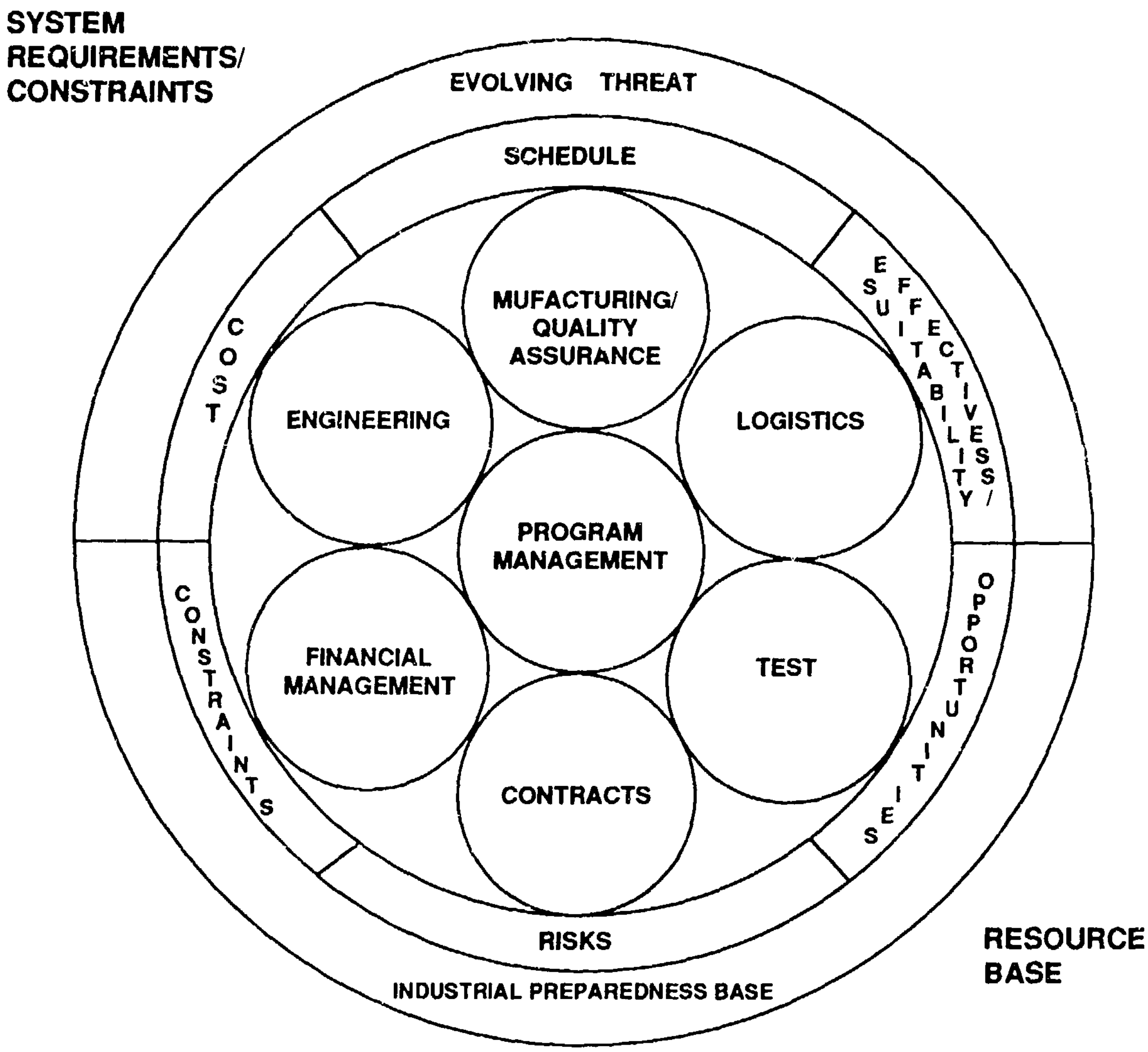


Figure 4-1 Systems Acquisition Strategic Environment

strategy. Each element has associated with it a set of costs and risks which need to be assessed against the specific program realities and technological challenges. Detailed discussion of each of these topics is provided elsewhere in this Guide, but the major decision issues in the strategy development process are described below.

Normally certain decisions are already made and serve as input to the strategy development process shown in Figure 4-4. The system to be developed and produced is described to some level of detail and some of the major milestones such as Initial Operational Capability are established. The total quantity to be produced and the estimated total funds forecast to be available are often established. Within these constraints, the detailed strateg;· is developed.

Production Competition

Decisions must be made on whether to utilize more than one source for manufacturing during the production phase. Normally, competition in this phase will act to reduce recurring manufacturing cost. The trade off is the increased non-recurring cost to establish the other source(s). Schedule and technical risk are reduced with multiple sources; however, the problem of end item variability is increased.

- INDUSTRIAL BASE CAPABILITIES
- STRATEGIC AND CRITICAL MATERIALS
- CRITICAL MANUFACTURING TECHNOLOGIES
- TOOLING AVAILABILITY
- TEST EQUIPMENT AVAILABILITY

Figure 4-2 Manufacturing Constraints and Risks

LEVEL OF PRODUCTION COMPETITION
TYPE OF PRODUCTION COMPETITION
ROLE OF PRODUCIBILITY ENGINEERING AND PLANNING
QUALITY PLANNING
QUALITY ASSURANCE APPROACH
ROLE OF INDUSTRIAL MODERNIZATION INCENTIVES PROGRAM
MANUFACTURING TECHNOLOGY INSERTION
GOVERNMENT MANUFACTURING REVIEW PROCESS
TOOLING AND TEST EQUIPMENT
GFP AND COMPONENT BREAKOUT APPROACH
CONTRACT PROVISIONS AND REPORTING
MANUFACTURING PROCESS PROOFING
PRODUCTION RATE

Figure 4-3 Elements of Manufacturing Strategy

Producibility Engineering and Planning

Decisions must be made on the structure and funding levels of the formal Producibility Engineering and Planning (PEP) program. The timing of initial formal Producibility Engineering and Planning (PEP) actions must be established and the objectives for the contracts in each acquisition phase need be determined. The activities in each acquisition phase need to build on the preceding activities and set the foundation for transition from development to production.

Quality Planning and Approach

The manufacturing approach to meeting TQM objectives must be defined. Early action by manufacturing is necessary to obtain optimum quality in the delivered system by ensuring that the constraints of materials and processes are explicitly considered.

Industrial Modernization Incentives and Manufacturing Technology

The Industrial Modernization Incentives Program (IMIP) and the Manufacturing Technology (MANTECH) Program are separate sub elements of industrial preparedness. Both programs seek to assure productivity, readiness and responsiveness of the defense industrial base through modernization of the manufacturing and management processes of the enterprise.

MANTECH focuses on advancing state-of-the-art manufacturing technologies and processes from the research and development environment (laboratory) to the production and shop floor environment. Technologies with generic application required for defense systems and having high technical and financial risk characterize the projects with the highest priority for MANTECH funding. MANTECH projects demonstrate production

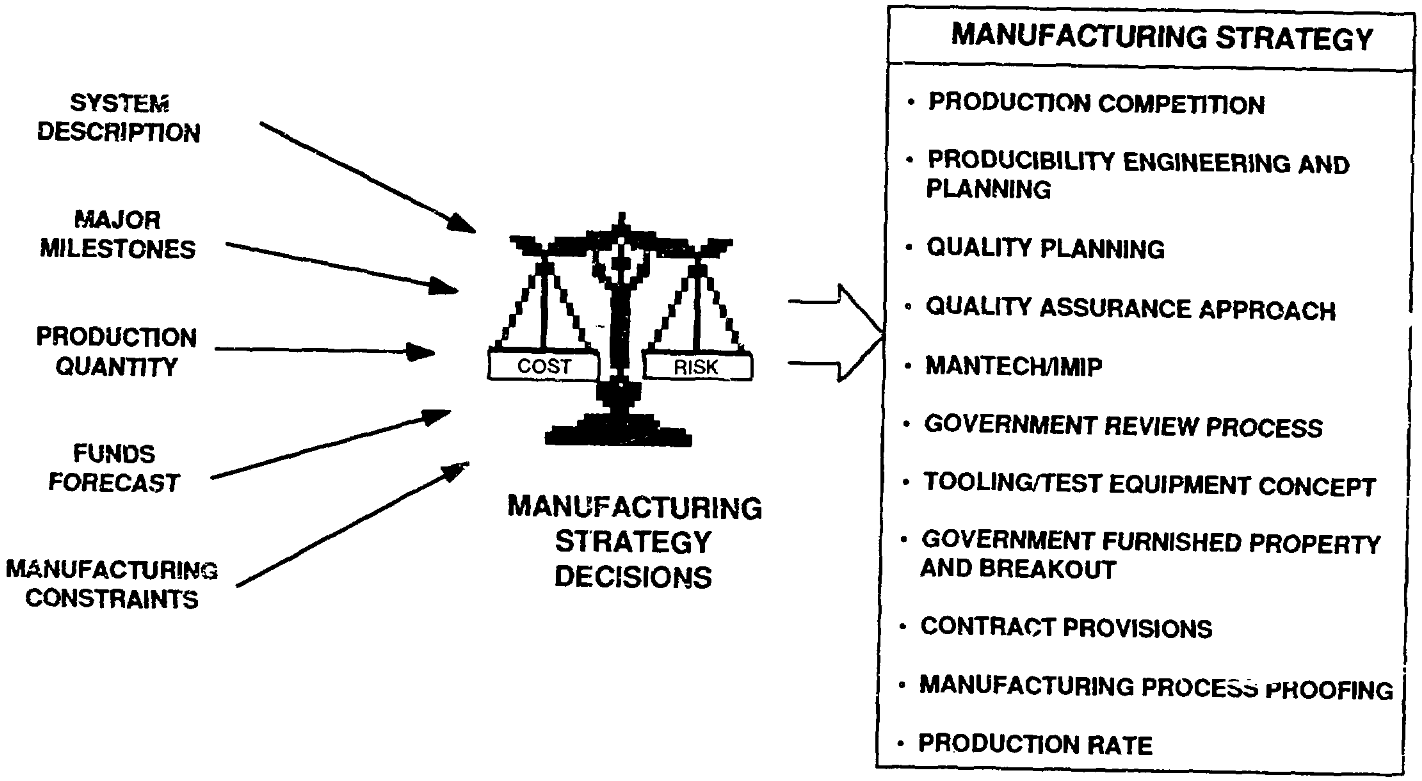


Figure 4-4 *Manufacturing Strategy Decisions*

application of emerging technologies. Proven technologies resulting from the MANTECH program are candidates for implementation under IMIP.

IMIP aims at improvements on a factory-wide basis by providing industrial incentives for modernizing the total enterprise through implementation of well established and proven state-of-the-art technologies. Although many IMIP projects have been established on an individual weapon system program basis, the government's preference is for a factory-wide approach that is applicable to all weapon systems and DOD product lines within the enterprise because it offers the greatest potential benefit to the DOD. Perhaps the most important distinction of IMIP is that it uses a business agreement to accelerate implementation of modern manufacturing technology across product lines and production contracts. IMIP couples contractual incentives with technology implementation.

MANTECH and IMIP work together to enhance productivity, reduce weapon system cost, improve industrial base capacity, and capability peacetime, surge and mobilization.

Government Review Process

Decisions need to be made concerning the amount of PMO and other government involvement during the life of the program. These decisions include the type and quantity of data items, on-site reviews, and issues and contractor decisions which will require PMO or other government organization approval. In addition to identifying the government reviews, initial decisions need to be made on the depth and extent of the reviews to serve as a basis for contractor and government resource planning.

Tooling/Test Equipment Concept

The general guidelines for planning for tooling and test equipment need to be established. The issues include contractor investment, the level of rate tooling and test equipment to be utilized, the transition from limited life to rate tools and the degree of similarity between production test equipment and depot test equipment to be required. Also, guidelines for maintaining tools and test equipment need to be set forth.

Government Furnished Property and Breakout

Providing equipment or subsystems to the prime contractor as Government Furnished Property (GFP) may reduce the acquisition cost and contribute to greater commonalty in deployed systems. There is however, a corresponding shift of responsibility for system performance and delivery from the contractor to the government. Consideration needs also to be given to the potential for later breakout of equipment of subsystems from Contractor Furnished Equipment (CFE) to GFP.

Contract Provisions

Each of the choices made in developing the manufacturing strategy must be supported by selection or development of appropriate contract clauses. Where specific actions may be planned for later phases for the acquisition process, it is often necessary to include enabling or planning provisions in the earlier phase contracts to create the proper environment and relationship for the later actions.

Manufacturing Process Proofing

The manufacturing strategy should include the criteria for determining which production processes will require proofing and the timing of such proofing activity. Process proofing can make a major contribution to risk reduction, but it may involve cost and/or potential schedule impacts during the development phase.

Production Rate

While the production rate will be constrained by the available funds profile, some allowance for variation may remain. In addition, total program cost may be significantly impacted by changes in production rate. These impacts need to be assessed and presented to the involved decision makers.

Type of Production Competition

Part of strategy development involves definition of the long term relationship between contractors and the government. Research and field experience indicate that competition between contractors can provide real benefits by encouraging contractor innovation and cost reduction. At the same time, a true strategic approach implies a long term partnership. Several approaches have been used to balance these apparent conflicts in development of a strategic government/contractor approach to system development and production. These approaches include: leader/follower contracting; component breakout, multi-year contracting, and industrial modernization incentive utilization.

DESIGN COMPETITION

Requirements should be delineated in both quantitative and qualitative terms at lower levels of detail as product development unfolds. Further requirements should always precede functional or physical means, which should then be designed or selected to satisfy the requirements.

It must be economically feasible to manufacture a quality product at a specified rate and to deliver end items capable of achieving the performance and reliability inherent in the design. This design requirement is not always well understood and historically has taken a back seat to the more popular objective of high performance. The results of this neglect have ranged from factory rework rates in excess of 50 percent to suspension of government acceptance of end items pending major redesign for producibility. A strong producibility emphasis early in design will minimize the time and cost required for successful transition to production.

DOD 4245.7-M, Transition from Development to Production specifically identifies the importance of the design disciplines enumerated in Figure 4-5. Contractor performance in these disciplines should be an important source selection evaluation criterion. Accordingly, competition should be maintained in the acquisition process until contractor performance in these critical design disciplines can be properly assessed.

DOD 4245.7-M and NAVSO P-6071, Best Practices, provide general guidelines which may be used in developing criteria for design effort evaluation. Specific criteria must be tailored to individual system requirements.

A high risk of acquisition program failure is always present at the outset of the design process. While some levels of risk associated with a new technical concept may be unavoidable, historically this risk has been magnified by the misunderstanding of the industrial design disciplines necessary to turn the concept into a mature product. The government and its contractors must share equal responsibility for this misunderstanding. The contractor's proposal and government source selection process provide the last cost-effective opportunity to ensure application of these critical disciplines during design and the achievement of design maturity.

LEADER/FOLLOWER CONTRACTING

Leader/follower contracting is a technique under which the developer or sole producer (leader company) of a product furnishes manufacturing assistance and know-how or otherwise enables another source (the follower company) to become a supplier of the product. This procurement method is sometimes referred to as "second sourcing," or leader company procurement.

Objectives of Leader/Follower Contracting

The objectives presented in Figure 4-6 represent a general outline of the elements that must be evaluated in considering the use of leader/follower contracting. Consideration of these objectives and individual program differences is essential to successful application of this approach. Vital program considerations include: supply restrictions; manufacturing quantities; program relationship to other programs; and potential improvement of product quality and/or cost reduction from the introduction of competition. Consideration of the relationship between program requirements, funding, and economic production quantities is vital, particularly when only small quantities are required.

There are several policy limitations to be considered by the program manager. For example, leader/follower contracting should be used only when the circumstances identified in Figure 4-7 are present.

Approaches

Several contractual approaches are available including:

1. Awarding a prime contract to the leader company which obligates the leader to subcontract a designated portion of the total number of end items to the follower company and to assist the follower in manufacturing

- DESIGN REFERENCE MISSION PROFILE IDENTIFICATION
- DESIGN REQUIREMENTS IDENTIFICATION
- TRADE-OFF STUDIES
- DESIGN POLICY DOCUMENTATION AND USE
- DESIGN PROCESS CONSIDERATION OF MANUFACTURING AND OPERATIONS
- DESIGN ANALYSIS INCLUDING STRESS AND STRENGTH ANALYSIS
- PARTS AND MATERIALS SELECTION CONSIDERING SPECIAL SYSTEM REQUIREMENTS
- SOFTWARE FUNCTION AND LOGIC DESIGN ANALYSIS
- COMPUTER AIDED DESIGN UTILIZATION
- DESIGN-FOR-TESTING
- CONFIGURATION CONTROL
- DESIGN REVIEW DISCIPLINE
- REALISTIC DESIGN RELEASE SCHEDULING

Figure 4-5 Critical Design Disciplines

2. Parallel production wherein two separate prime contracts are awarded. The leader company prime contract would contain a requirement that it provide the requisite assistance to the follower company for manufacturing of the items.

3. Designating the follower company as the prime contractor for the production of items, under which the follower company is obligated to subcontract with a specific leader company for the requisite know-how.

Certain factors should be considered in utilizing this acquisition strategy. It may be difficult if not impossible to maintain leader company commitment to the technology transfer without a contractually binding arrangement. Thus, if a program encounters delays or slippages because of funding or requirements changes, leader company decisions to reallocate resources to other government programs or commercial markets may seriously impact the program. This is especially pertinent if a follower company is experiencing technical problems. Maintaining control of the leader firm may be particularly difficult when the leader company is a subcontractor. Since the government has no direct contractual relationship with the leader, if a problem develops, the government's only recourse is through the follower (prime) company.

A second factor concerns the Technical Data Package (TDP). In many cases, the completeness of the TDP will be a function of the technology involved and the government's ability to both accurately state its data requirements and maintain configuration control. This implies a cost which the government must assume and is similar to costs associated with commercial practices involving licensing arrangements, joint ventures, or teaming.

A 1988 DOD Inspector General report identified cost estimating and analysis problems which have been encountered with dual source programs. Their findings indicate that the potential savings are overestimated by the cost-benefit analysis methods currently in use. They also determined that these estimates do not always consider all the pertinent costs. When developing a strategy for dual sourcing, the PM should ensure that the structure of the program is such that competition will be effective (i.e. the "loser" in a split buy does not get too high a percentage of the work). In addition, careful analysis of the full cost for implementing and maintaining the competitive environment should be accomplished, with special emphasis on the non-recurring costs to reach an effective competitive status. Systems should be in place to monitor the costs of dual sourcing for comparison with estimates and for use in evaluating potential changes to the acquisition strategy.

- SHORTEN THE TIME FOR DELIVERY
- ESTABLISH ADDITIONAL SOURCES OF SUPPLY FOR REASONS SUCH AS GEOGRAPHICAL DISPERSION OR BROADENING THE MANUFACTURING BASE
- MAKE MAXIMUM USE OF SCARCE TOOLING OR SPECIAL EQUIPMENT
- ACHIEVE ECONOMY IN MANUFACTURING
- ASSURE UNIFORMITY AND RELIABILITY IN EQUIPMENT PERFORMANCE, COMPATIBILITY OR STANDARDIZATION OF COMPONENTS, AND INTERCHANGEABILITY OF PARTS
- ELIMINATE PROBLEMS IN USE OF PROPRIETARY DATA
- EFFECT TRANSITION FROM THE FULL-SCALE DEVELOPMENT PHASE TO THE PRODUCTION PHASE AND TO SUBSEQUENT COMPETITIVE PROCUREMENT
- IMPROVE THE COMPETITIVE STATUS OF MAJOR ACQUISITIONS

Figure 4-6 General Leader/Follower Contracting Objectives

- THE LEADER COMPANY POSSESSES THE NECESSARY MANUFACTURING KNOW-HOW AND IS ABLE TO ASSIST A FOLLOWER COMPANY
- NO SOURCE, OTHER THAN A LEADER COMPANY, COULD MEET THE GOVERNMENT'S REQUIREMENTS WITHOUT LEADER COMPANY ASSISTANCE
- ASSISTANCE OF THE LEADER COMPANY IS REQUIRED TO PRODUCE THE ITEMS
- THE GOVERNMENT RESERVES THE RIGHT TO APPROVE CONTRACTS BETWEEN THE LEADER AND FOLLOWER COMPANIES

Figure 4-7 Leader/Follower Conditions for Use

COMPONENT BREAKOUT

The term "component breakout" can be defined as a program management decision of whether or not subsystems, assemblies, subassemblies, and other major elements of end items or systems should be purchased directly by the government and provided to the prime contractor as government furnished material. Here, consideration of component breakout will be limited to components that have been contractor-furnished material in a previous system buy. The approved and current acquisition plan should identify those milestones at which component breakout decisions should be made. These decisions include those which must be made early in the contracting cycle on such matters as initial program support levels of government furnished versus contractor furnished equipment and the contract provisions covering spare parts provisioning.

Objectives of Component Breakout

Whenever a prime contract for a weapons system or other major end item will be awarded without adequate price competition and the prime contractor acquires components without such competition, DOD policy is to break out those components if substantial net cost savings can be obtained without jeopardizing the quality, reliability, performance or timely delivery of the end item. Additionally, the desirability of component breakout should also be considered whenever substantial net cost savings will result from greater quantity purchases or improved logistics support. Component breakout also provides a firm basis for later direct purchase or competitive purchase of the required spare and repair parts.

Breakout Issues

There are many issues of importance to the program manager in the implementation of a component breakout program. How are breakout candidates to be identified? What logistics system risks are involved? How will economic and quantity change factors influence cost? What responsibilities will the government share or assume as a result of providing government-furnished components? Will the item be purchased competitively or on a sole source basis? The answers to these questions cross many disciplines including production, engineering, finance, and contract administration. Most weapon systems involve relatively large numbers of end items procured over the program life cycle which often extends over a number of years.

Guidelines

The program manager should base each component breakout decision on an assessment of the potential risks of degrading the end item through such contingencies as delayed delivery and reduced reliability of the component, calculation of estimated net cost savings over the program life cycle, and analysis of the technical, operational, logistic and administrative factors involved. Particular emphasis should be placed on assessing the stability of the design, the availability of item data required to support the breakout decision, and the ability of the government to transfer the design description to a potential source.

MULTI-YEAR CONTRACTING

A multi-year contract is a contract covering planned DOD requirements for an item for up to 5 years. In most cases, the contract is funded for only one year at a time. The contractor is protected against loss resulting from cancellation by contract provisions which allow reimbursement of costs included in a cancellation ceiling. This cancellation ceiling covers only nonrecurring costs, such as equipment investment which would have been amortized over the life of the contract. This technique offers significant potential for cost savings by enhancing program stability and providing contractors with the capability to optimize schedules, stabilize their workforce, purchase economic lot buys of material, and plan for investing in cost reducing capital improvements. Although multi-year contracts can benefit the government by saving money and improving contractor productivity, it can also entail certain risks, including increased cost to the government, should a multi-year contract later be changed or terminated.

Multi-Year Contracting Objectives

Multi-year contracting is encouraged to take advantage of one or more of the objectives presented in Figure 4-8.

In general, the primary objective for multi-year contracting is the potential for lower weapon system costs. Estimates of potential savings have been made in the range of 10 to 30 percent. Experience indicates that specific savings are difficult to calculate but that savings of 10 to 15 percent appear to be reasonable.

Guidelines

Multi-year contracting may be used when Congress authorizes funds for up to five years for the procurement of specified quantities. Although appropriations are still granted annually, the service agreements with the congressional committees almost guarantees the multi-year procurement (MYP) term and allows significant advanced procurement of long lead items. Multi-year contracting must make it possible to attain one or more of the objectives in Figure 4-8 where all the criteria in Figure 4-9 are present.

- LOWER COSTS
- ENHANCEMENT OF STANDARDIZATION
- REDUCTION OF ADMINISTRATIVE BURDEN IN THE PLACEMENT AND ADMINISTRATION OF CONTRACTS
- SUBSTANTIAL CONTINUITY OF PRODUCTION OR PERFORMANCE, THUS AVOIDING ANNUAL STARTUP COSTS, PREPRODUCTION TESTING COSTS, MAKE READY EXPENSES, AND PHASE OUT COSTS
- STABILIZATION OF CONTRACTOR WORK FORCES
- AVOIDANCE OF THE NEED FOR ESTABLISHING AND "PROVING OUT" QUALITY CONTROL TECHNIQUES AND PROCEDURES FOR A NEW CONTRACT EACH YEAR
- BROADEN THE COMPETITIVE BASE WITH OPPORTUNITY FOR PARTICIPATION BY FIRMS NOT OTHERWISE WILLING OR ABLE TO COMPETE FOR LESSER QUANTITIES, PARTICULARLY IN CASES INVOLVING HIGH START UP COSTS
- PROVIDE INCENTIVES TO CONTRACTORS TO IMPROVE PRODUCTIVITY THROUGH INVESTMENT IN CAPITAL FACILITIES, EQUIPMENT AND ADVANCED TECHNOLOGY

Figure 4-8 Multi-Year Contracting Objectives

- MULTI-YEAR CONTRACTING WILL RESULT IN LOWER TOTAL COSTS
- MINIMUM REQUIREMENTS FOR THE ITEM TO BE PURCHASED WILL REMAIN UNCHANGED DURING THE CONTRACT
- THERE IS A REASONABLE EXPECTATION THAT THE DOD WILL REQUEST NECESSARY FUNDS
- ITEM DESIGN IS STABLE
- COST ESTIMATES AND SAVINGS ESTIMATES ARE REALISTIC

Figure 4-9 Multi-Year Contracting Criteria

INDUSTRIAL MODERNIZATION INCENTIVES PROGRAM

The Industrial Modernization Incentives Program (IMIP) is an example of government/contractor partnership for mutual strategic benefit. Industrial modernization incentives may be negotiated and included in contracts for research, development, and/or production of weapons systems, major components, or material. The purpose is to motivate the contractor to invest in facilities modernization and to undertake related productivity improvement efforts that it would not have otherwise undertaken or to invest earlier than it otherwise would have done. Incentives may be in the form of productivity savings rewards, contractor investment protection, and/or other appropriate forms. They may be used separately or in combination. Contractor investment protection by government assumption of part of the investment risk is the keystone of IMIP. Program details including, specific goals and limitation are presented in Chapter 8.

CHAPTER FIVE

TOTAL QUALITY MANAGEMENT AS IT RELATES TO THE MANUFACTURING PROCESS

CONTENTS

TOTAL QUALITY MANAGEMENT
AS IT RELATES TO THE MANUFACTURING PROCESS

OBJECTIVE

The key objectives of DOD's Total Quality Management (TQM) approach are to broaden the focus on quality and to change the present culture dealing with the acquisition process, contractual requirements, design and manufacturing practices, and the concept of acceptable quality. This Guide is concerned only with TQM as it relates to the manufacturing process.

INTRODUCTION

Quality means meeting all of the user's needs--cost, schedule, reliability, maintainability, and all of the other attributes that contribute to a system's value. Operational superiority of U.S. weapon systems is associated with a high degree of technical sophistication and superior performance. However, that superior performance would be to no avail if industry could not produce quality equipment free of defects and consistent in performance, durability, and reliability.

Quality (excellence) is a matter of culture and behavior. We must change those cultural aspects that impede production of high quality systems. DOD is working with the services and industry to identify the key approaches to enhance quality. Many excellent tools have been developed, but DOD has not been fully successful in implementing them. Dr. Robert B. Costello, the Undersecretary of Defense (Acquisition), signed a memorandum to the service acquisition executives which initiated implementation of a DOD Total Quality Management approach. This memorandum strongly states that DOD is committed to taking a leadership position.

The TQM process is a total organizational approach to continuous improvement of quality and productivity. TQM requires management to exercise the leadership to establish the environment for the process to flourish. It involves an integrated effort toward improving performance at every level. This improved performance must satisfy goals of quality, cost, schedule, mission need, and suitability focusing on increased customer/user satisfaction.

To meet this challenge, DOD and industry must redirect the work force, change management styles, implement new processes, and most important, listen to employees, as well as their customers, the operating forces. Management must create the climate to establish challenging goals and to ensure that the work force is properly motivated. Tangible actions are necessary to stimulate changes.

Improvements in quality can provide the highest return on investment, because they involve the efficient use of existing people and material resources. The reduction of errors at every level reduces costs and improves the effective use of resources. Quality does not cost; it pays.

TOTAL QUALITY MANAGEMENT OVERVIEW

TQM is the application of methods and human resources to control the processes that produce defense materiel, with the objective of achieving continuous improvement in quality. The DOD TQM strategy also addresses the concurrent need to motivate U.S. industry to greater productivity. It is a strategy for improving the quality of DOD processes and products and achieving substantial reductions in the cost of ownership throughout a system's life cycle.

TQM draws on a rich heritage of research and experience reaching back to the development of Statistical Process Control (SPC) during World War II. The many distinguished scientists, engineers and practitioners have contributed to the rich body of knowledge include: Dr. Walter A. Shewhart (SPC), Drs. Harold F. Dodge and Harry Romig (Sampling), Ellis R. Ott (Process Quality Control), Eugene L. Grant (Statistical Quality Control), Dr. Amand V. Fiegenbaum (Total Quality Control), Dr. Joseph M. Juran (Industrial Quality Control), Dr. W. Edwards Deming (Quality and Productivity Management), Philip B. Crosby (Quality College), Genechi Taguchi (Experimental

Design), Dr. Kaoru Ishikawa (Cause/Effect Diagrams), Shigeo Shingo (Low-cost, high quality production).

At the current time, much of the implementation of TQM within American industry is being accomplished within the context of the "Fourteen Management Principles" of Dr. W. Edwards Deming. These points are shown in Figure 5-1.

The non-technical aspects of TQM include process improvement methodology including problem solving techniques, performance measurement techniques, reward and recognition system, team operating principles; dedicated, knowledgeable facilitators; intensive training; cross functional TQM teams; user and customer involvement and feedback.

- CREATE CONSTANCY OF PURPOSE FOR IMPROVEMENT OF PRODUCT AND SERVICE
- ADOPT THE NEW PHILOSOPHY
- CEASE DEPENDENCE OF INSPECTION TO ACHIEVE QUALITY
- END THE PRACTICE OF AWARDING BUSINESS ON BASIS OF PRICE TAG ALONE
- CONSTANTLY AND FOREVER IMPROVE THE PROCESS OF PLANNING, PRODUCTION, AND SERVICE
- INSTITUTE MODERN METHODS OF TRAINING ON THE JOB
- INSTITUTE MODERN METHODS OF SUPERVISION
- DRIVE OUT FEAR
- BREAK DOWN BARRIERS BETWEEN STAFF AREAS
- ELIMINATE SLOGANS, EXORTATIONS, AND TARGET FOR THE WORK FORCE
- ELIMINATE NUMERICAL QUOTAS FOR THE WORK FORCE AND NUMERICAL GOALS FOR MANAGEMENT
- REMOVE BARRIERS THAT ROB PEOPLE OF PRIDE OF WORKMANSHIP
- INSTITUTE A VIGOROUS PROGRAM OF EDUCATION AND SELF-IMPROVEMENT
- PUT EVERYBODY IN THE COMPANY TO WORK TO ACCOMPLISH THE TRANSFORMATION

Figure 5-1 The Fourteen Management Principles of Dr. Deming

The TQM concept embraces the effective integration of existing management initiatives and initiation of new techniques that have a positive impact on quality. Examples are: acquisition streamlining, statistical process control, continuous process improvement, value engineering, transition from development to production, warranties, gain sharing, Taguchi methods of experimental design, quality function deployment (QFD), simultaneous engineering and concurrent design; variability reduction and just in time, group technology or cellular methods for shop operation.

TQM is implemented by obtaining top-level commitment to TQM in both DOD and industry. It requires extensive training, review and reform of contract related policies and practices (e.g., FAR, specs and standards, administrative procedures) to radically change the acquisition culture. Pilot applications and contractor participation efforts are currently underway and much is being learned about the effectiveness of various approaches.

Current Environment

A 1987 Gallup Survey of Chief Executive Officers' views on quality revealed some disturbing conclusions. The survey found that while 81% of the CEOs laid claim to "visible top management commitment for total quality" and 63% claimed to use TQM "very often or often", only 38% of the companies used hourly employee involvement teams, only 39% used salaried involvement team, and only 45% used statistical process controls. Well over 50% of the CEOs felt that their company's cost of quality (COQ) was under 5%. Experts calculate the average COQ at 20-30% of sales. What is particularly frightening is that many CEOs don't know what percentage of their business is dedicated to avoiding waste and don't feel comfortable at guessing at a number.

This cost in terms of internal and external failures, prevention cost and appraisal costs is often 20% or more of DOD contract dollar value. This does consider reductions in performance, availability, reliability and maintainability that result from quality problems. While many contractors claim to have TQM systems, there has not been much improvement in product quality or integrity. Air Force Contract Management Division continues to find problems during their Contractor Operations Reviews, similar to those that they have found and documented in the past. The Defense Logistics Agency continues to find excessive rates of waivers and deviations, often in excess of 40%. This would indicate that problems exist in prevention, that industry is not building quality into DOD products and services. A recent "should cost" review documented that 45% of testing is really re-testing and that 80% of sustaining engineering is dedicated to Material Review Boards (MRB) and failure analysis.

This must be changed. One way is through greater use of process control in place of product inspection. An example is the Air Force Variability Reduction Program (VRP) to improve combat capability through defect reductions. The objective of VRP is to design and build to target value specifications rather than tolerances. These values are directly related to achieving the user's operational requirements. As the manufacturing process becomes more capable, the yields increase as defects decrease.

Good Enough Versus Continuous Improvement

For a long time, DOD followed the concept of "minimum acceptable" quality. America's manufacturers and DOD maintenance depots have pursued this concept with the resignation that a persistent level of errors, perceived as irreducible, was a way of life. This concept was a major contributor to high failure rates and the escalating cost of repairs. DOD cannot tolerate this concept if it intends to maintain a leadership role among industrial nations.

Previous DOD quality programs focused on inspection, or ensuring conformance to requirements. Total Quality Management changes the focus of quality from inspection to continuous process improvement. The essence of this approach is providing the impetus for improving requirements, design, and manufacturing processes.

Manufacturers must implement rigorous and effective defect prevention process control programs. The process operation should continuously strive for improvement rather than accept a predetermined level of defects. By building a series of quality checks into the process, all imperfections will eventually be screened out and corrected during the process. This approach will dramatically change the prevailing mind-set and be pivotal in the cultural change being advocated.

Unfortunately, in the past DOD accepted inefficient work and rework as a normal state of affairs. Yesterday's errors became the basis for planning today's contracts. Responses to some RFPs for production contracts have shown that 30 to 40% of the fabrication and assembly cost is for reprocessing. Forty-five percent of the test cost is for equipment and labor to troubleshoot and retest failed items. These figures are based on the time expended on contracts for correction of errors.

DOD uses specifications and standards to impose contractual requirements. These documents are essential to the acquisition process because they provide the baseline for the proposal and source selection process, as well as the legal basis to determine contractual compliance. One of the requirements found in these documents is Acceptable Quality Level (AQL) or the Lot

Tolerance Percent Defective (LTPD). These provisions were originally intended to institute standard sampling procedures to ensure quality integrity of large production lots. Such numerical values, however, have been used by many manufacturers to justify lack of action in instituting effective process controls to improve quality. These contractors have accepted the "good enough" concept, and have lost sight of good business practices aimed at customer satisfaction. Allowing a persistent level of errors as a way of life has contributed to unacceptable failure rates in defense equipment and to the escalating cost of maintenance and logistic support.

The DOD, to rectify the perception of allowable defects and stimulate changes to improve product quality, has recently directed its specification preparing activities to remove AQLs and LTPDs as fixed requirements in military product specifications. This action will provide opportunities to improve quality to the maximum extent possible by promoting competition based on excellence.

Intricate sampling plans based on prescribed AQLs required the inspection of products to determine acceptance, thereby relieving the contractor of further responsibility for quality. The new approach recognizes the value of sampling inspection techniques as a quality assurance tool. It removes, however, the inference that a predetermined amount of defects are expected and allowable. It enforces the concept that all delivered products are expected to comply with the established technical requirements.

Contractors must institute effective process controls and in-process inspection techniques that preclude out-of-tolerance conditions during manufacturing in order to achieve continuous improvement and the ability to compete on the basis of quality. By stabilizing the process well within acceptable limits, the "defect-detection" approach is replaced with the "defect prevention" technique. The latter does not leave the process to chance and then require screening of the good from the bad at the end of the process, nor does it rely exclusively on a sampling inspection that offers a measure of the degree of non-compliance.

The procurement system must become more flexible. Designers must work closely with manufacturing engineers and logisticians. This team must develop producible designs that meetperformance expectations and are affordable. DOD has already created such teams in the Office of the Secretary of Defense, with members from research and advanced technology, production, and logistics.

TQM is essential to achieve these goals. Therefore, contracts should be awarded to companies whose products and services reflect the application of TQM and who have demonstrated outstanding reliability. Recent changes to the FAR require that quality be considered as a factor in source selection.

PRINCIPLES OF TOTAL QUALITY MANAGEMENT

TQM is a term in general use, although there is no specific agreed-upon definition within DOD. The five principles of TQM have been identified as follows:

- User satisfaction; meet your customers' requirements
- Problem prevention - not problem detection
- Continuous process improvement
- Innovation in products, processes and services
- Involve everyone

The focus of the TQM efforts are directed toward assuring that the systems and equipment provided to the operational forces have, and will continue to have throughout their life span, performance characteristics which satisfy the required level of military capability.

These directions need to be interpreted within the structure of the DOD TQM approach and the DOD Posture on Quality shown in Figure 5-2.

TOTAL QUALITY MANAGEMENT TOOLS

Total Quality Management requires the synergistic interaction between management philosophy and procedures, and quality technologies. No single checklist or formula can be developed to institutionalize this philosophy in the DOD procurement community.

- QUALITY IS ABSOLUTELY VITAL TO OUR DEFENSE, AND REQUIRES A COMMITMENT TO CONTINUOUS IMPROVEMENT
* A QUALITY AND PRODUCTIVITY ORIENTED DEFENSE INDUSTRY, WITH ITS UNDERLYING INDUSTRIAL BASE, IS THE KEY TO OUR ABILITY TO MAINTAIN A SUPERIOR LEVEL OF READINESS
- IMPROVEMENTS IN QUALITY PROVIDE AN EXCELLENT RETURN ON INVESTMENT AND, THEREFORE, MUST BE PURSUED TO ACHIEVE PRODUCTIVITY GAINS
* TECHNOLOGY, BEING ONE OF OUR GREATEST ASSETS, MUST BE WIDELY USED TO IMPROVE CONTINUOUSLY THE QUALITY OF DEFENSE SYSTEMS, EQUIPMENTS AND SERVICES
* QUALITY MUST BE A KEY ELEMENT OF COMPETITION
* ACQUISITION STRATEGIES MUST INCLUDE REQUIREMENTS FOR CONTINUOUS IMPROVEMENT OF QUALITY AND REDUCED OWNERSHIP COSTS
- MANAGERS AND PERSONNEL AT ALL LEVELS MUST BE HELD ACCOUNTABLE FOR THE QUALITY OF THEIR EFFORTS
- COMPETENT, DEDICATED EMPLOYEES MAKE THE GREATEST CONTRIBUTIONS TO QUALITY AND PRODUCTIVITY. THEY MUST BE RECOGNIZED AND REWARDED ACCORDINGLY
- QUALITY CONCEPTS MUST BE INGRAINED THROUGHOUT EVERY ORGANIZATION WITH THE PROPER TRAINING AT EACH LEVEL, STARTING WITH TOP MANAGEMENT
- PRINCIPLES OF QUALITY IMPROVEMENT MUST INVOLVE ALL PERSONNEL AND PRODUCTS, INCLUDING THE GENERATION OF PRODUCTS IN PAPER AND DATA FORM
- SUSTAINED DOD-WIDE EMPHASIS AND CONCERN WITH RESPECT TO HIGH QUALITY AND PRODUCTIVITY MUST BE AN INTEGRAL PART OF OUR DAILY ACTIVITIES

Figure 5-2 DOD Posture on Quality

TQM must be based upon a recognition of the need for interactions between various disciplines. There is a natural tendency to search for the solutions to a problem within one's own discipline. For example, some promote the view that management commitment is the key to a successful TQM. Others focus on the use of quality technology. Any myopic view is disastrous in TQM because it is a team effort. Management must have a conceptual understanding of quality technology including statistical thinking and tools. Technical personnel must understand management's role and limitations. DOD managers, both in industry and government, must perform within the framework of DOD acquisition laws and regulations. Also, statisticians and other quantitatively trained personnel must avoid the pitfall that statistical thinking and tools are the total solution. The use of statistical techniques is certainly necessary, but definitely not the single sufficient condition for success. Experience has shown that use of statistics has a limited impact unless its use is supported by a larger system such as TQM. By institutionalizing TQM, the DOD program managers can help ensure the proper role and use of quality technology. Thus, TQM tools do not merely include statistical methods, but also include concurrent engineering, computer applications, CAD/CAM systems, producibility analysis, data-management and analysis systems, value engineering, transitioning from development to production templates, and several other techniques outlined in the various chapters of this guide.

This section will focus upon the TQM tools pertaining to quality technology.

Basic Tools of Statistical Process Control(SPC)

One key element of the continuous quality improvement concept is process control. For many manufacturing processes, statistical process control (SPC) is most effective. SPC is based on the premise that all processes exhibit variation; in other words, it is an analytical technique for evaluating the processes and taking action based on stabilizing the process within the desired limits.

SPC is one of the most widely used statistical quality control techniques in the United States. Two things have caused this to happen: first, the rediscovery of the works of Dr. W. Edwards during the early 1980's; second, the major push for SPC brought about through applications in the automobile industry.

SPC is an operator's tool. It assists the operator in making timely decisions about the process: adjust, leave alone, or shutdown and take corrective action before defects are produced. SPC provides evidence of how a process is performing. SPC helps distinguish between patterns of natural variation (expected), and the non-desirable, unexpected variations (assignable to malfunction). SPC provides a better understanding of how the processes affect the products. Assurance of conformance is, therefore, obtained through defect prevention by control of the various processes, rather than after the fact. Clear understanding of the causes and extent of variation can also be used as a basis for reducing the process variability, thus improving the quality of the output.

The Japanese have trained a large portion of their work force in the use of seven basic quality control tools. These are also sometimes referred to as the elementary SPC tools and are used by the production workers to solve day-to-day shop floor quality problems, mainly through their quality improvement teams and employee suggestion systems. The number of suggestions turned in by Japanese workers is legendary. While the average number of suggestions per employee per year in the United States is 0.1, the figure in Japan is 10. More important, over 80% of the worker suggestions are approved by the Japanese management. This is mainly because Japanese workers are trained in the basic tools of quality control and thus experiment with their own ideas, pilot runs, and submit their suggestions to management only when they are reasonably sure of success. Thus, instead of having a few professionals to tackle problems, they have an army of problem solvers. The following is an outline of the objectives and methodology for each of the seven (7) basic quality control tools:

1. P.D.C.A. (Plan, Do, Check, Act)

The PDCA cycle is a problem solving tool by trial and error and consists of the following iterations:

- Plan the Work

- Execute

- Check Results

- Take action if there is a deviation between desired and actual results

- Repeat the above cycle until deviation is reduced to zero.

This tool is used mostly by production workers and whenever more powerful techniques are unknown or unsuitable.

2. Data Collection and Analysis

This is generally the first step in identifying and reducing the variation in any process. The major steps involved are:

- Define specific reasons for the collection of data

- Decide on measurement criteria

- Assure accuracy of measuring equipment (minimum 5 times greater than product requirement)

- Randomize and stratify data collection (time, material, machine, operator, type and location of defects)

- Analyze data using several SPC, or Design of Experiments (DOE) tools.

3. Graphs/Charts

The most common types of graphs/charts are bar charts, line charts, and pie charts. These are tools for the organization, summarization, and statistical display of data. Their main objective is to display trends, reduce data, or communicate and explain data. It is important that the purpose of using graphs or charts be clearly established and the usefulness periodically examined.

4. Check Sheets/Tally Sheets/Histograms/Frequency Distribution Diagrams

There are several types of check sheets: for process distribution, for defective items, causes, defect locations (sometimes referred to as "measles charts"), and as memory joggers for inspectors while checking products. Their main function is to simplify data gathering and to arrange data for statistical interpretation and analysis.

Histograms and frequency distributions provide a graphical portrayal of variability. Their shape often gives clues about the process measured, such as mixed lots (bimodal distribution); screened lots (truncated distribution); amount of spread relative to specifications; non-centered spread relative to specifications. There are two general characteristics of frequency distributions that can be quantified--central tendency and dispersion.

5. Pareto's Law

Vilfredo Federico Pareto was a nineteenth-century Italian economist who studied the distribution of income in Italy and concluded that a very limited number of people owned most of its wealth. The study produced the famous Pareto-Lorenz normal distribution law, which states that cause and effect are not linearly related; that a few causes produce most of a given effect; and, more specifically, that 20% or less of causes produce 80% or more of effects.

Dr. Joseph M. Juran, however, is credited with converting Pareto's law into a versatile, universal industrial tool applicable in diverse areas, such as quality, manufacturing, supplier materials, inventory control, cycle time, value engineering, sales and marketing. In fact, in any industrial situation, by separating the few important causes from the trivial many, work on the few causes can be prioritized. Figure 5-3 is a typical example of a Pareto chart and its usefulness. Three items, which alone accounted for $2,800 per month of loss (or over 80% of the total loss) as shown in (a), were prioritized and reduced to $1,400 per month as shown in (b), before the remaining problems were resolved.

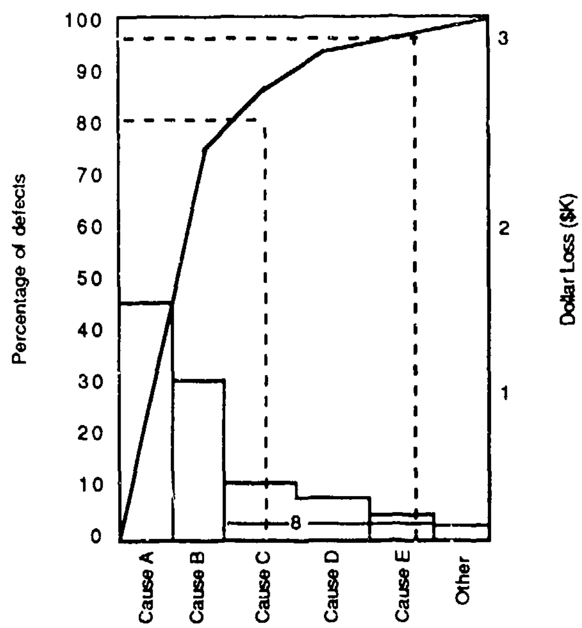
6. Ishikawa Diagram

This technique was developed by Dr. Kaoru Ishikawa, one of the foremost authorities on quality control in Japan. The Ishikawa Diagram is also known as cause-and-effect diagram or, by reason of its shape, a fishbone diagram. It is probably the most widely used quality control tool for problem solving among blue-collar workers in Japan. While it is a relatively simple tool, its effectiveness is less than optimal. This is mainly because it allows only one cause to be varied at a time and thus, the interaction effects are missed, which in turn results in only partial solutions and, thus, less than optimal improvement in quality.

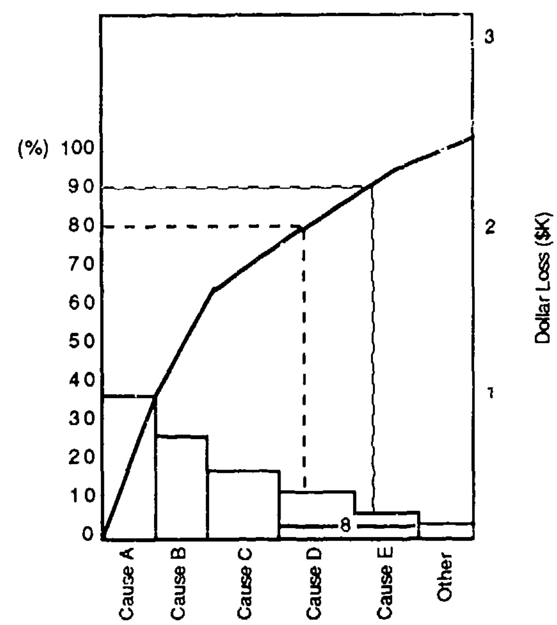
Figure 5-4 is an example of a cause-and-effect diagram, listing all the possible causes that can produce solder defects in a wave solder process. (For the sake of simplicity, only two major branches: machine and machine materials are shown. Figure 5-4 is an excellent compilation of all the variables that can cause a solder defect. It also highlights with circles those variables judged to be important.

7. Control Charts

In the minds of some quality professionals and nonprofessionals alike, the control chart is synonymous with SPC. In reality however, control charts are simply a maintenance tool. Their main function is to maintain a process under control, once its inherent variation has been established and minimized. The most common misuse of control charts is put them into effect in order to solve problem. If there is a known problem, the application of control charts will not solve it. It will simply confirm that a problem exists. Any improvement must come by reduction in the inherent variation in the process. This can be accomplished in a limited fashion by simple tools such as brainstorming and cause and effect diagram; or, more effectively through the use of sophisticated Design of Experiments.



(a) Before Improvement



(b) After Improvement

Figure 5-3 Examples of Pareto Chart Before and After Improvement

<u>Design of Experiments (DOE)</u>

The main objectives of Design of Experiment (DOE) techniques are to:

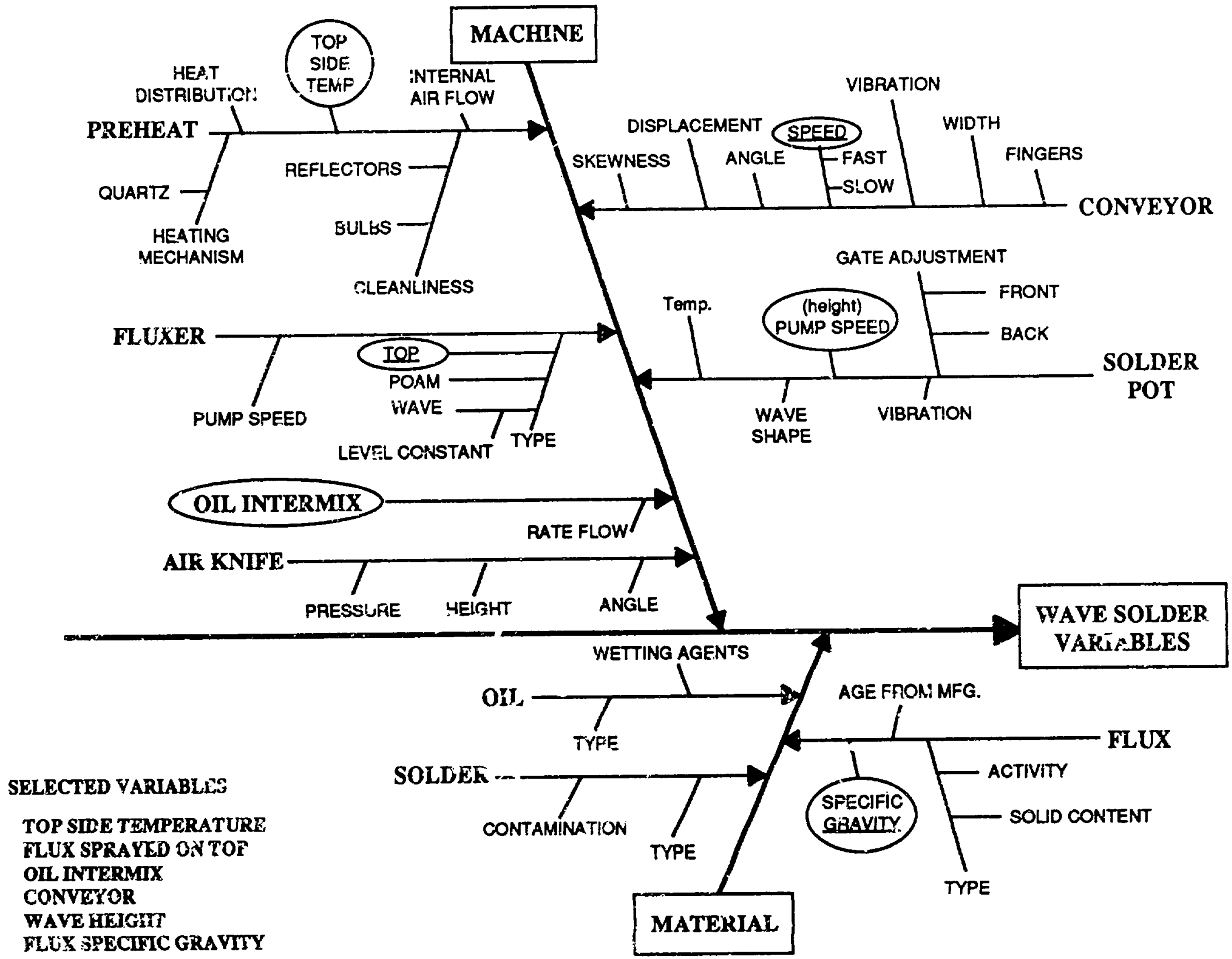


Figure 5-4 Sample of Ishikawa Diagram

- o Identify the important variables' whether they be product or process parameters, materials or components from suppliers, environmental or measuring equipment factors.
- o Separate these variables into one to four important variables
- o Reduce the variation on the important variables (including the tight control of interaction effect) through close tolerancing, redesign, supplier process improvements, etc.
- o Open up tolerances on the unimportant variables to reduce cost substantially.

The classical approach for DOE was pioneered in the early 1920's by Dr. R. A. Fisher, who devised techniques for running agricultural experiments in the imperfectly controlled conditions of the outside world, rather than in a greenhouse. His methods produced good results in medicine, education, and biology and were quickly adopted in these disciplines. In general, however, managers' understanding and support of DOE in mainstream industry in U.S. and Europe has been limited.

While the classical DOE developed by Fisher was based upon a factorial design, the Japanese have been very successful in using fractional factorial designs and other orthogonal arrays to improve products early in the manufacturing process. Dr. Genichi Taguchi, in particular, has emphasized the importance of DOE in minimizing variations and bringing the mean on target, in making products resistant to variations in components.

Taguchi's Quality Philosophy

Before dealing with Taguchi's DOE techniques, it is important to understand the basic elements of Taguchi's quality philosophy. The following seven points explain these basic elements:

1. An important dimension of the quality of a manufactured product is the total loss generated by that product to society.

2. In a competitive economy, continuous quality improvement and cost reduction are necessary for staying in business.

3. A continuous quality improvement program includes incessant reduction in the variation of product performance characteristics about their target values.

4. The user's loss due to a product's performance variation is often approximately proportional to the square of the deviation of the performance characteristic from its target value.

5. The final quality and cost of a manufactured product are determined to a large extent by the engineering designs of the product and its manufacturing process.

6. A product's (or process's) performance variation can be reduced by exploiting the nonlinear effects of the product (or process) parameters on the performance characteristics.

7. Statistically planned experiments can be used to identify the settings of product (and process) parameters that reduce performance variation.

These seven points do not cover all of Taguchi's ideas. Some of these points have also been made by other quality experts.

Variation Reduction

Perhaps the most important distinction between the conventional and Taguchi's approach to deal with process or product variability is the way the need for variation reduction is perceived. According to the conventional wisdom, no matter how narrowly a parameter falls within specification limits, the user will be 100% satisfied; and no matter how narrowly a parameter falls outside a specification limit, the user will be 100% dissatisfied. Taguchi's approach, on the other hand, surmises that loss occurs not only when the product is outside of specifications, but also when the product falls within specifications. In addition, the loss continually increases as the product deviates further from the target value. While a loss function may take on many different forms, Taguchi has found that the simple quadratic function approximates the behavior of loss in many cases. When the quality characteristic of interest is to be maximized (such as tensile strength) or minimized (such as part shrinkage) the loss function may become a half parabola. The loss function promotes efforts to continually reduce the variation in a product's functional characteristics. Taguchi's method of quality engineering can be used to attain such improvements.

Controllable Factors Versus Noise Factors

To minimize loss the product must be produced at optimal levels and with minimal variation in its functional characteristics. Two factors affect the product's functional characteristics: controllable factors and noise (or uncontrollable) factors. Controllable factors are factors that can easily be controlled, such as choice of material, cycle time, or mold temperature in an injection molding process. Noise factors, on the other hand, are nuisance variables that are either difficult, impossible, or expensive to control.

There are three types of noise factors: outer noise, inner noise, and between product noise. For the injection molding process, the ambient temperature and humidity may be the outer noise; the aging of the machinery and tolerances on the process factors may be the inner noises; while manufacturing imperfections are generally responsible for the between product noise. Noise factors, in general, are responsible for causing a product's functional characteristic to deviate from its target value. The goal is not to identify the most "guilty" noise factors so that an attempt can be made to control them. Controlling noise factors is very costly, if not impossible. Values should be selected for the controllable factors to make the product or process least sensitive to changes in the noise factors; that is instead of finding and eliminating causes, as the causes are often noise factors, the impact of the causes should be removed or reduced.

Parameter

The tool used to achieve the robustness against noise factors and reduce cost is called parameter design. Parameter design, Taguchi style, involves experimental design techniques utilizing orthogonal arrays and the signal-to-noise ratio. In the United States, most engineers are conditioned to spend money to reach required product performance levels. They jump from system design to tolerance design, often omitting parameter design-the step where they can reduce costs and improve quality most efficiently.

The strategy in Taguchi's experimental design is to recognize controllable factors and noise factors and to treat them separately. The search for interactions among controllable factors is de-emphasized, although there are exceptions. The key to achieving robustness against noise is to discover the interactions between controllable factors and noise factors. Specific interactions between controllable factors and noise factors need not even be identified. As long as the noise factors are changed in a balanced fashion during experimentation, preferred parameter values can be determined using an appropriate signal-to-noise ratio.

Summary of the Taguchi Approach

The Taguchi approach is displayed in Figure 5-5. According to John Vergoz, vice president of technology at the Budd Company in Troy, MI, "A definite benefit to the Taguchi methods is that design engineers and process engineers learn how to talk to each other in a common language." The two groups can quantify the relationships between the manufacturing process and the design requirements.

Vergoz adds that design and process engineers can pinpoint which variables have the strongest functional relationship to product's requirements. The Taguchi methods isolate the effects on the product of adjusting manufacturing variables that can be controlled. The methods isolate the effects on the product of adjusting manufacturing variables that can be controlled. The methods also determine what effect uncontrollable variation in the manufacturing process has on quality.

Vergoz points out three strengths of using the system. First, the methods help determine the functional relationship between those things that can be controlled and the outcome of the process. Second, the methods can be used to move the mean of the process results to the desired position by changing controllable variables. Third, the Taguchi methods determine the relationship of noise - data and variables the cannot be controlled, including the stackup of normal processing tolerances - to the variation in the product as manufactured.

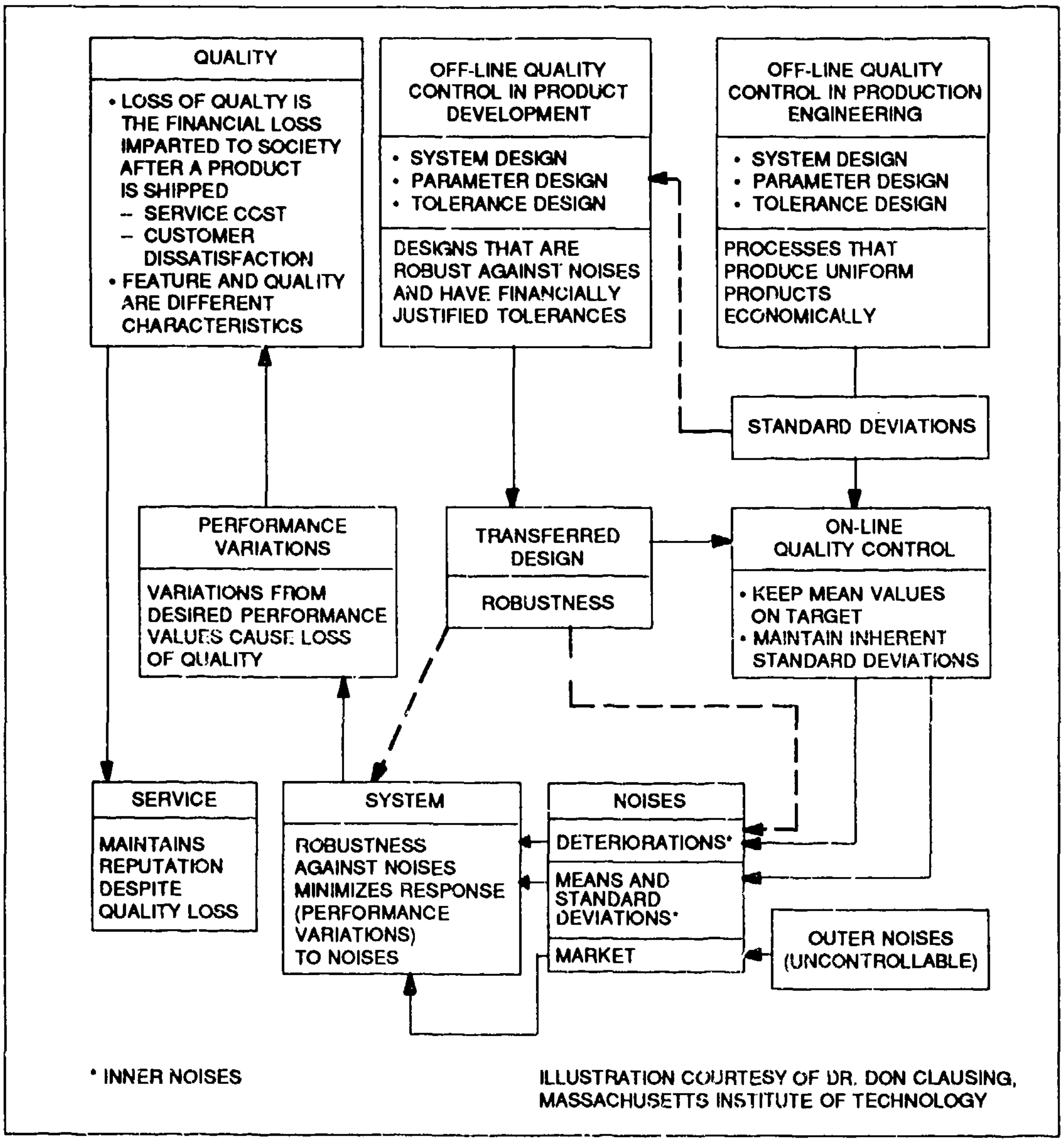


Figure 5-5 Off-line and On-line Quality Control Via Taguchi

Quality Function Deployment (QFD)

Quality function deployment (QFD) is an overall concept that provides a means of translating user requirements into the appropriate technical requirements for each stage of product development and production (i.e., marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production sales). This concept is further broken down into "product quality deployment" and "deployment of the quality function"

The basic idea of QFD originated in Japan and was introduced to U.S. industry by Dr. D. Clausing. Ford Motor Co. and several supplier companies were pioneers in the development of QFD as an operating mechanism to transform customer expectations into specific design and manufacturing requirements. The first U.S. automotive vehicle to benefit from this formalized form of QFD was the 1988 Lincoln Continental. In a recent speech, William E. Scollard, Ford's vice president of manufacturing operations, characterized QFD simply as the means to "build cars for the taker--not the maker."

In the past U.S. industry has concentrated more on meeting company or technical requirements, and less on customer expectations. Now, the task is "How can we deploy customer expectations into technical requirements with ali company functions integrated through a common set of work load determinants?" From a hardware standpoint, several U.S. companies (especially Ford) have been very successful in the application of QFD for product improvement; many case studies now available illustrate how matrix charts or binary tables have helped integrate various diverse activities within a company or division.

Key terms most frequently associated with QFD are as follows:

1. The Voice of the User
The user's requirements are expressed in their own terms.

2. Counterpart Characteristics
An expression of the user's requirements in technical language that specifies user-required quality; counterpart characteristics are critical final product control characteristics.

3. Product Quality Deployment
These are the activities needed to translate the voice of the user into counterpart characteristics.

4. Deployment of the Quality Function
These are the activities needed to assure that user required quality is achieved; the assignment of specific quality responsibilities to specific departments. The term "quality function" does not refer to the quality department, but rather to any activity needed to assure that quality is achieved, no matter which department performs the activity.

5. Quality Tables
These are a series of matrices used to translate the voice of the user into final product control characteristics.

To understand QFD, it must first be understood that the approach to quality is fundamentally different in U.S. and Japanese companies. In Japanese companies, the user's voice drives all activities, while in many U.S. companies, it is the executive's voice or the engineer's voice that prevails. Furthermore, as compared to many U.S. companies, Japanese companies pay more attention to fixing what the user doesn't like. That is, the Japanese put more effort into designing quality at the product design stage, while U.S. companies put a greater emphasis on problem solving.

In QFD, all operations of the company are driven by the "voice of the user"; QFD therefore represents a change from manufacturing process quality control to product development quality control. Kobe Shipyard, Mitsubishi Heavy Industries, Ltd., formalized QFD in 1972, marking the beginning of this movement in Japan.

QFD brings several benefits to companies willing to undertake the study and training required to put the system in place:

o Product objectives based on customer requirements are not misinterpreted at subsequent stages.

o Particular marketing strategies or "sales points" do not become lost or blurred during the translation process from marketing through planning and on to execution.

o Important production control points are not overlooked -- everything necessary to achieve the desired outcome is understood and in place.

o Tremendous efficiency is achieved because misinterpretation -- of program objectives, marketing strategy, and critical control points -- and need for change are minimized.

The QFD system concept is based on four key documents as follows:

1. <u>Overall User Requirement Planning Matrix</u>

This translates the voice of the user into counterpart control characteristics; that is, it provides a way of turning general user requirements--drawn from market evaluations, comparisons with competition, and marketing plans--into specified final product control characteristics.

2. <u>Final Product Characteristic Deployment Matrix</u>

This translates the output of the planning matrix--that is, the final product control characteristics--into critical component characteristics. Thus, it moves one step farther back in the design and assembly process.

3. <u>Process Plan and Quality Control Charts</u>

These charts identify critical product and process parameters, as well as control or check points for each of those parameters.

4. <u>Operating Instructions</u>

The operating instructions are based on the critical product and process parameters; these instructions identify operations to be performed by plant personnel to assure that important parameters are achieved.

The overall QFD system based on these documents traces a continuous flow of information from user requirements to plant operating instructions; it thus provides what W. Edwards Deming calls "a clear operational definition" -- common purpose, priorities, and focus of attention.

PROGRAM MANAGEMENT REQUIREMENTS

The DOD requires that the program management office (PMO) develop and manage quality programs to achieve the specific objectives shown in Figure 5-6.

Current DOD philosophy and procedures recognize that quality is not something that naturally results from the development or improvement of systems and equipment but, instead, is the result of focused effort and attention during program planning, design, and manufacture. To achieve quality objectives in deployed systems, DOD Directive 4155.1 charges the program manager with the responsibility for the development and execution of a program to assure the quality of systems being acquired for use. More specifically, the directive defines quality assurance as a planned and systematic pattern of all actions necessary to provide confidence that adequate technical requirements are established, products and services conform to established technical requirements, and satisfactory performance is achieved.

In developing material for field use the DOD quality effort is based on three mutually supportive objectives: quality of design, defect prevention, and quality of conformance. Quality of design reflects the inherent capability of the system or product to meet the needs of the user. Defect prevention involves those manufacturing or quality control techniques used to prevent defects in manufacturing or in equipment to be provided to DOD users. Quality of conformance is the measure of the extent to which the physical real system conforms to the design criteria and the needs of the user.

<u>Quality of Design</u>

The quality of a particular design is the inherent capability of the product resulting from that design to meet user's needs. The objective of the DOD acquisition process is to provide to the operational forces cost-effective products that are mission-capable upon receipt and throughout their operational life. This requirement is integral to the three basic quality of design issues:

- Performance
- Reliability
- Maintainability

Measures of quality of design may be characterized in terms of the emphasis on each of these issues received during design of the complete product -- including design effort to reduce exceptional manufacturing or support burdens.

Performance: What is the demonstrated level of military performance of the end system? In this regard, we look to those characteristics that give the item military utility -- such as payload, range, effective radiated power, thrust, probability of kill, speed, or any of a vast array of quantitative parameters. The quality of design is reflected in the level of the performance characteristics that can regularly be obtained under field conditions without damage or excessive wear and tear on the equipment. This perspective of the quality of design is intimately related to our military strategy regarding use of technology as a force multiplier and, thus, it is a significant element in successful design evolution.

Reliability: How long can the user count on the system to provide utility? Quantitative reliability engineering, as an aspect of quality of design, deals with the duration and probability of failure-free performance under stated conditions. Reliability is a function of the design complexity and the inherent ability of the parts of the system to continue functioning properly under operational conditions. It is influenced by design decisions on quantitative issues such as stress levels, design margins, part selection, part simplicity, redundancy, and operating temperatures. When the system as designed interacts with its use environment, the inherent reliability of the design is the basis for prediction of the duration and probability of failure-free service -- assuming that the design has not been degraded by the manufacturing processes. In this sense, the quality of design can be viewed as a boundary because the system, as produced, cannot be better than the theoretical quantitative quality of design.

Maintainability: What is the likelihood that the system can be retained in or returned to its specified capability while in the use environment? The maintainability of a system is a measure of the level of difficulty involved in retaining, through preventive maintenance, or restoring, through repair or replacement, function to the system when maintenance is performed by personnel having prescribed skill levels, and using defined procedures and resources. Maintainability of the design measures such quality of design choices as complexity, accessibility, and testability in the installed condition. The measures provide a quantitative relationship among quality of design decisions and the resulting skill level requirements, special equipment requirements, and related resource requirements for resolving test, repair and other similar issues.

- **ASSURE MISSION AND OPERATIONAL EFFECTIVENESS AND USER SATISFACTION WITH DOD PRODUCTS**
- **ASSURE THAT ALL SERVICES AND PRODUCTS IN WHICH THE DOD HAS AN INTEREST CONFORM TO SPECIFIED REQUIREMENTS**
- **ASSURE THAT ESSENTIAL QUALITY AND RELATED TECHNICAL REQUIREMENTS ARE CONSISTENT WITH CUSTOMER NEEDS**
- **TAILOR CONTRACTUAL QUALITY REQUIREMENTS FOR EACH ACQUISITION IN COMPLIANCE WITH DOD DIRECTION FOR SPECIFICATIONS AND STANDARDS APPLICATION**
- **ASSURE THAT ALL THE ABOVE ARE COST EFFECTIVE**

Figure 5-6 Objectives of DOD Quality Programs

The combined effect of the inherent reliability and maintainability quantifies the operational availability of the system. By "availability" we refer to the proportion of time in which the system is capable of performing its defined mission. Where the availability inherent in the design is low, it can be improved by special support and maintenance action or by restriction on system use, but these actions incur penalties in cost to support the system. Reliability and maintainability emphasis in design means that an operational availability approach to quantifying system parameters can result in higher quality of design than a fragmentary suboptimized approach would produce.

In developing designs that will exhibit the requisite quality, the PM office must continually evaluate the design as it evolves to determine the adequacy of contractor attention to quality issues and to determine the expected level of the resulting quality of the design. In their participation in the design process, the PM office should focus on the quality characteristics of the design. A quality characteristic can be defined as a basic element that is determined to be one of the requirements for arriving at a configuration or design that will satisfy the user need or mission involved. In one sense, all of the descriptors and characteristics of the design could be defined as quality characteristics, since the eventual performance is a composite of all the design details. This definition is too cumbersome to be of value in prescribing design review activity. The PMO should limit the field of definition to only that set of design elements or features that have quantitative and theoretically auditable impact on the system's performance and availability. This set could include issues such as parts' relative stress levels, materials, test parameters, dimensions and tolerances, grade of parts used, system and subsystem complexity, controlled manufacturing processes, system producibility, and inspectability. These elements represent characteristics that must be controlled during the production of the system to ensure that the quality of conformance is not degraded.

QUALITY ASSURANCE

The quality of DOD materials and equipment is the responsibility of every person involved in the acquisition and management of DOD materiel. The issue of product quality must be a central issue from the program initiation through the production and deployment phase of the life cycle. Within DOD, the "Quality Concept" illustrated in Figure 5-7, consists of quality of design, prevention of defects, and workmanship. The interrelationship of each is suggested by the size of each cell and its border relationship to the adjacent cell.

The quality of design effort begins with the Concept Exploration/Definition phase of the program life cycle, continues through Full-Scale Development, and many times continues into production and even redesign after deployment. Often mistakes in design are revealed due to production problems encountered when production is attempted or when customer complaints report problems relating to quality of design.

Defect prevention starts with the first development-production planning, and continues through the operation and deployment phase of the life cycle. Figure 5-8 shows the relative savings attainable by early focus on product quality. Workmanship is normally associated with the initial production efforts and continues throughout the production phase. Any time a problem in quality becomes evident, the required corrective action must be taken to correct or fix the problem and its causes.

DOD Directive 4155.1, Quality Program, provides broad and general policy for the implementation of quality programs throughout DOD.

Quality of Conformance

The production phase of the acquisition process has a major impact relative to quality characteristics. Quality of conformance becomes a reality or a failure as the result of production efforts. The manufacture, processing, assembling, finishing, and review of the first article and first production units, is where failure or success in the area of quality of conformance is first measured. The original design quality characteristics can be easily altered in production. Any operation which causes the characteristic to be outside of the specified limits will render the configuration of the product different from that which was originally intended. This sometimes results in the granting of waivers, deviations, or changes which may alter the fitness for use.

A quality program requirement in accordance with MIL-Q-9858A is used on major system acquisitions, in addition to a standard inspection requirement. MIL-Q-9858A requires the contractor to establish and maintain a quality program acceptable to the government in accordance with the military specification. This requirement is established when the technical require control of work operations, in-process requirements to the contract are such as to controls and inspection, as well as attention to other factors (e.g., organization, planning, work instructions, documentation control, advanced metrology).

MIL-Q-9858A requires the contractor to develop written procedures and make them available procedures before beginning production under the contract.

Contract Administration Office Role

In addition to specifying the proper contract quality requirement, the contract must also stipulate the place of performance of government acquisition quality assurance (Government source inspection) and the place of acceptance of the supplies or services. When government quality assurance actions are at source, the Contract Administration Services (CAS) element has the responsibility for assuring contractor compliance with all of the contract provisions including the contract quality requirements. Normally, the Defense Logistics Agency (DLA) is the CAS element responsible for contract administration, and DOD Directive 4105.59 provides a list of assignments. Plant cognizance may be assigned to the Army, Navy, or Air Force if they have predominant interest at a contractor's plant. The CAS component Quality Assurance Representative (QAR), who is assigned the responsibility for the contractor facility, is the individual charged with responsibility for assuring that the contractor complies with all contract quality requirements, including evaluating and determining the acceptability of contractor's inspection system or quality program, and for performing product inspection to assure quality of conformance.

DESIGN	WORKMANSHIP
DEFECT PREVENTION	

Figure 5-7 DOD Quality Concept

Quality Feedback

The last element which affects the product quality is the feedback after the item is in use. The results of the design and manufacturing efforts receive their real test when the item or system is actually placed in use. If all of the prior efforts have not been adequately performed, the resulting product may fail to meet the user's needs. The goal is to strive for no failures and full user satisfaction. If this is not achieved, there is still the potential for correction to remove the cause of failure and of the user discontent. Of course, this is most difficult at this late stage of the acquisition cycle. Engineering changes after this point cost more to implement than those discovered during initial design; therefore, it is important that all quality actions take place during design, development, and manufacture of the product.

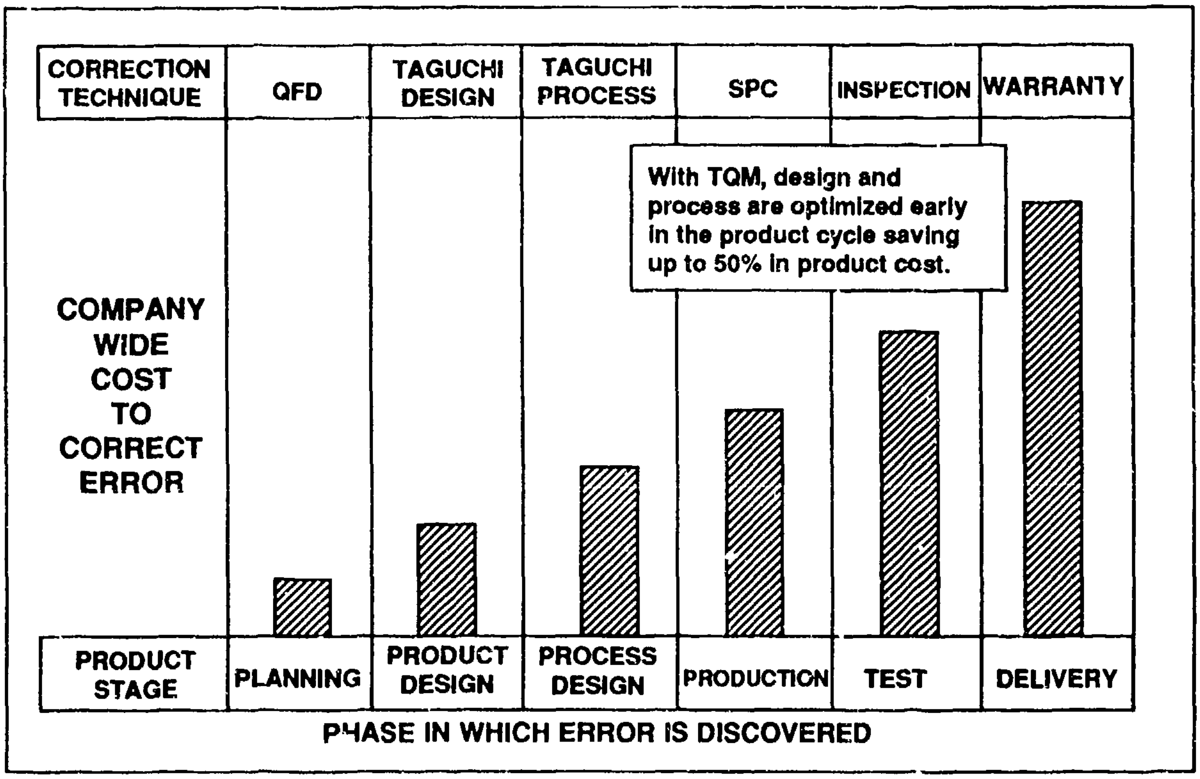


Figure 5-8 Potential Savings

RELIABILITY AND MAINTAINABILITY

DOD's policy on weapons system reliability and maintainability, as outlined in Directive 5000.40, July 1980, rates operational availability as equally important as operational performance and requires managers of military development programs to ensure that reliability factors are engineered into their systems from the earliest design phase.

The shift in DOD emphasis from performance as the single measure of a weapons system's effectiveness to one of performance set against a backdrop of the total life cycle cost of ownership has been an evolutionary process. The DOD Directive is an internal document that establishes the Defense Department's policy on reliability and maintainability, and will be used to convey that policy down to the level of systems program managers in the individual services.

The DOD reliability and maintainability policy has five major objectives as shown in Figure 5-9.

The intent of Directive 5000.40 is not only to inject reliability and maintainability into the early engineering phase but to document the achievement of required standards by establishing a series of reliability goals and thresholds for the program managers to meet from the start of the engineering and development process.

Reliability of Design

Reliability focuses on the issue of the duration or probability of failure-free performance under stated conditions. It is generally recognized that system reliability is a direct function of the system design and that success in achieving reliability in fielded systems is a result of two factors: attention to reliability during the design phase and testing to measure attained reliability as part of a planned reliability growth program.

O Apportionment of Reliability Requirements: establishing the necessary subsystem, equipment and part reliability required to meet system requirement.

O Parts Derating: the use of parts with specified performance characteristics much greater than the performance limits by the design.

O Parts Control and Standardization: minimizing the number of different part configurations and using parts with known performance.

- **INCREASE WEAPONS SYSTEM READINESS AND MISSION SUCCESS RATIOS**
- **REDUCE THE MILITARY SERVICES' MAINTENANCE AND LOGISTICS SUPPORT COST**
- **LIMIT THE MANPOWER NEEDED FOR MAINTENANCE AND SUPPORT OF ADVANCED WEAPONS SYSTEMS**
- **PROVIDE DOD MANAGERS WITH FEEDBACK INFORMATION ON THE PERFORMANCE OF WEAPONS SYSTEMS UNDER OPERATIONAL CONDITIONS**
- **ENSURE THE BEST RETURN ON INVESTMENT IN TERMS OF OPERATIONAL CONDITIONS**

Figure 5-9 Major Objectives of DOD Reliability & Maintainability Policy

There is a growing emphasis on the need to make reliability issues a more visible part of the design process. This emphasis reflects a recognition that reliability of the system is a basic function of the specific elements of the design, and that post-design fixes are an inefficient mechanism for achieving reliability targets. Some of the specific reliability activities which should be considered during design phase include:

O Failure Mode Effects Analysis: providing an evaluation of each potential mode and mechanism of failure, probability of occurrence and probable effect on performance.

O Design Simplicity: using the minimum number of parts, thus reducing complexity.

O Minimized Terminal and Component Temperature: reducing thermal stresses.

O Redundancy: assuring mission success in the event of single system failure.

O Increased Safety Margins: allowing for continued performance in over-stress situations.

These activities may lead to design solutions which invoke penalties within other design measures such as cost, weight or performance. The ultimate objective of the design process is to achieve, through appropriate trade-off, a balance between operational effectiveness and ownership cost.

Reliability Testing

An additional area of importance to the PMO is the requirement that programs include provisions for demonstration and test to show that the quantitative requirements have been achieved.

Reliability testing and the evaluation of test data provide tangible results concerning the reliability of design. The results of conducting the analyses based on test data are thus very critical since they serve as the cornerstone for many decisions such as design adequacy, assurance that reliability under field conditions will be adequate, and the need for design changes. The utilization of test data for reliability analyses must be very carefully planned and evaluated.

In general there are two categories of tests which can be used to provide information for supporting evaluations. These are the measurement tests (i.e., tests designed to measure reliability), and evaluation tests (i.e., tests which generally result in a regression analysis designed to evaluate relationships between environments or stresses and parameters which influence the reliability of an item). Properly used, both categories of tests can be used to provide information for monitoring reliability progress or for identifying the potential areas where greater concentration is required to achieve objectives. However, it should be pointed out that the approach to planning, analysis, and use of results depends, in a large measure, on the category of test being conducted.

Since test data can be extremely valuable in monitoring, it is important to be able to identify the types of tests that are often applied. These tests, shown in Figure 5-10, can frequently be used as sources of reliability oriented information, provided of course that planning has been such that the appropriate reliability data will be recorded along with information normally obtained from these tests:

It should be pointed out that the assurance of reliability program effectiveness requires a continuous monitoring and evaluation based on various data developed either through design analysis or through test. A considerable amount of test data, which is particularly useful as a means of evaluating reliability and maintainability, can often be made available in early stages of a program through proper planning and utilization.

Reliability Growth

Reliability growth is a function of the maturity of design and the application of engineering and test resources. It provides visibility to the decision-makers of how reliability is improving throughout the program. In general, reliability growth is the result of an interactive design process. As the design of various items/systems matures, the designer identifies actual or potential sources of failures and proposes product redesign or manufacturing process improvements to resolve problems.

Reliability growth assessments (Figure 5-11) are used in controlling the growth process through examination of reliability growth curves which are generated and maintained for the items under consideration. Reliability growth curves (Figure 5-12) show both the planned and assessed growth, and a comparison of these values will indicate program progress. On the basis of these comparisons, the contractor or PMO can develop appropriate strategies involving reassignment of resources or adjustment of time frame. The monitoring of reliability growth involves comparisons of the on going activities against the applicable reliability program plans. The activities are monitored to establish whether performance conforms to the management plan. An additional area of importance of reliability monitoring is the design review at various stages of the development effort to determine whether the product design adheres to the expressed and implied performance requirements.

Reliability in Manufacturing

The reliability of the as-built product is bounded by the inherent reliability of the design. In achieving design reliability in the manufactured product, it is critical for the design team to specify the physical and functional requirements which must be achieved in the parts and components. Whenever possible these requirements should be described in a manner that will allow

- QUALIFICATION TEST
- PREPRODUCTION TEST
- LOT ACCEPTANCE TEST
- INDIVIDUAL ACCEPTANCE TEST
- CRITICAL WEAKNESS RELIABILITY TEST
- TEST TO FAILURE

Figure 5-10 Typical Tests Yielding Reliability Information

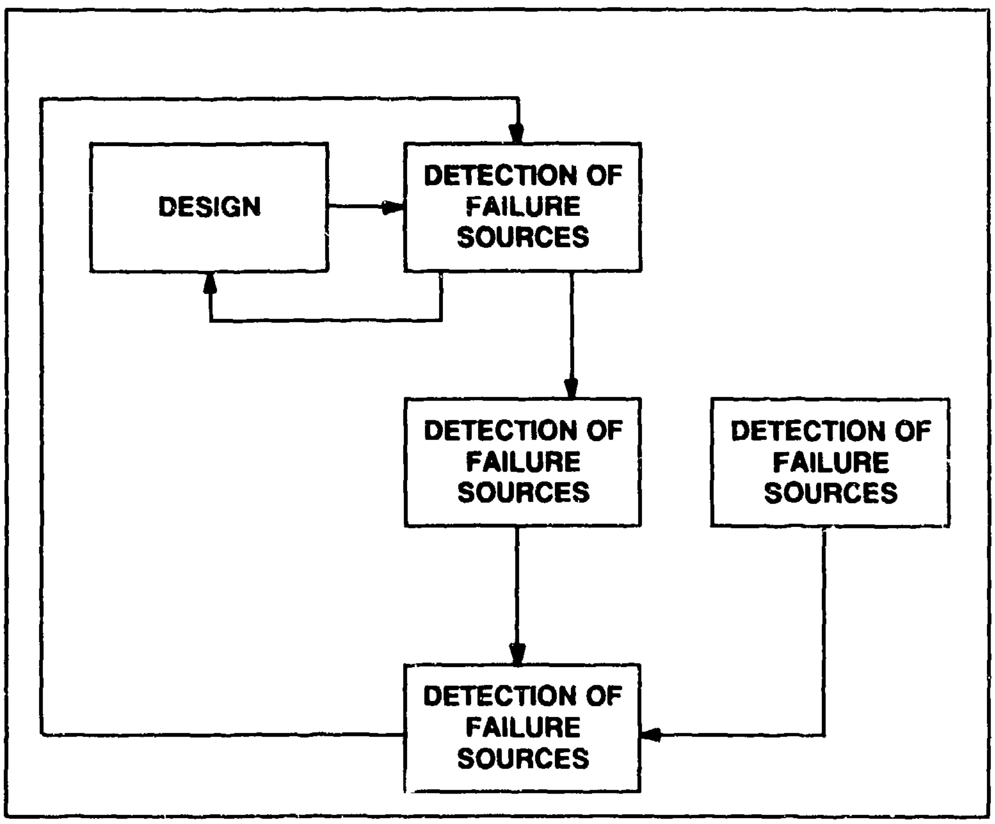


Figure 5-11 Assessment of Reliability Growth

in-process control during manufacture. These requirements should be included in the company's quality planning for both in-house and subcontractor manufacturing.

significant improvements in achieved reliability and quality.

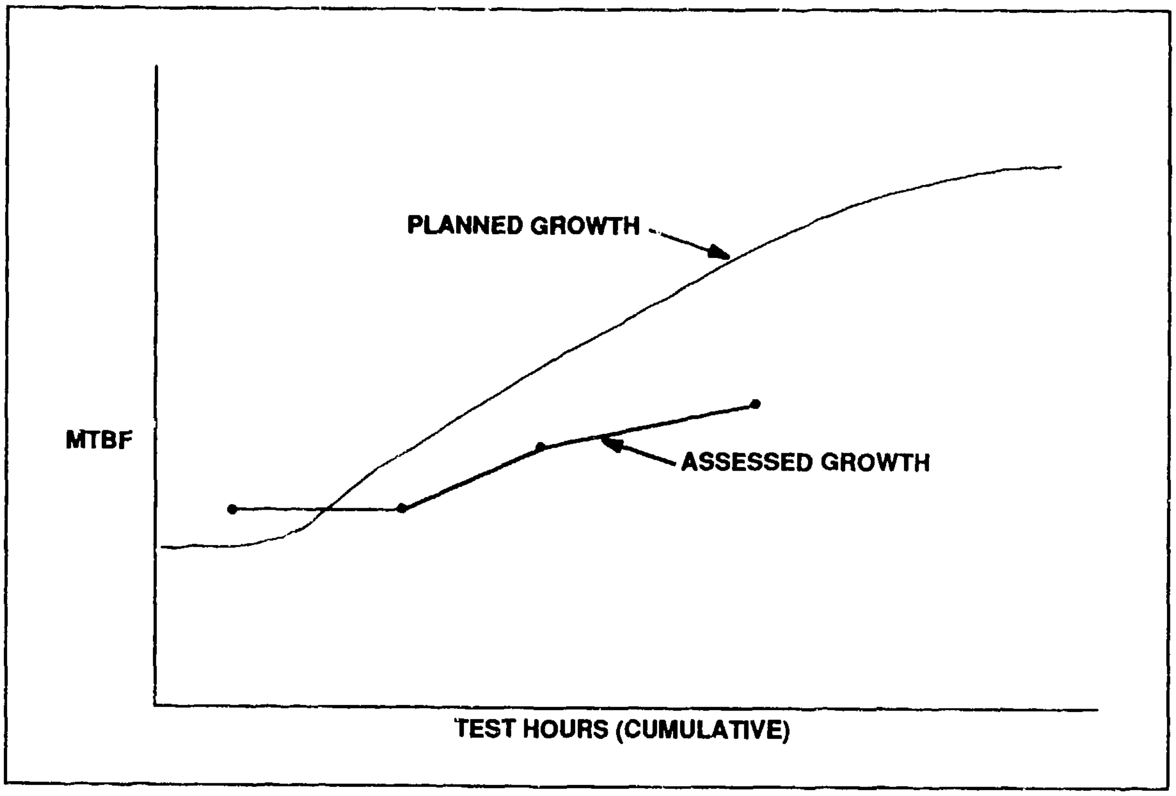


Figure 5-12 Reliability Growth Curve

Even where the controls above are specified, there is some risk that reliability of the hardware may be degraded by changes in tooling, processes and work flow. These types of changes are a normal part of most manufacturing programs. To assure that these changes do not have a negative impact on hardware reliability, Production Reliability Acceptance Testing (PRAT) can be required by the PMO. These tests are accomplished on delivered or deliverable production items under specified conditions, to assure that the manufacturer has complied with the specified reliability requirements. The PMO must specify the particular items to be tested, the test duration, frequency and test plan and environment. In addition, focused emphasis on continuous process improvement can yield

Reliability and Maintainability Quality Team Concept

Because of its potential value, it is important to briefly describe the Reliability and Maintainability (R&M) quality team concept which has been used successfully. The new concept is the idea of Major James F. Guzzi, when he was serving as R&M Manager for the C-17 Aircraft being developed by Douglas Aircraft Company as the airlifter of the future. The concept uses R&M Quality Teams and a Review Council.

Industry's approach to building a weapon system -- a complex engineering and manufacturing task -- emphasizes the need to recognize and understand the dynamic process that defines total system R&M. Any program organization must be innovative in its approach to achieve the desired understanding of this process. R&M are always addressed; however, today the need to achieve better R&M can be enhanced by a new integrated approach. The technology and management system are equal partners in this effort.

The R&M Quality Team concept provides an enhancement of the R&M management approach during the Full Scale Engineering Development phase of a weapon system program and does not disturb the integrity of the organization. During this phase, the design requirements of the weapon system are engineered "in" and the resultant inherent R&M characteristics and the related combat capability are "locked in".

With the focus being placed on the importance of R&M, the opportunity to do it right the first time becomes the challenge for both industry and the government who work as a team to meet the goal. The team approach provides an atmosphere of understanding for a win-win solution.

In multi-functional organizations, the objective to achieve system R&M requirements requires that the organization use a system engineering approach that has a focus on system level R&M design requirements throughout the total development process. The system R&M concept allows an organization to successfully manage the R&M efforts across the total design organization.

The basic premise of the R&M Quality Team concept supports the R&M design process and the need to provide an innovative approach to enhance the management of system R&M during the design process. The following basic assumptions provide a foundation for an understanding of the development of the concept.

- R&M is co-equal in importance to cost, schedule and other performance factors.

- R&M is a total system design process that affects the whole organization.

- The management of R&M is not the responsibility of a single function. It is the responsibility of the organization to "manage" the system approach to R&M through the integration of all functions.

- Management commitment drives the program, provides guidance and control, and ensures R&M requirements are met.

A system level management approach is used to achieve the R&M design goals through the leadership of its members. The effective manager understands the dynamics of team communication and effectively carries out these tasks. In addition to team management, information dissemination is a critical factor and must also be clearly carried out. Once established, communication and information influence changes and allow enthusiastic workers to establish and reach individual, team, and organizational goals. A total system level process allows feedback and insures a team solution will be successful. The method of team solution can be defined as participative or power-sharing concept, the R&M Quality Team concept achieves equality with the other factors in the solution.

Participative decision making (PDM) is straight forward -- a mode of joint decision-making in a participative, focused climate. Decisions are made by a group of people with each member of the group making an input to the final decision. It is truly a system engineering approach. PDM is also considered as a continuum with managers varying the level of team and individual participation according to immediate task requirements, participation characteristics, situational conditions, and likely task outcome. R&M Review Councils and Quality Teams are designed to use PDM to achieve integrated solutions.

An R&M Quality Team concept has been conceptualized and developed to focus management attention on the system level R&M process during Full Scale Engineering Development. The concept is simple, but well founded, and it provides a powerful means to streamline and enhance the communications and system engineering process in a total organization. This concept has provided the capability for a directed response to system R&M problems while creating an atmosphere for system change. The approach facilitates R&M engineers and systems designers to work as a chartered team under the guidance and direction of an R&M Review Council.

The R&M Quality Team concept, which is defined in Figure 5-13, establishes and integrates the lines of communication among the functions of the Review Council shown in the vertical direction in the figure and in the horizontal direction by the Quality Teams. This process creates a R&M management network within an existing organization. Activity is managed by the Review Council to insure that the "focus" is not diluted in the functional activities and insures that R&M is part of the design effort. In essence, the concept creates a system engineering approach that drives the R&M goals to meet the total system level requirements.

most R&M for the process is assured. The results to date using this concept have been very impressive and have demonstrated a potential for enhancing the acquisition process for a weapon system. The concept provides the invaluable ability to effectively manage transition of a program from development to production. For example, the concept links design to manufacturing through the Review Council and the team interactions. Further, it provides an R&M focus throughout the production process and this translates to production quality.

TOTAL QUALITY MANAGEMENT INTEGRATION

There are a number of related efforts which can make major contributions to achieving TQM objectives. As the program

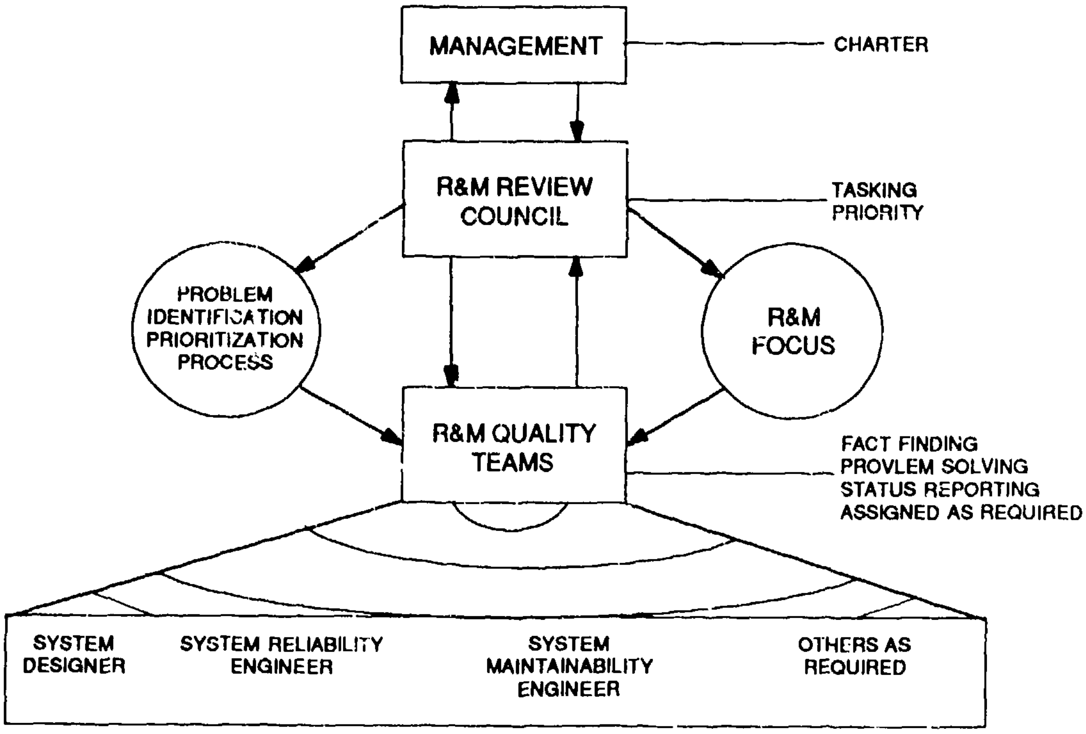


Figure 5-13 Reliability and Maintainability Quality Team Model

Through enactment of an R&M Quality Team concept, management commitment is built-in and the necessary focus to provide the plans in these areas are developed, attention to the TQM principles and objectives is necessary to maximize the impact of TQM on the acquisition process.

Concurrent Engineering

Concurrent engineering is a systematic approach to product design that considers all of the elements of the product life cycle. Concurrent engineering defines the product, its manufacturing process and other required life-cycle processes such as maintenance.

The advantage of concurrent engineering is illustrated in Figure 5-14. See Chapter 11 for an additional discussion about Concurrent Engineering.

Recent changes to the Federal Acquisition Regulations make quality a factor in the source selection process. The intent is not to exclude any potential bidder, but to raise the quality consciousness of those companies/suppliers who plan to bid on a newcontract, and to give due consideration to those companies/suppliers with a good record and with products and services that reflect the application of continuous quality improvement techniques. Through this approach, the acquisition cost is placed in the proper perspective as related to the total cost of product ownership.

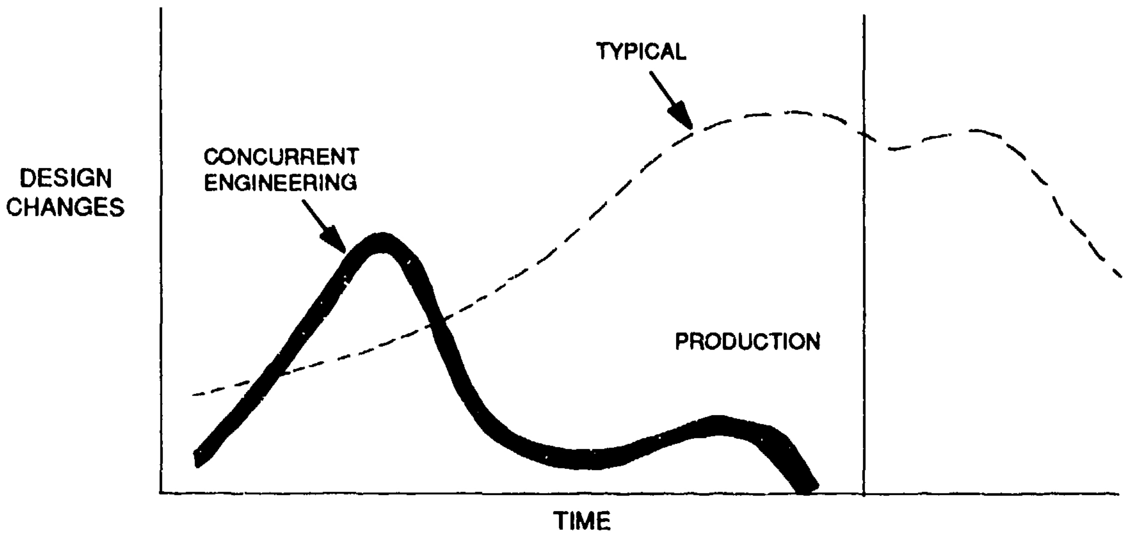


Figure 5-14 Concurrent Engineering Approach vs. Typical Approach

Quality in the Source Selection Process

The procedures used to award contracts have traditionally focused on the lowest bid. While this approach enhances competition; quality is not always given adequate consideration. To further compound the problem, past history of performance does not always play a role in determining eligibility for contract award. In other words, contractors with poor performance history may continue to compete on an equal basis with contractors who are more capable of producing quality products and who have a good reputation in dealing with the government.

Industrial Modernization Incentive Program

The Department of Defense IMIP is a joint venture between government and industry to accelerate the implementation of modern equipment and management techniques in the industrial base. An IMIP is considered when competitive market forces are insufficient to motivate independent contractor modernization. An IMIP can also be implemented when significant benefits such as cost reduction, elimination of production bottlenecks, improved quality, reliability, maintainability and improved surge capability will result.

The short term IMIP objectives are to reduce defense costs and lead times and increase the quality of manufacturing through productivity gains. The long term objective is a strong responsive industrial base capable of meeting current needs as well as surge and mobilization requirements.

Benefits of IMIP can be measured in terms of stimulating capital investments, increasing manufacturing flexibility and production capacity to respond to defense requirements, and realizing savings throughout the life of a more reliable weapon system that is produced in modern facilities. IMIP offers contractors the opportunity to pursue something that under "business as usual" conditions, would be unacceptable financially, or too risky technically. The program is expanding and in the future it will take on a broader focus in the DOD support infrastructure.

Warranties

Much has been said about warranties in the context of providing assurance of quality. Warranties are used successfully in the commercial world, and they do present a good tool in our quest for quality. As contrasted with the commercial market, however, the majority of DOD purchases are for unique equipments and systems produced in small quantities. Moreover, these equipments are handled and serviced by government personnel and, considering the number of people involved, the complexity of the supply system, and the various performance requirements that cannot be readily tested, it becomes very difficult to effectively administer warranties.

The primary intent for using warranties should be to motivate contractors to improve the quality of their products, so that they would reap financial benefits by avoiding the warranty cost of repairs and replacements. Warranties are no substitute for quality, and should not be used as a crutch. Simply put, when a system fails to accomplish the mission for which it was intended, the warranty can never compensate for potentially devastating results.

Acquisition Streamlining

Acquisition streamlining is a major initiative directed at the development of realistic and cost effective contract requirements. The program objectives are to reduce the time and cost of weapon system acquisition, and to improve quality. It ensures that only the necessary requirements are imposed during each acquisition phase through tailoring of military standards. This approach gives program managers greater latitude to defer imposition of military specifications and other detailed "how to" contract requirements until industry has had the opportunity to recommend the most technically appropriate and cost effective approaches.

Efforts are underway to enhance streamlining policies to encourage early analysis and tradeoffs to weapon system cost and performance, in order to achieve the best value for the DOD. The military departments and industry are working together to identify outdated and unnecessary military specifications and standards, and come up with better procurement documents that are compatible with new technology. A recent survey indicated that streamlining is resulting in significant reductions in lead time and cost of weapon system acquisition, as well as enhanced quality due to better understanding and timely imposition of requirements.

Value Engineering

Value engineering is a systematic effort directed at analyzing the function of systems, equipment, facilities, services, and supplies, to achieve essential functions at the lowest life-cycle cost without compromising the required performance, reliability, quality, and safety. Value engineering is also used to improve quality and reliability, thereby achieving additional long term benefits.

The DOD Value Engineering Program has two elements: one is the in-house activity performed by DOD personnel; the other is the DOD contractor program. Both elements have provided financial rewards. During the 1986 fiscal year, the in-house program yielded approximately one billion dollars in savings, while contractor proposals amounted to an additional savings of $450 million.

CHAPTER SIX

MANUFACTURING PLANNING AND SCHEDULING

CONTENTS

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:

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

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

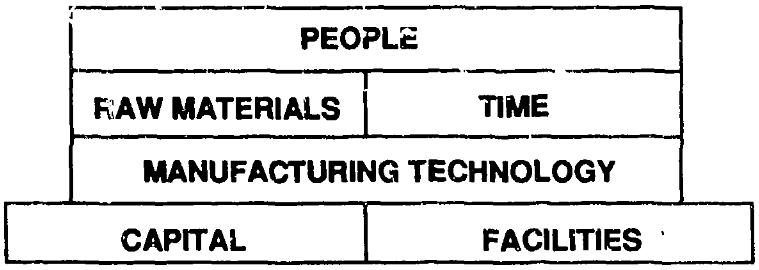


Figure 6-1 Manufacturing Resources

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 (probably 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

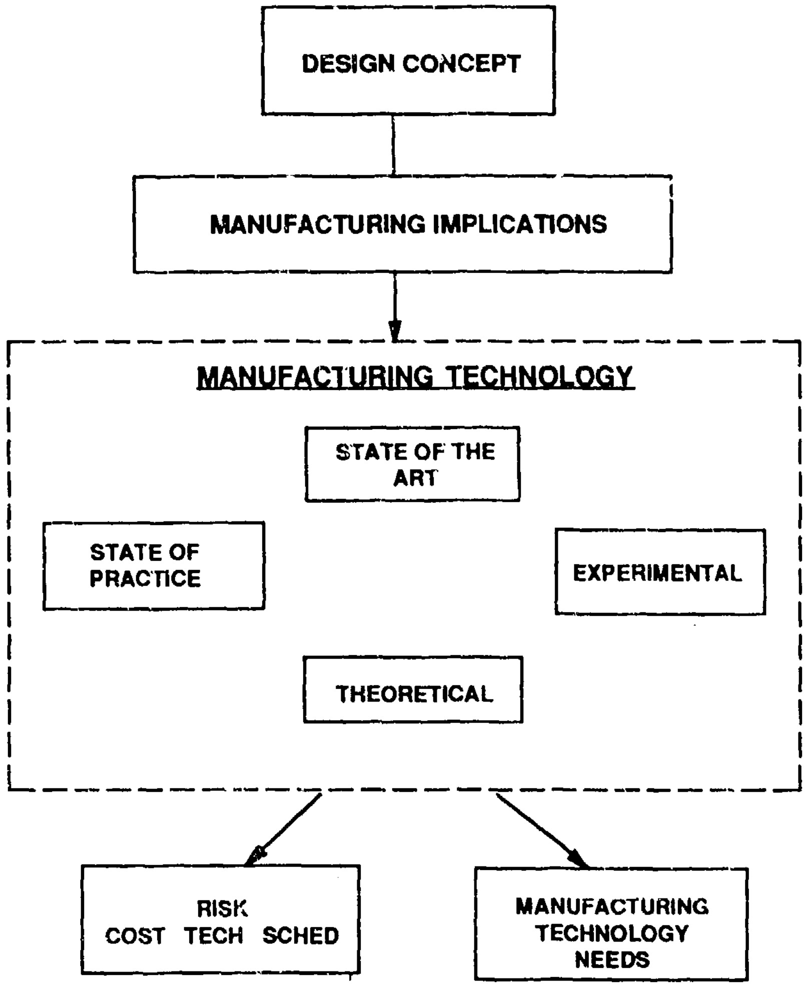


Figure 6-2 Manufacturing Risk Assessment

of the manufacturing elements such as tooling, receipt of purchased parts and materials, fabrication, assembly, test, product assurance, and delivery.

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

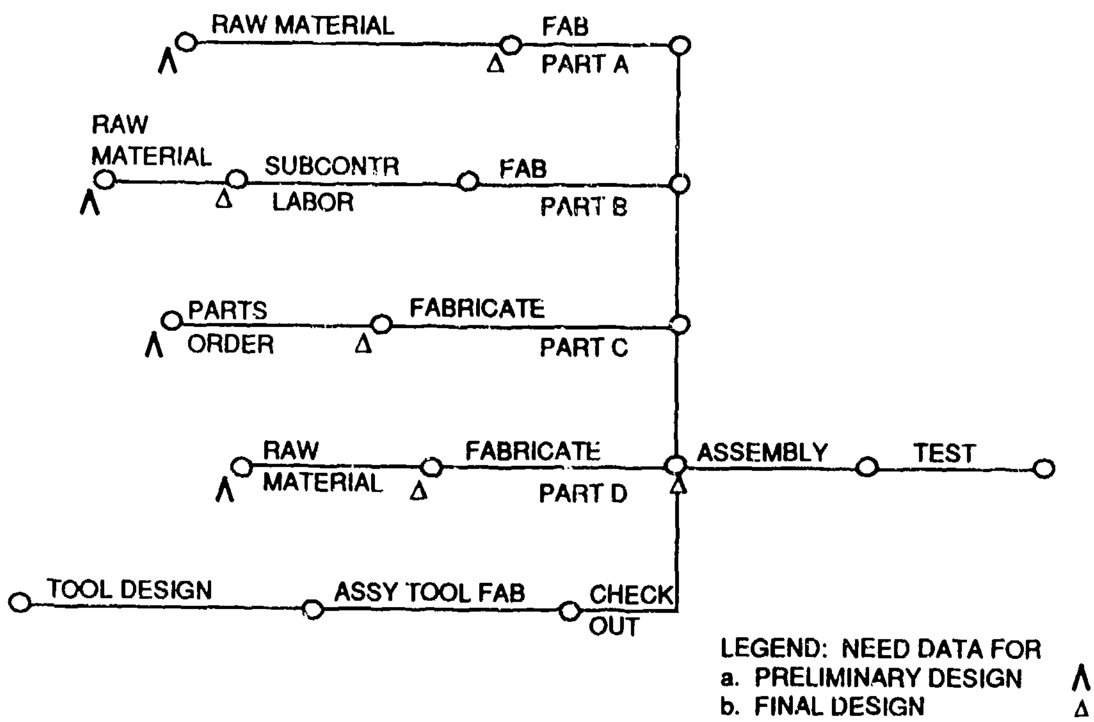


Figure 6-3 Extract from Manufacturing Plan

dates and the release schedule, replanning of either the release schedule or the manufacturing schedule must be accomplished.

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.

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

EVENTS	SCHEDULE
PROGRAM MILESTONES	(SHOW APPROPRIATE START AND COMPLETION DATES BY MONTHS OR WEEKS IN THIS SECTION OF THE SCHEDULE)
PROGRAM GO-AHEAD	
LONG-LEAD GO-AHEAD	
MANUFACTURING DECISION	
START DESIGN LAYOUTS	
ENGINEERING DRAWING RELEASE	
CONTRACT DELIVERY SCHEDULES	
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)

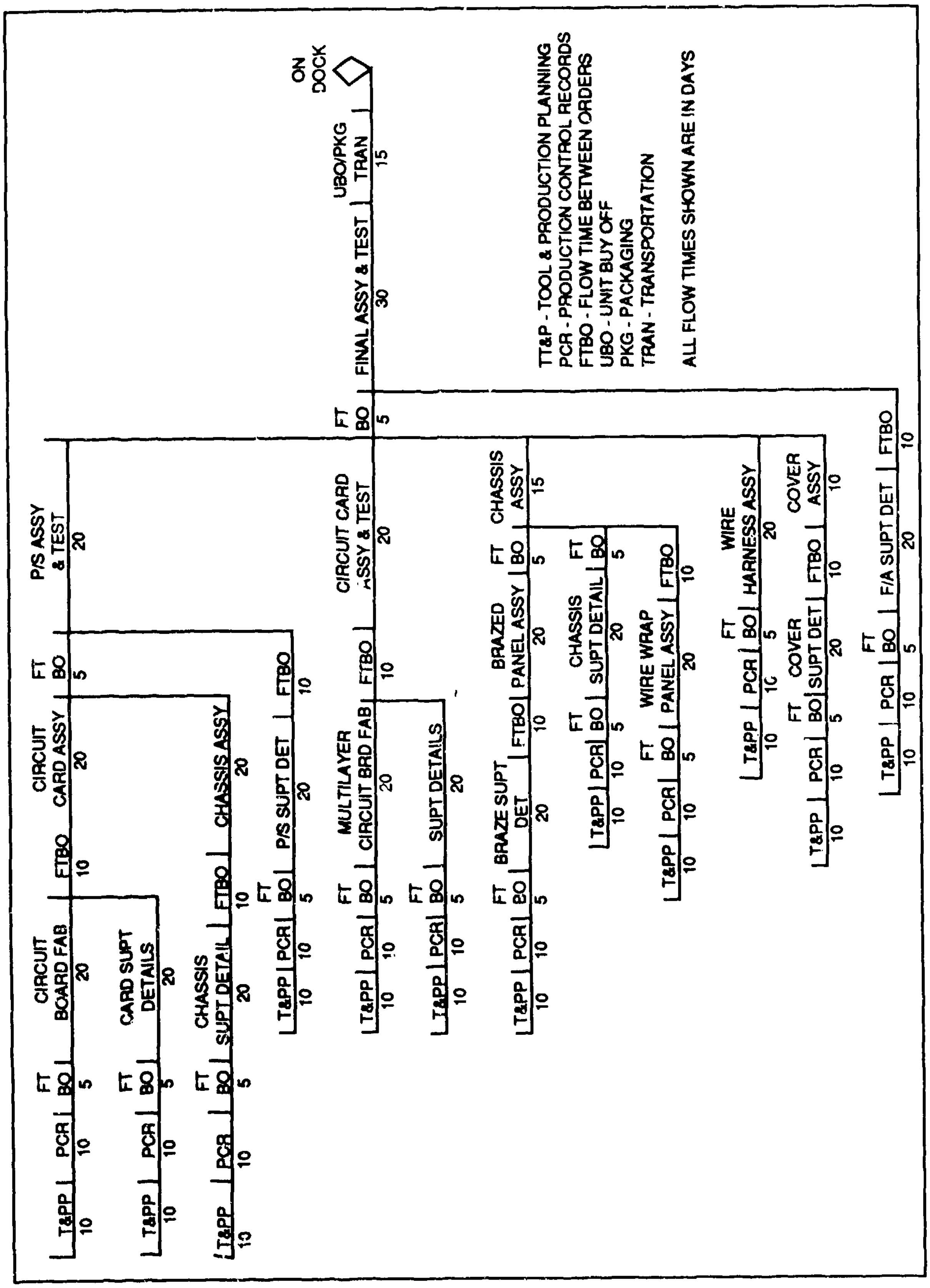


Figure 6-5 Example of First Unit Flow Chart for a Symbol Generation

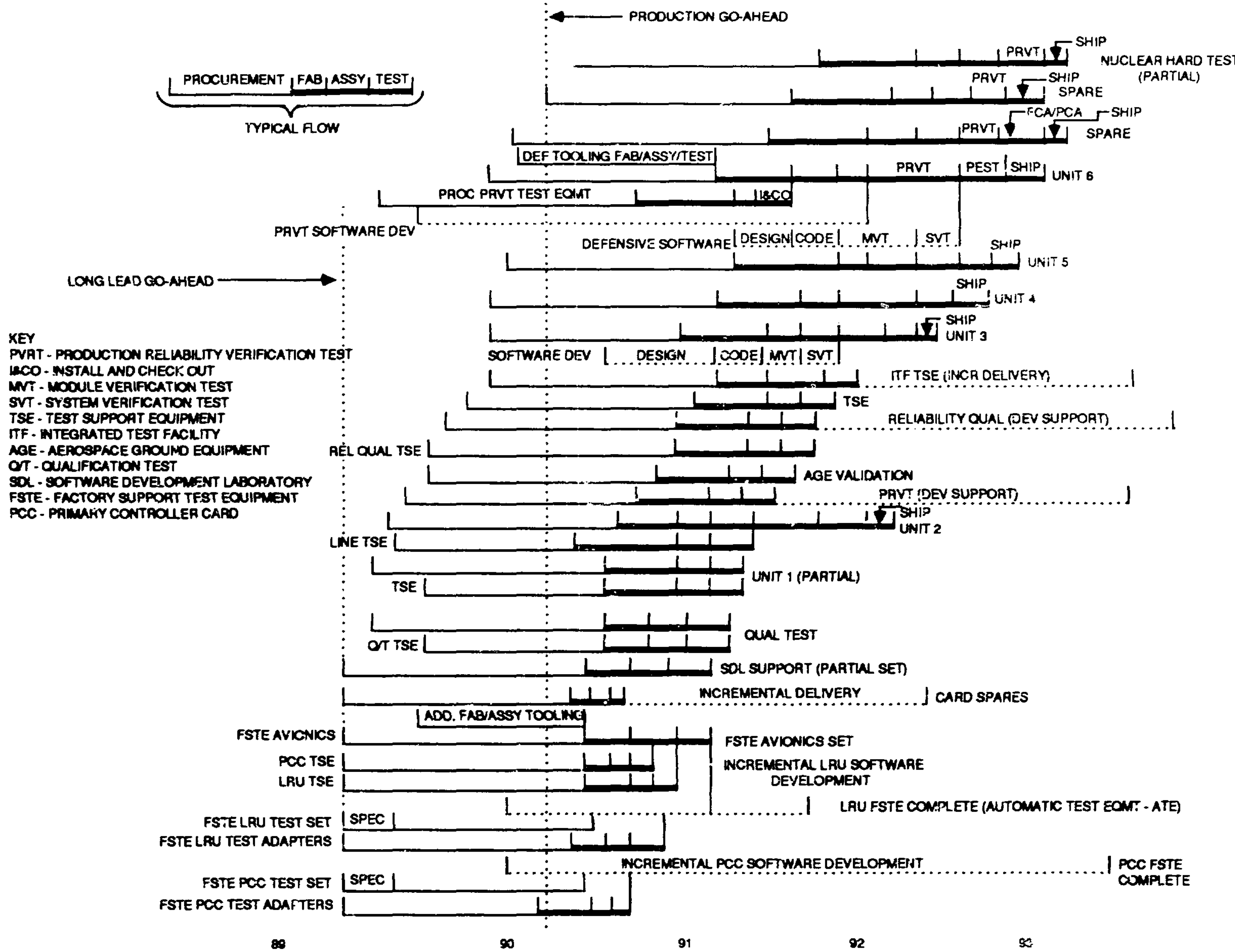


Figure 6-6 Master Schedule for an Electronics LRU

A. Shipping Schedule

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: Work days per month = 21

Delivery rate 21: 10 = 2.1

Thus, the basic cycle rate is one unit every two work days.

B. First-Unit Labor Hours

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

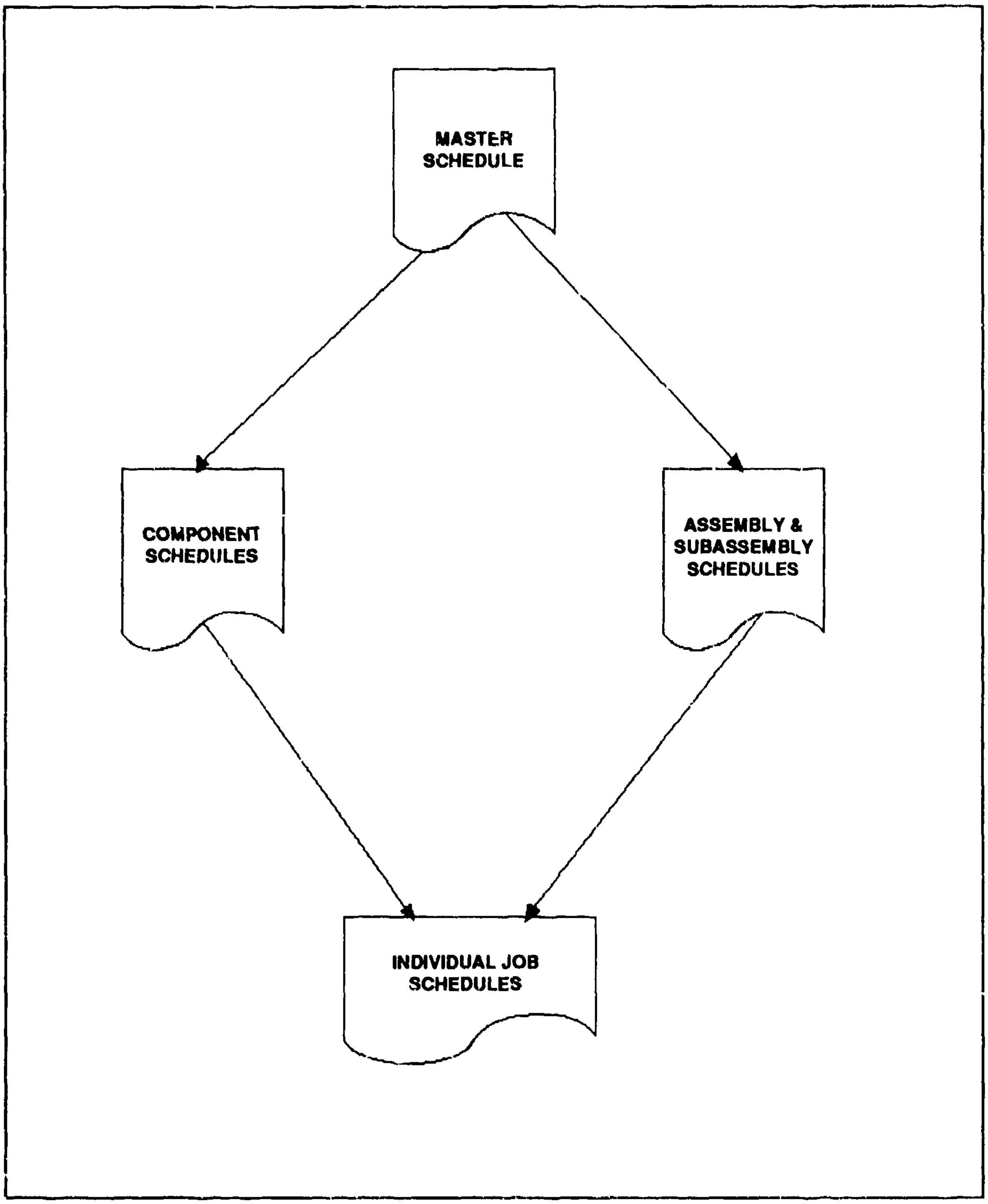


Figure 6-7 Hierarchy of Schedules

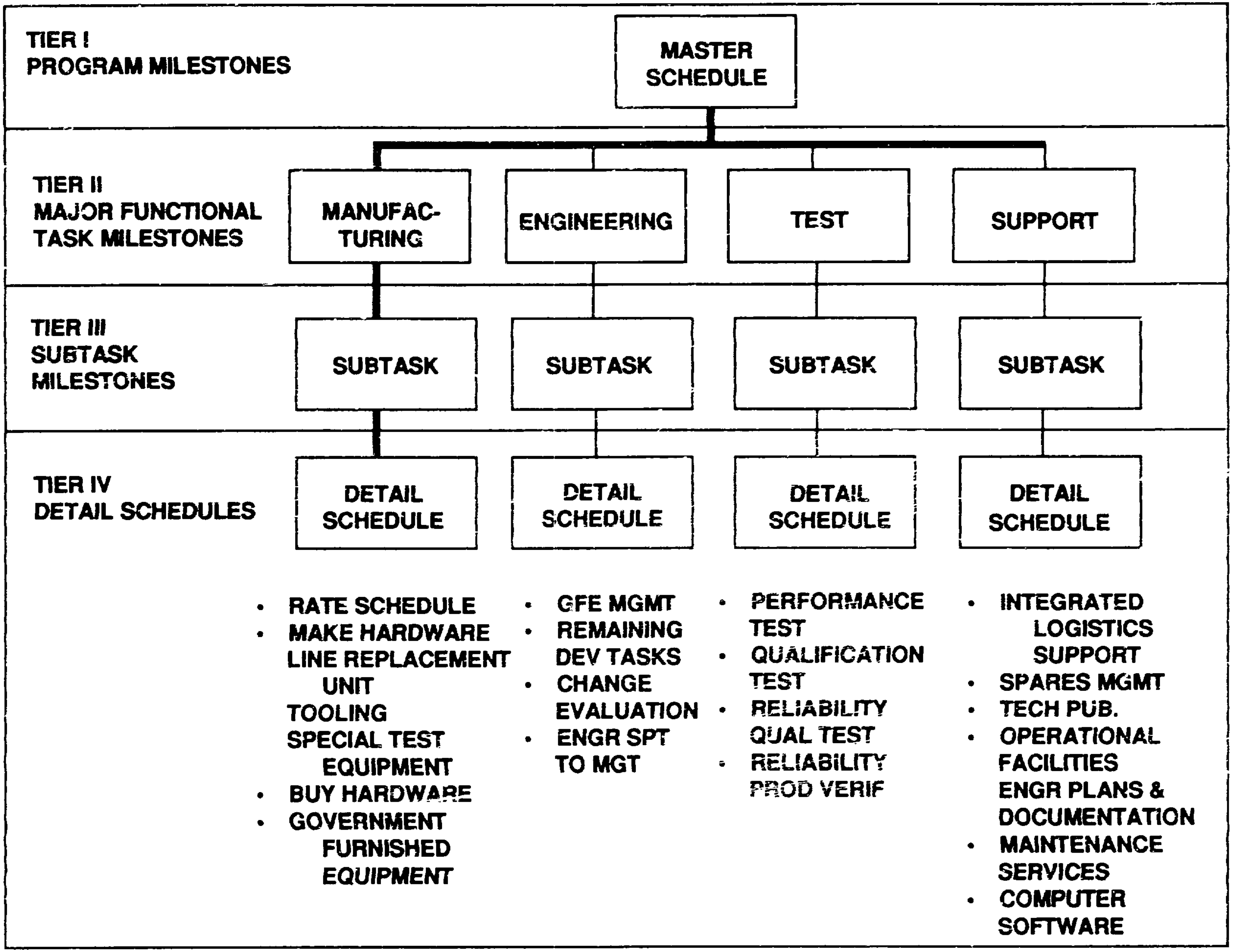


Figure 6-8 Typical Hierarchy of Schedules

manufacturing management in developing the manufacturing plan.

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:

o 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.

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.

Determinants Of Lead Time

The lead time for a particular material or component is not static. It varies with a

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

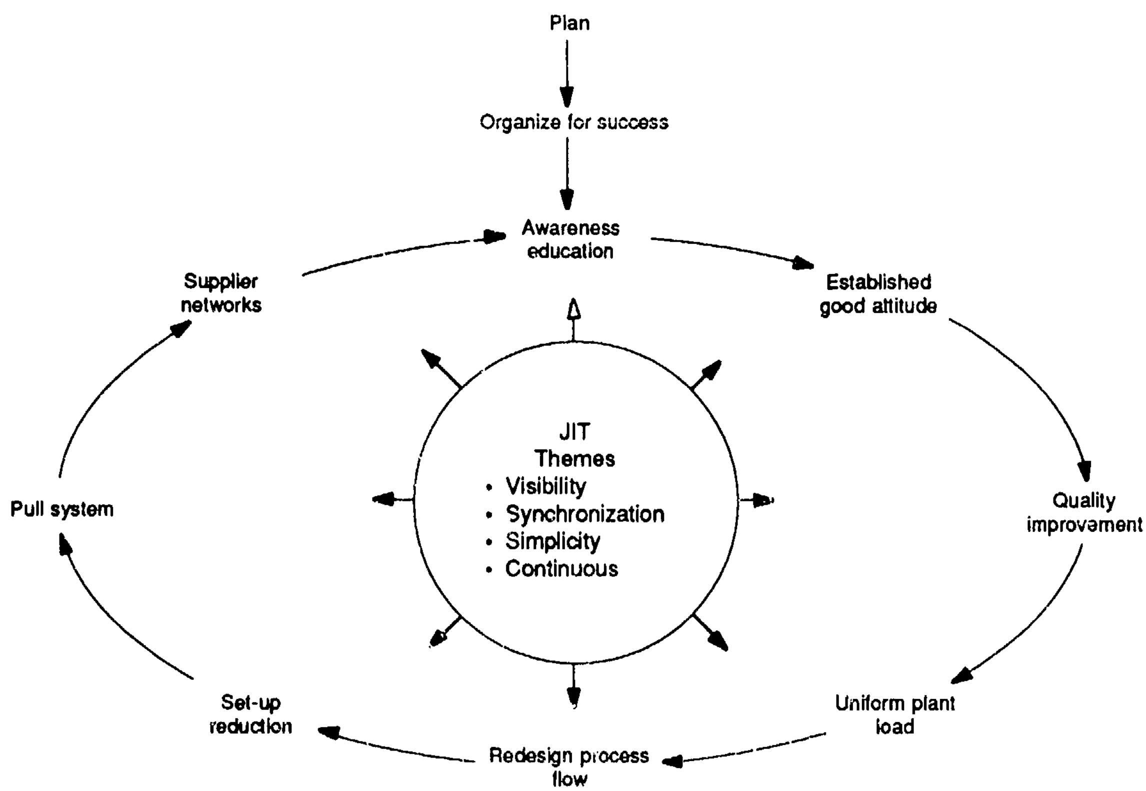


Figure 6-9 Proposed Steps in a JIT Manufacturing Program

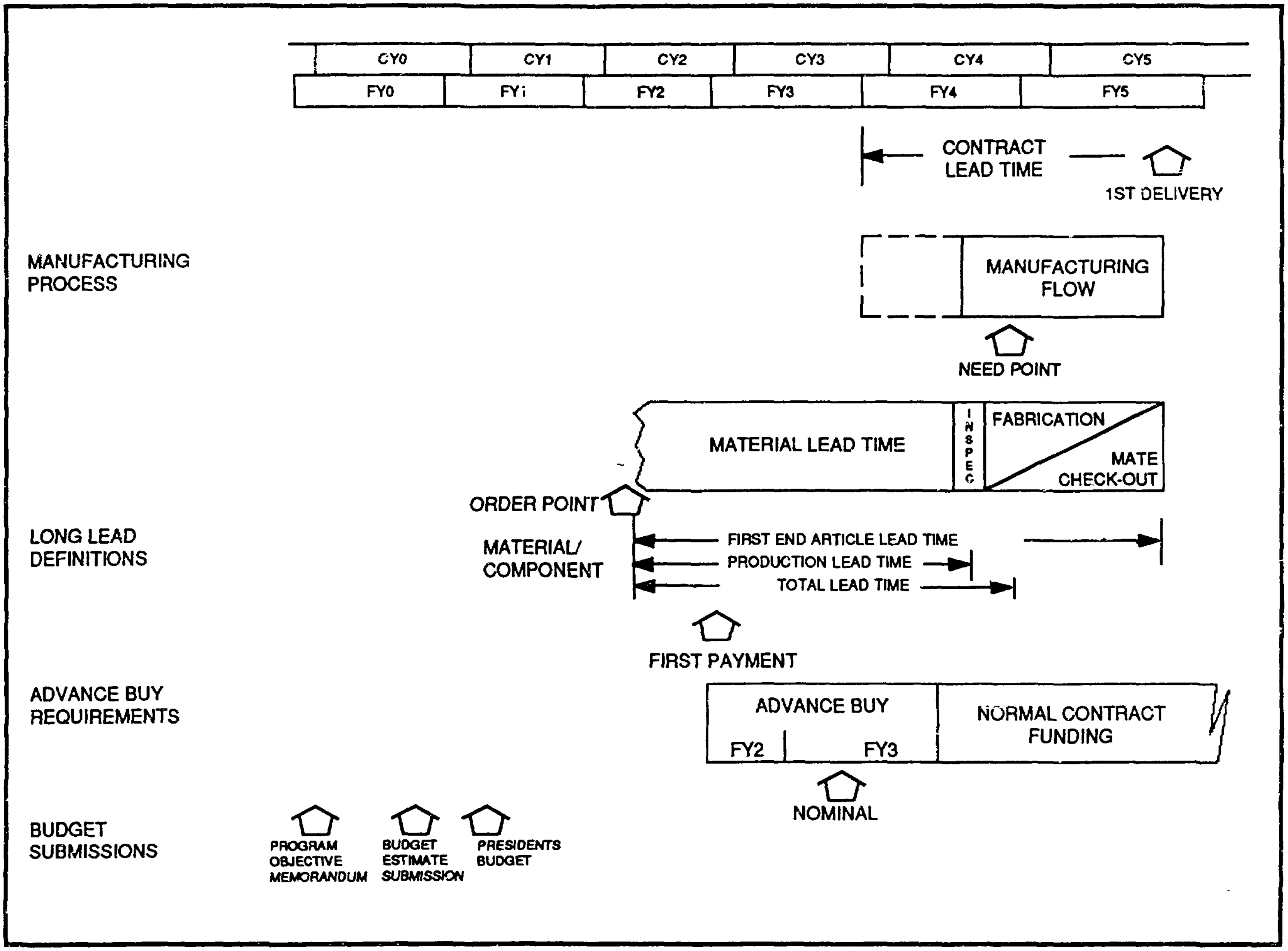


Figure 6-10 Lead Times

number of economic or other type conditions. Some of the elements which affect lead times are:

- o Number of industrial sources,
- o Industrial source workload,
- o Raw material availability,
- o Raw material costs,
- o Overall industry demand,
- o Technology level of parts and materials,
- o Cost of money,
- o Escalation due to inflation, and
- o 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.

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

- 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

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 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,

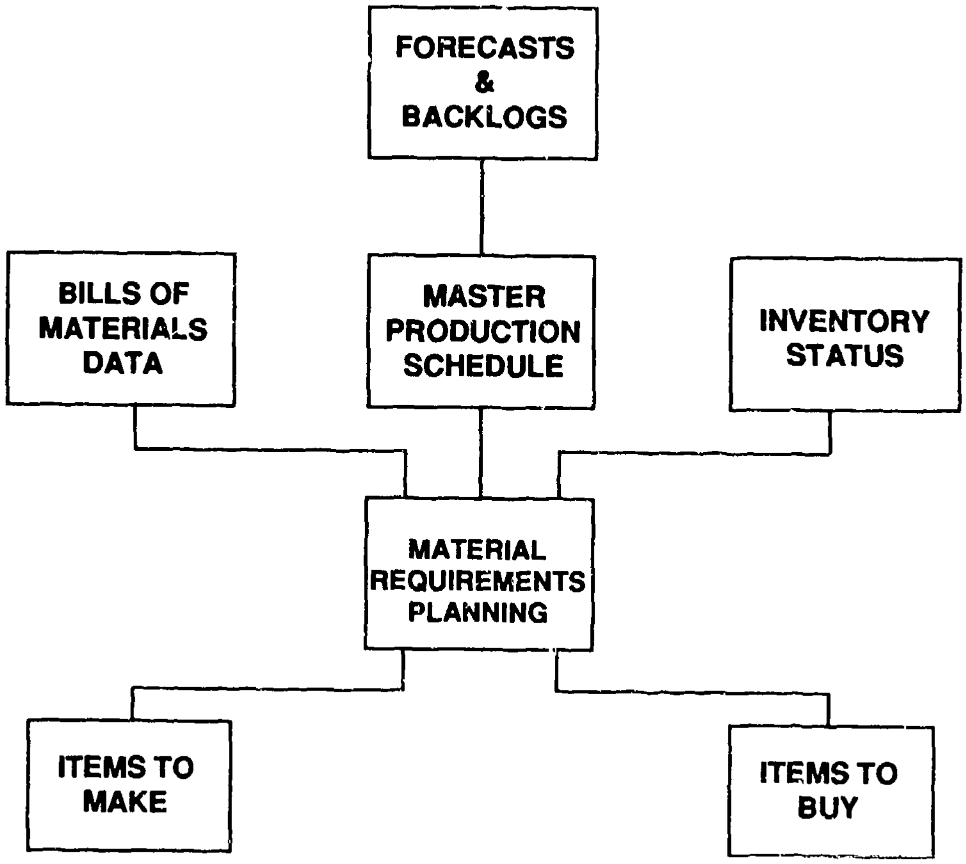


Figure 6-12 Materials Requirements Planning Information Flow

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.

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

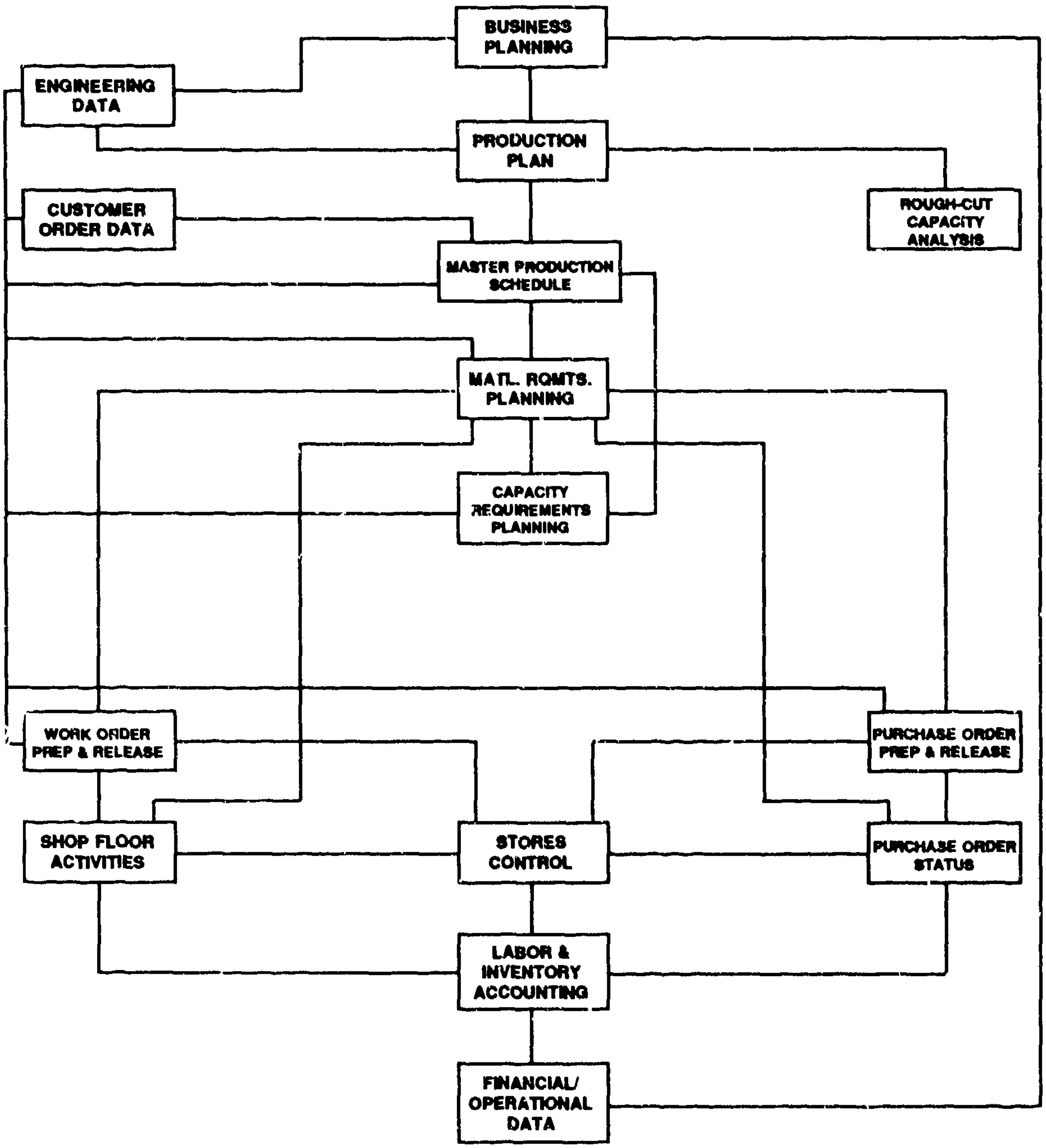


Figure 6-13 Manufacturing Resources Planning II Information Flow

- 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.

<u>MRP-MRP II Problems From The DOD And DCAA Perspective</u>

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."

In May, 1987, the DCAA sent letters to 196 major defense contractors, requiring them to assess their MRP-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.

<u>An Approach To MRP-MRP II System Assessment</u>

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.

CHAPTER SEVEN

PRODUCIBILITY

CONTENTS

OBJECTIVE

Much attention is focused on the development of producible designs during the acquisition process. This chapter builds on a definition of producibility and its relationship to the engineering design process. Approaches to the contractual implementation of producibility provide a basis for integrating Producibility Engineering and Planning into the acquisition process. The chapter also provides a framework for evaluation of the prime contractor's producibility program and organization and a description of the Value Engineering process and its role in producibility.

INTRODUCTION

Producibility is an engineering function directed toward achieving a design which is compatible with the realities of the manufacturing capability of the defense industrial base. More specifically, producibility is a measure of the relative ease of producing a product. Producibility is a coordinated effort by design engineering and manufacturing engineering to create a functional design that can be easily and economically manufactured. The product must be designed in such a manner that manufacturing methods and processes have flexibility in producing the product at the lowest cost without sacrificing function, performance, or quality. Producibility also supports the Total Quality Management (TQM) objectives by minimizing the likelihood of defects and establishing compabitility between the engineering design and the manufacturing processes.

Recently producibility, as a function, has received greater attention both in commercial industry and in defense systems programs. Department of Defense policy on major system acquisitions has made producibility considerations a requirement prior to the start of FSD, possibly as early as concept exploration validation phase if the program plans call for production. Additionally, a growing number of industrial firms have initiated formal producibility functions.

Systems design and manufacture should incorporate a structured producibility program. History has demonstrated that as the complexity of systems increases, so does the acquisition cost. Therefore, producibility programs are imperative as a management means for assuring that practicality is addressed and that the cost increases associated with the growing complexity of systems are minimized. It should be recognized that the producibility analysis accomplished by the PMO must be performed by a team of specialists assembled from the program office and supporting organizations. One functional organization cannot possibly accomplish the total producibility effort without assistance from other functional organizations. Consequently, the PMO approach to organizing for producibility is of prime importance to a successful defense system.

Basically, the program manager has responsibility for assuring that producibility is an integral consideration during the design process. Generally, the discharge of that responsibility involves the following basic elements:

1) Establishing producibility requirements in acquisition strategy and in system development contracts ensuring a producible design, selection of available industrial base resources, and availability of qualified production processes;

2) Creating support for producibility efforts throughout the entire acquisition process;

3) Ensuring that sufficient attention is given to technical areas involving risk and needing corrective action;

4) Reviewing designs for attained producibility; and

5) Evaluating the contractor's producibility program to ensure a continuum throughout development, production, and operational support.

While evaluating contractor's producibility program, the data and documentation demands placed on the contractor should be held to a minimum. Evaluations should make use of contractor's internally prepared information required in the execution of his producibility efforts and design review process. Specific information about requirements is discussed in succeeding paragraphs along with contractor producibility activity and approaches to the design review process. Of the five elements listed above, the program manager support of producibility may be the most critical in achieving a successful producibility program.

Generally, the prime contractor attempts to respond to all of the requirements of the contract, but the degree of emphasis and management attention is a function of the perception of the priorities of the PM. Design for producibility revolves around communication. If the contractor believes that the requirement for producibility has a very low priority, the emphasis will be minimal. In the typical system design environment, where producibility is not strongly supported, the need to create a design which meets performance goals, (within the available funding and development schedule), can motivate the contractor to structure a producibility program with form but little substance. If the beneficial effects on the design process, unit production cost and system producibility are to be realized, the program manager will need to emphasize producibility activity and be willing to allow time and funds for the accomplishment of design trade studies which are the foundation of the producibility effort.

RELATION TO ENGINEERING ACTIVITIES

During the creation of a design, the primary objective is to satisfy the specific functional and physical objectives established in the requirement documents. Coordination of design engineering with manufacturing engineering is effective in creating a functional design: a product designed in such a manner that manufacturing methods and processes allow for flexibility in producing the product at the lowest cost without sacrificing performance or quality. The development of a successful producibility program is dependent upon the ability of the PMO to integrate the producibility task into the mainstream of the acquisition program.

The requirement documents establish, for the designer, what the system must accomplish. These statements are the performance objectives for the system. Subsequent statements in the requirements document describe the physical, functional, and support framework for the system. These statements operate as constraints on the design. The relationships between the performance objectives and the constraints establish the potential standards of producibility for the design. If the statements of constraints rigidly specify the system, subsystem, component, materials, and manufacturing processes, the producibility of the design is essentially predetermined (even though it may not have been a primary consideration in establishing the specification). The issue of design producibility and capabilities of the production system should be specifically considered when the PMO is tailoring the system specification and other contractual requirements for the development contract.

The statement of physical characteristics for the system reflects the first constraints placed upon the designer. The statements may include the elements shown in Figure 7-1.

These characteristics place constraints upon the level of producibility that can be attained. (The system might, for example, be more simply designed and more easily fabricated if the weight limitations could be increased by 5%.) Regardless of the degree of complexity of an item, the objective of a balanced design is to create an item that will satisfy all of the specified performance and physical objectives and concurrently maximize producibility. Certain design practices can make a substantial contribution to attaining a high level of producibility in the system. Among these are the following:

a) <u>Simplicity of Design:</u> Eliminate components of an assembly by building their function into other components or into integral components through application of unique manufacturing processes. In one case, the objective may involve working with the design engineer to identify and eliminate excess components. In another case, the focus may be on working with a manufacturing engineer to combine components.

- REQUIRED PHYSICAL LIMITATIONS OF THE PROPOSED SYSTEM
  - -- DIMENSIONS
  - -- WEIGHT
  - -- MAJOR ASSEMBLIES
- REQUIREMENTS FOR OPERATOR STATION LAYOUT
- INTENDED MEANS OF TRANSPORT
- ENVIRONMENTAL REQUIREMENTS
  - -- STORAGE
  - -- TRANSPORTATION
  - -- USE
- POTENTIAL EFFECTS OF EXPLOSIVES
- HAZARDS
  - -- BIOLOGICAL
  - -- MECHANICAL
  - -- RADIATION
  - -- OTHER

Figure 7-1 Physical Characteristics

b) Standardization of Materials and Components: A wide variety of off-the-shelf materials and components are available. When these items are incorporated in the design, cost is generally reduced and parts availability greatly increased.

c) Manufacturing Process Capability Analysis: Determinations of the available manufacturing capacity, and its capability to produce the desired end item without special controls, is a critical activity in the producibility analysis. This normally includes analysis of the degree of process variability, the causes of variability and the definition of methods to reduce it.

d) Design Flexibility: The design should offer a number of alternative materials and manufacturing processes to produce an acceptable end item. Unwarranted limitations of materials or processes seriously constrain the producibility analysis.

CONTRACT IMPLEMENTATION

Designing for Producibility

The contract should include specific requirements for the integration of producibility considerations into the design process. During each stage of development, an organized and systematic pattern of events must take place if a design is to meet fully all of its objectives. Implicit in these objectives is the requirement that a design achieve the highest possible degree of producibility. However, producibility goals are rarely defined in documents describing the end item.

No fixed pattern of producibility activity is applicable to all design programs. The specific sequence and nature of events must be governed by factors such as system complexity, the extent to which new processes and techniques are to be employed, the structure of the design organization, program schedule, and other variables. Even with an effective approach, the design effort must remain an iterative process in which all the principal steps must be followed if an optimized design is to be achieved. There is a substantial constraint on this iterative process in most programs because manufacturing schedules are based on a time limit on the release of the design.

As conditions depart from ideal, increasing consultation among the various specialists contributing to the design is needed. Regardless of the design structure, it is imperative that all of its special aspects be considered simultaneously throughout the entire design cycle. Only with such recurring attention can optimum results be achieved.

The design process can be modeled as sequential steps as shown in Figure 7-2. The process is not a one-pass operation but is a chain of iterative loops and interactions. With a number of possibilities to consider, analysis is required to choose the approach that shows the greatest promise. The nature of the particular problem may dictate that several approaches be developed in parallel; however, the steps remain the same. This phase requires, as a minimum, the analysis of four items: (1) risk involved in design alternatives; (2) function versus cost; (3) schedule versus cost; (4) and components required versus manufacturing capability.

Schedule is very much a producibility factor. An end item that must go into production in six months cannot use a manufacturing technique that will not be available for one year. However, a possible tradeoff of a potential manufacturing development with substantial cost savings may justify rescheduling.

In analyzing components for manufacturing capability, the contractor shoud be considering factors such as:

1. Will the item be manufactured in the United States or overseas?

2. Will a commercial component be available several years from now, or does the design specification greatly limit future off-the-shelf procurement, thus reducing its cost effectiveness?

3. Is the component material on the critical list?

4. Are special tools or skills needed?

5. Have unnecessary functions and costs been eliminated?

When these preliminary analyses have been made and the approaches have been given a relative cost-effectiveness rating, the approach to be developed can be selected. Relative ratings and the peculiarities of the specific problem, schedule, funds, etc., will determine whether one or more approaches should be carried further in the design process.

Concern for producibility must be exercised at the start of the concept exploration phase and will influence the entire design effort from that point on in every item of the life cycle. Inherent producibility limitations must be recognized and addressed at each stage of the life cycle process. Broad producibility considerations might include the selection of materials and manufacturing processes. The iterative design process mapped in Figure 7-2 is filled with decision points, each of which permits a potential trade-off against some other requirement. However, all demands upon the system such as reliability, availability, maintainability, safety, or producibility heavily interact with each other throughout the design process, creating the need for trade-offs.

<u>Producibility Objectives in Design</u>

Considerations should include, but not be limited to the issues shown in Figure 7-3. Too often, it is assumed that designing for the use of existing tooling is the most economical approach, without giving due consideration to new more economical materials and processes. Further, designers also tend to design around their existing processes without due consideration to ongoing manufacturing technology developments. This can have detrimental effects on producibility which may result in excessive engineering change orders. The producibility plan discussed later in this Chapter should identify the contractor's system of review of engineering design to assure that the composite of characteristics which, when applied to equipment design and manufacturing planning, leads to the most effective and economic manufacturing approach.

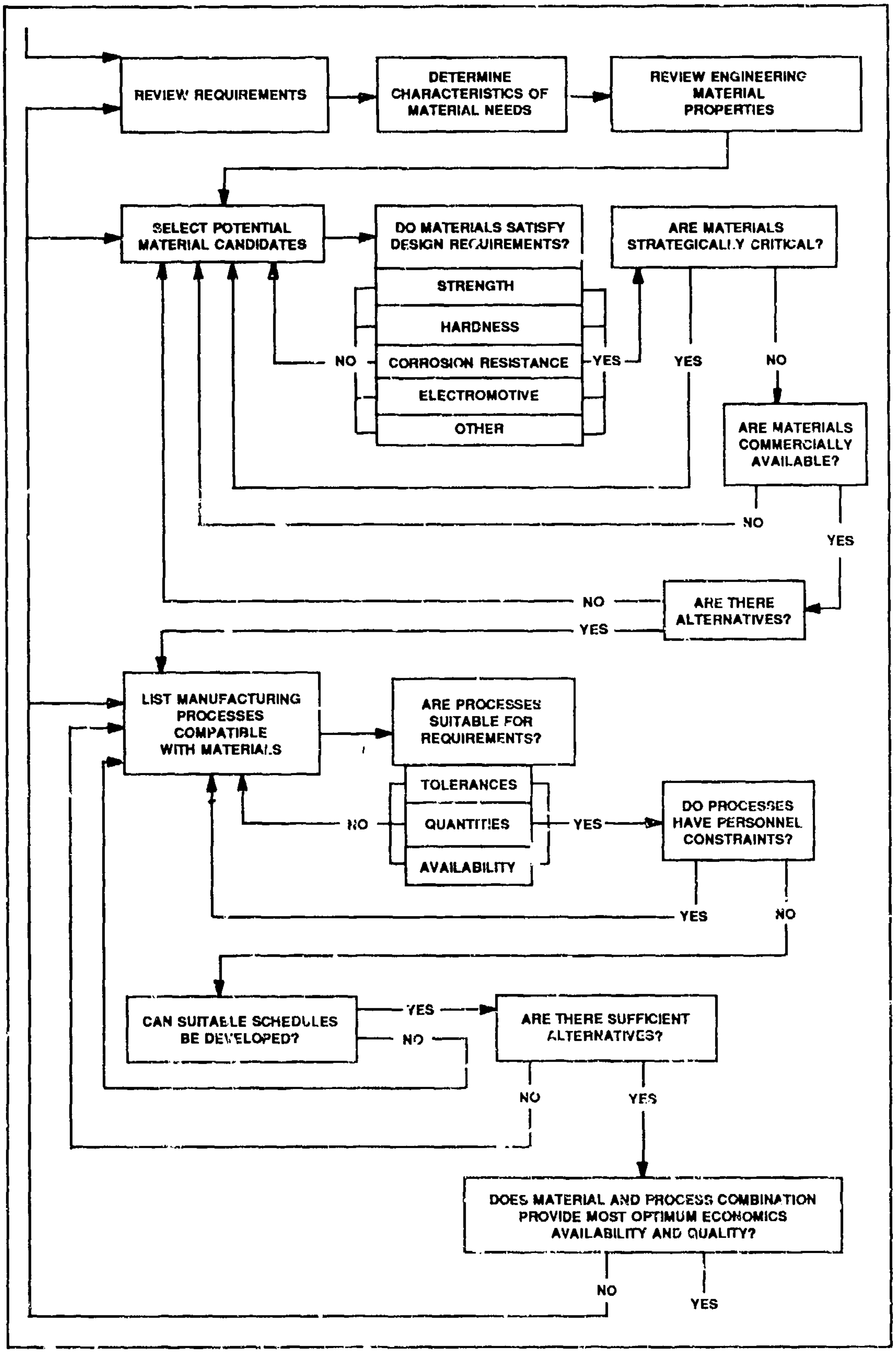


Figure 7-2 Producibility Considerations During the Iterative Design Process

MAXIMIZE	MINIMIZE
• SIMPLICITY OF DESIGN	• PROCUREMENT LEAD TIME
• USE OF STANDARD PARTS	• USE OF CRITICAL (STRATEGIC) MATERIALS
• NUMBER OF POTENTIAL SUPPLIERS AND PRODUCERS	• SPECIAL PRODUCTION TOOLING
• PROCESS REPEATABILITY AND PREDICTABILITY	• SPECIAL TEST SYSTEMS
• USE OF PROVEN MANUFACTURING TECHNOLOGY AT THE SCHEDULED PRODUCTION START	• USE OF CRITICAL PROCESSES
• EASE AND SPEED OF ASSEMBLY	• SKILL LEVELS REQUIRED IN MANUFACTURING
• USE OF ECONOMICAL MATERIALS	• UNIT COSTS
• USE OF CAD/CAM	• DESIGN CHANGES DURING MANUFACTURE
• CONFIRMATION OF DESIGN ADEQUACY	• USE OF LIMITED CAPABILITY ITEMS AND PROCESSES
	• USE OF PROPRIETARY ITEMS WITHOUT "PRODUCTION RIGHT" RELEASES
	• REMOVAL OF EXCESSIVE MATERIAL
	• UNREALISTIC TOLERANCES

Figure 7-3 Engineering Design Criteria

PRODUCIBILITY ENGINEERING AND PLANNING

The primary purpose of producibility engineering and planning (PEP) is to ensure a smooth transition from development to production. To accomplish this objective, the PEP effort must be an explicit part of the developmental activity and encompass those tasks necessary to assure weapon system or element producibility prior to quantity production. It should be noted that DODD 4245.6, "Defense Production Management," requires a contractually authorized PEP activity as part of the engineering development.

The Focus of Producibility Engineering and Planning

The focus of the PEP effort is evaluation of the systems design as it evolves to identify potential manufacturing problems and to suggest design trade-offs which would facilitate the manufacturing process. In order to ensure contractor availability of the necessary disciplines, such as those required to develop data packages, design special purpose production equipment and perform computer modeling or simulation of the manufacturing process from a producibility assessment standpoint, a Statement of Work (SOW) must be developed to establish both general and specific requirements.

Objectives and Funding

The objectives of PEP can be segregated between producibility engineering design criteria described above, and the producibility planning data requirements as shown in Figure 7-4. With approximately 60 percent of weapons system acquisition dollars expended in the production phase, it is important that the Request for Proposal for earlier program phases clearly identify the government's PEP needs. This is especially important because contractor PEP efforts will be dependent on the level of funding provided by the government in this area. Thus, the early identification of design criteria and data requirement objectives, along with the corresponding funding, will be instrumental in achieving meaningful results. Clearly, the

- MAKE OR BUY
- MANUFACTURING AND PROCUREMENT LEAD TIME
- FIRST ARTICLE LEAD TIME
- MANUFACTURING SCHEDULES AND DELIVERY RATES
- PARTS, MATERIALS, AND PROCESS PLANNING
- QUANTITY MANUFACTURING SKILL LEVEL REQUIREMENTS
- CRITICAL PATH ALTERNATIVES
- YIELD RATES FOR CRITICAL PROCESSES

Figure 7-4 Planning Data Requirements

requirements govern the level of contractor effort. The contractual provisions, as well as corresponding Contract Data Requirements List and definitive data items, should reflect individual program needs. Special emphasis should be placed on producibility training for design, manufacturing, and quality assurance engineers. The training is likely to eliminate the chasm which often exists between these engineers. By implementing an adequately funded PEP effort early in the engineering design cycle, a strong manufacturing program will emerge.

Contract Functions

The program manager should ensure that PEP objectives are identified early in the development cycle and that corresponding levels of funding will be available. As indicated by Figures 7-3 and 7-4, the SOW items establishing the PEP effort may involve many specialized contract functions and monitoring organizations. For example, in designing to meet prototype fabrication and low rate initial production schedules, special hard and soft production tooling and special test equipment requirements will normally be generated, requiring the use of attendant government property clauses. These clauses differ as a function of contract type (cost or fixed-price), degree of competition (sole-source or competitive), and category of government property. Because contractors may be influenced by factors such as desire to use contractor-peculiar capabilities and proprietary process/equipment, or to maintain a certain work force skill mix, the government's program management organization must include the flexibility to ensure focus on program goals. Government production engineers must be continuously involved with contractor design engineering in order to evaluate design proposals (such as specifications, trade-off studies and producibility analyses), configuration management, and production plans.

Producibility Engineering and Planning Measures

The purpose of PEP is to ensure that materiel designs reflect good producibility considerations prior to release for manufacture. PEP measures include the engineering tasks undertaken to ensure a timely and economic transition from development to production. PEP measures also include the confirmation of producibility during the latter stages of development. The objectives of PEP include, but an not necessarily limited to, the areas shown in Figure 7-5.

Producibility considerations can have extended horizons beyond conventional and existing production capabilities. For example, consider:

1) Computer modeling or simulation of manufacturing processes to assess producibility.

2) Performing risk analysis of new manufacturing processes.

- DEVELOP TECHNICAL DATA PACKAGES
- DESIGN AND PROVE OUT SPECIAL-PURPOSE MANUFACTURING EQUIPMENT AND TOOLING
- COMPUTER MODELING/SIMULATION
- ENGINEERING DRAWINGS
- ENGINEERING, MANUFACTURING, AND QUALITY SUPPORT INFORMATION
- DETAILS OF UNIQUE PROCESSES
- DETAILS OF PERFORMANCE RATINGS, AND DIMENSIONAL AND TOLERANCE DATA
- MANUFACTURING ASSEMBLY SEQUENCE METHOD SHEET SCHEMATICS
- MECHANICAL AND ELECTRICAL CONNECTIONS WIRING DIAGRAM
- MATERIAL AND FINISHING INFORMATION
- INSPECTION, TEST, AND EVALUATION REQUIREMENTS
- CALIBRATION INFORMATION
- QUALITY CONTROL DATA

Figure 7-5 Producibility Engineering Planning Objectives

3) Determining the need for manufacturing technology development efforts.

4) Group technology considerations in part design and fabrication plan.

5) Planning for new plant layouts.

6) Exploitation of foreign manufacturing technologies for enhanced producibility.

Application of Producibility Engineering and Planning in the Acquisition Process

PEP efforts are funded early enough to be essentially complete by the end of the full-scale development phase of a program. PEP should be started early in the acquisition cycle as shown in Figure 7-6 to preclude reiteration of designs resulting from changes brought about by producibility analyses. The efforts accomplished during the full-scale development phase will primarily address producibility of critical components, and extend sufficiently into the low rate initial production phase to ensure producibility analysis of the total end item. Simultaneously, it will assure the adequacy of the technical data package. This includes changes resulting from low rate initial production.

PEP should be treated as a separate task in a research, development, test and evaluation project and should have complete visibility and traceability during the project. To ensure this visibility, the subject of producibility should be an agenda item at all program reviews and production readiness reviews.

Responsibility for Producibility Engineering and Planning Effort

The program manager is responsible for planning, budgeting and contractually specifying PEP efforts. The contractor is responsible for the effective execution of the PEP program. In achieving a producible design, a contractor has numerous tools

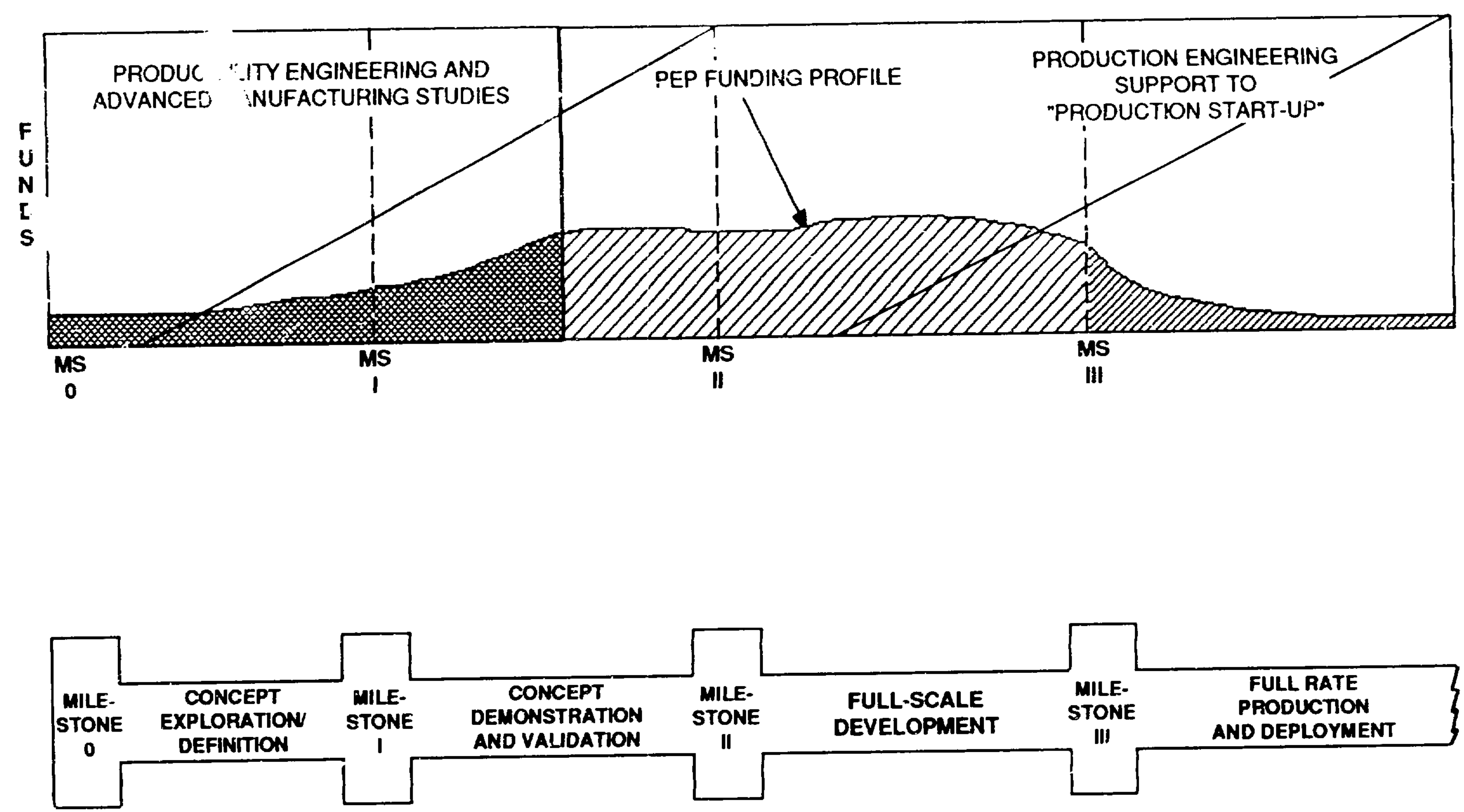


Figure 7-6 Producibility Engineering Planning Funding Profile

available to him; however, none is more important than a well-engineered and well-executed producibility program plan.

PRODUCIBILITY PROGRAM PLAN

The producibility program plan details the organizational structure, authority, and responsibilities of the personnel that will be utilized to monitor producibility and perform the required analyses. Normally prepared by the contractor for the PM, the plan should outline organizational functions, methodology, objectives, and reporting procedures that will be used to ensure producibility in the design of an item. The importance of the program plan as a contractual clause cannot be overemphasized. A producibility analysis will often involve data that will require a predetermination of rights to proprietary data. Many manufacturers classify their manufacturing process information as proprietary and it is advisable to clarify this point with a contract clause on the predetermination of rights. It must be recognized that some processes are proprietary and will remain so. It will frequently be necessary to purchase producibility engineering as a data item under a research and development contract for an end item. To assist the program office in the preparation of the data item description, the information in the following paragraphs may be helpful.

Data Item: Producibility Program Plan

The producibility program plan permits the determination of the manufacturer's ability to maximize the system, subsystem, and/or component producibility through the utilization of an effective organization to identify, establish, and accomplish specific producibility tests and responsibilities. This data item description is applied when the producibility task has been included in the contract statement of work.

The contractor's producibility program, which is documented in the producibility program plan, should contain (but not be limited to) these items:

1. A detailed listing of tasks and procedures used to conduct the producibility program.

2. A description of each task.

3. An identification of the unit or persons having the task assignment and their responsibility and authority.

4. An assessment of known or potential problem areas and their impact on the progress of the program.

5. A milestone planning chart or other graphic portrayal of scheduled events.

6. The plan shall provide for and schedule producibility analyses to be conducted on each design concept being considered.

7. Alternate approaches will be reported.

8. Detailed procedures and checklists for accomplishing the producibility analyses prepared for design reviews.

Data Item: Producibility Analysis

The producibility analysis plan permits the evaluation of manufacturer's methods of conducting the analysis to determine the most effective manufacturing methods of the end product. This data item description can be applied throughout the acquisition cycle of any program whose end result is a production program. The purpose is to assure that the systems, subsystems, and component designs meet the standards of producibility.

In establishing a requirement for producibility analyses, the PM may require the contractor to develop an appropriate set of checklists applicable throughout all the program phases. The checklists in Figure 7-7 should aid manufacturers in performing productivity analysis.

CONTRACTOR ORGANIZATION FOR PRODUCIBILITY

There are a number of alternatives for the contractor when organizing to achieve producibility. Four approaches often used are:

1. Assign responsibility for the achievement of producibility to those personnel in the various existing functions as a part of their basic work tasking.

GENERAL ASPECTS OF DESIGN

a) Have alternative design concepts been considered and the simplest and most producible one selected?
b) Does the design exceed the manufacturing state-of-the-art?
c) Is the design conducive to the application of economic processing?
d) Does a design already exist for the item?
e) Does the design specify the use of proprietary items or processes?
f) Is the item overdesigned or underdesigned?
g) Can redesign eliminate anything?
h) Is motion or power wasted?
i) Can the design be simplified?
j) Can a simpler manufacturing process be used?
k) Can parts with slight differences be made identical?
l) Can compromises and trade-offs be used to a greater degree?
m) Is there a less costly part that will perform the same function?
n) Can a part designed for other equipment be used?
o) Can weight be reduced?
p) Is there something similar to this design that costs less?
q) Can the design be made to secure additional functions?
r) Are product assurance provisions too rigorous for design or fluctuations?
s) Can multiple parts be combined into a single net shape?
t) Have packaging and accessibility of electronic components and [illegible]ibiles been given sufficient consideration?

SPECIFICATIONS AND STANDARDS

a) Can the design be standardized to a greater degree?
b) Can the design use standard cutting tools to a greater degree?
c) Is there a standard part that can replace a manufactured item?
d) Can any specifications be relaxed or eliminated?
e) Can standard hardware be used to a greater degree?
f) Can standard gages be used to a greater degree?
g) Are nonstandard threads used?
h) Can stock [illegible]s be used to a greater degree?
i) Should packaging specifications be relaxed?
j) Are specifications and standards consistent with the planned product environment?

Figure 7-7 Producibility Analysis Checklist

DRAWINGS

a) Are drawings properly and completely dimensioned?
b) Are tolerances realistic, producible, and not tighter than function requires?
c) Are tolerances consistent with multiple manufacturing process capabilities?
d) Is required surface roughness realistic, producible, and not better than function requires?
e) Are forming, bending, fillet and edge radii, fits, hole sizes, reliefs, counterbores, countersinks, o-ring grooves, and cutter radii standard and consistent?
f) Are all nuts, bolts, screws, threads, rivets, and torque requirements appropriate and proper?
g) Have requirements for wiring clearance, tool clearance, component space, and clearance for joining connectors been met?
h) Have all required specifications been properly invoked?
i) Are adhesives, sealants, encapsulants, compounds, primers, composites, resins, coatings, plastics, rubber, moldings, and tubing adequate and acceptable?
j) Has galvanic corrosion and corrosive fluid entrapment been prevented?
k) Are welds minimal and accessible? Are the symbols correct?
l) Have design aspects which could contribute to hydrogen embrittlement, stress corrosion, or similar conditions been avoided?
m) Are lubricants/fluids proper?
n) Are contamination controls of functional systems proper?
o) Have limited life materials been identified, and can they be replaced without difficulty?
p) Have radio frequency interference (RFI) shielding, electrical, and static bond paths been provided?
q) Have spare connector contacts been provided?
r) Are identification and marking schemes for maximum load pressure, thermal, nonflight items, color codes, power, and hazards on the drawings properly?
s) Do drawings contain catch-all specifications which manufacturing personnel would find difficult to interpret?
t) Have all possible alternatives of design configuration been shown?

Figure 7-7 Producibility Analysis Checklist (Cont'd)

INSPECTION AND TEST

a) Are inspection and test requirements excessive?
b) Is special inspection equipment specified in excess of actual requirements?
c) Is the item inspectable by the most practical method possible?
d) Have conditions or aspects anticipated to contribute to high rejection rates been identified and remedial action initiated?
e) Have required mock-ups and models been provided?
f) Are special and standard test and inspection equipment on hand, calibrated, proofed, and compatible with drawing requirements?
g) Are master and special gages complete?
h) Have nondestructive testing techniques been implemented?
i) Have adequate provisions been provided for the checkout, inspection, testing, or proofing of functional items per operational procedures?
j) Is nonstandard test equipment necessary?

MATERIALS

a) Have materials been selected which exceed requirements?
b) Will all materials be available to meet the required need dates?
c) Have special material sizes and alternate materials been identified, sources verified, and coordination effected with necessary organizations?
d) Do design specifications unduly restrict or prohibit use of new or alternate materials?
e) Does the design specify peculiar shapes requiring extensive machining or special manufacturing techniques?
f) Are specified materials difficult or impossible to fabricate economically?
g) Are specified materials available in the necessary quantities?
h) Is the design flexible enough so that many processes and materials may be used without functionally degrading the end item?
i) Can a less expensive material be used?
j) Can the number of different materials be reduced?
k) Can a lighter gage material be used?
l) Can another material be used that would be easier to machine?
m) Can use of critical materials be avoided?
n) Are alternate materials specified where possible?
o) Are materials and alternates consistent with all planned manufacturing processes?

Figure 7-7 Producibility Analysis Checklist (Cont'd)

FABRICATION PROCESSES

a) Does the design involve unnecessary machining requirements?
b) Have the proper design specifications been used as regards metal stressing, flatness, corner radii, types of casting, flanges, and other proper design standards?
c) Does the design present unnecessary difficulties in forging, casting, machining, and other fabrication processes?
d) Do the design specifications unduly restrict production personnel to one manufacturing process?
e) Can parts be economically subassembled?
f) Has provision been made for holding or gripping parts during fabrication?
g) Is expensive special tooling and equipment required for manufacturing?
h) Have the most economical manufacturing processes been specified?
i) Have special handling devices or procedures been initiated to protect critical or sensitive items during fabrication and handling?
j) Have special skills, facilities, and equipment been identified and coordinated with all affected organizations?
k) Can parts be removed or disassembled and reassembled or reinstalled easily and without special equipment or tools?
l) Is the design consistent with normal shop flow?
m) Has the consideration been given to measurement difficulties in the manufacturing process?
n) Is the equipment and tooling list complete?
o) Are special facilities complete?
p) Can a simpler manufacturing process be used?
q) Have odd-size holes and radii been used?
r) In the case of net shape processes have alternate processes been specified?
s) Can a fastener be used to eliminate tapping?
t) Can weld nuts be used instead of tapped holes?
u) Can any machined surfaces be eliminated?
v) Can roll pins be used to eliminate reaming?
w) Do finish requirements prohibit use of economical speeds and feeds?
x) Are processes consistent with production quantity requirements?
y) Are alternate processes possible within design constraint?

JOINING METHODS

a) Are all parts easily accessible during joining processes?
b) Are assembly and other joining functions difficult or impossible due to lack of space or other reasons?
c) Can two or more parts be combined into one?
d) Is there a newly developed or different fastener to speed assembly?
e) Can the number of assembly hardware sizes be minimized?
f) Can the design be changed to improve the assembly or disassembly of parts?
g) Can the design be improved to minimize maintenance problems?
h) Have considerations for heat-affected zones been considered when specifying a thermal joining process?

Figure 7-7 Producibility Analysis Checklist (Cont'd)

COATING MATERIALS AND METHODS

a) Are protective finishes properly specified?
b) Has corrosion protection been adequately considered from the standpoint of materials, protective measures, and fabrication and assembly methods?
c) Have special protective finish requirements been identified and solutions defined?
d) Can any special coating or treating be eliminated?
e) Can precoated materials be used?

HEAT TREATING AND CLEANING PROCESSES

a) Is the specified material readily machined?
b) Are machining operations specified after heat treatment?
c) Have all aspects of manufacturing involving heat treating and cleaning processes and their interaction with other manufacturing areas been reviewed?
d) Are heat treatments properly specified?
e) Are process routings consistent with manufacturing requirments (straightness, flatness, etc.)?

SAFETY

a) Have static ground requirements been implemented in the design?
b) Have necessary safety precautions been initiated for pyrotechnic items?
c) Have RFI requirements been implemented in the design?
d) Have necessary safety requirements for processing materials such as magnesium and beryllium copper been considered?

ENVIRONMENTAL REQUIREMENTS

a) Have adequate provisions been included to meet the thermal, humidity, or other special environmental requirements?
b) Has adequate heating and/or cooling been identified and implemented?
c) Are specifications overly stringent?
d) Can specifications be waived for unique conditions

Figure 7-7 Producibility Analysis Checklist (Cont'd)

2. Assign responsibility for producibility engineering to an existing product or design engineering function. They already have responsibility for product design and consequently are in the best position to ensure producibility in the design.

3. Assign responsibility for producibility to the production or manufacturing engineering function. They are already in the best position to understand the production processes and their effect on producibility.

4. Establish a new function of producibility engineering and staff it with personnel of product engineering and manufacturing engineering background with emphasis on the latter.

Each of the listed alternatives offers some benefits and each has its limitations. Since producibility in an interdisciplinary activity, the fourth alternative is strongly favored. However, it may not be entirely suitable. Split responsibilities can be the spawning ground of management indecisiveness. A division of responsibilities for the achievement of a specific task not only impedes the ability to address the task as a whole but at the same time undermines the assignment of accountability. The specific approach to be utilized on any individual program should be dictated by the facts and circumstances of that program. It should be noted that the inclusion of the responsibility for producibility within an organization with a potentially incompatible function can result in a less than acceptable execution of the producibility responsibility. In this regard the program manager might consider the potential benefits of the contractor establishing a new function for the producibility task.

The establishment of a new function with primary responsibility for producibility engineering can take many forms: (1) it can be a completely new organization; (2) it can be a review team made up of personnel from currently assigned project functions, or; (3) it can be a permanently assigned committee made up of personnel currently assigned to functional areas. Whether the organization consists of a permanent staff, or a part-time staff, is not significant, for such organizations function in much the same manner. There is also a need, because of the accelerating advances being made on materials and processes, for an organization which allows for a close interaction between design and manufacturing.

Considering the technology explosion of recent years and the number of new processes and materials that are currently being developed, it would seem wise to bring materials specialists into the areas of manufacturing and test and evaluation, as well as specialty vendors, into the design process at an early stage. This can be done in various ways and might involve such people as process engineers, cost analysts, tool engineers, industrial engineers, quality control engineers, chemists, and metallurgists. Consequently, the form of the new organization is not important to this discussion. The main point is that detailed interaction should occur between the product design engineers and such personnel having specific knowledge of the available manufacturing technologies and their relevant costs.

VALUE ENGINEERING

Value engineering (VE) is based on the concept that a design will cost less to manufacture if it is value engineered from its inception. However, initial product design often precedes or is accomplished independent of selection of a manufacturing system and VE then operates as a reappraisal of a design.

VE brings together all the specialized knowledge within an organization. If representatives from engineering, methods, manufacturing, and quality are brought together as a VE team activity, the value characteristics may be determined and significant benefits in cost reduction, reduced manufacturing time, and improved quality, may be realized.

DOD Policy

DOD policy has always been to encourage value engineering because it saves money. Increasing emphasis in the 1980's led to Congressional interest in 1987 and the OMB Circular A-131 in January, 1988. Policy has shifted from DOD encouragement to OMB directed use of Value Engineering Program Requirements Clauses for contracts in initial production or research and development, unless a waiver is justified. Agencies are now required to "actively elicit" Value Engineering

Change Proposals (VECP's) from contractors and are to emphasize VE to government and contractor personnel.

Elements

There are seven basic elements of the VE methodology, although they may not always be distinct and separate. In practice, they often merge or overlap. The seven elements referred to are:

1. Selection of Product -- Selection of the hardware system, subsystem, or component to which VE efforts are to be applied;

2. Specification of Function -- Analysis and definition of function(s) that must be performed by the hardware;

3. Collection of Information -- The pulling together of all pertinent facts concerning the product; i.e., present cost, quality and reliability requirements, development history, and the like;

4. Development of Alternatives -- The creation of ideas for alternatives to established design;

5. Selection of Alternatives -- Estimation of the cost of alternatives and the selection of one or more of the more alternatives for testing of technical feasibility;

6. Test and Verification -- Test of alternatives(s) to ensure it/they will not jeopardize fulfillment of performance (functional) requirements;

7. Submittal of Proposal and Follow-Up -- Preparation and submission of a formal VE change proposal.

As an organized discipline, the VE effort should comprise all seven elements. In some contracting agencies or firms, these elements of the VE job are assigned as collateral responsibilities to design engineers, production engineers, purchasing specialists, or engineering cost analysts under the assumption that, collectively, VE efforts are being accomplished.

Another means of describing the substance of the above elements is to point out that performing the effort describes answers to the following questions about a product:

1. What is it?
2. What does it do?
3. What is it worth?
4. What does it cost?
5. What else might do the job?
6. What would that cost?

Value Engineering in the Contractual Environment

The objective of VE in defense contracts is to reduce the cost of acquisition and/or ownership to the government. In addition VE is also used to enhance the worth of effectiveness of the system. To accomplish these goals, special contract clauses can be utilized (FAR 48.2). These clauses can either allow or require contractors to initiate, develop and submit cost reduction proposals during the performance of the contract. Through the VE clause, the contractor is offered the opportunity to share the attained savings with the DOD.

It should be noted that a contractor-generated value VECP may be submitted, and approved by the government, even if the contractor did not use VE techniques in developing the VECP. However, in order for a VECP to be accepted, a change to the contract must be negotiated.

Value Engineering Incentive Clause

The objective of this clause is to encourage contractors to develop and submit VECPs by providing for the sharing of any savings, although the contractor is not required to do VE. The clause merely describes the sharing that will take place should the contractor submit a VECP which the government accepts. Entirely permissive in intent, it allows the contractor to ignore this provision and still otherwise perform under his contract.

Value Engineering Program Requirement Clause

The objective of the VE program requirement clause is to reduce development, production, or use costs by requiring the contractor to establish a VE program. This clause should be used when a sustained VE effort at a predetermined level is desired. The VE program requirement is a separately priced line item in the contract and may apply to all or to selected phases of contract performance.

There are two sources of savings to be shared under the VE clauses. These are acquisition savings and collateral savings. Each will be described in the subparagraphs that follow.

Acquisition Savings

The FAR provides guidance on the meaning of instant, concurrent, and future contracts. For computing instant savings, the instant contract does not include supplemental agreements, options, add-ons, or other quantity modifications entered into after the VECP is approved. These savings become future acquisitions in which the contractor may share if there is such a sharing arrangement included in his contract. Prior orders are considered to be existing contracts; subsequent orders, future contracts. For multiyear contracts, the instant contract shall be the funded contract at the time the VECP is approved and items purchased under subsequent funding under this contract shall be treated under the future contract VE sharing provisions.

In regard to computing instant cost savings and the net amount to be shared, FAR provides that the government's cost to develop and implement the change is also included in computing the net savings to be shared.

Collateral Savings

Collateral savings are those measurable net reductions in the cognizant military department's overall documentable projected cost of operation, maintenance, logistic support, or government furnished property (GFP) when such savings result from the VECP submitted by the contractor -- whether or not there is any change in the acquisition cost. The collateral savings may be excluded from a contract or class of contracts when it is determined that the cost of computing and tracking collateral savings will exceed the benefits to be derived.

CHAPTER EIGHT

MANUFACTURING TECHNOLOGY

CONTENTS

OBJECTIVE

This chapter describes the role and impact of manufacturing technology on the systems acquisition process. Manufacturing process evaluation and selection establish the manufacturing cost and risk. The chapter treats both the physical processes and management structure in which process decisions are made. The impact of and tools for encouraging industrial modernization are described. Emphasis is also placed on the impact on computers on process selection and control to prepare the Program Manager (PM) to deal with their program impacts.

INTRODUCTION

Manufacturing processes are the activities which change the form or properties of materials to give them the physical and functional characteristics which are required by the end item design. To achieve production phase objectives it is necessary to use efficient, shop-proven processes for material transformation. These two process descriptors -- efficient and shop-proven -- often tend to be mutually exclusive. New processes and new approaches to manufacturing execution, such as computer-aided manufacturing, often do not have extensive shop experience. The challenge to the PMO is to obtain maximum efficiency of manufacture within the risk levels deemed acceptable for the specific program. This chapter identifies some of the mechanisms for describing and proofing manufacturing processes. There is also a discussion of the integration of advanced manufacturing technology into the manufacturing program. It is important to recognize that advanced manufacturing technology generally brings certain levels of risk to a program along with the potential benefits of improved efficiency.

PROCESS PLANNING AND SELECTION

In manufacturing planning, it is necessary to define the specific process which will be used in manufacturing the product. Part geometry, size, material to be used, number of parts to be produced and dollar value of the finished product are important factors to be considered. The variety of processes available for producing the part are numerous, and selection of a particular process requires consideration of process capabilities and limitations in order to reduce the number of alternatives to a reasonable number for a final selection. The variety of processes available for metal fabrication, as an example, are illustrated in Figure 8-1.

Process selection is based on the issues of economy, risk and the end application of the product. The choice of a process is based on several requirements. The following discussion provides an introduction to the process selection procedure based on design requirements.

Design Requirements

Design requirements constrain process selection by establishing performance requirements on the system and, by implication, on the individual parts. For example, metal parts which are highly stressed by directionally stable loads may require a forging operation so that the directional properties of the material can be aligned with the load paths.

Material Requirements

The choice of raw material will be determined by the mechanical characteristic desired. Ultimate strength, fatigue and corrosion properties often lead to the selection of specific materials. There may also be design limitations, such as weight and size, which constrain the material selection. If the material to be used is specified in the design package this often limits, or even dictates, the processes which can be used. Materials such as magnesium and titanium impose limitations on the choice of processes which can be used for their transformation due to the metals' special physical or chemical properties. For example, grinding or welding magnesium should be avoided due to the metal's flammability if not properly shielded from air or oxygen. Titanium tends to weld to steel surfaces of forming tools and is more easily formed at elevated temperatures. When materials thus limit the process selection, the cost of the processes can be extremely high. As another example, fracture toughness requirements in structures may lead to selection of a ceramic material, if brittleness is

PROCURED ITEM COSTS	MATERIAL REMOVAL COSTS	DETAIL FABRICATION COSTS	MATERIAL TREATMENT COSTS	PERMANENT JOINING* COSTS	ASSEMBLY* COSTS
• <u>FORGINGS</u> HAND CONVENTIONAL BLOCKER PRECISION • <u>CASTING</u> SAND PERMANENT MOLD INVESTMENT DIE CASTING • <u>EXTRUSIONS</u> • <u>MATERIALS</u> • <u>FASTENER SYSTEMS</u> • <u>EMERGING PROC</u> ISOTHERMAL FORGING POWDERED METAL PULTRUSION HIP HEALING CAM	• <u>MACHINING</u> TURNING MILLING DRILLING • <u>CHEM MILLING</u> • <u>ELECTRO-DISCHARGE MACHINING</u> • <u>ELECTRO-CHEMICAL MACHINING</u> • <u>EMERGING PROC</u> LASER FLUID-JET CAM EB CUTTING	• <u>METALLIC</u> FORMING CUTTING • <u>NON-METALLICS</u> FORMING CUTTING MOLDING LAMINATING • <u>EMERGING PROC</u> SUPERPLASTIC FORMING FLOW FORMING HYDROSTATIC FORMING THERMOPLASTIC FORMING CAM	• <u>HEAT TREATMENT</u> • <u>SURFACE TREATMENT</u> • <u>EMERGING PROC</u> LASER TREATING NON-ENVIRONMENTAL POLLUTING TREATMENTS	• <u>WELDING</u> • <u>ADHESIVE BONDING</u> • <u>BRAZING</u> • <u>EMERGING PROC</u> DIFFUSION BONDING WELD BONDING LASER WELDING ULTRASONIC WELDING PLASMA ARC * SUBASSEMBLY	• <u>METALLIC ASSY</u> MECHANICAL FASTENING • <u>NON-METALLIC</u> MECHANICAL FASTENING • <u>EMERGING PROC</u> BIMETALLIC RIVETS MICROWAVE CURING * MAJOR AND FINAL ASSEMBLY

Figure 8-1 Manufacturing Processes Available for Metal Fabrication

not a problem. Generally, the least expensive material which meets the requirement is chosen, but the impact of high cost processing may lead to selection of materials whose initial cost is higher, but whose total processing cost is less.

Finish Requirements

In most cases, the design engineer will specify a particular finish for the part. In the case of surface roughness, the impact of requirements on process selection is illustrated in Figure 8-2. As the smoothness requirement on metal parts becomes more stringent, the processing cost increases dramatically.

Shape and Form

In the majority of manufacturing operations, parts go through a series of stages of processing. Manufacturing economies for metal parts can often be obtained through selection of appropriate initial product forms such as castings, forgings or extrusions. In electronic parts, economies can be obtained by utilizing denser integrated circuits, thus reducing the complexity of the circuit boards which accomplish the final performance function. In this regard, it is critical that the series of manufacturing steps to be used be considered in total to ensure that the cost of the total manufacturing sequence is optimized, rather than optimizing individual steps in the process.

Operation Sheets

After selection of processes to be used, process instructions must be communicated within the facility. In many firms, operation or route sheets are used to identify the processing methods for materials and parts through the manufacturing area, as well as to provide the authorization for requisitioning the necessary tools, materials, and parts. The operation sheet also provides the basis for detailed planning, estimating, and scheduling of the manufacturing effort. A completed process sheet will normally provide identification data including:

1. Part number. Engineering drawing number to identify the part.

2. Part name. Noun to aid in identifying of part.

3. Date. A record of when the document was prepared.

4. Drawing number. Provide a record for the part. Often, part numbers are based on a code to indicate relationships, such as subassemblies.

5. Drawn by. Identify the planning or process engineer.

The body of the operation sheet provides the detail of the necessary operations and inspections through the shop to complete fabrication, and where necessary, final assembly and test of the part being considered. Operation sheets are normally structured to provide the following data:

1. Operation Identification. Sequential numbering of operations necessary to process the part.

2. Required Description. Brief, concise definition of each operation.

3. Material Required and Quantity. Describe both type and quantity.

4. Parts Required and Quantity. This information identifies the number of previously fabricated parts which will be required for the part being planned.

5. Machine Assigned. Designation of machine to be used.

6. Jigs, Tools and Fixtures Required. Any production equipment to be used for fabrication or assembly. Tools required to provide the specifically desired manufacturing operation. The method of feeding, holding, positioning, and/or releasing the work may require use of jigs or fixtures.

7. Department. The department name or work center in which the work is to be performed.

8. Standard Time. Standard times determined by the company through use of accepted estimating methods.

Care must be used in setting standard times since these will be used later to establish machine and personnel requirements. Setting required times may be delayed if there is likelihood of routing change during later process planning. Regardless of when set, standard times must be established by

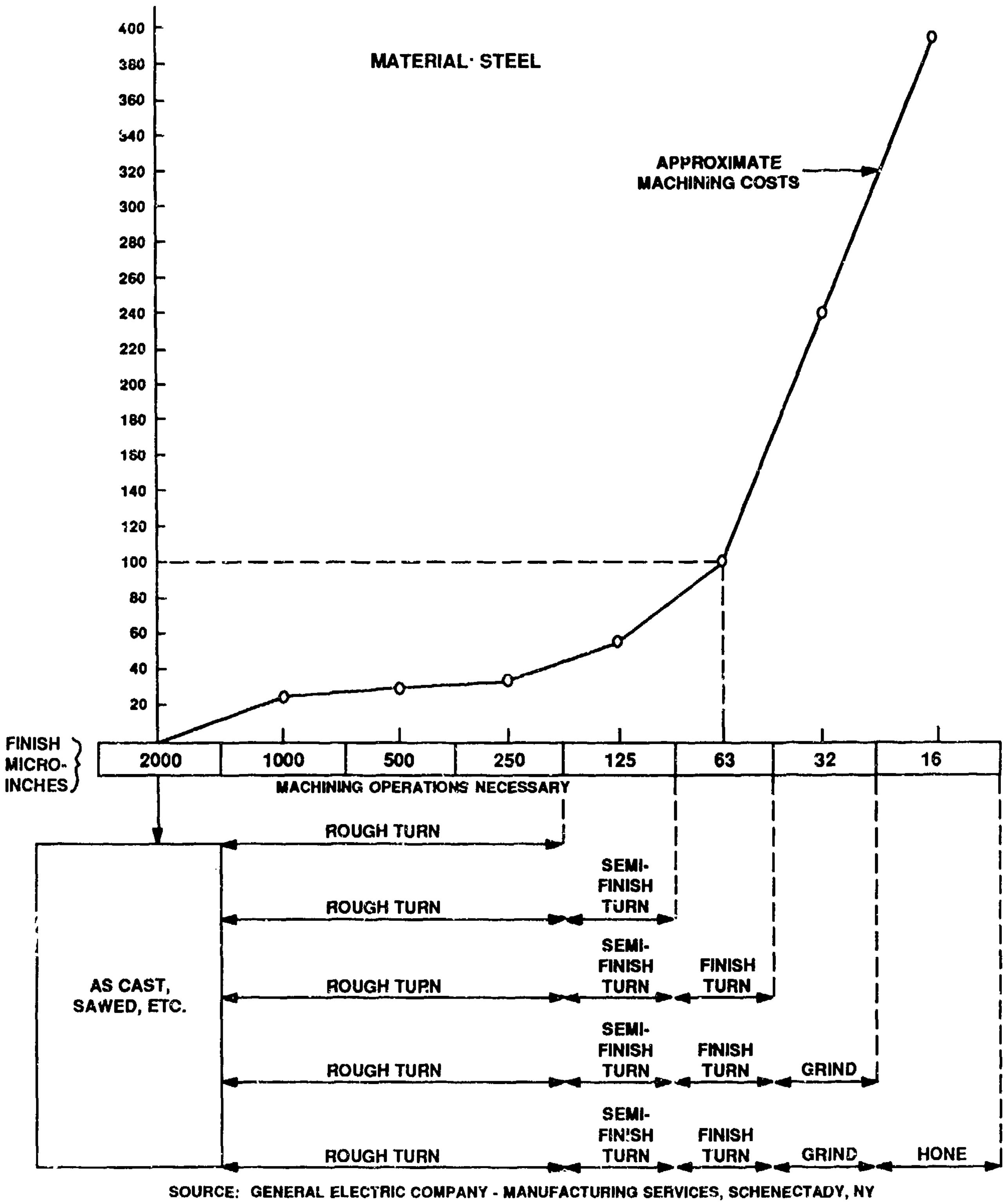


Figure 8-2 Relative Machining Costs and Surface Finish

persons qualified in the techniques used. The development and use of standard times are described elsewhere in this guide.

FACILITY ARRANGEMENT

After preliminary decision as to the flow patterns for work in the facility, thought must be given to the development of work facilities to conform with the selected flow patterns. The work station is the combination of equipment and people necessary to satisfy the requirements of an individual work task assignment. The individual work stations are combined, by either process or product arrangement, to form departments or cells which facilitate supervision and manufacturing planning and control. These departments are then combined to provide the total manufacturing facility.

In evaluating facility layout, certain conditions may be observed that indicate the facility arrangement is not as effective as it should be. Some of the symptoms of poor layout are shown in Figure 8-3.

developed if these technologies are to become part of real developed deployed systems. If the system performance forecasts are based on advanced applications such as those in Figure 8-4, the PM should ensure that manufacturing technology development is occurring in concert with the specific engineering development.

MANUFACTURING TECHNOLOGY

The objective of the DOD manufacturing technology (MANTECH), program, discussed previously in Chapter 4, is to develop or improve manufacturing processes, techniques, materials, and equipment to provide timely, reliable, and economical production of defense material. It is designed to "bridge the gap" between research and development (R&D) innovations and production. The MANTECH program was initiated to stimulate research in modern manufacturing systems, processes, and equipment with the goal of reducing system acquisition costs. It is a program to establish, validate, and implement advanced

- MATERIALS MOVE SLOWLY THROUGH THE PLANT
- MATERIAL HANDLING COSTS ARE HIGH
- LARGE NUMBERS OF INTERNAL EXPEDITORS ARE USED
- STOCKROOMS AND WORKPLACES ARE CROWDED
- WORK IN PROCESS IS FREQUENTLY DAMAGED OR LOST
- WORK MOVES IN ERRATIC FASHION THROUGH THE PLANT
- FAILURES TO MAKE SCHEDULES ARE COMMON

Figure 8-3 Symptoms of Poor Facility Layout

TECHNOLOGY TRENDS

A number of technology areas have been identified by DOD as having significant potential benefit to DOD systems. These are shown in Figure 8-4. In each case, the application of the technology will require that the underlying scientific problems in the technologies be solved. In addition, cost effective manufacturing processes must be manufacturing capabilities for: 1) producibility, 2) productivity, 3) cost/price reduction, and 4) quality assurance. An important MANTECH program goal is to ensure that the results of laboratory research and development investments can be translated into the production of defense equipment at the factory level.

Very High Speed Integrated Circuits
Focal Plane Arrays
Uncooled Detectors
MMW Seekers/Sensors
Multi-mode/multi-color seekers
Fiber Optics
Advanced Algorithms Processing
Advanced Warhead Concepts •• Aimable •• Explosively formed penetrator
Directed energy/high power MW
Low Observables
Passive Sensing and Detection
Satellite Navigation Systems

Figure 8-4 Future Trends in Technology

The MANTECH program is designed to stimulate effective industrial innovation by reducing the cost and risk of advancing and applying new and improved manufacturing technology. The integration of MANTECH and acquisition programs is illustrated in Figure 8-5. To obtain the maximum benefit on units manufactured using the improved technology, new manufacturing technology should be available, in proven condition, early in the production phase of a program.

DOD funding of manufacturing methods and technology efforts is intended for projects which meet the following criteria:

o Satisfies a current or anticipated requirement for which manufacturing technology will increase general productivity.

o Not a duplication of effort of either government or private programs.

o Emphasis should be on development of processes, techniques, or equipment rather than R&D oriented efforts.

o State-of-the-art must have been demonstrated.

o Substantial benefit potential in three areas: 1) improve responsiveness to current and projected requirements, 2) improve the defense production posture, 3) reflect the most advanced manufacturing state-of-the-art.

Information concerning the MANTECH program and the results of the projects are made available through four methods.

First: End of Contract Briefings - Generally, MANTECH contracts require the contractor to demonstrate the results to its peers. A list of the tentatively scheduled briefings is compiled early each calendar year and distributed to the private sector through a number of societies and associations which interact with the Manufacturing Technology Advisory Group (MTAG).

Second: Technical Reports - Each MANTECH contractor is required to prepare a technical accomplishments report. The Services distribute these reports to those companies known to be interested in the particular

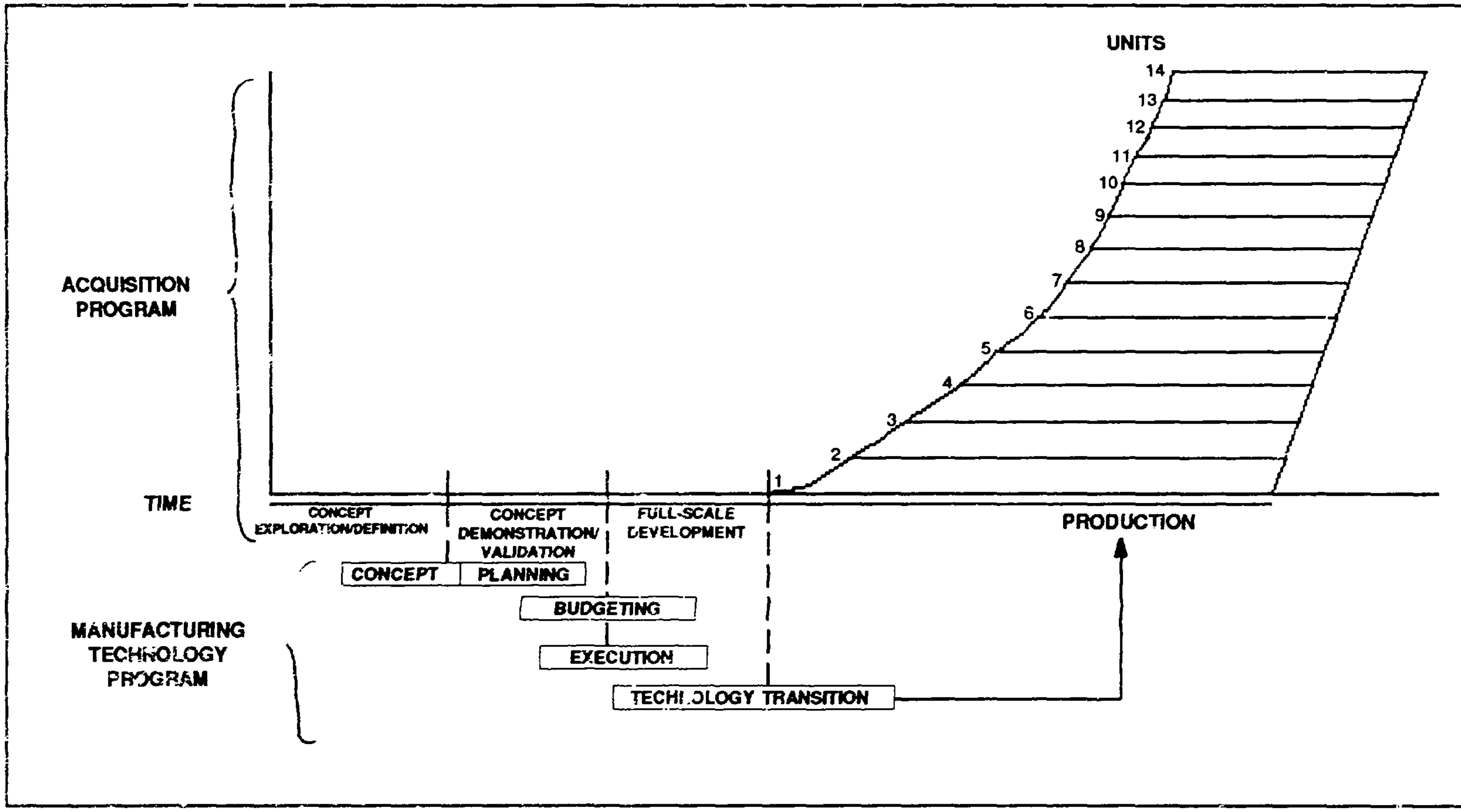


Figure 8-5 Manufacturing Technology/Acquisition Management

technology. In addition, copies are sent to the Defense Technical Information Center (DTIC), where the report is entered into a bibliographic data base. DTIC's bibliographic data base is accessible by remote terminals from many government and contractor locations throughout the country. In addition, those reports which can be released to the public for unlimited distribution are automatically sent to the National Technical Information Service (NTIS) by DTIC where they can be purchased by anyone for a nominal sum.

Third: The Manufacturing Technology Information Analysis Center (IAC) in Chicago is one of several Information Analysis Centers established by DOD in recognition that it might be difficult to find specific technical information within the vastness of the DOD community. This particular IAC focuses on manufacturing technology. It has on-line access to the DTIC data bases and has created its own data base for other literature. It has also produced technical reports of interest to the DOD MANTECH community such as "High Order Languages for Robotics" and "Uses of Artificial Intelligence in Manufacturing".

Fourth: Perhaps the most effective MANTECH program technology transfer vehicle is the organization known as the MTAG. This group provides inter-Service coordination of the MANTECH program. It consists of an Executive Committee and six Technical Subcommittees (Computer Aided Manufacturing, Metals, Non-metals, Test and Inspection, Electronics, and Ammunition). The MTAG maintains liaison with about a dozen industrial societies and associations throughout the year. The Subcommittees' interaction with the groups provides the opportunity for the technical experts to discuss and exchange information of mutual interest. The MTAG also holds an annual plenary meeting attended by MTAG members and the industry groups.

INDUSTRIAL MODERNIZATION INCENTIVE PROGRAM (IMIP)

In the Defense industry, two problems have been cited most frequently as inhibiting modernization and progress in the productivity area. These are program uncertainties and a profit policy which, in certain cases, is based on cost. In the first instance, risks are introduced which hinder investment amortization and inhibit long term planning. In the case of the government's cost based profit policy, a contractor may actually see profits reduced as a result of efforts to improve productivity and reduce costs.

These factors have worked to accentuate what some have criticized as contractor management's emphasis on short term profits and maximizing return on invested capital. Return on assets has often been used as a yardstick in measuring corporate progress and executive performance. This management philosophy results in a reluctance to invest large sums of capital due to effects on the current financial balance sheet. Figure 8-6 graphically demonstrates the main problem in justifying cost reduction investments involving large outlays of capital. The problem is profits (cost savings/avoidances) do not increase in the short run, while costs (capital invested) increase significantly because capital must be invested in advance or "up-front" of the expected benefits. This phenomenon can lead to extremely conservative capital asset management, and long term productivity gains are often lost.

The IMIP provides a common framework for an extension of the military services' "TECHMOD" and MANTECH programs. MANTECH is a well established program with objectives which are in some ways similar to IMIP, i.e., making improvements in manufacturing productivity. But there are some very significant distinctions. The main focus under IMIP is to encourage contractors to make capital investments which will result in increased productivity, improved quality, reduced DOD acquisition costs and an enhanced industrial base. IMIP is aimed at improvements on a factory-wide basis, and involves both well established and state-of-the-art technology. Perhaps the most important distinction is that the main thrust of the IMIP is on contractor funding for investments.

The IMIP is intended as a tool to overcome the previously discussed impediments to increased capital investment. Under the IMIP, incentives can be provided to motivate a contractor to invest corporate funds which result in reduced acquisition costs. The

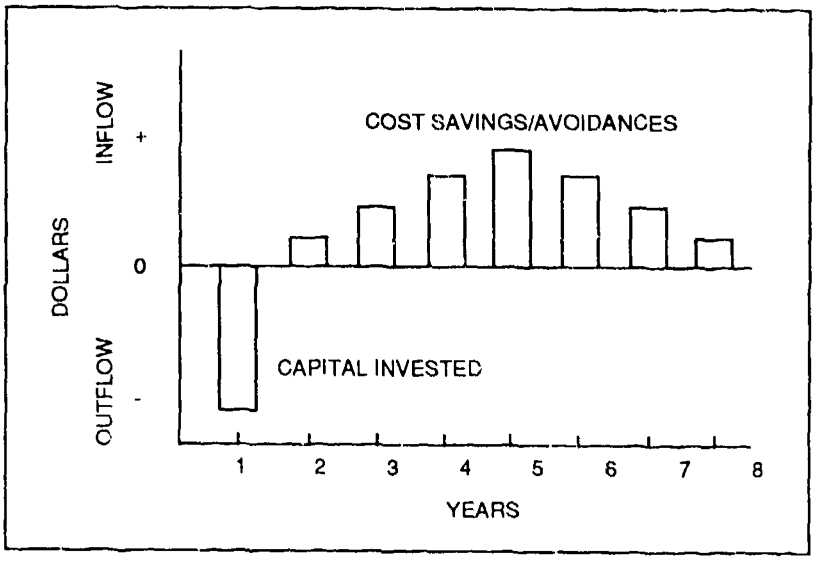


Figure 8-6 Cost Reduction Example

idea is to negotiate a business arrangement with benefits to both parties that may not have been possible otherwise.

The principal incentives are shared productivity savings and contractor investment protection. The shared productivity savings allow industry to share in the savings which are a product of making these capital investments. The contractor investment protection permits amortization of plant and equipment through a contingent liability guarantee.

The Services and their program managers must continually identify programs where application of advanced technology would increase productivity, result in savings to the government and increase profits to the contractor. Some programs that have adopted advanced manufacturing practices have experienced significant results. The Air Force F-16 program is a classic example. A $25 million Air Force investment in advanced manufacturing technology was negotiated in conjunction with a commitment of the contractor to invest $100 million in severable plant equipment. The government provided termination protection for the $100 million contractor investment over 1158 aircraft. An agreement was made to adjust the contract target and ceiling amounts for savings according to a prescribed formula. An award fee of $1 million per year for four years was allowed. The potential F-16 manufacturing cost savings was calculated to be in excess of $370 million over 1388 aircraft, with the Air Force share of this savings in excess of $220 million.

Figure 8-7 illustrates the effect an IMIP would have on a program baseline. The program baseline, with and without the IMIP, is shown during its various stages, and the difference between the two as shared savings is shown.

The technical aspects of the IMIP are divided in three phases:

1. Analysis and Planning. This consists of identification of high cost manufacturing areas, analyses, and development of initial approaches to improve factory manufacturing. Analyses are made of advanced manufacturing technologies, contemporary equipment, quality assurance, production control, and management information systems. Cost saving potential, return on investment and conceptual design of

factory layouts required to implement specific improvements are developed.

and implementing these into production must be developed.

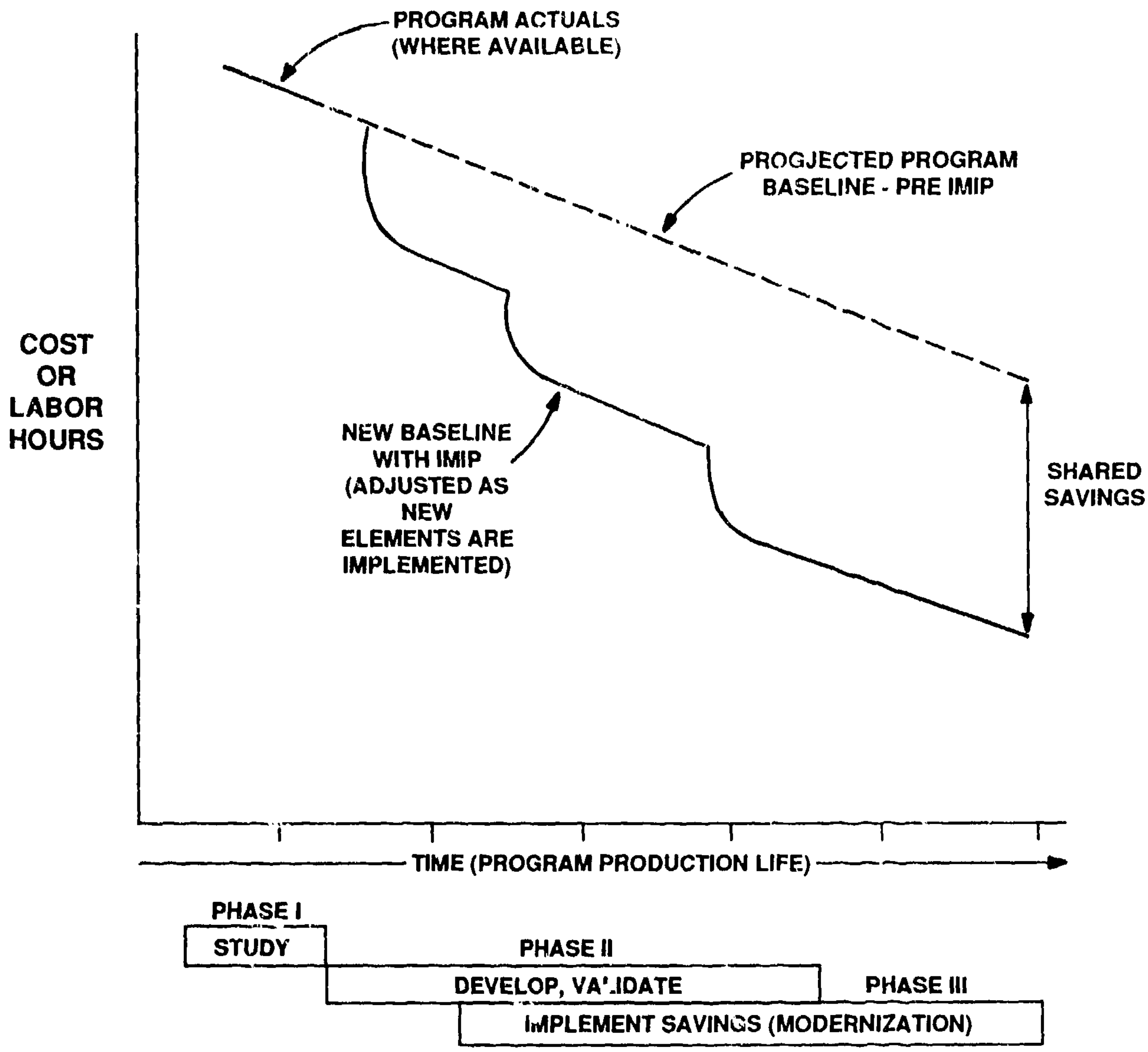


Figure 8-7 IMIP and Program Baseline Adjustments

2. Technologies. This includes establishing and validating enabling technologies which are voids in the manufacturing state-of-the-art that must be overcome to attain higher levels of factory integration. A detailed definition of factory enhancements and a plan for accomplishing

3. Implementation. In this phase, detailed factory designs are completed and enabling technology programs are integrated into manufacturing operations. Advanced management information systems, manufacturing planning tools, and the cost analysis and performance assessment system are made ready for implementation.

FACILITY MODERNIZATION

The annual rate of productivity improvement in the United States is lower than any major industrial country of the Western World. This can be attributed largely to the fact that our manufacturing plants are operating with tools and processes that have not kept pace with emerging technology. The result is that we are losing our position as the world leader for production of manufactured goods of the highest quality. Peter Drucker, a founding father of the discipline of management, has called for a restoration of our international competitiveness based on three approaches: 1) moving to more automation, 2) the redesign of entire plants and processes as integrated flow systems, and 3) the integration of mini and microcomputers into our tools.

The technology exists for drastic advances in manufacturing processes and companies that have introduced innovative methods such as Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) or Computer Numerical Control (CNC) systems are experiencing phenomenal productivity increases. Advanced computer technology and the development of a theory of factory architecture has changed many old ways of doing business. The opportunity exists to start designing directly to the capabilities of our manufacturing and quality tools, rather than incrementally adapting a design to the limitations of a traditional manufacturing operation.

Not all of the obsolence that exists within the defense industry can be attributed to government policies. Nor is the use of standard equipment and tools which have proven their value over a great many years a valid indicator of an inefficient factory. Some changes are desirable; some should be undertaken with caution; but any change has to be justified in the eyes of the investor.

There is a continuing need for basic operations such as milling a flat surface; broaching a key slot; and number of casting, forging and forming methods which will not justify automating. Production requirements must justify the cost of special fixtures in order to realize a return on the investment. In a great many cases, general purpose tools, such as vises, will be adequate for securing parts during milling, drilling or grinding. Low volume printed circuit boards may be more economically supported with a foam pad than a Class A holding fixture, and hand assembly may be less costly than developing a program for mechanically inserting components in the board. The economics of lot size is a fundamental consideration in tooling and mechanization decisions.

Some processes seem natural candidates for numerical control. Spot welding, for example, has been automated in the auto assembly plant. However, a case where the part can't be moved to the machine presents another set of conditions to be considered. Complete mechanization or automation may not be the most productive alternative in many plants due to quantity requirements, special product characteristics or a particular plant's equipment inventory. In some cases the most attractive alternative may be to have the part produced in another plant or by another contractor. Economics is generally the basis for a contractor to subcontract to other companies and a critical consideration (as discussed earlier in this chapter) in any modernization or expansion program for a contractor.

The following factors should be stressed with the involved contractors: (1) adopt greater innovation in the use of materials and processes; (2) develop a strong link between manufacturing R&D and operations to ensure that technology which is ready for the manufacturing floor gets there; (3) initiate innovative approaches from the financial and contracting standpoint to develop risk sharing mechanisms effective over longer periods; and (4) make a commitment for capital investments to update obsolescent facilities and equipment.

Companies that utilize very few new manufacturing processes lack a potential for productivity improvement, a potential for lower cost manufacturing and increased profit-making opportunities. The high cost of failure scares off many firms and is the prime reason for management resistance to implementation of potentially money-saving projects that involve new, more expensive, and complex manufacturing equipment, controls, or processes. The Department of Defense has strongly advocated the utilization of advanced technology as a means of reducing manufacturing costs and to help in the resolution of other production base problems. DOD MANTECH and IMIP have as basic objectives the improvement of productivity and responsiveness of the defense industrial base by sharing with industry the risks and costs of establishing and applying new and improved manufacturing technologies.

A division of one of the larger U.S. corporations, while preparing to install what is reported to be the largest concentration of electron beam (EB) production welding machines in the world, developed a set of guidelines designed to minimize the risk associated with the new process implementation. The general nature of these guidelines is applicable to nearly any prospective new process application:

1. Experiment with as many process alternatives as possible. Make certain that, before the decision is made to select a particular new process, it is the optimal choice for the task that must be accomplished. Consideration should be given to reliability and maintainability, return on investment, productivity improvement potential, adaptability to design changes, and any special feature that would enhance the manufacture of the required product.

2. Advice from product design personnel must continually be sought during the decision process

3. Obtain names of users of processes under consideration from equipment builders. Observe both successful and unsuccessful process applications.

4. Obtain from current users:
   a. Level of operator skill required,
   b. Level of maintenance skill required,
   c. Cost of "consumables",
   d. Indirect labor required,
   e. Long term efficiency of the process,
   f. Most frequent causes of breakdowns,
   g. Expected number and severity of breakdowns,
   h. Cost of back-up tooling and maintenance items, and
   i. Rework and scrap rates.

PRODUCTION INNOVATIONS

New methods in manufacturing developed in recent years are drastically changing the production process, and the extent of their adoption will be the key factor for most companies to remain competitive. The advent of the computer has by far been the single factor that has most influenced the shift toward an automated factory system. Factory automation includes the use of such methods as: 1) numerical control machines, 2) transfer machines, 3) robots, 4) automated warehouse systems, and 5) material handling devices that are hardware systems for processing, handling, or storing factory products.

Technologically we are at the dawn of another industrial revolution brought about by the inexpensive computer power available through today's electronic technology. The selection of processes driven by today's technology are discussed in this chapter. Professor David Acker, DSMC, contributed the information on robotics, and computer-aided design and manufacturing which are included in this chapter as well as the information on automated systems discussed in Chapter 14.

The areas that lend themselves most readily to computer control or monitoring are the following:

a. Direct Process Control -- Utilization of components for the direct control of machine tools, referred to as computer numerical control (CNC). Such a system usually contains a large computer as a part program generator, a medium-scale computer as the active supervisor, an interpolator that feeds data to a number of machine tools, and a minicomputer as the controller of each machine tool. Also, direct computer control is utilized for the control of conveyors, stacker cranes, plating operations, heat treat furnaces and many other factory operations.

b. Process Monitoring -- Computers are used to collect data and provide reports to management on process parameters, machine utilization and maintenance status. Powerful minicomputers and more sophisticated hardware have created the ability to link computer hardware as a means of providing a broad-based plant monitoring and control system, referred to as distributed processing.

c. Testing and Inspection and Computer Aided Testing (CAT) -- Computers test and automatically adjust electrical and mechanical components and assemblies. Performance statistics and overall quality reports can be provided to management.

d. Plant Management and Information Systems -- Data collection systems use shop floor terminals for data originated from foremen, tool operations and other shop personnel. Data collection is often used in conjunction with the material requirements planning (MRP) function as well as with inventory control, scheduling, and work in-process reporting.

e. Engineering Support -- Special computer aids to the manufacturing engineering function include interactive graphics systems for product and tool design and tolerancing, time study, machine tool capability analysis, line balancing, and group technology packages.

f. Environmental Control -- Computer systems are used for monitoring and controlling heating and air conditioning, air and water purity, and power usage.

Successful factory utilization of the above control techniques requires a systematic planning process. Detailed planning must properly define the company's needs and apply the appropriate solutions to the problems. The following questions must be considered:

1. What is the present level of automation?

2. How well does the current system meet company needs?

3. What level of automation is needed to satisfy current demands, future growth and productivity requirements?

4. What are the system uses?

5. Where can the current system be used?

ROBOTICS

Industrial robots, for the most part, perform simple, repetitive motions with some degree of precision. They perform such tasks as welding, forging, material handling, machine loading/unloading, palletizing, grinding, deburring, polishing, spraying, assembling, machining, inspecting, and packaging. Industrial robots have the potential to increase productivity, provide manufacturing flexibility, reduce manufacturing costs, and replace workers in hot, dirty, hazardous, monotonous, and fatiguing jobs.

The Nature of Industrial Robots

In a factory, robots represent off-the-shelf automation. They fill the gap between special purpose automation and human endeavor. Practically speaking, they are machines that are capable of duplicating human skills and flexibility with both accuracy and precision.

The Robot Institute of America (RIA) defines a robot as "a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." An industrial robot can control and synchronize the equipment with which it performs. With this kind of capability, it can eliminate the need for people to work in environment that may be dirty, dull, or dangerous.

Typical tasks assigned to robotics are shown in Figure 8-8.

Growth of Industrial Robot Installations

Although there are obvious advantages to installation of robots in our factories, U.S. industry has been relatively slow in adapting them. Reluctance to do so may stem from management's perception that the average worker in a factory subconciously fears robots. Workers fear robots because, at first glance, they appear to be part of the ultimate scheme of management to eliminate workers from the work place. Actually, industrial robots represent a long awaited advancement. Ultimately, the robots will free workers from tasks that (1) present serious health hazards, (2) require human agility and mobility, but are mundane and/or repetitive, (3) require human skill, but which cannot be performed effectively for long periods of time because they cause fatigue. In the future, workers will not become obsolete, but some of their present skills will.

motions to human arm movements. However, the potential for cost savings is greater if ways are also found to use robots to save materials.

Palletizing
- ☐ Glass
- ☐ Metal
- ☐ Plastics
- ☐ Bricks
- ☐ Ceramics
- ☐ Yarn
- ☐ Furniture parts
- ☐ Food products
- ☐ Toy products
  Housewares

Spraying
- ☐ Finish materials
- ☐ Fiberglass polyester
- ☐ Urethane, polyester foam

Grinding/Deburring/Polishing
- ☐ Metal parts
- ☐ Plastic parts
- ☐ Wooden parts

Searching
- ☐ Depalletizing
- ☐ Palletizing

Machine Load/Unload
- ☐ Die casting
- ☐ Injection molding
- ☐ Blow molding
- ☐ Thermoset molding
- ☐ Ultrasonic welders
- ☐ Inspection devices
- ☐ Stamping presses
- ☐ Machine tools

Packaging
- ☐ Loading into cartons
- ☐ Placing into strapers

Post Operations
- ☐ Degating
- ☐ Deflashing
- ☐ Rough trimming
- ☐ Quenching

Assembly
- ☐ Small to large plastic products
- ☐ Small to large metal products

Tool Carrying
- ☐ Spot welding
- ☐ Arc welding
- ☐ Drills
- ☐ Routers
- ☐ Staple guns
- ☐ Automatic nailers
- ☐ Flame drying guns
- ☐ Water jets
- ☐ Lasers

Line Tracking
- ☐ Automatic welding
- ☐ Glass handling
- ☐ Conveyor loading/unloading

Forging/Foundry Handling
- ☐ Upset
- ☐ Die forging
- ☐ Press forging
- ☐ Roll forging
- ☐ Swaging
- ☐ Heat treating
- ☐ Loading/unloading oven
- ☐ Handling parts through presses
- ☐ Flame cutting

Figure 8-8 Typical Robot Tasks

Manufacturing Cost Distribution

It is important to recognize today's manufacturing environment. Figure 8-9 presents a breakdown of typical manufacturing costs, by percentage. This breakdown is representative of the situation in defense, aerospace, electronics, and heavy industries in the United States. Materials account for the biggest "slice of the pie."

The opportunity for reducing manufacturing costs by introducing robots has generally been in the area of direct and indirect labor tasks. With costs distributed as shown in Figure 8-9, the first inclination is to consider replacing direct and indirect labor with a robot due to the similarity of robot

For many years robots were marketed as the answer to many of the problems faced by industry in the United States. U.S. industry was beset by (1) rising direct labor costs, (2) pressures to improve productivity, (3) challenges posed by environmental and occupational health and safety authorities, based upon unpleasant and hazardous working conditions, and (4) need for better product quality. A modest, but increasing number of robots have not only been able to solve these problems, but have been able to save materials and provide a manufacturing flexibility not available previously.

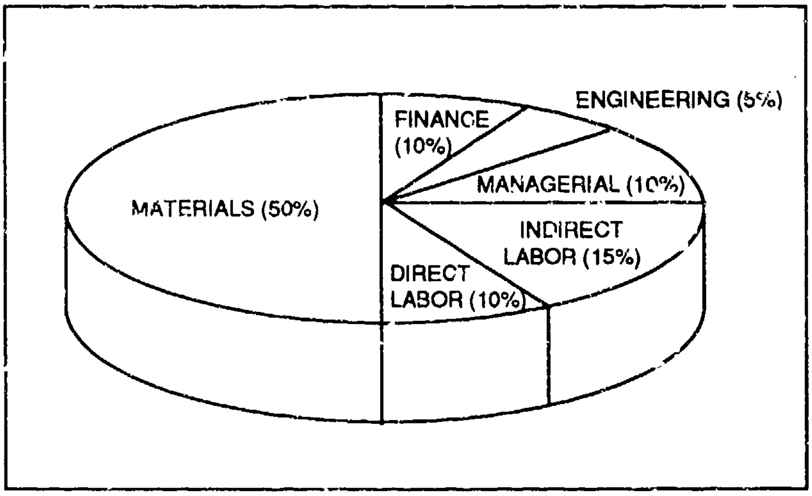


Figure 8-9 Typical Manufacturing Cost Distribution

Robotic Integration

Industrial management generally recognizes that factories need to be designed as systems. Unfortunately, about three-quarters of the new robots are being integrated into existing production lines. The robots are not being made a part of a new "system," i.e., a manufacturing center composed of cells, each having several work stations. Robots will gain wider acceptance if they become a part of such work cells in manufacturing centers instead of becoming just another piece of equipment in an existing production line. The centers provide significantly greater efficiency, flexibility, and effectiveness in manufacturing operations than do the production lines of older factories.

In the factory the hard-technology view and the soft-technology view should form a global perspective of manufacturing systems. The hard-technology view will focus on the production of the product. This view will be represented by centers with cells containing robots and the other processing equipment as just discussed. The soft technology view will focus on communicating the requirements for monitoring, controlling, and reporting the status of the systems. In other words, the technical and business systems will be integrated to become a part of the overall manufacturing system. If we understand this concept, then we can recognize why far-sighted industrial management is inclined to be more concerned with manufacturing centers than with individual robot applications.

Robots are justified within the production volume ranges shown in Figure 8-10. When less than 200 parts are to be manufactured per year, manual labor is usually less costly. Above 20,000 parts per year, hard automation is generally more cost effective.

Today, about 80 percent of the U.S. industrial robots are being applied to welding, material handling, and machine loading/unloading. The remainder of the robots are being used in such activities as spraypainting, machining, assembling, and palletizing. About 40 percent is divided almost equally between foundries and the light manufacturing industry that is producing nonmetal products. The remainder of the applications are in the heavy equipment, electrical/electronics, and aerospace industries.

Over the years, the capabilities of robots have continued to increase. Much of the current robot technology was unknown just a decade ago -- particularly control technology and programming. Now, robot manufacturers have discovered electronic logic and computer software. These technologies are making robots adaptable to an increasing variety of complex tasks. Therefore, it is very important that each proposed application be carefully considered and that the robot selected be properly engineered to ensure success. Such a robot will inherently increase manufacturing flexibility and improve product quality and productivity.

1. Structures. The structures of robots will have to be made sufficiently stiff and rigid to overcome the fundamental problem of accuracy and repeatability.

2. Sensing. Robots in the factory will have to be able to see, feel, hear and measure the position of objects in many different ways. Therefore, the data from sensors will have to be processed, and information extracted that can be used to successfully direct robot actions.

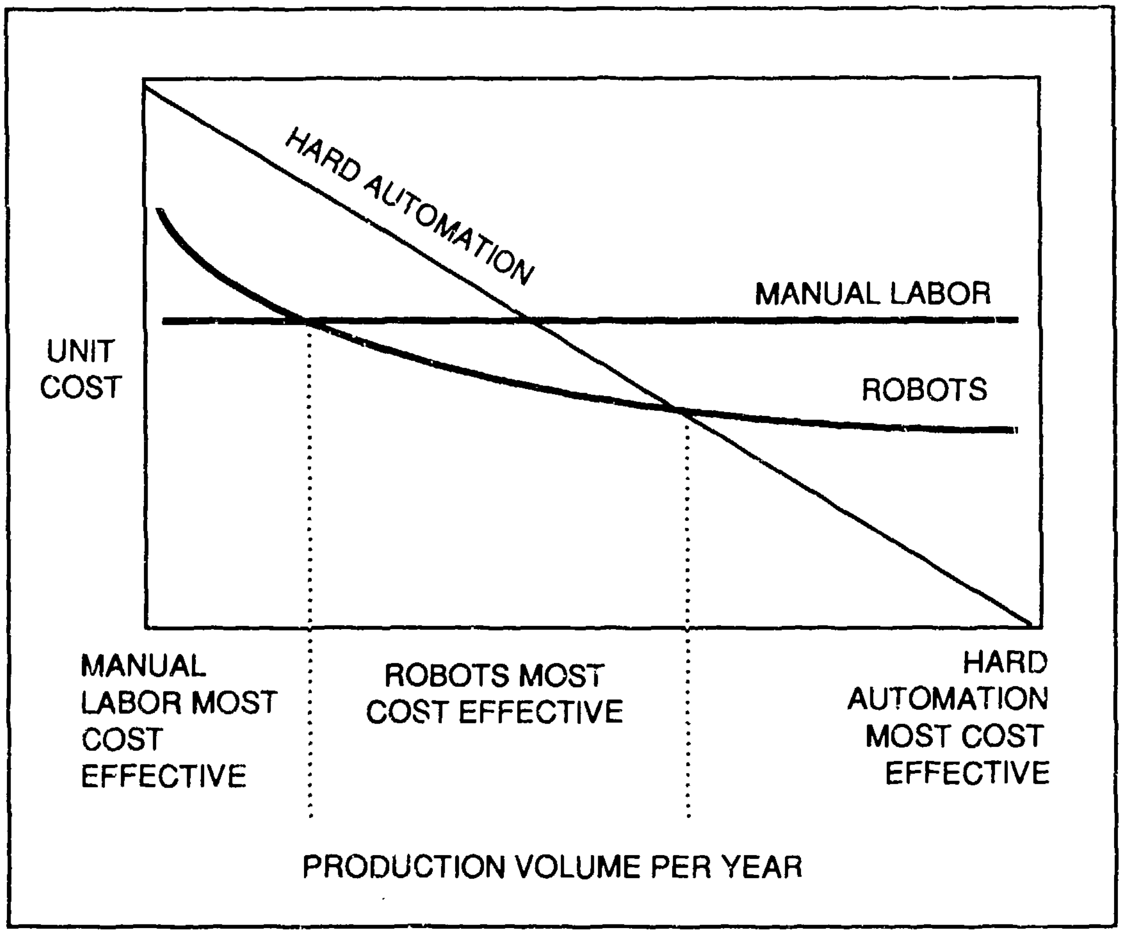


Figure 8-10 Comparison of Manufacturing Method Unit Costs, By Level of Production

Impediments to Application of Robotics

James Albus of the National Institute of Standards and Technology indicates there are six problems associated with robotics that have to be solved. The problems are identified below:

3. Control. Robots with sensors will have to be able to accept feedback data at a variety of levels of abstraction and have control loops with a variety of loop delays and predictive intervals.

4. World Model. Robots will have to store and recall knowledge of the world about them that will enable them to behave intelligently and show some insight regarding the spatial and temporal relationships inherent in the work place.

5. Programming Methods. The techniques for developing robot software will have to be improved.

6. System Integration. Robots will have to be integrated into the overall factory control system.

Fortunately, the technical problems are amenable to solution. However, until the problems are solved, robot capabilities will be limited and robot applications will continue to be relatively simple.

Today, robots can handle parts that are similar in size and orientation, and placed in the same general location. And a few advanced state-of-the-art robots can "look" for a part. However, future robots will be able to find specific parts with "TV" eyes and orient the parts as required. Also, sophisticated sensors will be able to "feel" the difference between various part sizes and/or orientations. A memory, linked to the eyes, will be able to tell the arm which part to select Further, robot memories will help in sorting out and removing wrong or broken parts. The major problem that has to be overcome, before these advances are possible, is to reduce the cost of vision sensors. Presently, the sensor cost start at about $120,000. This is usually too high a price to pay, if one takes into consideration the length of the payback period.

OVERVIEW OF COMPUTER AIDED DESIGN AND MANUFACTURE

CAD - computer aided design - represents the merger of computer technology with mechanical drawing. The three essential functions that can be better accomplished with CAD are: line drawings that can be created and stored for future reference; libraries of common symbols used to create line drawings that can be easily accessed; and plotting and dimensioning functions that save numerous hours of manual drawing and computation and establish a database for future reference.

CAD represents a significant advance over manual design work in three subareas: geometric and surface construction, three-dimensional modeling, and structural or stress analysis. Manual design analysis requires extensive generation of mathematical formulas to describe a surface or shape. With a manual system, stress factor calculations are accomplished by the computer. With CAD graphics systems, the input process is aided significantly by the computer, and the resulting analysis data are presented graphically on the system screen, a significant advancement.

Computer aided manufacturing (CAM) has five subsets: production programming, manufacturing engineering, industrial engineering, facilities engineering, and reliability engineering.

Production programming involves the preparation of numerical control tapes or patterns to be used in the manufacturing process. Manufacturing engineering relates to the design of the product and the tools necessary for actual production. Industrial engineering involves analysis of labor and equipment utilization and process control considerations. Facilities engineering involves equipment design and plan and equipment layout. Reliability engineering is concerned with quality control, coordinate measuring, and failure analysis. These components of the manufacturing process represent a major opportunity for the use of CAM graphics systems.

Computer integrated manufacturing (CIM), is an extension of CAD/CAM. CIM utilizes the database created through computer aided design. The manufacturing control subsystem interfaces with numerically controlled machines, makes quality assurance checks during process manufacturing, and compiles time and attendance records. Computer integrated manufacturing links computer aided design and manufacture. A corporate database unites business data processing; computer-aided designs and reporting and control of manufacturing operations, including material control, quality assurance, and shipping and billing.

Computer aided design (CAD) and computer aided manufacturing (CAM) systems comprise a class of computer-driven systems that offers the potential for significant productivity gains in specific areas of manufacturing and other labor-intensive design and documentation.

Graphics systems are available for integrated circuit design; design of automotive, aircraft, and other manufactured parts; numerical control applications; design of plants in automotive and aircraft industries.

The CAD/CAM concept has gained quick acceptance in the industrial and design services marketplaces due to the resulting immediate gains in productivity. In addition to direct cost savings, CAD/CAM graphics systems can be justified on the basis of greater accuracy, application to automatic manufacturing processes, the reduction of errors through automatic error-checking procedures, reduced design turnaround time, uniformity of design quality not achieved through manual procedures, and reduced dependence on highly skilled and highly paid engineers for design. Three major advantages for users of CAD/CAM graphics systems are centralized database creation, data extraction capabilities, and documentation of engineering drawings.

The strong demand for CAD/CAM systems is due to four factors. First, productivity is increased from 3-10 times, depending on the task to be performed. Second, the lack of trained draftsmen and technicians is partly compensated through the use of turnkey systems. Third, the systems can produce more complete and better quality designs than existing design teams can produce. Fourth, use of the CAD/CAM systems eliminates repetitive routine tasks for designers.

Computer Aided Design

As currently applied in the defense industry, product design engineering utilitizes computer aided design (CAD) to provide descriptive geometry on an interactive graphics terminal. This essentially allows the designer to shape/size/dimension a given part via the computer. CAD is currently moving into Phase III of its evolution. Phase I can best be characterized as the descriptive geometry phase. Phase II added three-dimensional oriented methodologies to provide visualization that facilitates the design effort. Phase III will encompass three-dimensional physical part modeling along with the analysis and simulation tools to allow the designer to "stress and test" the design before finalization.

Figure 8-11 illustrates the interrelationship between conceptual design, preliminary design, and production design. The shaded area through the middle is currently accomplished through CAD. As CAD moves into Phase III the unshaded tasks will be accomplished "real time" through CAD and the associated computer aided design analysis.

CAD has shown impressive payoffs in productivity as compared to manual methods. Among the reasons for enhanced productivity are: complex constructions can be done faster with a computer; repetitive construction entities do not have to be redrawn, but can be instantaneously called from storage; geometric constructions are performed by the computer and do not have to be calculated, and the concentration of a designer on the video screen in an interactive mode is more intense than the designer is able to sustain on the drawing board.

Computer Aided Manufacturing

Computers have also been widely applied to manufacture and the term "computer aided manufacturing" (CAM) is used to describe manufacturing procedures that use computers to assist in the planning and production process, from inventory control to the programming of machine tools.

Like CAD, CAM applications are almost limitless. Among them are computer aided process planning (CAPP) to standardize and optimize production methods by transferring decision making to the computer. Also, a very close cousin to CAM is computer aided material planning and processing (CAMPP) which eliminates much of the labor intensive effort associated with these tasks. In the material planning and purchasing, the ultimate step in computer automation would be CAD generated data in a centralized product definition data base which purchasing could access such that purchase planning and order writing could be accomplished automatically.

Computer Aided Design and Computer Aided Manufacturing

Combining CAD with CAM (CAD/CAM) is the most active manufacturing initiative today, ahead of Flexible Machining Systems

(FMS) and even group technology. An accurate in-depth understanding of CAD/CAM, however, has fallen behind the popularity of the term. It really means integrated product engineering and manufacture in the broadest sense of the word. Too many users today have settled for CAD, or worse yet, a small segment of CAD such as computer graphics. Similarly, some have seen CAM as numerical control (NC) tools; others have seen it as manufacturing resource planning (including material requirements). Fortunately, now these people are extending the limits of their thinking. They are looking to the high pay-out from the synergism of an integrated manufacturing system.

many parts can be produced from start to finish by CAD/CAM; in some cases, drawings and paperwork have been eliminated entirely. Overall lead time has been reduced by as much as two-to-one, and design time by five-to-one. It has also been found that the efficiency of the approach has reduced computing time itself by 25 percent. Designs are improved because more alternatives can be evaluated and communications have been improved throughout the design/manufacture process. CAD/CAM can have a major impact on management by providing better information on the use and productivity of capital.

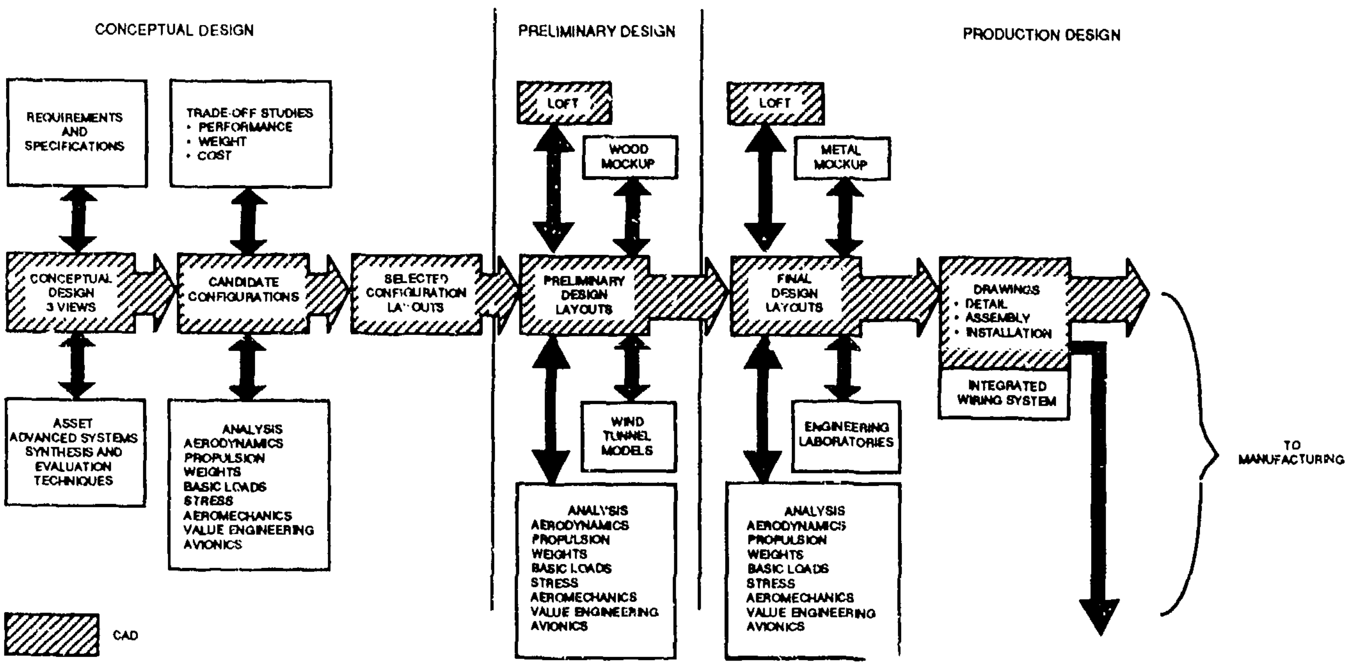


Figure 8-11 Interrelationships of Discrete Design Phases

CAD/CAM can revolutionize industrial production. CAD/CAM has been known to cut the entire design, drafting, manufacturing process time by factors of four, five and even more. The companies that have pioneered with this revolutionary tool have found that

Figure 8-12 is a schematic layout of the CAD/CAM process illustrating the functions and procedures that take place. Computer aided design is a system for the design, problem solving and drafting phases of

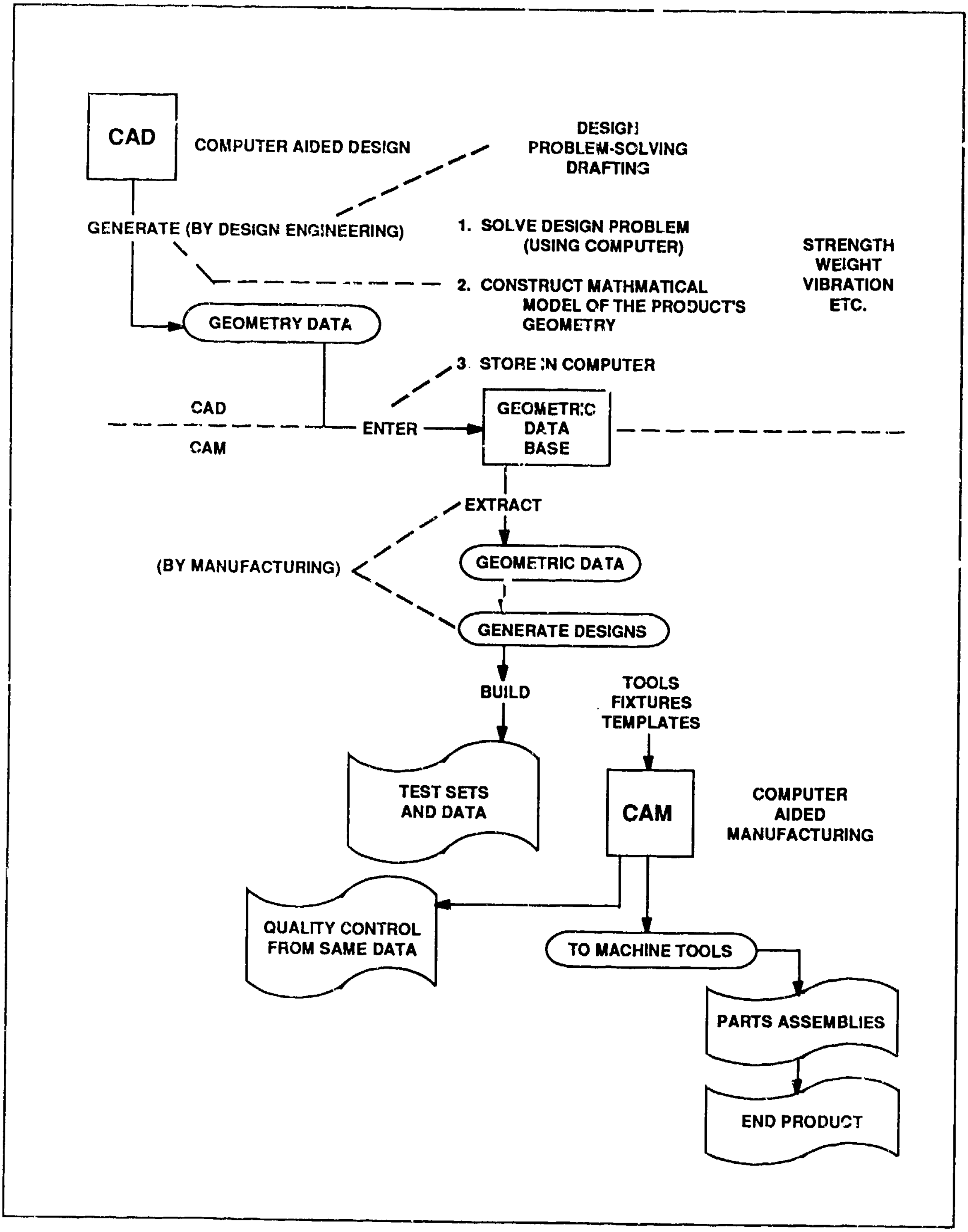


Figure 8-12 CAD/CAM - How It Works

engineering. This system provides computerized input to the manufacturing process and its prime mission is the manufacture of engineering drawings. A graphics console (Interactive Computerized Graphics (ICG)) terminal (consisting of a special keyboard, cathode ray screen and a cursor control) provides rapid drafting capability. After solving design problems such as strength, weight, noise, vibration, etc, engineers construct a mathematical model of the product's geometry and store it in the computer Geometric Data Base (GDB).

The next step is the start of the manufacturing cycle. Tool programmers or part programmers retrieve a drawing previously created by the design engineer and stored in the GDB. A part program is developed using a large, arithmetically powerful computer as a part program generator. The program is then fed to a smaller, medium-scale computer that performs the functions of active supervisor and interpolator, feeding data to the controller of machine tools. Parts and even complete assemblies, are produced by instructions from the part program with constant monitoring to ensure that established tolerances are maintained. The results are a higher work quality and a much more efficient manufacturing operation, since errors are reduced to a minimum, and scrap parts are all but eliminated.

The requirements for CAD/CAM utilization within a defense contractor company are threefold:

1. Strong leadership must exist within the firm. Decisions to adopt CAD/CAM will mean large, initial outlays of capital. Long term dedication and support by top executives is essential.

2. There must be a willingness of management to take the risk of innovation. Upper management must be convinced the bottom line risk of new technology is not too great.

3. Imaginative government policies to stimulate production initiatives are required. The contract provisions,discussed in the MANTECH section of this chapter, under which the government assumes a portion of the risk is a first step.

The services must continually identify programs where application of computer and advanced machine tool technology would increase productivity, resulting in savings to the government and increased profits to the contractor.

Computer Integrated Manufacturing System

An important element of a computer integrated manufacturing system (CAM) is the business information system. Illustrated in Figure 8-13, this is the system that serves the information needs of the entire business.

Another element of a computer integrated manufacturing system (CIMS) is the data base management system. This has been talked about and under development for twenty years, but only in the late 1970s did it become a practical reality. It is a powerful set of software programs that control complex file structures with a practical balance of integrity, security, resource costs, and ease of understanding. These elements and the CAD/CAM inputs are no longer separable; they must function together in a smooth running, total system. Together, these three are called "Computer Integrated Manufacturing," (CIM) integrating all of the manufacturing related functions into one neutral monolithic computer system. This is going well beyond the traditional CAD/CAM concepts, and really extending the limits of today's systems.

The ultimate payoff of CAD/CAM in the defense industry will occur when the geometric definition and other product definition information are defined and stored in a data base which can be accessed directly by manufacturing in order that the large variety and number of manufacturing operations can benefit in "real time" from this product definition. Advances have been somewhat impeded by traditional methods and the nature of the engineering/ manufacturing interface. Real success has resulted from the introduction of computer systems with data bases shared by both engineering and manufacturing organizations. It has been demonstrated, in a very practical way, that if the engineering organization can define or describe a new weapon in terms of standardized machine language, that same machine language can be used directly by manufacturing in the creation of tooling, jigs, fixtures, and other means of production, as

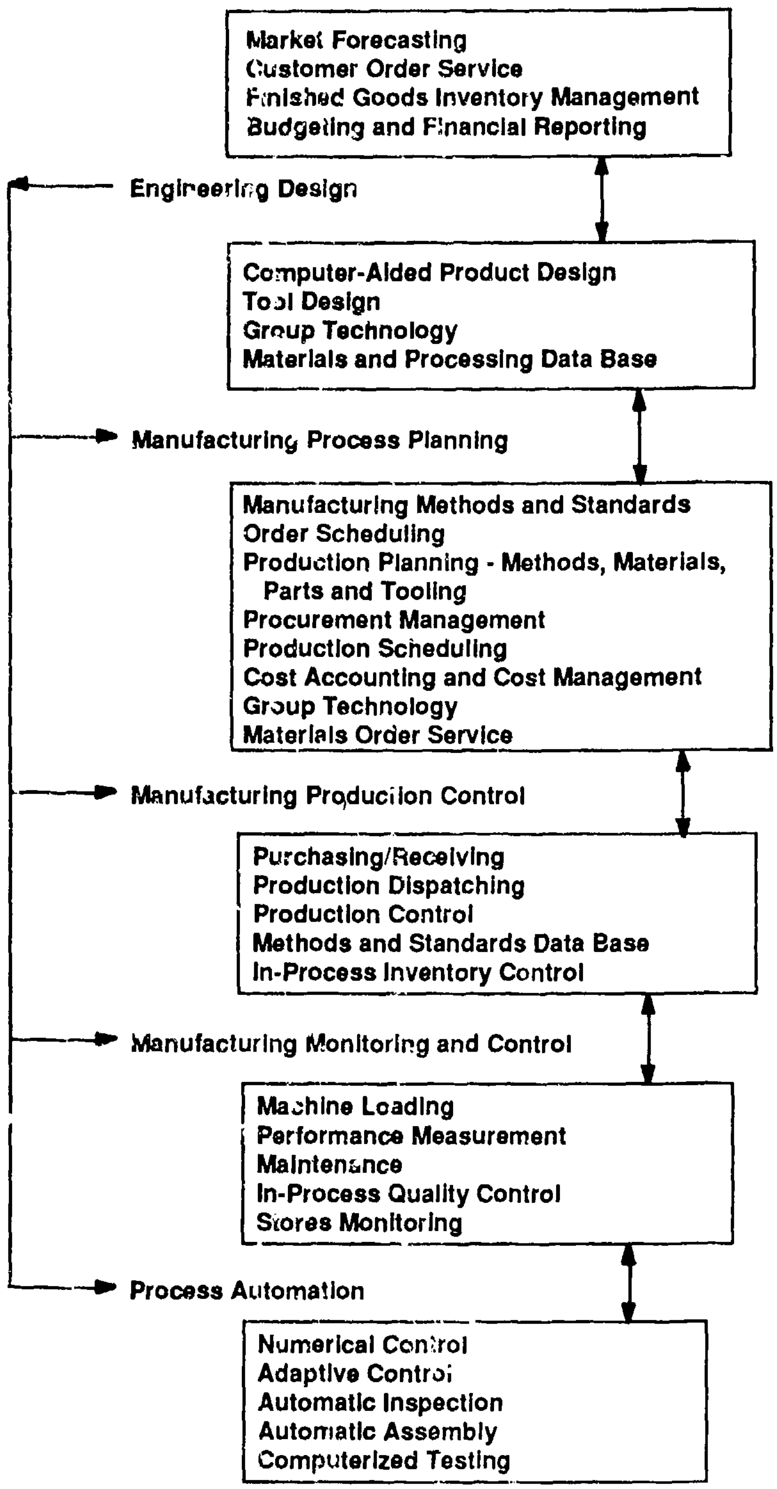


Figure 8-13 Integrated Manufacturing System

well as for quality control functions and the operation of numerically controlled machines. Virtually every major U.S. defense contractor is involved in various facets of modernization and productivity enhancement. In anticipation of the dramatic changes sweeping through the civilian defense establishment, the U.S. Air Force has stepped in and committed millions of dollars to bring order and consistency to the multi-billion dollar, industry wide automation effort. A similar effort in the electronics industry, entitled ECAM, is being sponsored by the U.S. Army with the support of a large industry coalition.

There are economic advantages to be derived from the integration, or at least the interfacing, of computerized engineering and computerized manufacturing systems. Thus, it logically follows that the benefits of generative planning can be derived from these common systems. Generative planning interactively interfaces the design engineer with the computerized system in such a way that the designer is not only able to optimally design a part, but concurrently subject that part to a performance evaluation, and plan for the most economical fabrication of the part within the constraints of time schedules, availability of raw materials, and the variability of materials or manufacturing processes. Upon conformance of the proposed part to the performance objectives, part production may then be automatically introduced into a computerized fabrication, assembly, and inspection system. Printed circuit board and integrated circuit manufacturing are the best examples of current efforts to utilize generative planning. It is not uncommon in the electronics industry to go directly from a computer simulated product design to production without an intermediate prototype or preproduction model.

A number of experimental generative planning systems are now undergoing development and testing, but it is expected that it will be several years before such systems are common in any except the electronics industry.

It is generally recognized that weapon developments are often "time paced" by machine part structural elements. CAD and CAM offer the best solution to this problem by significant reductions in engineering and manufacturing planning/tooling flow times on critical tasks. CAD has demonstrated a greater potential for reducing programming time for parts fabricated on 3, 4, or 5 axis machines.

The time planned to coordinate, tool proof, and produce an NC machined part has been cut in half. An additional non-quantifiable, but equally important, benefit of CAD is that the designer can spend more time thinking about a technical problem and less time on mundane measuring, coding, and data preparation tasks. Also, the designer's ability to immediately review loft drawings on a video screen results in significant savings by avoiding the time required for inputting curve fitting programs. The continuity of the interactive iterative process allows many more trials to be made while eliminating time required for manually coding each new trial.

CHAPTER NINE

MANUFACTURING COST ESTIMATING

CONTENTS

MANUFACTURING COST ESTIMATING

OBJECTIVE

This chapter describes the structure of manufacturing costs and the various techniques used to estimate cost. Emphasis is placed on understanding the basis for potential variability in how individual contractors may present cost information. The impact of standards and the learning, or manufacturing improvement curve, is described to help the Program Manager (PM) analyze manufacturing efficiency and improvement. The final sections deal with techniques which may be applied by the PM to establish programs for the management and control of manufacturing costs. The objective is to establish an understanding of the composition of manufacturing costs and discuss the manufacturing cost estimating process.

INTRODUCTION

Cost is one of the primary measures of management effectiveness, along with performance and schedule, applied to defense programs. The focus of this chapter is on the identification and characterization of manufacturing costs as they are estimated and incurred by defense contractors. Certain government and contractor policies and actions, which can have significant impact on manufacturing cost, need to be considered during the planning and execution of weapon system development programs. These activities include decisions on production rate, long lead funding, and capital investment. The final perspective developed in this chapter concerns the use of cost as a management planning and system design tool. With the increasing emphasis within the DOD on system affordability, cost (both manufacturing and support) must be considered as a design and program planning criterion throughout the acquisition process. Only by explicit consideration of cost can the program manager obtain the optimal mix of weapon system performance and weapon system acquisition cost and operating and support cost.

NATURE OF MANUFACTURING COSTS

The cost to manufacture a weapon system or equipment results from a combination of the engineering design, the physical facility (factory, personnel, and equipment) used to build the design and the management efficiency of the operation. This is illustrated in Figure 9-1. As such, the manufacturing cost for a product should be viewed within the context of the factory in which it will be built. Where the place of manufacture is not yet defined, assumptions as to the physical facility and efficiency will need to be made to support the estimating activity.

Direct and Indirect Costs

A classic division of manufacturing cost is between direct and indirect costs. A direct cost can be defined as any cost that is specifically related to a particular final cost objective, but not necessarily limited to items that are incorporated in the end item as material or labor. The majority of the direct cost is involved in the direct labor and direct material used in designing and fabricating the system or equipment. An indirect cost is one which is not directly identified with a single final cost objective, but is identified with two or more final cost objectives, or with at least one intermediate cost objective, on the basis of benefits accruing to the several cost objectives. An example of indirect cost is manufacturing overhead which may include such things as supervision, material handling and production engineering support. The division of effort between direct and indirect is a function of the particular contractor's cost accounting standards and the relationship of the specific contract to the total manufacturing effort within the facility. It is imperative that the program office and supporting government personnel develop a clear understanding of the accounting and cost estimating approach in use by the contractor.

ANALYSIS OF DIRECT COSTS

Classifying Direct Costs

While there are general guidelines established in Cost Accounting Standards and FAR Part 31, the contractor is given some latitude in classifying costs as direct or indirect. In all cases, it is very important that costs are classified in a consistent manner

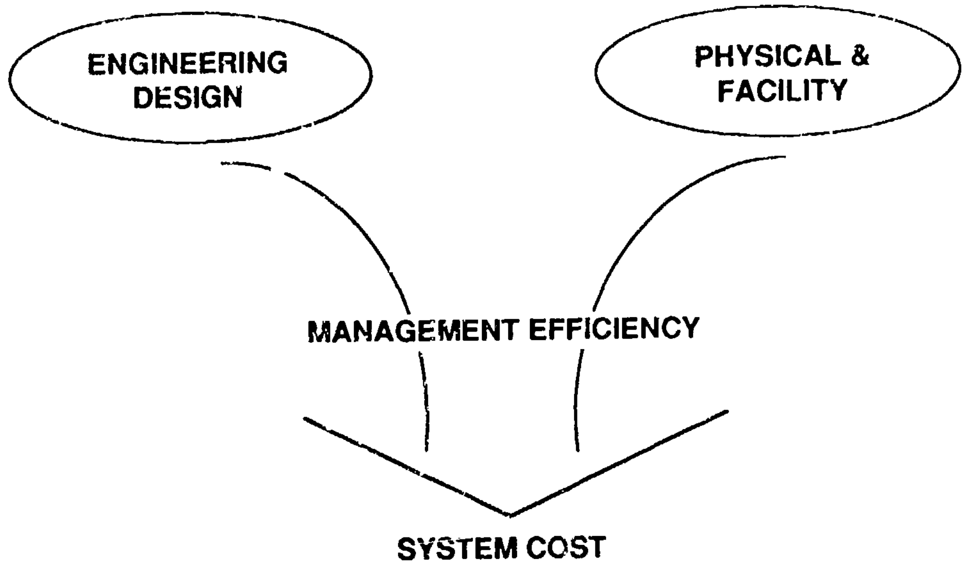


Figure 9-1 Manufacturing Cost Genesis

within a specific contractor cost accounting system. When comparing one firm with another, remember that practice in direct cost classification does vary among contractors. Typically, such items as manufacturing labor, production test and design engineering are classified as direct costs. In the production phase, some design engineering effort in support of production may be classified as indirect. Quality control is classified as direct by some contractors and indirect by others.

Importance of Direct Costs

Direct costs are important elements of cost, often accounting for 30 to 60 percent of total cost. But equally important, direct cost is usually the basis for allocating most of the indirect (overhead) cost. Direct costs of material, manufacturing labor, and engineering labor, in particular, often serve as bases for the application of costs from overhead pools. If we define price to the government as the total of direct cost, indirect cost, general and administrative cost, cost of facilities capital and profit, a change in direct cost can produce a much larger change in price to the government.

Fixed and Variable Cost

Costs can also be described as fixed or variable based on their behavior as production volume changes within broad limits. Costs may be fixed, variable, or semivariable as production volume changes in the short run. The short run is defined as a period too short to permit facilities expansion or contraction that might change the overall production relationships. Fixed costs remain relatively constant as production volume is varied over the short run. Examples of fixed costs include fire insurance, depreciation, rent, and property taxes. Of course, if production requirements change significantly, even over the short run, the fixed cost assumption could disintegrate. Variable costs fluctuate directly and proportionately with volume. These proportions remain relatively fixed between certain production limits. Costs such as direct labor and direct material illustrate variable costs. Semivariable costs fluctuate irregularly with volume, often in a stepwise manner. Costs such as supervision illustrate semivariable costs.

Recurring and Nonrecurring Costs

At the beginning of a production program, the contractor expends certain funds to establish the specific capability to manufacture the weapon system or equipment. These nonrecurring costs are one time expenditures and generally include such things as special tooling, special test equipment, plant rearrangement and the preparation of manufacturing instructions. The costs which must be incurred each time a unit of equipment is produced, such as direct labor and direct materials, are the recurring costs. The relative levels of recurring and nonrecurring costs can be evaluated in investment terms since the nonrecurring costs provide the capability to manufacture the equipment with a lower direct labor input per unit. The objective of the contractor and program office should be the definition and achievement of a level of nonrecurring cost that will minimize total cost of manufacture. The investment in nonrecurring costs can be evaluated as a tradeoff decision in that improved tools, test equipment and planning can result in lower recurring cost. The total cost to manufacture is then the sum of the recurring cost plus an amortized share of the nonrecurring cost. As a result of the relationship, decisions on the level of nonrecurring cost should be based on a specific quantity to be produced and rate of production.

Tooling Costs

Preproduction (start-up) costs, such as tooling, will usually be treated as nonrecurring direct charges to the contract. Cost proposals as well as cost analysis should separately identify the amount of preproduction cost included in the program cost estimate.

Tooling is one of the major categories of preproduction cost. As discussed here, tooling refers to special tooling consisting of jigs, dies, fixtures, and factory support equipment used in the production of end items, and does not include machines, perishable tool items, or small hand tools.

The key issue in estimating and analyzing tooling costs is the planned rate and duration of production. The production rate and duration will establish whether there will be hard (durable) or soft (limited life) tooling; whether the tooling will be limited to the production rate required under the proposed contract, or whether it also anticipates production rates of future requirements or the need for surge or mobilization. If tooling is planned in anticipation of future orders, the justification for these plans should be verified. Follow-on purchases should always be analyzed in light of the type and extent of tooling authorized by the government in prior contracts.

There should be an inverse relationship between the amount of tooling and the number of direct labor hours expended per unit of product. It is important that the contractor's tool planning be based on the needs of present and reasonably predictable future purchases. Analysis of tooling cost requires evaluation of material requirements recognizing that many contractors purchase all or a significant part of their basic tooling requirements. Analysis of the labor hours, labor rates, and overhead rates applied to the tool design, fabrication and maintenance efforts is still a significant cost item to be examined, even though passed on to a vendor.

Special Test Equipment Costs

Special test equipment may present a unique problem. While it may be proper to evaluate it in the same manner as jigs, dies, and fixtures, the test equipment may be modified standard commercial equipment. An example of special test equipment might be a microprocessor linked to a printout device so that specific reliability data required by the contract can be accumulated. If the cost of this equipment is large and the equipment has a useful life beyond the contract, the contractor should consider the equipment as a capital investment subject to depreciation over its useful life. While the capitalization of special test equipment may be determined by a policy consistently applied by the contractor, certain contracting rules will govern. The contractor's policy on capitalization should be discussed with the Administrative Contracting Officer (ACO) as to what practices would apply under the circumstances.

COST ACCOUNTING

When costs are estimated, a close look at how a contractor accumulates cost data is an important part of the manufacturing control process. Contractor decisions regarding estimated effort required for manufacturing a system will be largely influenced by the contractor's cost accounting system and the data generated therefrom. Thus, projected effort in such manufacturing process efforts as fabrication, assembly, and other cost categories which in turn can be broken down into specific operations such as welding, setup, windings, etc., must be reviewed from an overall systems standpoint. This section, thus, focuses on cost accounting systems from a manufacturing management viewpoint so that the process of cost incurrence and measurement will be better understood.

Uniformity in Cost Accounting Systems

In the field of cost accounting there are pressures for uniformity and comparability, but most of these arise from special circumstances and they are of less force than appear in the area of financial accounting. This is understandable, since cost accounting is a matter of managerial (internal) information for the most part. When prices are established under less than fully competitive conditions cost data play a large role in contract negotiation and settlement. Under such conditions, the method of cost accounting can make a substantial difference in results, and variations in cost assignment may become a matter for concern.

Every firm has its own characteristics and individuality. These arise from sources that may even be somewhat beyond the control of owners or managers and are useful in adapting to the environment as to markets, products, supply or resources, and other factors. Further, the operation of systems to collect and process data about operations is a part of the task of management, and the outputs of such systems are generally regarded as proprietary to the company.

The idea of standards is used to a considerable extent in all business and accounting data. If cost figures are to be used with confidence, they must meet standards as to their content. Direct costs should be discernible from indirect costs, not by how computations are made or by convenience in making such computations, but by some specified idea of what makes them different.

Until Public Law (PL) 91-379, 15 August 1970, technical evaluators and contracting personnel were required to "decipher" the intricacies of the variations of cost accounting systems existing in the marketplace. PL 91-379 represented a major step toward uniformity in cost reporting. This law, essentially, requires contractors to ensure consistency and uniformity in their cost accounting practices in estimating, accumulating, and reporting cost; and to disclose such practices to the government.

Cost Accounting Systems

The two basic cost accounting systems are the job order cost system and the process cost system. Each can be classified as either a historical cost system or a predetermined cost system, which makes possible four "pure" types of cost systems: (1) the historical job order cost system, (2) the predetermined job order cost system, (3) the historical process cost system, and (4) the predetermined process cost system. Most contractors, however, accumulate both historical data and predetermined data for use in estimating contract costs, and many contractors apply their own variations to the job order cost system and the process cost system.

Under the job order cost system, direct and overhead cost data are accumulated by each contract or order. The contractor's direct employees identify on their time cards the jobs on which they work, and a calculated overhead rate is applied to the direct labor time recorded for each job order. The direct material requirements for each job order can be identified by bills of materials and charged to the particular job order.

The process cost system is used when identifying each individual end product cost is impractical. Under a process cost system, total cost for producing a group of items and the number of units produced are determined for regular accounting periods, and an average unit cost for the period is determined. Under a job order cost system, unit costs are not available until the job is completed; in process costing, average unit costs are determined at the close of cost accounting periods and are available, although a "lot" required by a contract may not even be completed.

Historical Cost Systems

When actual cost data are accumulated after operations have taken place, the cost accounting system is a historical cost system. To prevent distorted projections from historical data, the following should be analyzed in determining expected costs for new products.

- Changes in plant layout and equipment;
- Changes in products, materials, and methods;
- Changes in organization, personnel, working hours, conditions, and efficiency;

- o Changes in cost;
- o Changes in managerial policy;
- o Lag between incurrence of cost and reporting of manufacturing; and
- o Random influences such as strikes and weather.

Historical data are used in all cost accounting systems, at least as a base for comparing actual results with predicted results. The accumulation and application of historical data are important ingredients of a reliable cost estimate.

Predetermined Cost Systems

Predetermined cost systems are cost accounting systems in which data about the manufacture of an end product are accumulated before the end product is produced. A contractor using a predetermined cost system uses process and material information about a job to predict the costs for doing that job. When contractors use predetermined cost data, normally these data are substantiated by actual costs identified on previous end products.

CONTRACTOR ESTIMATING SYSTEM REQUIREMENTS

The DOD promulgated new regulations in 1988 requiring major defense contractors to improve the systems they use in estimating costs for negotiated procurements. These regulations apply to defense contractors who, in their last fiscal year, received prime contracts or subcontracts totaling $50 million or more for which certified cost and pricing data were submitted. Partial coverage may apply to contractors and subcontractors receiving contracts totaling $10 million or more.

The regulations stem from hearings of the House Committee on Government Operations, and from General Accounting Office (GAO) and Defense Contract Audit Agency (DCAA) studies in the mid-1980's which indicate that the government is routinely overcharged by 10-15% on negotiated contracts as a result of deficient contractor estimating systems. The regulations define the term "estimating system" broadly, to include not only a contractor's or subcontractor's estimating policies, practices and procedures but also its organizational structure, internal controls and management reviews, among other functions. The new rules required that all contractors have estimating systems that consistently produce "well supported proposals," although the specific requirements apply only to large volume contractors.

The new regulations require that the accounting systems: establish clear responsibility for preparation, review and approval of cost estimates; have written descriptions of the duties of persons involved in estimating; assure adequate personnel training, experience and supervision; provide for consistent applications of established practices and for safeguards to detect errors; and protect against duplication and omissions. Adequate systems will also provide for management review of estimating practices and methods, and for a program of internal reviews, as well as procedures for updating estimates as required. Adequate systems also assign responsibility for review of subcontract prices.

ESTIMATING

Estimating is the method of generating a measure of an amount of work to be accomplished or resources required. It requires systematic study of the activity to be estimated and application of knowledge and skills to form a valid judgment regarding the cost of that work. The resulting estimate provides management with quantitative data for making decisions concerning these programs.

The initial decision that must be made in most estimating situations is the selection of an approach that will yield the most accurate, timely and current cost estimate. The choice of an estimating technique is not solely dependent upon the estimator's preference but is dictated by the estimating environment. The conditions that must be considered are:

1. Comprehensiveness of the statement of work.
2. Availability of pertinent actual cost data and product information.

3. Type of contract, program and category of estimate.

4. Customer and program requirements.

5. Time available for preparation.

6. End use of the estimate.

Estimating Methodologies

Cost estimating is based on interpretations of observed historical factors relevant to the task to be performed which are then projected into the future. These projections can be made in several different ways as discussed below.

The selection of a particular cost estimating method will be guided by the following considerations:

1. Availability of historical data

2. Level of estimating detail required

3. Adequacy of the technical description of the item being estimated.

4. Time constraints

5. Purpose of the estimate

The manufacturing cost estimator should consider using more than one method to generate the cost estimate. One may use a catalog price or an estimate prepared by a specialist to arrive at a cost estimate for a piece of equipment that represents a technological advance over existing hardware. The estimator may compare the cost of an analogous system element with that derived from using a Cost Estimating Relationship (CER). Finally, even if one estimating method will suffice to estimate the cost of an item, the estimator should, whenever possible, use a different estimating method to check on the initial estimate.

Parametric Cost Estimating

Costs of equipment may vary with design/performance characteristics such as weight, speed, or range (cost-to-noncost) or with costs of other items (cost-to-cost). As an example of the latter, the cost of spares may vary with the cost of the prime equipment. The estimator must select the appropriate estimating relationships and consider the availability of statistical information. "Cost-to-noncost" estimating relationships (ERs) are frequently used to estimate costs for equipment items; for example, airframe procurement cost estimated as a function of airframe weight, and turbine engine procurement cost estimated as a function of engine thrust. A variant of this method, a "noncost-to-noncost" ER, may be used to complete a system description, before addressing the cost of the system. For example, the number of administrative personnel required to support a system may be estimated as a function of the number of personnel estimated to operate the system. "Cost-to-cost" ERs may be used to estimate development, investment, and operating costs. For example, equipment installation costs may be estimated as a percent of equipment procurement costs, or replacement personnel training costs as a percent of initial personnel training costs.

Specific Analogies

Specific analogies depend upon the known cost of an item used in prior systems as the basis for estimating the cost of a similar item in a new system. Adjustments are made to known costs to account for differences in relative complexities of the performance, design, and operational characteristics. This is a practical method since many new systems involve essentially new combinations of existing subsystems, major equipment, and components. A specific analogy is frequently used in checking an estimate developed through other methods.

Specialist Estimates

Estimators may obtain an estimate directly from an organization or person having specialized knowledge, for example, an engineer, a program office, training or logistics specialist, or other technical expert. This method is usually applied when ERs and other estimating methods are not available or appropriate, or to verify other estimates. In addition, specialists can often assist the estimator in applying or developing specific analogies. In applying this method, a cost estimator must describe the item to be costed to the specialist. The description can take the form of work statements, technical parameter measures, design specifications, or analogies.

Rates, Factors, and Catalog Prices

Rates are usually based on historical experience plus judgments relative to future price level trends. Factors represent average costs or ratios of costs for designated types of products or services. The estimator can develop factors or obtain them from commercially available or government publications. Catalog prices represent published prices for standard off-the-shelf products or services. When a specific type and quantity of a standard material or component must be identified, this method provides acceptable estimating data.

Industrial Engineering Standards

Industrial Engineering Standards (IES) define and measure, in unit hours or dollars, the work content of the discrete tasks to be performed in accomplishing a given operation or producing an item. IES represent average skills, times, and performance. These standards are used primarily to estimate contractor functional costs such as tool fabrication, manufacturing, and product assurance.

Cost Model Applications

A cost model consists of the estimating relationships and logic used to derive a cost estimate. The unique contribution offered by a model exists within the logic framework which structures the application of the cost estimating techniques. Additionally, the speed of manipulation of computerized models may be advantageous when many design alternatives are being estimated. The cost model might be a checklist of program elements, used to avoid omitting relevant elements from an estimate. Each element would be estimated by the most appropriate cost estimating techniques available. The most complex form might be a computerized model complete with estimating relationships, factors, analogy matrices, standards, and catalog prices.

Trend Analysis

Trend analysis is a quantitative method for relating a variable -- direct labor, manufacturing overhead -- with time or other measures and represents a common statistical technique employed for both monitoring and estimating costs. Trend analysis, with costs modified to reflect the reasonableness of past, present, and future overhead expenditures, is frequently used to forecast overhead expenses. Similarly, trend analysis is applied to information contained in the various cost reports, where contractually required, or available from internal contractor cost records, to analyze contract performance and forecasting future costs. In this regard, such analysis of cost/schedule trend patterns during the development and production phases of the system life cycle has proven to be one of the most accurate methods of estimating cost of the contract at completion for ongoing programs.

Inflation (escalation) indices are often used in conjunction with trend analysis to ensure comparability of data in different time periods. Inflation/escalation indices are used to estimate the effect on price of the changing value of the dollar over time. In forecasting escalation, the PMO should attempt to utilize indices which reflect the realities of the specific program. The DOD or Office of Management and Budget (OMB) indices should be viewed in light of their past record in predicting actual inflation for the economic activities involved in the individual acquisition program. Where there is a significant difference in the historical data, the PM should attempt to develop program-specific indices which can be presented to the decisionmakers in the Services and DOD to illustrate the potential problems which may arise from use of the DOD or OMB indices.

ESTIMATES BASED ON ENGINEERED STANDARDS

Engineered standards are useful for developing cost estimates once there is a clear definition of the detailed system configuration. Engineered standards are those developed using a recognized technique such as time study, work sampling, standard data or a recognized predetermined time system. These standards provide the benefit of detailed description of required manufacturing operations and provide a base line for the evaluation of actual incurred costs. An industrial engineering standard (IES) is developed as follows:

1. A work statement, set of drawings, or specification is received or developed.

2. Each engineering or production operation required to produce the item or accomplish the designated task is specified.

3. The work stations where each operation will be performed are designated.

4. The kinds of labor and material required to produce the item or accomplish the operation are given in detail.

5. Industrial Engineering studies determine the most economical method of performing each manufacturing operation.

6. An estimated time standard for performing each task is established using time-and-motion studies or predetermined time systems plus experience in performing similar tasks.

7. Labor standards for specific operations may be combined to provide a labor standard for a component, subassembly, major equipment, or subsystem.

8. Labor efficiency factors are used to adjust standard labor hours to actual labor hours. In general, labor efficiency, utilization, or effectiveness measures represent the ratio of standard hours planned to the actual hours expended for a given work operation.

9. Periodically, time standards are adjusted to reflect changes in production methods. Over a period of years some standards become stabilized to such an extent that they become plant, product, or industry standards.

Standard Cost

A standard cost basically represents an expected value of the cost of a system. Standard costs are used as a basis for the development of proposal pricing and also as a benchmark to monitor day-to-day performance and signal when deviations from predetermined policies are occurring. They are based on a defined level of material usage and a standard time for the manufacturing operations. Our focus in this discussion will be on the time component of the standard cost. When directed towards operations involving human performance, the standard time required to perform a task may be defined as the time necessary for a qualified worker working at a pace ordinarily used, under capable supervision, and experiencing normal fatigue and delays to do a defined amount of work of specified quality following a prescribed method. It is obvious from the definition, that on a regular basis, actual shop performance will not reflect the standard time. In most cases, the time proposed by the contractor will be greater than standard time, reflecting either realization factors or efficiency factors representative of the facility and the impact of the learning or manufacturing improvement curve. These two concepts are discussed below. For operations which are machine controlled, the standard time is dictated by the situation of the process and the equipment (including tooling). In most cases machine controlled operations should be relatively consistent and reflect actual costs close to standard. Standards can be developed through job analysis or based upon historical costs, and sometimes are affected by constraints introduced in the contract with the employee bargaining unit.

Variations of Standards

When considering a standard cost, it is important to understand that it is "standard" only within the confines of the system used to develop it. Two different, yet valid, approaches to establishing a standard may yield estimates for the same task differing by as much as 25%. These differences are inherent in the various approaches to establishing standards, but they do not reduce the usefulness of the resultant standard. In looking at a particular contractor facility, the critical issue is that the system used in that facility be internally consistent, i.e., the standard time for a particular task should be independent of the estimator developing the estimate. It is also important to note that the estimate is driven by the particular manufacturing process utilized and the completeness of the description of that process.

Realization Factors or Efficiency Factors

Realization factors or efficiency factors are utilized to reflect the fact that standard performance is seldom maintained during manufacturing. Unpredictable delays do occur and the criteria for standard performances may not be found throughout the facility. For estimating the time that will actually be required, the contractor uses historical relationships between standard and actual times. As an example, a realization factor of 1.5 would indicate that actual time required for a task is 50% greater than standard time. The contractor determines realization factors by recording time actually spent on the specific tasks and comparing that to standard for those tasks. By averaging historical realization factors, the contractor can then determine an appropriate realization factor to use in forecasting actual time requirements.

Some contractors use efficiency factors rather than realization factors. Whether the contractor uses realization or efficiency factors the approach reflects a reasonable method of estimating the time which will actually be required to perform the tasks. There is, however, one major area of concern. There is a reasonably good understanding of "what" realization factors are but "why" is not well understood. It is generally accepted that realization factors may represent shop inefficiencies which could be cured by appropriate management action. A critical issue is to assure that the contractor has taken action to identify and remedy these inefficiencies.

THE LEARNING CURVE

Concept

The learning curve was adapted from the historical observation that individuals performing repetitive tasks exhibit an improvement in performance as the task is repeated a number of times. Empirical studies of this phenomenon yielded three conclusions on which the current theory and practice is based:

1. The time required to perform a task decreases as the task is repeated.

2. The amount of improvement decreases as more units are produced.

3. The rate of improvement has sufficient consistency to allow its use as a prediction tool.

The consistency in improvement has been found to exist in the form of a constant percentage reduction in time required over successively doubled quantities of units produced. This can be seen graphically in Figure 9-2.

Components of Improvement

By its title, the learning curve focuses attention on the worker learning, or job familiarization. This is just one of the components which contribute to the reduction of time requirements. Table 9-1 lists a number of elements which have been shown to contribute to the manufacturing improvement. From Table 9-1 it can be seen that the total improvement is a combination of personnel learning and management action. While some study has been done, there is no general rule concerning the relative contribution of the specific elements. Figure 9-3 illustrates the results of a study by the Air Force Materials Laboratory on the components of learning in a production fighter program. The critical issue is to recognize the role of management in achieving these reductions and to ensure that appropriate management actions are taken.

Characteristics of Learning Environment

While learning is found in almost all elements of the defense industry, its impact is most pronounced when certain characteristics are present. The first characteristic is the building of a large complex product requiring a large number of direct labor hours. The second is continuity of manufacturing to preclude loss of accrued improvements during production breaks. The third characteristic is an element of continuing change in the product. This third characteristic can present some problems in analysis using the manufacturing improvement curve.

The historical data on which a company's improvement curve is based contain the effects of an engineering change activity which can be characterized as "normal." During the analysis of the program of interest, changes which are developed need to be evaluated to determine whether they are "normal" and already accounted for by the learning curve, or major changes which must be the subject of a contract modification. The decision needs to be made on the basis of the unique situation involved in the program. This should be done in the context of the nature of the historical contractor activity which was used to develop the learning curve used in the contract negotiation.

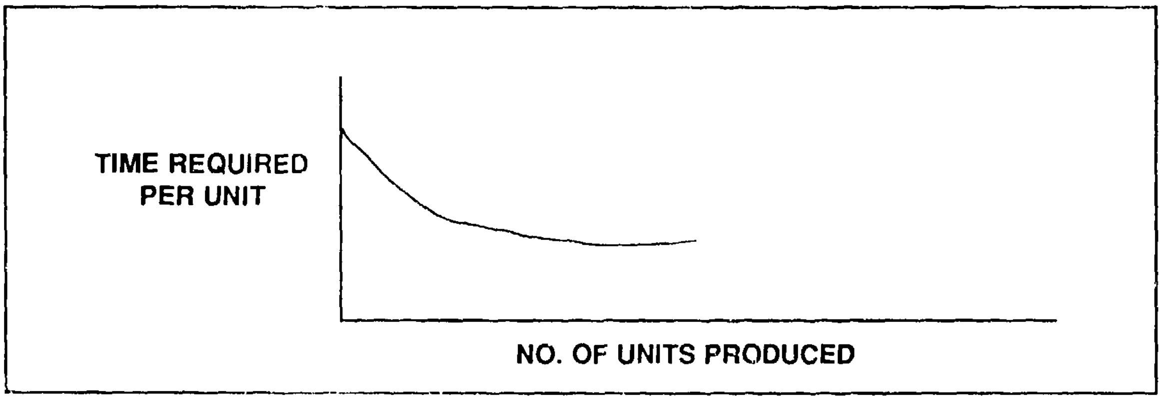


Figure 9-2 Manufacturing Improvement Curve

WORKER LEARNING
SUPERVISORY LEARNING
REDUCTIONS IN CROWDED WORKSTATIONS
TOOLING IMPROVEMENTS
DESIGN PRODUCIBILITY IMPROVEMENTS
IMPROVED WORK METHODS
IMPROVED PLANNING AND SCHEDULING
INCREASED LOT SIZES
REDUCED ENGINEERING CHANGE ACTIVITY
REDUCTION IN SCRAP AND REWORK
BETTER OPERATION SEQUENCING AND SYNCHRONIZATIONS

Table 9-1 Factors Leading to Manufacturing Improvement

Key Words Associated with Learning Curves

To utilize learning curve theory, certain key phrases listed below are of importance:

o Slope of the Curve -- A percentage figure that represents the steepness (constant rate of improvement) of the curve. Using the unit curve theory, this percentage represents the value (e.g., hours or cost) at a doubled production quantity in relation to the previous quantity. For example, with an experiecence curve having an 80% slope, the value at unit two is 80% of the value of unit one; the value at unit four is 80% of the value at unit two; the value at unit 1,000 is 80% of the value at unit 500; and so on.

o Unit One -- The first unit of product actually completed during a production run. This is not to be confused with a unit produced in any preproduction phase of the overall acquisition program.

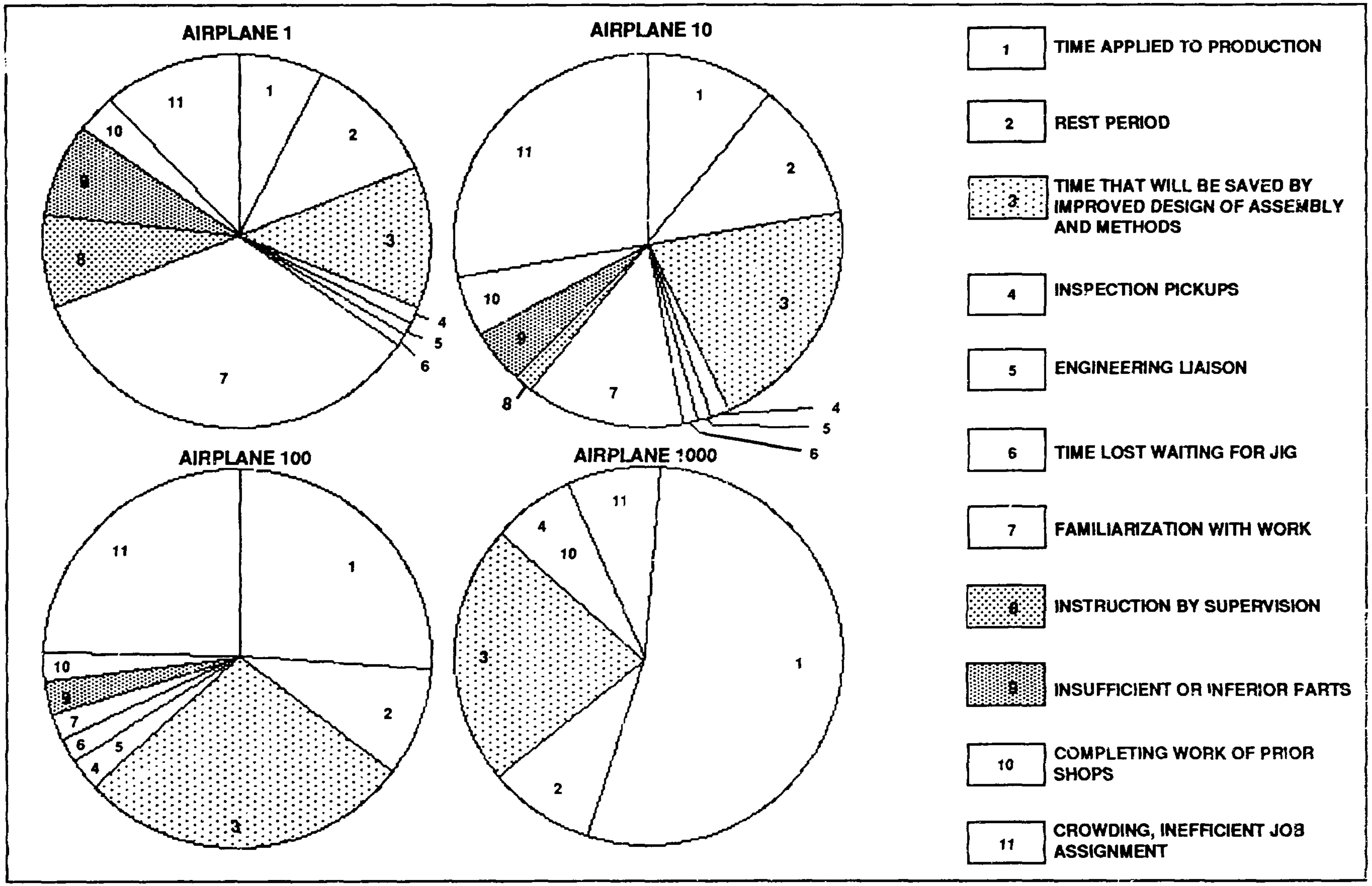


Figure 9-3 Components of Learning

o **Cumulative Average Hours** The average hours expended per unit for all units produced through any given unit

o **Unit Hours** The total direct labor hours expended to complete any specific unit.

o **Cumulative Total Hours** The total hours expended for all units produced through any given unit

Unit Curve

There are two fundamental models of the learning curve in general use: the unit curve and the cumulative average curve. The unit curve focuses on the hours or cost involved in specific units of production. The theory can be stated as follows

> As the total quantity of units produced doubles, the cost per unit decreases by some constant percentage.
>
> The constant percentage by which the costs of doubled quantities decrease is called the rate of learning.
>
> The "slope" of the learning curve is related to the rate of learning. It is the difference between 100 and the rate of learning. For example, if the hours between doubled quantities are reduced by 20% (rate of learning) it would be described as a curve with an 80% slope.

The difference or amount of labor-hour reduction is not constant. Rather, it declines by a continually diminishing amount as the quantities are doubled. The amount of change over the "doubling" period has been found to be a constant percentage of cost at the beginning of the doubling period.

A labor-hour graph of this data curve drawn on ordinary graph paper (rectangular coordinates) becomes a hyperbolic line. Figure 9-4 pictures the relationship between two variables, units produced in sequence and labor hours per unit. When labor hour figures that conform to the learning process are plotted on log-log paper against the units of production to which they apply, the points thus produced lie on a straight line.

[illegible]

Research [illegible] Research [illegible] different slopes were experienced [illegible] manufacturers [illegible] programs [illegible] from the [illegible] industry [illegible] 80% [illegible] of 80% [illegible] manufacturers [illegible] sample [illegible] interpretation [illegible] frequently misapplied [illegible] as a standard [illegible] slopes without the benefit [illegible] The chart of the manufacturer [illegible] learning curve slopes [illegible] of the manufacturer's chart [illegible] the industry averages

The analyst needs to know the slope of the learning curve for a number of reasons. One is to facilitate communication as it is part of the language of the learning curve theory. The steeper the slope (lower the percent), the more rapidly the resource requirements (hours) will decline as production increases. Accordingly, the slope of the learning curve is usually an issue in production contract negotiation. The slope of the learning curve is also needed to project follow-on costs using either the learning tables or the computational assistance of a computer.

Selection of Learning Curves

Existing experience curves, by definition, reflect past experience. Trend lines are developed from accumulated data plotted on logarithmic paper (preferably) and "smoothed out" to portray the curve. The type of curve may represent one of several concepts. The data may have been accumulated by product, process, department, or by other functional or organizational segregations, depending on the needs of the user. But whichever experience curve concept or method of data accumulation is selected for use, based on suitability to the experience pattern, the data should be applied consistently in order to render meaningful information to management. Consistency in curve concept and data accumulation cannot be overemphasized because existing experience curves play a major role in

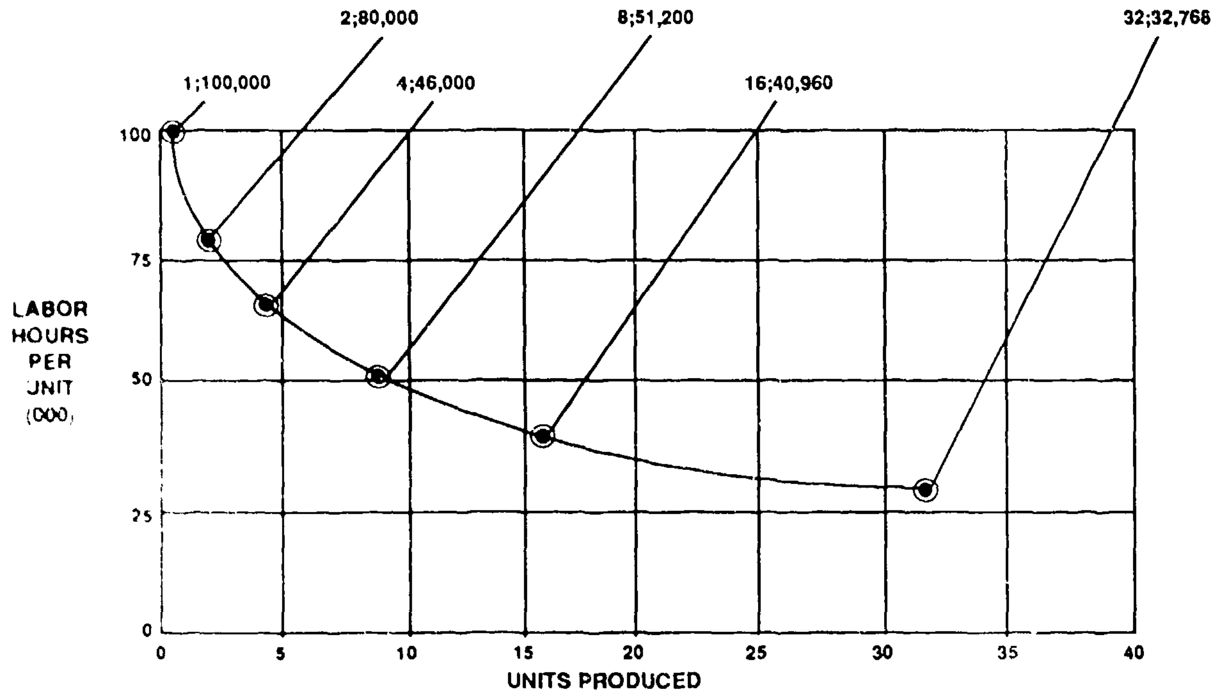


Figure 9-4 An 80 Percent Learning Curve Drawn on Arithmetic Graph Paper

determining the projected experience curve for a new item or product.

When selecting the proper curve for a new production item when only one point of data is available and the slope is unknown, the following, in decreasing order of magnitude, should be considered:

--Similarity between the new item and an item or items previously produced.

--Addition or deletion of processes and components

--Differences in material, if any

--Effect of engineering changes in items previously produced

--Duration of time since a similar item was produced

--Condition of tooling and equipment

--Personnel turnover

--Changes in working conditions or morale

--Other comparable factors between similar items

--Delivery schedules

--Availability of material and components

--Personnel turnover during production cycle of item previously produced

--Comparison of actual production data with previously extrapolated or theoretical curves to identify deviations

It is feasible to assign weights to these factors as well as to any other factors that are of a comparable nature in an attempt to quantify differences between items. These factors are again historical in nature and only comparison of several existing curves and their actuals would reveal the importance of these factors.

When production is underway, available data can be readily plotted, and the curve may be extrapolated to a desired unit. However, if production has yet to be started, actual unit one data would not be available and a theoretical unit one value would have to be developed. This may be accomplished in one of three ways:

- A statistically derived relationship between the preproduction unit hours and first unit hours can be applied to the actual hours from the preproduction phase.
- A cost estimating relationship (CER) for first unit cost based upon physical or performance parameters can be used to develop a first unit cost estimate.
- The slope and the point at which the curve and the labor standard value converge are known. In this case a unit one value can be determined. This is accomplished by dividing the labor standard by the appropriate unit value.

Manufacturing Breaks

A manufacturing break is the time lapse between the completion of an order or manufacturing run of certain units of equipment and the commencement of a follow-on order or restart of manufacturing for identical units. This time lapse disrupts the continuous flow of manufacturing and constitutes a definite cost impact. The time lapse under discussion here pertains to significant periods of time (weeks and months) as opposed to the minutes or hours for personnel allowances, machine delays, power failures, and the like.

It is logical to assume that because the experience curve has a time/cost relationship, a break will affect both time and cost. Therefore, the length of the break becomes as significant as the length of the initial order or manufacturing run. Because the break is quantifiable, the remaining factor to be determined is the cost of this lapse in manufacturing (that is, the additional cost incurred over and above that which would have been incurred had either the initial order or the run continued through the duration of the follow-on order or the restarted run).

The S-Curve

The S-Curve is a formulation of the learning curve which has been supported by actual cost experience observed in industry. This S-Curve describes the situation where the initial units in the production cycle exceed the anticipated "normal" learning curve values by a significant percentage and at a relatively low learning rate. This is illustrated in Figure 9-5.

As the production cycle continues to produce units of the product, these unit costs begin to drop sharply, actually dropping below the normal learning curve generally anticipated at that point and then begin to proceed at a lesser improvement rate.

This pattern may reflect the fact that during the introduction of a new product, intensive demands are placed upon the entire organization. These demands are the result of frequent design changes and production interruptions causing new requirements for training production and supervisory personnel in new manufacturing techniques and possibly requiring the development of new procedures for production planning and control.

If this situation exists and is not recognized by using an analysis based upon the S-Curve rather than the standard learning curve, the result could be that sufficient funds would not be available during the early part of the program.

If the PMO decides to use the S-Curve approach, Figure 9-5 illustrates a method that could be used for modeling this procedure. The figure reflects an initial period of slow learning, followed by a period of more rapid learning, and then followed by a slower learning level. To use this approach it would be necessary to evaluate the specific company's experience to determine where the break points would occur and the appropriate slopes for the curve segments. This illustration (Figure 9-5) indicates the first break point at unit 3; the actual break point may come much later in the program and some research has indicated that near unit 30 is the most likely point for the first break.

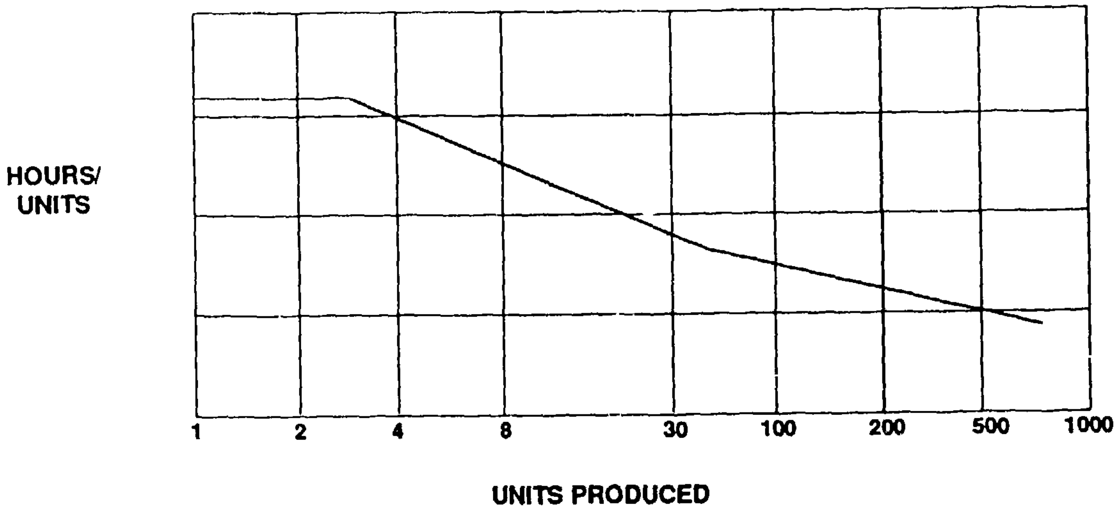


Figure 9-5 An S-Curve Model

Learning Curves Applied to Standard Times

It should also be recognized that different areas of the contractor operations will exhibit different learning patterns. In a detailed evaluation of the cost to perform, it may be advisable for the contractor and program office to utilize these specific curves (for areas such as assembly, fabrication, etc.) rather than a composite curve summarizing all the differing types of activity within the facility.

When utilizing the learning curve to develop program or contract estimates from engineered standards, we rely on a model such as that shown in Figure 9-6. The time required at standard is reflected by the portion of the learning curve which can be considered to be essentially horizontal. In order to estimate the costs of the early units, such as those to be purchased on the first production contract, three determinations are required:

1. The hours required at standard,

2. The unit number of which standard is reached, and

3. The slope of the learning curve.

The determinations required in 2 and 3 should be developed based on historical records for the specific manufacturing facility involved and the nature of the manufacturing operations (a high proportion of tasks with machine dictated times tends to appear horizontal at a lower unit number). The potential impact of variation in the unit determined as standard can be seen in Table 9-2. Contractor historical manufacturing data should be reviewed to select the appropriate point for standard.

The appropriate slope for the curve also should be developed from contractor experience. It should also be recognized that the historical rate of learning may not be the most appropriate for the program under consideration.

MANUFACTURING RATE/COST RELATIONSHIP

The rate at which items are completed and delivered is directly related to the manufacturing cost of the program. Generally, higher manufacturing rates will allow for greater economies of scale and result in lower unit cost and lower program cost for a fixed quantity.

The PM must be aware of manufacturing rate characteristics impacting cost. These characteristics include the extent to which the manufacturing process is machine paced, the number of shifts employed or available, and the mechanism by which

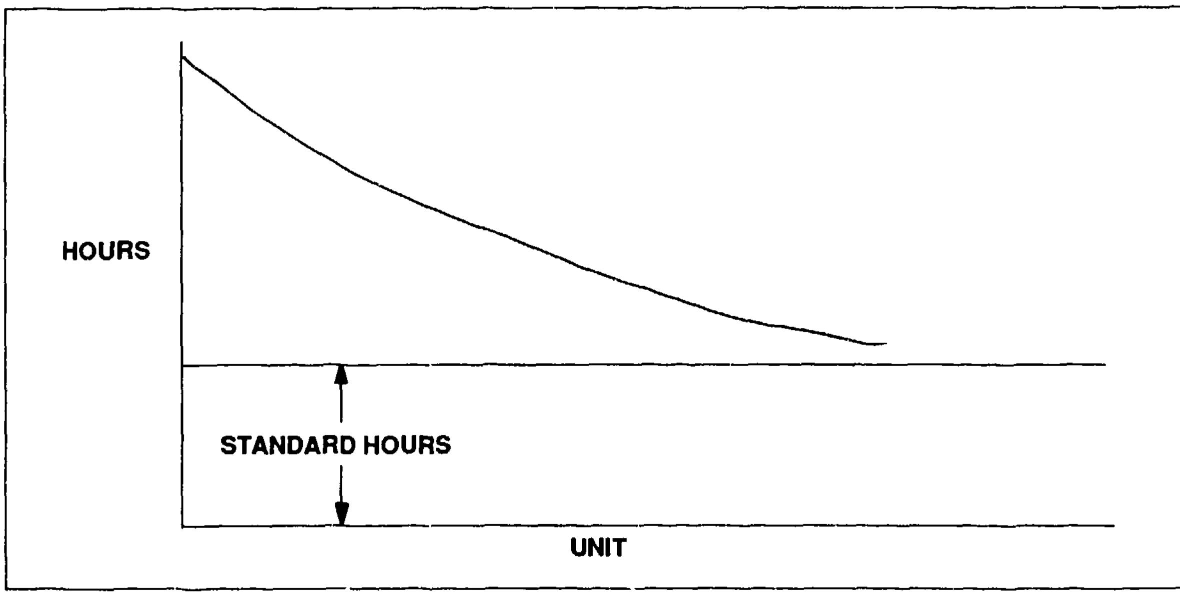


Figure 9-6 Learning Curve

STANDARD 10,000 HOURS 80% CURVE		
STANDARD AT UNIT	**FIRST UNIT HOURS**	**TOTAL HOURS: FIRST 20 UNITS**
400	68,810	721,510
500	73,940	775,250
1,000	92,400	968,810

Table 9-2 Cost Impact of Varying Baseline Unit for Standard

different rates are accommodated. Each program's manufacturing characteristics will beunique -- ranging from low volume, labor intensive to highly automated scenarios. The variety of circumstances encountered might include steady manufacturing rates, breaks in manufacturing, rates buffeted by multinational considerations, extended periods of low rate manufacturing while awaiting improved version approval, and the like.

In evaluating the cost for either a unit or total DOD acquisition program, one of the most substantial impacts has come from inflation. By running a program at an accelerated rate, systems are produced earlier and are subject to a lower inflation effect. Within the context of a specific product/manufacturing environment set, other benefits can be operative. Within many manufacturing facilities, total overhead is relatively insensitive to changes in manufacturing rate. Increases in the rate thus provide more units to which those costs can be applied within a specific area. The facility also benefits from some of the economies of scale such as:

- -- Increased specialization
- -- Greater opportunity for tooling
- -- Increase use of shop aids
- -- More intense facility usage

Figure 9-7 defines some of the general boundaries for the rate decision. If the program has a high level of technical risk, it is generally better to hold to lower rates until the risk is reduced and the value of the manufacturing output is known. There is a boundary shown on the right side of the figure relating to the issue of technological obsolescence. If the rate is held too low, it is possible that units produced at the end of production phase of the program will represent technology that is obsolete in terms of its ability to meet the defined threat.

There also tends to be a maximum rate which can be supported by the defined manufacturing facility. These rates are rarely reached in most DOD programs except for short periods. This is due to the effects of the learning curve on the manufacturing environment.

DESIGN TO COST

The term "design to cost" means the management and control of future acquisition, operating and support costs during the design and development process under established and approved cost objectives. A design to cost goal is a specific cost number (in constant dollars for a specified number of systems at a specified production rate) established as early as possible in the acquisition process, but not later than the time of entry into the full-scale development phase.

The decision to apply design to cost principles to most defense system programs was made in the light of hard realities of likely future levels of DOD budgets and the ever increasing costs of unit acquisition, manpower and support.

In almost every area in the projected DOD budget the estimated costs of new systems substantially exceed the ability to buy them in needed quantities. The cost of manning and maintaining these systems is also increasing.

Commercial Practice

In industry, design to cost is not a new concept. It has been used by many manufacturers of commercial products, ranging from radios to automobiles. Managers and engineers in commercial industry are generally well aware of the item cost target for a manufactured item, which must be achieved if the product is to be competitive. Cost goals, compatible with projected markets, are regularly established as design objectives.

As the design evolves, anticipated production costs are fed back to designers and managers to inform them of progress toward the production cost goal and to identify areas needing corrective action. When required, nice but less essential features may be reduced or eliminated to achieve the cost goal.

DOD Experience

In contrast, DOD had traditionally operated under the assumption that defense systems and equipment, on an individual basis, must have the best performance that technology can provide -- cost being, at best, a secondary consideration. This practice has frequently resulted in a reduction in the number of items to be purchased, and the advanced technology equipment has frequently had a lower field reliability than desired. Extensive and costly modifications and delays in upgrading the operational capability were not infrequent.

Because of the emphasis on performance, the subsequent costs of manufacturing, operation and support were not emphasized in the design and development of defense systems and equipment. Consequently, information obtained concerning such costs during the design phase was seldom fed back to development managers and design engineers. In addition, there was little motivation for designers to consider future manufacturing, operation and support costs, and to direct their efforts accordingly; yet the original requirements and the subsequent engineering design are the most important factors driving such costs.

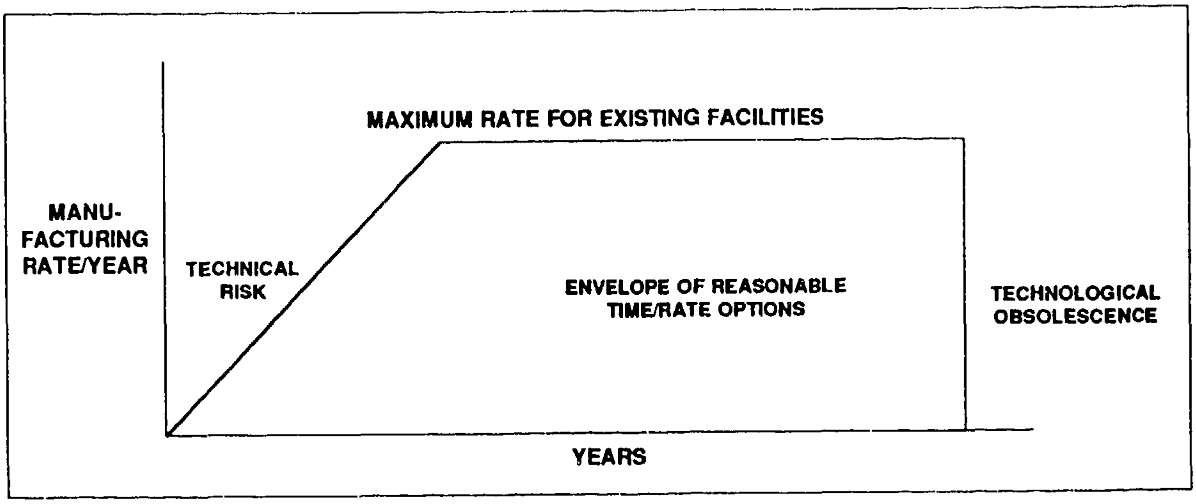


Figure 9-7 Manufacturing Rate Options

The application of the design to cost concept attempts to recognize these economic and motivational realities. It recognizes that the "best" system design is not necessarily achieved by maximizing individual unit performance only; rather, it is a function of need, performance, life cycle cost and quantities needed to address the threat. It recognizes that actions in the engineering budget area significantly affect budgets in other areas; and that all of these trade-offs must be made within realistic total resource constraints.

SHOULD COST

Should cost reviews provide an effective method for assessing contractor cost proposals. The in-depth analysis used in the should cost approach provides a basis for clear understanding of the details of contractor operations. These details can be used in making a comprehensive evaluation of proposal costs. The evaluation can then be used to reduce the cost to the government of the systems and equipments which are required to meet DOD's worldwide operational commitments.

Should cost evaluations are cost estimates done by the government and provided to buyers and contracting officers as a tool for use in price negotiations. They consist of an engineering analysis, associated drawings, and detailed reviews of all related cost elements which, together, represent an independent estimate of what an item should cost.

A should cost review uses an integrated team having a variety of skills and experience to conduct coordinated, in-depth cost analysis at a contractor's plant. These reviews are normally accomplished on programs requiring DAB approval. The purposes of the review are to identify inefficient and uneconomical contractor practices, to quantify the impact of these practices on system cost, and to use the findings to develop a realistic price objective.

The performance of a should cost analysis represents a significant investment by the government in time, resources and personnel. Its use is justified in instances where the government anticipates a major return on investment. This return is manifest in the negotiation of contract cost objectives which have imbedded in them attainable improvements in contractor economy and efficiency. The should cost approach is most attractive for application to production contracts with large dollar expenditures and a potential for substantial follow-on, with no competition, and with some production effort already completed.

In this environment, the should cost review offers an outstanding opportunity for substantial benefits. Attaining these benefits requires that a team of highly qualified individuals, who represent a large number of disciplines, be assembled to make an in-depth evaluation of the contractor's proposal. This evaluation goes beyond the normal cost analysis in which the expected cost outcome of a planned series of contractor actions is validated. In the should cost approach those proposed actions which form the basis of the proposal need to be examined in a critical fashion to identify and challenge inefficient or uneconomical practices within the contractor's management and operations. As these weaknesses are identified, their cost impact is quantified and reflected in the government negotiation objectives. The objectives must then be supported with a clear description of the basis for the positions taken, the rationale underlying the positions taken, and a description of contractor actions that can improve or eliminate inefficient and uneconomical practices.

In a report issued in September 1985, GAO reported that when used, should cost analysis was an effective tool in reducing contractors' proposed prices. GAO concluded there were inadequacies in DOD should cost policy that resulted in under-utilization of the should cost concept.

GAO has recommended that OSD revise its policy to require that the Military Departments perform at least one should cost analysis early in the production cycle for each major program and has better defined the conditions that identify the applicability of these pricing techniques. These recommendations were implemented through changes to the Federal Acquisition Regulation and the DOD Supplement. Congress has passed legislation which closely parallels DOD should cost audits.

Normally, the manufacturing management group supporting the program manager is tasked to evaluate the manufacturing material and labor costs.

CHAPTER TEN

CONTRACTING ISSUES IN MANUFACTURING

CONTENTS

CONTRACTING ISSUES IN MANUFACTURING

OBJECTIVE

The contract is the vehicle used to establish the formal relationship between the government and a prime contractor. There are two basic types of contractual provisions which impact manufacturing--requirements and incentives. Requirements establish minimum levels of performance which the contractor must achieve. Incentives reward the contractor for risk-taking or cost, schedule and technical achievements beyond the minimum requirements of the contract. This chapter will consider five issues which will significantly affect the relationship between the two management teams.

INTRODUCTION

Because the vast majority of defense systems and equipment are produced by contractors, structuring of the contractual relationship is of critical importance. The issues of contracting approach and contract provisions need to be addressed early in the acquisition planning cycle to ensure that proper requirements are generated during each phase of the systems acquisition process and included in the acquisition contracts. This chapter provides information on a number of manufacturing management issues from the perspective of the contract relationship. Each of the topics is independent and no attempt has been made to tie them together. Many of the topics are treated elsewhere in the handbook from a more general standpoint.

MANUFACTURING MANAGEMENT PROGRAM

Aggressive and responsive contractor manufacturing management is essential throughout the acquisition process. Such management does not just happen. Of course, contractor manufacturing management must be considered during the Source Selection process, but more is required to assure a positive ongoing relationship. The contract must define what the government expects from contractor manufacturing management.

One way of defining contractor manufacturing management requirements is to include MIL-STD-1528A, Manufacturing Management Program, in the contract. MIL-STD-1528A requires the contractor to establish and maintain an effective manufacturing management program. The program must provide for detailed planning and control of manufacturing functions and for timely and effective transition from development to full-rate production. The standard also provides for program review and approval by the government. General manufacturing management program goals are defined in Figure 10-1.

Specific Requirements

MIL-STD-1528A defines specific contractor manufacturing management program requirements in five management areas: planning, design analysis, operations management, system manufacturing assessment, and contractor/government interface. Figure 10-2 outlines the major requirements in each management area.

INCENTIVE STRUCTURES

Another vital element is contractor motivation. Contractual structure motivates contractors by providing the opportunity to earn larger profits through improved performance, effective cost control, reduced lead time, and new or additional efforts that would not have occurred without the incentives. Different types of incentives may be appropriate at different times during system development and/or production. Incentive structures may be divided into contract type and contract provisions that can be used regardless of contract type. Figure 10-3 depicts several important manufacturing management elements commonly considered in contract incentive structures.

Contract Types

The primary means of motivating contractor performance is through appropriate selection of contract type. There are two basic contract types, fixed price and cost reimbursement but there are several variations of each. The most common fixed price

Establish and maintain a manufacturing system which provides efficient and effective manufacture of quality hardware.

Increase productivity and reduce production unit cost.

Identify and reduce the impact of critical and strategic materials.

Identify and reduce manufacturing risk.

Plan according to a consistent manufacturing strategy.

Figure 10-1 Manufacturing Management Program Goals

Management Area	Requirement
Planning	Identify and Obtain Production Resources Identify and Resolve Risk Identify and Obtain Capital Commitments Identify and Obtain Tooling and Test Equipment Verify Manufacturing System Integrate Program and Factory Planning Integrate Make-or-Buy Analysis Integrate Industrial Material Management
Design Analysis	Producibility Analysis Process and Methods Analysis Design and Manufacturing Engineering Integration Production State-of-the-Art Analysis
Operations Management	Production Scheduling and Control Work Measurement Manufacturing Surveillance Control of Subcontractors and Vendors
System Manufacturing Assessments	Manufacturing Feasibility Manufacturing Capability
Contractor/Government Interface	Manufacturing Management Program Review Manufacturing Management/Production Capability

Figure 10-2, MIL-STD-1528A Requirements

Cost	Schedule	Technical
Cost Reduction Design-to-Cost Life-Cycle Cost	Expedited Development Early Delivery On-Time Delivery	Quality Reliability Maintainability Product Improvement

Figure 10-3 Incentive Improvement Goals

contracts are Firm Fixed Price (FFP) and Fixed Price Incentive Firm (FPIF). The most common cost reimbursement contracts are the Cost Plus Fixed Fee (CPFF), Cost Plus Incentive Fee (CPIF), and Cost Plus Award Fee (CPAF).

There are two major differences between fixed price contracts and cost reimbursement contracts. The differences relate to the contractor's acceptance of performance risk and cost risk. Under a fixed price contracts the contractor assumes substantial performance risk. The contractor is required to deliver the specified product or service; and final payment is not made until after final delivery. Under a cost reimbursement contract, the contractor is only required to deliver a best effort to complete the contract. Cost risk assumption is related to assumption of performance risk. Normally under a cost reimbursement contract, fee may increase or decrease based on performance, but all allowable costs are reimbursed up to the maximum amount specified in the contract. All fixed price contracts include a maximum amount that the government may be obligated to pay. If contractor costs plus profit exceed this amount, the government is not obligated to pay more than this maximum. Additional costs come from contractor resources. Contract type selection should be based on the amount of performance/cost risk involved and the ability of the contractor to control that risk.

In an FFP contract, a firm price is set at the beginning of the contract. All cost risk is assumed by the contractor. In such situations, the contractor should have the maximum motivation to control cost. This type of contract should be used in situations where performance and cost risk are relatively low, predictable, and controllable by the contractor. In follow-on production, for example, where specifications and work methods are set, an FFP contract would normally be the preferred choice.

In situations involving greater risk, FPIF or CPIF contracts provide contractor incentives to control costs while sharing cost risk with the government. Both types have target costs and government/contractor cost sharing arrangements if costs are above or below those targets. If costs are less than target cost, contractor profit (fee in cost contracts) increases. If costs are more than target cost, contractor profit/fee decreases. FPIF contracts include a ceiling price. If total cost and profit reach this ceiling price, the contractor must assume all cost responsibility. CPIF contracts include a maximum and minimum (which may be negative) fee. Cost responsibility remains with the government. In general the FPIF contract would be used in situations where specifications and methods are somewhat defined, but substantial risk remains. CPIF contracts should be used where cost control is important but there is less overall definition. The amount of risk and contractor ability to control that risk should be the determining factor. A CPIF contract might be used for developmental units. An FPIF contract could be used for initial production after development.

While FPIF and CPIF contracts always include a cost incentive, they may include multiple incentives covering areas such as schedule performance, technical performance and others. Each incentive may be weighted by relative importance. One caveat -- as many incentives are combined within an individual contract, the resulting complexity may defeat the purpose of the incentive. The goal of the incentive is to motivate contractor effort in a specific direction. Highly complex incentive structures often defeat this goal because the contractor is unable to determine, at any point in time, the behavior that is most likely to result in earning higher profits. This occurs because behavior that may improve the likelihood of earning one part of the incentive may lead to outcomes which reduce the potential in other areas. For example, design efforts to obtain better technical performance may result in higher costs and schedule delays.

A CPAF contract provides a means of applying incentives in contracts which are not susceptible to the finite measurement of performance necessary for structuring other incentives. The fee established in a CPAF contract consists of a fixed amount called the base fee which does not vary with performance, and an award fee amount for excellence in contract performance in areas such as quality, manufacturing technology implementation, and management ingenuity. Award fee provisions involve the subjective measurement of performance. The amount of award fee to be paid is based upon a subjective evaluation by the government of contractor performance, judged in the light of criteria set forth in the contract. The number of criteria used and the requirements which are represented will differ widely from one contract to another. CPAF contracts have been used to motivate contractors achievements in design to cost, design to life cycle cost, reliability and maintainability improvement and other areas where incentive goals may not bo precisely definable at the outset of the contract.

A CPFF contract provides no direct profit incentive to the contractor. A fixed fee is negotiated at the outset and remains fixed regardless of cost or performance. Still there are indirect incentives. In research and development efforts, for example, contractors are motivated to accept risky contracts to do such things as develop state-of-the-art systems. The motivator is the potential for future development and/or production contracts.

Contract Provisions

In addition to incentives provided by the various types of contracts, there are a variety of contract provisions that may be included in contracts to motivate contractors toward desired objectives. Three of the most important are value engineering, warranty, and capital investment incentive provisions.

Value engineering provisions may be included in contracts to reward voluntary value engineering suggestions or to require value engineering analysis to identify methods of performing more economically. Value engineering attempts to eliminate, without impairing essential functions or characteristics, anything that increases acquisition, operation, or support costs. Value engineering is discussed in greater detail in Chapter 7.

Warranties are required on all weapons systems with a unit cost of $100,000, or total procurement cost of $10,000,000. Prime contractors must certify in writing that weapons systems provided conform to contract requirements, are free from defects, and meet performance requirements. If units fail to meet requirements the government may require the contractor to: repair or replace the item; reimburse the government for the cost of repair; or equitably reduce the contract price considering the cost of repair.

Capital investment incentives are included as a major part of DOD profit analysis. Industrial modernization incentives also may bo negotiated and included in contracts for research, development, and/or production of weapons systems, major components, or materials. The purpose is to motivate the contractor to undertake productivity improvement efforts it would not have otherwise undertaken or to invest earlier than otherwise planned. More details on the Industrial Modernization Incentives Program (IMIP) may be found in Chapter 5 and 8.

MAKE-OR-BUY PROGRAM

The prime contractor is responsible for managing contract performance, including planning, placing, and administering subcontracts as necessary to ensure the lowest overall risk to the government. Although the government does not expect to participate in every management decision, it may reserve the right to review and agree on the contractor's make-or-buy program when necessary to ensure: negotiation of reasonable contract prices; satisfactory performance; or implementation of socio-economic policies. A make-or-buy program is a contractor's written plan identifying major items to be produced or work efforts to be performed in the prime contractors facilities, and major items to be contracted.

Make-or-buy programs are required only where the work is complex, the dollar value is substantial, and price competition is lacking. Regardless of the type of contract intended, prospective contractor make-or-buy program information is required for all negotiated procurements except when the proposed prime contract:

1) Is estimated to be less than $2 million;

2) Is for research and development, unless the contract is for prototypes or hardware and it can reasonably be anticipated that significant follow-on quantities of the product will be procured.

3) Is determined by the contracting officer to be priced based on adequate price competition, or established catalog or market prices of items sold in substantial quantities to the general public, or on prices set by law or regulation; or

4) Involves only work that the contracting officer determines is not complex.

Contractor Actions

In responding to the solicitation, the contractor identifies in the proposed make-or-buy program work categorized as "must make," "must buy," or "can make or buy." A make item is one produced, or work performed, by the contractor or its affiliates, subsidiaries, or divisions. The information required to support this determination is detailed in Figure 10-4.

Government Evaluation

Contracting officers must evaluate and negotiate proposed make-or-buy programs as soon as practicable after their receipt and before contract award. In preparing to evaluate and negotiate prospective contractor's make-or-buy programs, the contracting officer must request the recommendations of appropriate personnel, including technical and program management personnel, and the small and disadvantaged business utilization specialist.

In the evaluation, primary consideration must be given to the effect of the proposed make or buy program on total contract price, quality, delivery, and performance. Socioeconomic considerations, such as labor surplus area and small business support, must also be considered. The government will not normally agree to proposed "make items" when the products or services are (1) not regularly manufactured or provided by the contractor and are available from another firm at equal or lower prices or when they are (2) regularly manufactured or provided by the contractor, but available from another firm at lower prices.

Post Award Changes

In addition to special provisions containing the make-or-buy program features, the FAR clause 52.215-21, "Changes or Additions to Make or Buy Program," must be included in the contract. This clause describes procedures that must be followed to make changes to the make-or-buy program described in the contract.

SUBCONTRACT MANAGEMENT

The prime contractor is responsible for managing the planning, placing, and administering of subcontracts. Make-or-buy program analysis considers the prime contractor's decisions in determining if certain components or services will be subcontracted. In this section, we will consider means available to the government to evaluate how those decisions are implemented.

Weapon systems contractors have always needed support from other firms in meeting their contractual obligations. Prime contractors must purchase a wide variety of raw materials, parts, subassemblies, and

- Description of each major item or work effort
- Categorization of each major item or work effort as "must make," or "can either make or buy"
- For each item or work effort categorized as "can either make or buy," a proposal either to "make" or to "buy"
- Reasons for (i) categorizing items and work efforts as "must make" or "must buy" and (ii) proposing to "make" or to "buy" those categorized as "can either make or buy"
- Designation of the plant or division proposed to make each item or perform each work effort
- Identification of proposed subcontractors, if known
- Any recommendations to defer make-or-buy decisions
- Any other information the contracting officer requires in order to evaluate the program

Figure 10-4 Contractor Make-or-Buy Program Support

services. While definitions vary, we will consider all these suppliers as subcontractors.

In this age of increasing specialization, prime contractor reliance on subcontractors has become increasingly important. Typically, one-third to two-thirds or more of total prime contract dollars are eventually paid to subcontractors. Effective management of subcontractors therefore becomes essential to effective contract performance. As a result more government attention is being directed toward the prime-subcontractor relationship.

Special care must be exercised when considering government involvement in this relationship. The government has no privity of contract (direct contractual relationship) with subcontractors. Any government efforts to control subcontractors must be accomplished by affecting the prime contractor's management of subcontracts. Subcontractors should not be asked or expected to follow government direction. If they do and problems result, the government will likely be open to substantial claims from both the prime and subcontractors. Remember also that prime contractors are paid to manage the entire contract effort including subcontractors.

In addition to make-or-buy program analysis, examined in the last section, government involvement in subcontracting has traditionally centered on consent to subcontract and contractor purchasing system review (CPSR). Increasingly, the government is also becoming directly involved in supporting prime contractor subcontract management by directly participating in prime contractor evaluation of subcontractors.

Consent

Government consent to subcontract placement may be required when subcontract work is complex, the dollar value is substantial, or the Government's interests are not adequately protected by competition and the type of prime contract or subcontract. The consent requirement is implemented through the subcontract clause in the prime contract. This consent does not establish any direct contract relationship between the government and the subcontractor nor does it relieve the prime contractor of any responsibility for selection and management of subcontractors.

Contractor Purchasing System Review

The Contractor Purchasing System Review provides the Administrative Contracting Officer (ACO) with the information needed to grant, withhold, or withdraw approval of the contractor's purchasing system. The CPSR objective is to evaluate the efficiency and effectiveness with which the contractor spends government funds and complies with government policy when subcontracting. Approval of the contractor's purchasing system significantly reduces requirements for review and consent to individual subcontracts.

All contractors with more than $10 million annually in negotiated government contracts are subject to CPSRs. Procedures call for an intensive initial review with annual surveillance using on-site visits and more detailed subsequent reviews in alternate years. These reviews devote special attention to the items identified in Figure 10-5.

CONTRACTOR DATA

Manufacturing Management activities require accumulation and manipulation of large amounts of data. To properly manage system development and production, the government must obtain and evaluate this information particularly: manufacturing management data; progress reporting data; and technical data.

- **Degree of price competition obtained**
- **Pricing policies and techniques**
- **Methods of evaluating subcontractor's responsibility**
- **Treatment accorded affiliates and other concerns having close working arrangements with the contractor**
- **Policies and procedures pertaining to labor surplus area concerns and small business concerns**
- **Planning, award, and postaward management of major subcontract programs**
- **Compliance with Cost Accounting Standards in awarding subcontracts**
- **Appropriateness of types of contracts used**
- **Management control systems, including internal audit procedures, to administer progresspayments**

Figure 10-5 Contractor Purchasing System Review Special Concerns

Subcontractor Evaluation Support

Because subcontractors are performing larger and larger portions of contract effort, government organizations are becoming more directly involved in prime contractor evaluation of subcontractor cost and price proposals and subcontractor ability to manufacture systems. Government personnel have participated as team members in prime contractor Should Costs, Manufacturing Management/Production Capability Reviews (MM/PCRs), and Production Readiness Reviews (PRRs) at subcontractor facilities. Government participation is based on government responsibility to evaluate the total contract effort and special provisions in the prime contract.

Data Requirements Definition

Requirements to perform work tasks such as manufacturing analyses, reviews, and preparation of plans, which result in the generation of data, must appear in the contract Statement of Work (SOW). These SOW requirements are based on the need to manage or support the manufacturing function as well as overall program management requirements. Data are generated by and directly traceable to the technical requirements or other work effort established in the SOW.

While the SOW sets forth the contractual tasks required, an attachment or exhibit to the contract called the Contract Data Requirements List (CDRL), DD Form 1423, contains the list of data required to be delivered under the contract. Properly developed, the CDRL permits DOD managers to attain the data objectives described in Figure 10-6.

- Specify the minimum amount of data needed
- Identify individual data item prices
- Assure on-time acquisition of required data
- Establish data requirements to meet manufacturing management needs
- Specify data requirements in solicitations or proposals to provide full, understanding of total data requirements at contract award
- Provide for administration of contracts requiring data to ensure that all contract data provisionsare fully satisfied
- Provide quality assurance procedures to ensure the adequacy of the data for its intended purpose
- Provide for the continued currency of acquired data
- Prevent the acquisition of duplicate data

Figure 10-6 Contract Data RequirementsList Data Objectives

The CDRL should contain an explanatory Data Item Description (DID) for each data item listed. DIDs specifically describe the purpose of the data item, applications involved, interface references, and data preparation requirements. Accordingly, they play a key role in obtaining needed information in such critical areas as production plan development and execution, production capability and feasibility assessments, production readiness review accomplishment, production progress reporting and engineering data.

An individual DID is required for each data element. Detailed DIDs are listed in the DOD Acquisition Management Systems and Data Requirements Control List (AMSDL), DODD 5000.19L, Volume 11. If a particular data requirement is not listed in the AMSDL, special Service or Agency approval will be required.

There is considerable latitude in the amount of information or data to be obtained under the various contract vehicles. Manufacturing data content and format should be tailored for each program phase. Tailoring is basically the exclusion of those sections, paragraphs, or sentences of standards, specifications or data items and the substitution thereof, addition, or creation of specific data requirements to meet the needs of manufacturing managers.

Manufacturing Management Data Items

The need for manufacturing data exists throughout the product life cycle and can be defined as recorded information, regardless of form or characteristic, which may be retained by the contractor or provided to the government. Whether retained and made available for review or provided, data may be necessary for any number of purposes including those listed in Figure 10-7.

- Preparation for quantity manufacturing
- Design adequacy review
- Manufacturing feasibility
- Manufacturing capability
- Program visibility
- Risk assessment
- Discipline interfacing
- Manufacturing planning
- Facilities planning
- Subcontractor management
- Manufacturing surveillance

Figure 10-7 Typical Manufacturing Management Data Items

Progress Reporting

A number of different techniques and reports are utilized by program managers to obtain status on manufacturing efforts. These include: Cost Performance Reports (CPR); Cost/Schedule Status Reports (C/SSR); Production Progress Reports (PPR); Line of Balance (LOB); Performance Evaluation and Review Technique (PERT)/Critical Path Method (CPM) reports; Gantt or phase-planning charts; and internal contractor management information system outputs. No one technique is applicable to all programs or program phases.

The information generated is targeted for use at different levels of program management, procuring agency, or contract administration office. System requirements, such as the Cost/Schedule Control System Criteria (C/SCSC), are intended to provide criteria for the management system from which data will be generated for management visibility in five areas: organization, planning and budgeting, accounting, analysis, and revisions. Other requirements, such as PERT/CPM and Gantt charts, are intended to ensure that manufacturing progress is commensurate with the contract schedule. This topic is treated in detail in Chapter 13.

Technical Data

The term technical data is defined as recorded information, regardless of the form or method of the recording, of a scientific or technical nature (including computer software documentation). The term does not include computer software or data incidental to contract administration, such as financial and/or management information. Examples of technical data include: research and engineering data; engineering drawings and associated lists; specifications; standards; process sheets; manuals; technical reports; catalog identifications and related information; and documentation related to computer software.

The Government has extensive needs for many kinds of technical data and the rights to use such data. Its needs may well exceed those of private commercial customers. For defense purposes, millions of separate equipment and supply items, ranging from standard to unique types, must be acquired, operated, and maintained, often at points remote from the soruce of supply. Functions requiring varied kinds of technical data are described in Figure 10-8.

systems, prior to entering full-scale development. It is also important that contractors be required to provide early identification of any technical data that they intend to deliver with any restrictions on Government use.

• PERSONNEL TRAINING	• INSPECTION
• OVERHAUL AND REPAIR	• PRODUCT SURVEILLANCE
• CATALOGING	• PACKAGING
• STANDARDIZATION	• LOGISTICS OPERATIONS
• MODIFICATION	• REPROCUREMENT
• INTERFACE CONTROL	• SERVICE TEST

Figure 10-8 Uses of Technical Data

There is not necessarily a correlation between the Government's need for technical data and the contractor's economic interest in such data. Commercial and non-profit organizations have property rights and a valid economic interest in technical data pertaining to items, components, or processes which they have developed at their own expense. Such technical data are often closely held in the commercial sector because their disclosure to competitors could jeopardize the competitive advantage they were developed to provide. Public disclosure of such technical data could cause serious economic hardship to the originating company and would not be in the interest of the United States in encouraging innovation as well as encouraging contractors to develop at private expense items, components, or processes for use by the government.

Because of the possible different government/contractor views on technical data, it is particularly important for the government to identify its various uses of and needs for technical data as early as is practicable in the acquisition of any item, component, or process. Such identification should be made before contract award or, for major weapons

Normally, delivery of the technical data package occurs at the end of full-scale development or during the production phase. Timing of the delivery is based on the planned use of the data and the expected magnitude of design changes during the early part of the production phase.

Of all these uses, the one which provides the greatest difficulty is reprocurement. If DOD wishes to acquire systems or spare and repair parts for the systems under competitive procedures, unlimited rights in data is normally required. Conflict with contractor economic interest is obvious. Most contractors are not anxious to support future competition. The technical data package for reprocurement needs to contain the information necessary to enable a competent manufacturer to build the part or component. This should include such items as: purchase specifications, inspection and test requirements, and packaging data. Special care should be taken to assure that data packages do not contain restrictive markings. Data packages must include explanations of references such as contractor specification numbers.

CHAPTER ELEVEN

TRANSITION FROM DEVELOPMENT TO PRODUCTION

CONTENTS

TRANSITION FROM DEVELOPMENT TO PRODUCTION

OBJECTIVE

The challenge of program management is to find the practical middle ground between producing underdeveloped systems and extended development and testing to the nth degree of a few high cost systems that never reach rate production. Key guidelines to follow are:

1. Select an acquisition strategy and risk management plan in context with the unique aspects of the program.

2. Avoid planning a development to production gap into the program.

3. Enter full-scale development only with a solid technology base and a management commitment for timely support and continuity of effort, provided that the need still exists and satisfactory progress is maintained.

4. Plan for transition to production starting at program initiation.

INTRODUCTION

This chapter discusses some of the organizational and functional issues which are involved in the transition from development to production and the process for evaluation and management. The changes in organizational focus and activity are presented along with a discussion of the impact of gaps between development and production. The relationships among engineering design release, initial production facilities and producibility engineering and planning (PEP) are discussed as they impact the transition process.

Management of a major weapon system from development through production requires effective administration and coordination of many activities. At the production phase, large financial commitments are made based on the detailed planning of previous phases. The transition is a highly visible, highly reactive time that is characterized by emphasis on preparation for production and change management. A program manager should recognize the fundamental principle that systems acquisition is an industrial process which demands both an understanding of that process and the implementation of basic engineering disciplines and their control mechanisms. The Defense Science Board (DSB) Task Force on Transitioning from Development to Production, in their May 1983 report "Solving the Risk Equation in Transitioning from Development to Production," provided abundant evidence that transition from full scale development into production places particular demands on engineering design, test, and manufacturing, in both application and timing, and emphasizes assurance of design stability and certification of the manufacturing process. The Board determined that the problems with the acquisition process were not administrative, but instead were technical. They further determined that this technical process focused on three critical activities: design, test and production.

TRANSITION PROCESS OVERVIEW

Transition from development to production is not an event with a readily identifiable starting point in the acquisition process. The transition process incorporates many activities shown in Figure 11-1. It is a continuum of interrelated and interdependent activities. Military acquisition has time and time again extended the product development effort well into the production phase. As a consequence, numerous product changes are introduced, planning essential for manufacturing is delayed, and the burden on manufacturing to "make up time" for engineering delays is a monumental task for what could otherwise be a successful acquisition program. "Fast tracking" is a high risk venture. The transition process is very broad and it is impacted by activities that are or, more accurately, are not done in the early design and test activities.

Planning for production and manufacturing engineering, following the design process, is a major transition risk. Documented early producibility engineering and planning integrated with advanced development offers benefits of increased

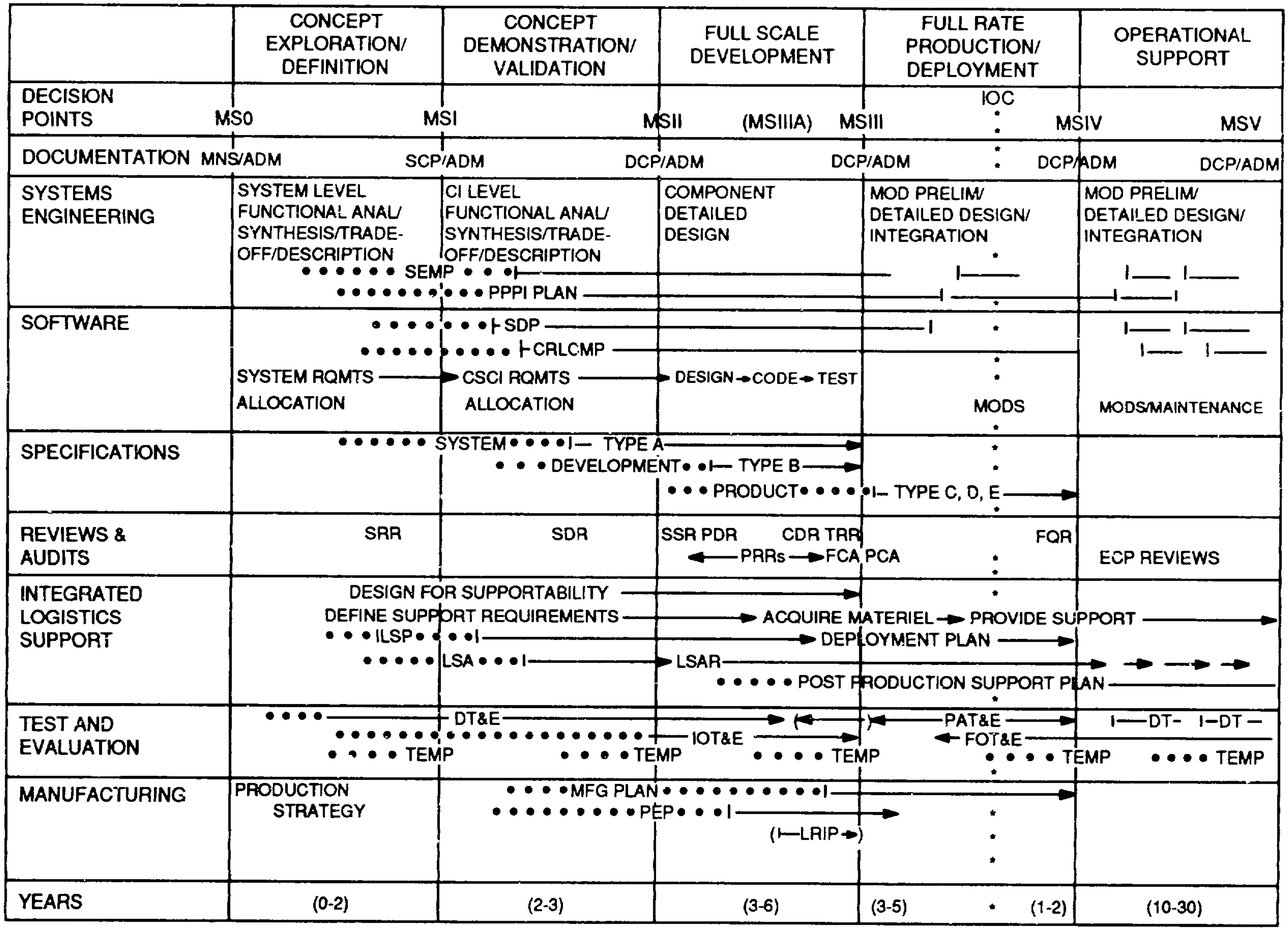


Figure 11-1 Acquisition Process for Major Weapon Systems

end-item compatibility with the process and procedures necessary to produce the item, and reduces the number of changes in the product configuration introduced on the factory floor. Acquisition costs and schedule delays will be reduced when the program is structured to accommodate the transition to production.

Documented early planning focusing on the specifics of the manufacturing practices and processes required to build the end item should be initiated while the design is fluid, and completed before the start of rate production. A manufacturing plan should be a comprehensive document, provide guidelines for action, identify and give visibility to high risk factors, and then provide direction by which risk can be minimized. The report cited earlier, "Solving the Risk Equation in Transitioning from Development to Production," lists the essential elements of a manufacturing plan which will significantly reduce the risk of transitioning a program from development to production.

- Master delivery schedule which identifies by each major subassembly the time spans, need dates, and who is responsible
- Hard tooling requirements to meet increased production rates as the program progresses
- Special tools
- Special test equipment
- Assembly flow charts
- Receiving inspection requirements and yield thresholds
- Production yield thresholds
- Producibility studies
- Design improvements
- Production control
- Critical processes
- Cost/schedule reports
- Trend reports
- Product assurance
- Fabrication plan
- Engineering release plan

Further, items that represent new processes may also be considered when generating a manufacturing plan. They are usually driven by unique aspects of the acquisition, capabilities of the contractor, or initiatives of the military procurement agency.

The transition process is a very broad one and it is very dependent upon certain activities to take place in order for the program to have a smooth, orderly progression. The activities that must take place during the transition of a weapon system's program are specified by the templates shown in Figure 11-2. The templates can be thought of as wickets to pass through before the major template function may be achieved. For example, the major template of Design has fourteen supportive templates, each of which must be addressed in a disciplined manner before the design template can achieve design maturity and thus fulfill the requirements for transition from R&D to production.

In the Introduction, we stated that the DSB task force identified design, test, and production as the most critical functions of the industrial process, and thus they were identified as the original templates. Since that time the DOD conducted an industry - wide review and additional templates have been identified. These additional templates of funding, facilities, logistics, management and transition plan have joined the original three as shown in Figure 11-3. They are arranged in what would be considered a logical sequence from a program manager's viewpoint. For example, the Funding templates is shown in a position that influences each of the other templates and the transition plan template is shown in a position of depending upon other, preceding templates.

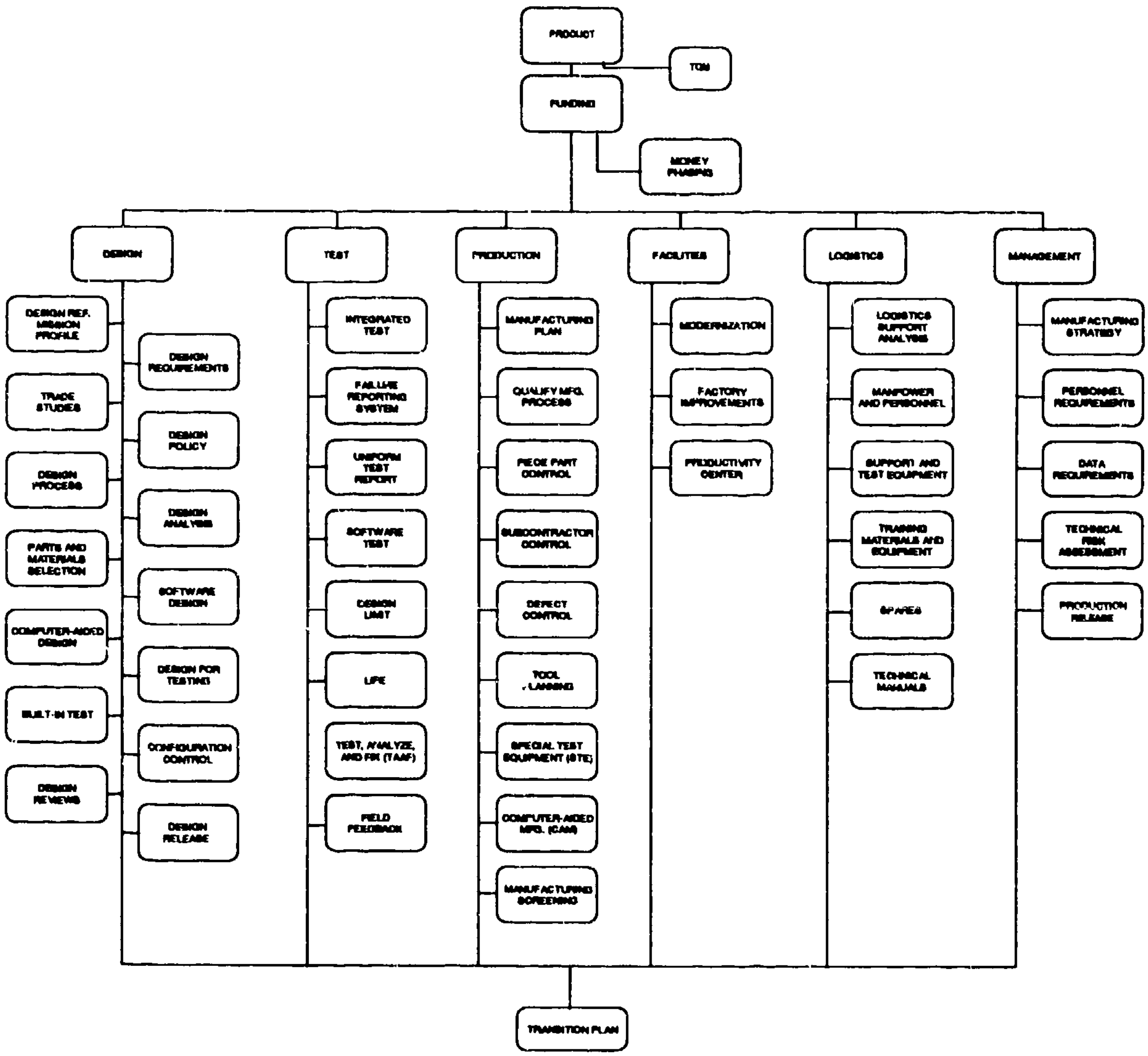
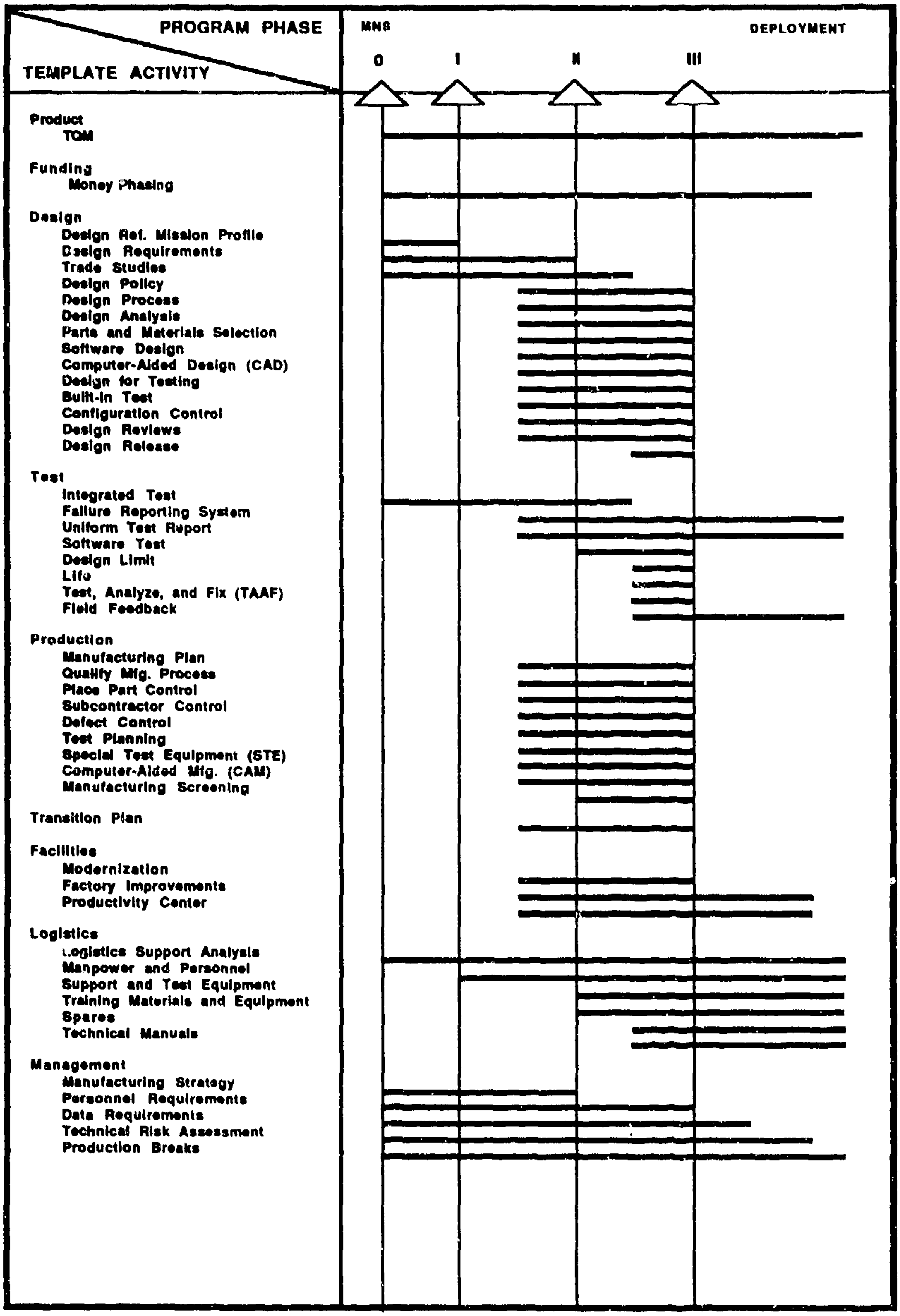


Figure 11-2 Critical Path Templates



PROGRAM RISK IS INTRODUCED WHEN A PARTICULAR TEMPLATE ACTIVITY IS STARTED LATE OR CONTINUES BEYOND THE TIMELINE

Figure 11-3 Template Timelines

By showing the template activities as a timeline chart in 11-3 one can see that the template activities - which comprise an orderly transition process - are interrelated and interdependent. The chart shows the activities of the templates and their starting times in relation to other template activities. For example, one can see that the production template activities are started after the initial activities of the Design template, but in conjunction with the design templates with would affect producibility, i e., the activities of tool planning, and qualification of the manufacturing process happen in conjunction - and coordination - with those of design analysis, and parts and material selection.

This chart also shows that design and production template activities have concluded by Milestone III A, which is the start of low rate initial production (LRIP). The chart indicates a stable, mature, design release, accompanied by manufacturing processes that have qualified for production, which illustrates a smooth transition from design to production. The chart also shows the desired relationships of some templates whose activities continue into the deployment phase, such as field feedback (Design) and logistics support analysis (Logistics).

DOD Directive 4245.7M "Transition from Development to Production" consolidates established policy, prescribes procedures, and assigns responsibilities on the application of fundamental engineering and technical disciplines in acquisition programs to expedite the transition from development to production. It requires a rigorous, disciplined application of fundamental engineering principles, methods and techniques, and the identification and assessment of elements of program risk throughout the acquisition cycle.

Additional guidance on the transition process is contained in DOD 4245.7M "Transition from Development to Production." It provides assistance to program managers in structuring technically sound programs, assessing risk, and identifying areas needing corrective action. DOD 4245.7M identifies and addresses the "templates" designed to introduce discipline into the acquisition process, to identify and give visibility to high risk factors, and then to provide the tools by which risk can be minimized progressively.

So the program continues, the templates are applied, and the contractor's progress is evaluated in relation to milestone achievement through Production Readiness Review (PRR) described above. The PRR team structures the review according to the templates of DOD 4245.7M. Figure 11-4 shows the topics by which a PRR is structured, and the applicable template for that topic.

MAJOR CHALLENGES IN TRANSITION

The challenge of program management is construction and implementation of a program acquisition strategy that by a series of disciplined events and planning, results in the scheduled delivery, performance, and required quality of the end item. The disciplined series of events comprises the transition of a program from design to production. A program manager should recognize that system acquisition demands an understanding of the transition process and its control mechanisms. The transition process is very board and it is impacted by the activities that occur, or fail to occur, from the early design phase of a program to the production phase. The control mechanisms, or disciplines, of the transition process are called templates. The attainment of, and compliance with the templates results in a disciplined transition process. DOD 4245.7M "Transition From Development to Production", states that transition is not a discrete event in time, but rather a process composed of three elements: design, test, and production. These three are joined by four other key elements - funding, facilities, logistics, and management - to comprise seven critical path templates which, along with their respective risk assessment templates, comprise a disciplined transition process applicable to any program.

There are certain factors and events that present challenges to the implementation and success of the transition process. In some cases these challenges are addressed directly by the transition templates; in others they are not. This chapter addresses some of those challenges.

Producibility

Producibility, in the manufacturing process, is the compatible result of an interdependent relationship involving the

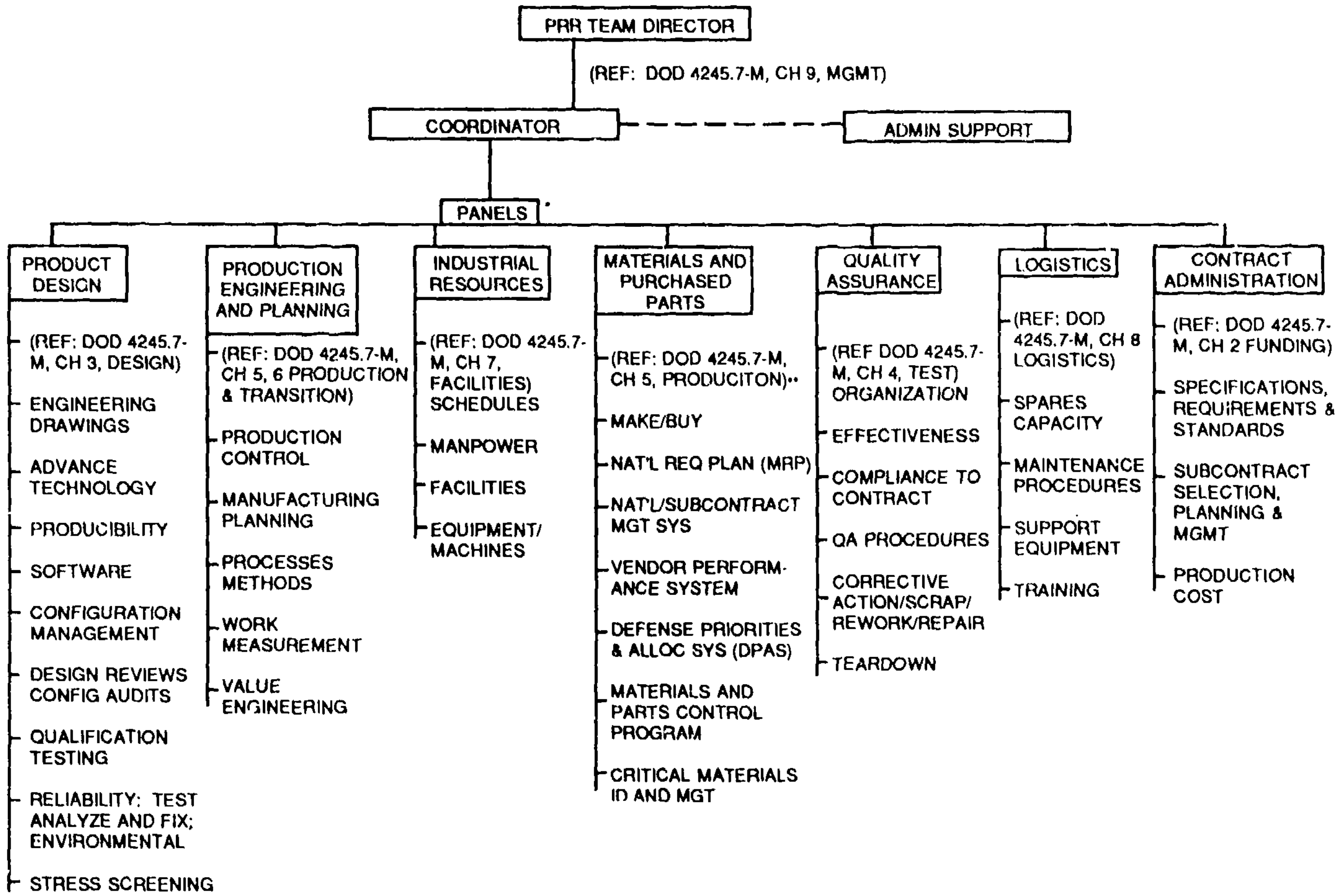


Figure 11-4 PRR Template Relationship

elements of Design, Test, and Production. Not everything that a designer puts on paper is producible. To qualify as producible a design must be such that it can be produced and tested by practical, cost-effective processes.

Producibility engineering and planning is an integral element of the design process. In order to achieve this, close coordination and communication between production, and design engineering must be established early in the design process. To simplify, production engineering should be looking over the shoulder of the design engineer as the design is being defined and stabilized, in order to provide input regarding material selection, design producibility and other manufacturing related issues. If the design is so intricate and detailed that it cannot be made by other than expensive model-shop process when the requirements are for large, production-line quantities, it is the responsibility of the production engineer to work closely with the design engineer to attain a more producible design. The Design, Test, and Production templates include the fundamental elements by which producibility can be attained when addressed in disciplined manner, as stated in DOD 4245.7M.

Design Maturity

A design is not mature unless it can be produced, tested, function to requirements, and be supported properly in the field. Before these requirements can be met, the necessary communication must take place during the design phase between the functional elements of design engineering, test engineering, production, logistics, and procurement.

In order to achieve design maturity, producibility and testability must be designed - into the product. If a design is so complicated that it cannot be tested, then there is also an excellent chance that it cannot be manufactured; if the design cannot be manufactured, then it is not a mature design.

Design maturity is almost synonymous with producibility. As the design matures, it reaches a higher level of producibility. An indication of design maturity is a lack of, or decline, in the number of formal engineering change notices (ECN) being processed. This indicates that producibility and testability problems are becoming fewer.

Many of the same Design, Test, and Production templates that are used to attain program producibility are also used to achieve design maturity because of the interdependency of the two functions.

Quality Assurance Planning and Defect Prevention

Quality Assurance (QA) Planning and Defect Prevention is another subject that is very interdependent with other program conditions, such as producibility and design maturity. The more producible the program, the higher the level of program QA and the higher the resulting quality.

Another significant template is introduced with this subject; the Failure Reporting System (Test) template. The implementation of the Failure Reporting and Corrective Action System (FRACAS) is critical to the Failure Reporting System template. The template informs us of the need or requirement to have a failure reporting system, and FRACAS describes that system.

A failure reporting system is necessary for the timely dissemination of accurate failure information in order that remedial actions may be taken promptly to prevent the recurrence of the failure. By the implementation of FRACAS those requirements can be met. FRACAS is a closed-loop system that initiates failure reports, analyzes the failures, and provides corrective actions for those failures back into the design, manufacturing, and test processes in order to prevent that same type of failure from happening again.

QA planning and defect prevention however, is an extremely wide requirement and is present throughout the transition template structure, as well as being a central tenet of DOD Total Quality Management. Without an effective QA planning and defect prevention program the cost of rework and repair would be excessive; the "hidden factory" would become larger and larger. Consequently, for a QA and defect prevention program to be effective, it cannot be localized to just one or two templates, but it must extend to all concerned areas, or in this case, templates. Those "concerned areas" are the three primary manufacturing risk areas of Design, Test, and Production, and each of these templates is supported by templates that share an ultimate goal to improve quality, and prevent defects.

With the disciplined implementation of the transition templates the subject of Total Quality Management and defect prevention becomes more than a milestone, it becomes a manufacturing "atmosphere."

Production Cost Analysis

The impact upon production cost as the result of the use of the templates for a successful transition from R&D Design to Production, is that production costs are ultimately lower. As the template principles and guidelines are applied to a program in a disciplined manner, efficiency is increased and errors are reduced or eliminated, thereby greatly reducing the costs incurred by the "hidden factory" while performing rework and/or repair. The templates address risks and situations that are technical, and not administrative which have significant impact on production cost.

Production Planning

A successful, thorough production planning activity must be in place in order for a program to successfully transition from development to production. Production planning is an element that comprises activities that are critical to a disciplined program and its transition to production. These activities, along with the templates to which the relate, are shown in Figure 11-5.

Qualify Manufacturing Process have taken place.

Activity	Template
Policies and Procedures	Management Strategy Qualify Manufacturing Process
Master Phasing Schedule	Manufacturing Plan
Manufacturing Lead Times	Manufacturing Plan
Critical Component Identification/ Control	Manufacturing Plan
Production Schedule/Control	Qualify Manufacturing Process Manufacturing Plan
Bottlenecks & Work-Arounds	Manufacturing Plan
Manufacturing Job Sheet	Qualify Manufacturing Process
Design Release Risk Analysis	Qualify Manufacturing Process
Machine/Plant/Loading Capacity	Manufacturing Plan
Make or Buy Plan	Manufacturing Plan

Figure 11-5 Production Planning - Template Relationship

The production planning is usually based on documented procedures that maintain consistency in planning from one project to the other. Although there are other critical elements comprising production planning, one of the most critical is the Master Phasing Schedule. This is used during the initial production planning and depicts a logical time - phasing of program milestones established in order to comply with the program schedule from contract initiation to product delivery. The Master Phasing Schedule serves as a basis for establishment of the Manufacturing Plan.

Another example of inter-dependency between Production Planning and the templates is that the manufacturing job sheets, which are an integral part of production planning, cannot be prepared until after the template activities of Design Release, and

Planning for resource availability must take place during the very early phases of a program; and the transition templates of Facilities, and Management assist the PM to accomplish this. The Facilities template is supported by three templates: Modernization, Factory Improvements, and Producibility Center, all of which impact Resource Availability. The Personnel Requirements template supporting the Management template helps the PM plan to ensure personnel availability when it will be needed. In summary, the templates to assist the PM to plan for resource availability are available.

Production Design Change Introduction

Introduction of a design change after the production phase of a program has started is always a cause for concern and caution. This is something that should be avoided if at all possible. When a design change is introduced after production has started, any chance for a smooth transition from Development to Production that may have existed is significantly reduced, if not eliminated.

A Production Readiness Review (PRR) is conducted prior to the approval for the contractor to start the production phase of the program. At that time, the status of the program design is evaluated. If the design is to be mature, it must be considered qualified and ready for production; if the design is not considered to be mature, the program should not be allowed to go into the production phase. Theoretically, it is reasonable to assume that if a design change is introduced after production has started, the design was not really mature at the time of the PRR. By the time that a program starts production, the manufacturing process has been qualified and tooling built. Consequently, any design change introduced after the start of production could require changes in process, new tooling, personnel retraining and a number of other impacts, all of which can be very costly, both from a financial and a schedule standpoint.

So how do we avoid this undesirable activity? We avoid it by using the two templates of Design Release, and Qualify Manufacturing Process. These templates provide the Program Manager (PM) with tools by which to avoid an undesirable production design change introduction. The templates, when used in conjunction with each other, can do much toward the assurance of a smooth transition from Development to Production.

PRODUCIBILITY ENGINEERING AND PLANNING (PEP)

Initial production uncertainties need to be analyzed and contingencies addressed to avoid or minimize program disruptions and associated cost overruns as a weapon system progresses from Development to Production. The purpose of PEP is to insure that product designs reflect good producibility considerations prior to release for manufacturing. As in R&D, risks are inherent in the system during early production. PEP begins with those activities and events occurring perhaps three or four years before Milestone III and extends to the state of routine production. Although there is no commonly accepted starting point for PEP, it is prudent to anticipate production system requirements as early in the program as in the concept demonstration/validation phase, when only a small percentage of the total expected program life cycle costs has been incurred.

PEP involves the engineering tasks necessary to ensure timely, efficient and economic production of essential material and is primarily "software" in nature. It includes efforts related to development of the Technical Data Package (TDP), Quality Assurance (QA) procedures, and evaluation of special production processes through trade studies. Also included are development of unique processes essential to the design and manufacture of the material and details of performance ratings; dimension and tolerance data; manufacturing methods; sequences; assembly; schematics; physical characteristics including form, fit and function; inspection test and evaluation requirements; calibration information and quality control procedures.

PEP is, in effect, a qualification process that will confirm the adequacy of the production planning, tool design, manufacturing process, and procedures before rate production begins.

It is DOD policy that factors affecting producibility and supportability shall be fully integrated during full scale development. The design and test cycle shall be structured to provide a continuum in development for production, as opposed to discrete phases that cause iterative and redundant activities. The PEP program should be defined contractually and contain specific tasks and measurable performance that will support an orderly transition. PEP progress should be tracked by means of production readiness reviews required before initial or full production decisions. The objective of a transition plan is to provide visibility of how well each activity is being executed. To be effective, progress should be regularly compared against the transition plan.

Integrate Initial Production Facilities with Producibility Engineering and Planning

Only minimum manufacturing tools are required in the development phase to build and assemble prototype or test articles to be used for testing and evaluation of the engineering design. Off-the-shelf tools are utilized as much as possible and often prototype articles are, for all practical purposes, hand assembled. At some point in the development phase, consideration must be given to production tooling requirements. The Initial Production Facilities (IPF) effort is performed during the initiation of the Production Phase and provides the special tooling and test equipment needed to enter the production phase. The design and supporting documents for special tooling and test equipment are provided under Producibility Engineering & Planning. IPF translates these designs into a functioning production facility. Specific tasks include:

- O Fabrication and validation of special manufacturing equipment.
- O Fabrication and validation of Special Acceptance and Inspection Equipment (SAIE) and other special inspection equipment and gages.
- O Initial set-up of the manufacturing line, if appropriate.
- O Maintenance of special equipment.

Integrate Long Lead Items with Producibility Engineering and Planning

Manufacturing documentation is prepared as a part of the PEP effort, and includes the master tooling plan, the manufacturing line layout and identification of long lead time items. Product design specifications should be relatively mature, at least with regard to special or scarce material requirement, major production equipment and special purpose production tooling which has to be ordered well in advance of start-up time. The early stages of development characteristically produce many Engineering Change Proposals (ECPs) and the PM must ascertain that the contractor is doing the necessary planning for manufacturing with special consideration for the long lead items.

DEVELOPMENT/PRODUCTION GAPS

Previous acquisition policies have been such that a gap can be created between phases in the acquisition cycle. The gap is most pronounced between the development activity and the production of the system for inventory. One need only to examine some of the past directives to understand the reasons that such a gap is inherent in our systems acquisition cycle. The Deputy Secretary of Defense, David Packard, in a 31 July 1969 memo to the Service Secretaries stated, "There is a general deficiency in the amount of test and evaluation before we commit significant resources to production. While it is generally a mistake to schedule a complete break between development and production, we have tended to drift too far in the direction of concurrency, and this must be reversed." A Blue Ribbon Defense Panel reported in July 1970, "guard against concurrent development and production.... Defer production decision until successful demonstration of developmental prototypes." A GAO Report in March 1973, "Cost Growth in Major Weapon Systems," had the following recommendations: "Avoid concurrent development and production.... Adhere to orderly and sequential design, test, and evaluation," and, . . . clear separation of development and production." DOD Directives 5000.1 and 5000.2 clearly state that the production phase will not be initiated until all engineering is reasonably complete and all significant design problems have been identified with solutions in hand. These directives further specify that Initial Operational Test & Evaluation (IOT&E) will be accomplished prior to the first major production decision. The current policy is that concurrency will not be used unless there exists exceptional justification.

A development-production gap will cause some additional delay in moving the concept to deployment, but this could easily be outweighed by the considerable potential savings in resources that might result. Some potential benefits of the development/production gap are:

1. It bounds the government risk by preventing the initiation of a costly manufacturing program before all engineering problems are solved and the design is proven.
2. It provides time to learn and evaluate the development results prior to the production start, thus preventing potentially costly mistakes in manufacturing techniques.

3. An improvement in predictability of cost, schedule and performance will result.

4. It allows for incorporation of required changes that surface as a result of the development and operational testing.

5. Wasted effort, such as premature planning, incorrect tooling, improper production line setup, and possible retrofits are avoided,

6. It presents a more conservative face to the Congress who must approve commitment of funds to systems production.

There are also some potential impacts that might negatively affect a program:

1. During a period when there is a high rate of inflation, a long gap would severely escalate the cost of a system.

2. There would be a loss of the learning which was accrued in the development phase.

3. Overhead rates could increase.

4. It could break up the management team approach that is essential to a smooth-running acquisition.

5. The program would be much more vulnerable to budget cuts or cancellation.

What is the net effect of the development production gap and what influence can the program manager have over it? Undertaking production before development is completed greatly increases program risk. It may substantially reduce the time span from concept to deployment but it involves a commitment to incurring substantial costs which may be wasteful in the event of program design modification, cancellation, or redirection. This kind of concurrency is to be avoided and will be approved by the Secretary of Defense only in rare instances. Steps may be taken in the development process that will smooth the transition into the production phase. One example is long lead time materials which may have to be ordered in advance to prevent an unbearable delay in the transition from the full-scale development phase to the production phase.

Program planning in such a case would evaluate the trade-off between probability of delay and waste. Risk assessment is a means of estimating the amount of potential waste, and the probability that the waste will occur. Usually advanced procurement of long lead items represents a relatively small part of the total program budget and is an attractive program alternative.

Successful programs tend to be characterized by a continuity of effort. Initiation of a full production program does not take place until after development is completed but, by deft use of program acquisition strategy and skillful risk management, the spirit of current policies can be accommodated and still avoid a significant program gap between development and production.

1. Release for long lead material or effort which is discussed in Chapter 6 of this guide

2. Pilot or Low Rate Initial Production (LRIP) and

3. Additional systems for test and evaluation.

<u>LOW RATE INITIAL PRODUCTION</u>

Low rate initial production (LRIP) is a term describing a low rate of output at the beginning of manufacture to reduce the government's exposure to large retrofit programs and costs. LRIP has two major purposes. First, it demonstrates that the production process and techniques are capable of producing the required quality and quantity of output. Second, it may provide production representative items for the completion of development (to include live-fire) and/or operational testing.

If full scale-development or pre-production prototypes are used for both development and initial operational testing in the FSD phase, they must be sufficiently representative of the expected production items to provide a valid estimate of operational effectiveness and suitability. These prototypes and any pilot line/tooling costs under a development contract should be funded by the RDT&E appropriation. Retention of the pilot line capability for LRIP and production is funded with the appropriate procurement account.

Often, the prototypes are handmade (albeit to government specification), then a production line manufacturing process changes the operating characteristics of the item, or it is discovered that the item can not be successfully produced using methods different from the hand-tooled article. These problems lead to significant rework, additional testing, producibility changes, and may cause schedule and cost growth.

To reduce the risks mentioned above, it may be desirable to acquire a limited number of LRIP items to complete IOT&E. However, an operational test assessment is still required prior to LRIP approval. There is still the risk that the additional operational testing may reveal deficiencies resulting in significant changes to the production line or article; however, these problems are mitigated by the ability to correct deficiencies prior to fielding. Tooling and other costs to start LRIP should be borne by the appropriate procurement appropriation. LRIP items to be consumed in IOT&E should be funded by RDT&E. LRIP items to be used in IOT&E, but returned to the operational inventory, should be funded by a procurement appropriation.

For major defense acquisition programs, the OSD Director of Operational Test and Evaluation must provide an operational test assessment to the SECDEF and to the Congress before the Secretary can authorize full rate production. All production line costs for follow-on-test and evaluation (FOT&E) and inventory should be funded from a procurement appropriation.

ORGANIZATIONAL ISSUES

At the completion of the development process, a review is normally held at the Service level to determine if the system is ready to enter the production phase of the program. Approval to proceed into the production phase is based upon:

a. Assurance that risks have been resolved, including the threat.

b. Cost, schedule, and performance estimates/requirements for production phase are credible and acceptable.

c. Determination that: a practical engineering design has been completed, tradeoffs have optimized production, maintenance, and operating costs and contractual aspects are sound.

Evaluating the production readiness of a weapon system prior to a production decision point is an important element of the DOD weapon system acquisition process. Production readiness is assessed by means of a Production Readiness Review (PRR). The objective of a PRR is to verify that the production design, planning and associated preparations for a system have progressed to the point where a production commitment can be made without incurring unacceptable risks of breaching thresholds of schedule, performance, cost, or other established criteria. The Production Readiness Review is discussed in detail in Chapter 12 of this guide.

Producing a system for inventory is the ultimate goal of the weapon system acquisition process and the success of transitioning from development to production is one key to how well this goal will be attained. In terms of resources, the production phase consumes approximately half of the Defense budget and about three times what is spent in the development effort.

The OSD focused attention on minimizing the risks associated with transitioning defense systems from the full-scale development phase to the production phase by the issuance of DOD Directive 5000.34, "Defense Production Management." This document assigned specific production management responsibilities within the OSD and the Services. Among those assigned is the exercise of policy and operational control of the DOD Product Engineering Services Office (DPESO). The DPESO mission includes:

- Providing production management assistance to DOD components.

- Providing independent assessments of producibility and production readiness to major programs.

Among the responsibilities assigned to the heads of DOD components (that include the Services) and their program managers that relate directly to the transition process are:

- Assuring that consideration is given to the producibility of proposed concepts during the concept demonstration and validation phase.

- Assuring that program funding and schedule for reduction of production risk through production engineering and planning and manufacturing technology activities.

- Conducting production readiness reviews in support of limited production and full production decisions. These reviews may include participation by consultants and other DOD Components and attendance by OSD representatives.

- Employing pilot production lines when necessary to validate production readiness, manufacturing operations and cost, and to provide production articles for test and evaluation.

ENGINEERING RELEASE OF THE PRODUCTION DESIGN

As the development and test effort nears completion, the design function must make the necessary revisions to the design media such as drawings, schematics, and bills of materials. These changes are the result of the outcomes of full and subscale tests, producibility studies and other design changes and refinements. As is discussed in Chapter 6 on Manufacturing Planning and Scheduling, the product design is one of the bases of planning development. In most cases, the firm production design does not exist at the time of transition and, consequently, part of the transition planning involves planning for the design release.

A specific design release plan should be developed through a joint effort of the manufacturing and engineering groups. The plan should provide specific dates for release of the individual design details and the assembly concepts. The actual timing of the release often represents a compromise between the manufacturing need date and the ability of the design function to complete and review the design media. The manufacturing need date for engineering release is based upon the lead time required to tool and make the parts when the part will be used in the assembly sequence. The delay in the design engineering function is a result of the workload peak resulting from the need to complete, review and release the total design. The PMO should evaluate the contractor planning for engineering release to assure that proper set back times have been established and that the release schedule will support the manufacturing planning.

When the design release process is initiated, contractor progress should be tracked by the PMO. Delays in release often result in factory schedule slippages and/or increased cost as additional resources are applied to regain schedule.

IMPACT ON PROGRAM MANAGEMENT

In accomplishing the transition, there is a need to change the basic focus of program management. During design and development, there is a premium placed on direct interaction between designers and the floor manufacturing personnel. As the design test articles are being produced, there is a continuing inflow of design change which must be fed into the fabrication facility. As preliminary test data identify problems, fixes are defined and implemented. The control of shop drawings tends to be somewhat loose, reflecting the primary thrust of this phase which is interactive design. The fabrication effort tends to be focused within the more experienced personnel, often involving the use of highly skilled model shop personnel. Quality requirements are specified via drawings and inspection and test documentation to the production facility.

To achieve success in the production phase, the operating style must change toward complete definition of the fabrication and assembly tasks and the transfer of those tasks to the general factory work force. This results in a need for more detailed work instructions and a closely controlled system for changes to the documents used in the factory, such as drawings and process specifications, to build the quantities required to meet the acquisition objective. Extensive documentation required for production planning (discussed in Chapter 8, Manufacturing Technology) must be based on a stable design, quantity requirements and delivery schedule. The amount and timing of engineering changes must be controlled to minimize disruption to production documentation and planned manufacturing schedules.

There is often a need for the contractor to make basic changes in the manufacturing planning and control systems reflecting a change from small lots of parts with relatively dynamic design, to economical lots with fixed design for quantity production. The measures of effectiveness of the manufacturing function also may change to reflect the efficiencies which would be expected in repetitive production and the balancing of work flow through the facility. The program manager should assure that the contractor has evaluated the planning and control systems used in the factory to determine the need for changes to reflect the difference in the fundamental objectives of development and production. Where change is required, an attainable plan for the system transition should be defined by the contractor.

CHAPTER TWELVE

MANUFACTURING SURVEYS AND REVIEWS

CONTENTS

MANUFACTURING SUI VEYS AND REVIEWS

OBJECTIVES

The material in this chapter is directed toward describing the nature and purpose of the various manufacturing surveys which are required during the life of a defense program and the elements of planning and execution which have historically been viewed as critical to the successful attainment of survey objectives. The major focus within this chapter is on the Production Readiness Review (PRR), reflecting its importance within the milestone review process. It should be noted that the planning and procedural guidance provided for the PRR are also applicable to other reviews and surveys. In using the material for these purposes, it is necessary for the program management office (PMO) to adjust the procedures to reflect the differences in objectives, scope, breadth of coverage and depth of involvement.

ITRODUCTION

Manufacturing surveys are conducted to obtain some measure of the capability of defense contractors to perform the manufacturing tasks and to develop estimates of the production risk inherent in the design and the proposed manufacturing approaches. The areas of interest generally reflect analysis of th physical, managerial and financial capability of the contractors to accomplish the work required, especially when other demands ma e placed upon the available production re ces. Manufacturing reviews are co .ted to focus on issues related to the ade y of the manufacturing management systems, and the application of the systems to the specific product to be produced.

Survey (jectives

A survey may be conducted to identify and . nize the uncertainties inherent in acquisition of major or complex defense systems. Specific objectives of a survey may include:

- O Substantiating program adequacy
- O Selecting contractor sources
- O Structuring contracts
- O Supporting internal program decisions
- O Supporting milestone decisions

TYPES OF SURVEYS

Manufacturing surveys can be divided into two broad categories; system centered and product centered. In most cases, the PMO will be involved with the product centered surveys since the PMO mission is to manage development and production of a specific system or product.

A manufacturing management system survey is concerned with the basic system which has been developed by a contractor for planning, executing and controlling the manufacturing function within the specific facility. Except when the Cost/Schedule Control Systems Criteria (C/SCSC) is applied on a contract, surveys such as these are most often accomplished by the designated Contract Administration Office (CAO) as a part of their continuing review and evaluation of contractor operations effectiveness. When C/SCSC is applied, the CAO provides one or more members to the C/SCSC Review Team and, after acceptance of the contractor's management system, the CAO provides continuous surveillance. The basic thrust behind the accomplishment of system surveys is the hypothesis that the success of a contractor on a specific program is strongly dependent upon the existence of a defined, well operating management system.

The specific system to be used by the contractor will be unique to that company's business objectives, size, product mix and operating style. The focus on these types of reviews should be on the capability of the management system to support effectively the current and planned levels of manufacturing operation. To make this determination, the review team needs to ensure that the system is structured, defined and communicated to the individuals within the company who are charged with making it work. It is also necessary to make a determination that the system is, in fact, functioning as it is described. A company often has an apparently well structured system which, unfortunately, is not used by its personnel. Where specific manufacturing management requirements such as C/SCSC or MIL-STD-1528, Production Management, are established within the contract, there is a need to determine contractor compliance with these requirements. For this type of system survey, the team is composed of both CAO and buying office personnel, but the basic thrust remains the same. Where these types of surveys have been accomplished, the program office should use the findings as an element of the manufacturing risk assessment and as an input to the evaluation of schedule attainability. Where management system weaknesses are defined, the program manager should consider ways to motivate the contractor to correct the problem.

Product Centered Surveys

A number of surveys (reviews) are accomplished on specific equipment or systems. Some of the more common ones are listed in Figure 12-1 and defined in Appendix B. In addition to these manufacturing based reviews, issues concerning design, producibility and manufacturing planning are integral parts of the continuing design review process and should be addressed at the reviews listed in Figure 12-2.

system. These surveys are fundamentally similar in approach since they all seek to define industry's capability to produce proposed systems or to measure the manufacturing risk level inherent in specific programs. The primary differences in the procedures for accomplishing the surveys are driven by differences in the:

- o Nature of the required output of the survey
- o Depth of evaluation
- o Breadth of evaluation
- o Degree of design definition existing at the time of the survey
- o Amount of completed manufacturing planning
- o Existence of competition in the program.

To define the management approach to product oriented surveys, the focus will be on the production readiness review. This review has been a relatively high visibility requirement during the system acquisition process and is expected to retain significance

- PRODUCTION READINESS REVIEW (PRR)
- PRODUCIBILITY REVIEW
- PRODUCTION FEASIBILITY REVIEW
- PRE-AWARD SURVEY
- PRODUCTION CAPACITY REVIEW
- PRODUCTION PLAN REVIEW

Figure 12-1 Product-Centered Surveys

in any service decision to initiate the manufacture of defense systems. The PRR procedures and techniques can be tailored for use in other reviews by making appropriate

MANAGING THE SURVEY AND REVIEW TASK

As was noted earlier in the chapter, a number of product centered surveys may be required during the acquisition of a specific

- SYSTEM REQUIREMENTS REVIEW (SRR)
- SYSTEM DESIGN REVIEW (SDR)
- PRELIMINARY DESIGN REVIEW (PDR)
- CRITICAL DESIGN REVIEW (CDR)
- FUNCTIONAL CONFIGURATION AUDIT (FCA)
- PHYSICAL CONFIGURATION AUDIT (PCA)

Figure 12-2 Design Reviews

adjustments based upon the differences described previously.

PRODUCTION READINESS REVIEW

A Production Readiness Review (PRR) is a formal examination of a program to determine if the design is ready for production, if production engineering problems have been resolved, and if the producer has accomplished adequate planning for the production phase. Because adequacy is an imprecise issue, the degree of adequacy should be addressed within the context of the specific program, in terms of the risk levels that have been determined to be acceptable for that program. The production readiness review attempts to verify that the production design, planning and the associated preparations for producing the system have in fact progressed to the point where a manufacturing commitment can be made without incurring unacceptable risks of breaching the established thresholds of cost, schedule, performance or other criteria.

Obviously, there is no such thing as a risk-free program. The objective of the PRR is to measure the level of manufacturing risk. After measuring the risk, the next step is to identify actions that will resolve that risk. Two key issues should be noted: First, the extent of conformance with a model state of production readiness is related to the time at which the assessment is made. While it is possible to accomplish the PRR immediately prior to initiation of the Production Phase, so doing loses the opportunity to identify problems early and solve them prior to production start. A number of program offices have taken an incremental approach to PRR risk assessment by starting early in the development phase. The review is accomplished incrementally as the design evolves and the testing is accomplished. The PM office continually rolls the knowledge from those efforts into the assessment of readiness and the assessment of risk identification and resolution. The second issue is whether the assessment is in support of a limited release for manufacture or a full release. For full production release, a complete evaluation of system readiness, problem resolution, and adequacy of planning are needed. Where possible, the objective is to quantify the validating data.

INDICATORS OF PRODUCTION READINESS

A number of indicators have been identified by the DOD Product Engineering Services Office (PESO) which can be used to develop meaningful and measurable data concerning readiness of the product to enter production based on information that is normally required as a part of defense contracts. In the development of the indicators, the following factors should be considered:

1. Each system is made up of a number of factors which make it unique in terms of its problems, time scales, state of the art applications, budget restraints, and the necessity for change during development.

2. Data for the individual indicators should be available either in the program office or at the contractor's facility as

a result of normally imposed contractual requirements. No new data items should be required.

3. The indicators should be simple in concept and easily understood.

4. Because numerical values for the indicators are variable in time, trend data are considered to be of more value than point data.

Based on these considerations, hardware and software indicators listed in Figure 12-3 may be evaluated.

subcontracted equipment, or in system specifications. When the number of engineering changes made is plotted against a time scale which includes the development cycle, a pattern such as that shown in Figure 12-4 will normally occur.

The number of changes starts at a zero point prior to the engineering release. As hardware fabrication is initiated, the number of changes increases to a maximum and should decline as engineering problems are resolved. At the completion of the prototype build, the number of changes should have followed a downward trend to a reasonable level. During prototype testing an increase in changes is noticed due to problems detected during the tests. The curve depicting the number of changes versus time should, again, follow a downward trend to a reasonable level, based on the program complexity.

HARDWARE INDICATORS

- ENGINEERING CHANGE TRAFFIC
- RELIABILITY GROWTH PATTERNS
- YIELD RATES FOR SPECIAL MANUFACTURING PROCESSES
- YIELD RATES FOR TEST OPERATIONS
- SCRAP AND REWORK LEVELS
- LEVEL OF EFFORT ON NONCONFORMING MATERIALS
- OUT-OF-STATION WORK PERFORMED

SOFTWARE INDICATORS

- RATE OF DISCOVERY OF ERRORS
- RATE OF CHANGE OF REQUIREMENTS
- RATE OF CHANGE OF REVISION LEVEL
- PERCENT MEMORY AND SPEED CAPACITY UNCOMMITTED

Figure 12-3 Production Readiness Indicators

Data from current and past programs can be analyzed to develop basic trend patterns for each of these indicators. These patterns can then be used as a baseline for comparison with new programs and to identify areas which may represent problems or risks to success in production. An approach to use three of these indicators is described below to indicate the types of analyses required.

Engineering Change Traffic Profiles

Examination of the engineering change traffic profile can be revealing in terms of the design maturity of a system, as well as symptoms of specific problems in the areas of fabrication, inspection and test operations,

Sustained levels of high change rate indicate a risk to cost, schedule, and/or performance. The appearance of an excessive number of changes at the completion of the prototype build should raise questions as to cause. It is obvious that both cost and schedule requirements would be extremely difficult to meet with an extended

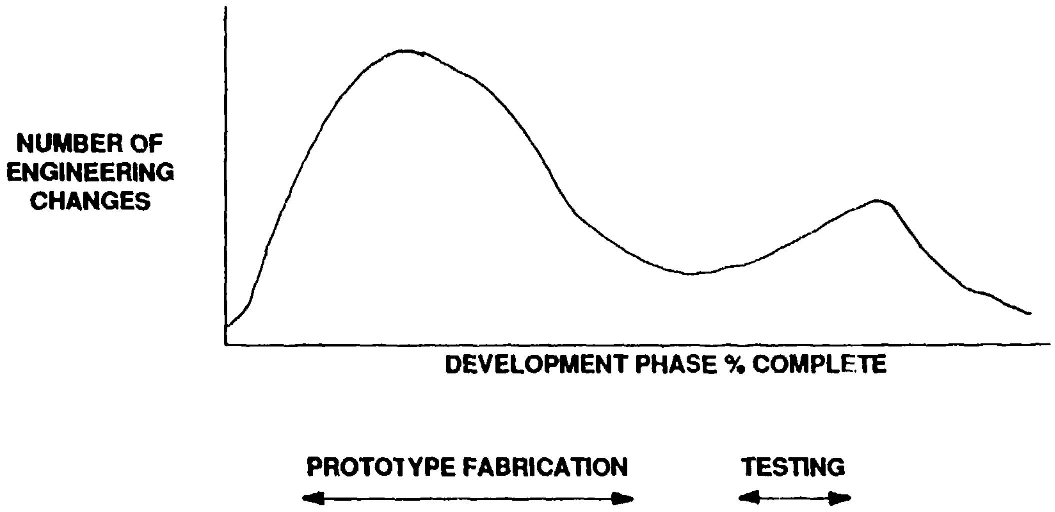


Figure 12-4 Projected Profile for Engineering Change Traffic

period of high change rate. Empirical data indicated that the shape of the engineering change traffic profile was of a similar shape for different kinds of systems including aircraft, electronic systems, tracked vehicles, and gun systems. The profile is sufficiently defined such that anomalies can be identified and investigated.

Yield Rates for Special Manufacturing Processes

A significant problem in meeting cost and schedule can result from low yield rates for manufacturing processes. Also, it would be unusual to find a new weapon system in which one or more "state of the art" manufacturing processes was not employed. Under the sponsorship of contractor R&D programs, and under the sponsorship of the Department of Defense (DOD) Manufacturing Technology Program, a significant number of special processes are under development at any given time. This constant development is necessary in order to reduce costs, increase performance, increase productivity, and advance the technology base. Examples of these special processes in the electronics field include methods for producing very high speed integrated circuits, multilayer printed circuit boards, and high density memory devices. Examples of these processes in the mechanical area include laser machining and joining, inertia welding, electrochemical and electrical discharge machining, vacuum plasma coating, and advanced methods for nondestructive testing.

Low yield rates for any of the special processes could have adverse effects on program cost and/or schedule and, therefore, could represent a program risk. The projected profile for special process yield rates is shown in Figure 12-5. As a new process is developed, the initial yield rate will be lower than the ultimate yield rate as the process variables are being defined and controlled. Normally, the major process variables are controlled first, leading to significant gains in the yield rate. In the later stages of development, the "fine tuning" of the process takes place. The "fine tuning" generally leads to smaller gains in yield. Because of this, the process yield approaches an ultimate yield value asymptotically.

A plot of the process yield rate versus time should have the following characteristics:

1. A significant growth should be evident in the yield rate as a function of time or units processed.

2. The yield rate attained during the latest period should be acceptable in terms of dollar risk. It is difficult to place limits on the yield rate from a special process since the economic consequences represent a wide variation from one process to another.

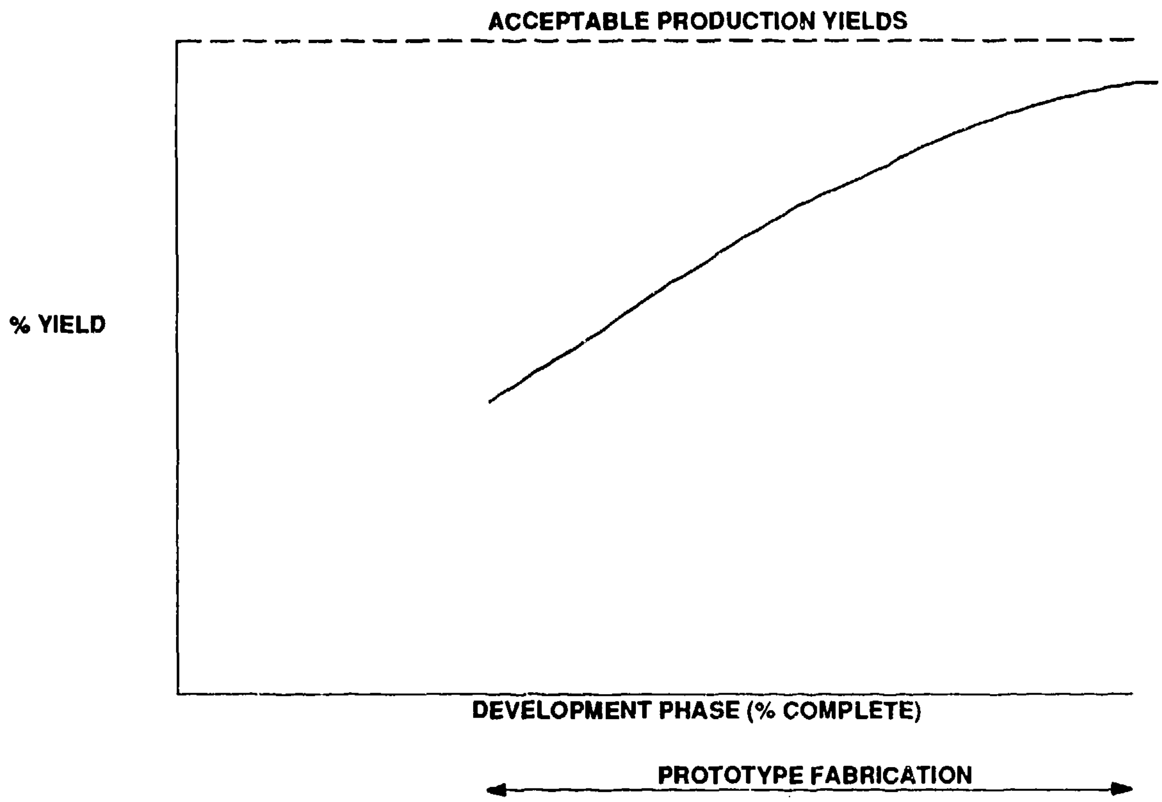


Figure 12-5 Projected Profile for Test/Process Yields

Restated, the cost of a reject from one process may represent a few cents, while a reject from another process may represent thousands of dollars.

Rate of Discovery of Software Errors

Experience on a number of software development programs indicates that the rate of discovery of errors appears to follow predictable patterns. Starting with coding checks and proceeding into each successive test phase, error discovery starts out at a relatively high level and follows a downward slope as problems are corrected. Errors typically are discovered during system integration testing. The contractor test team should show an initial high rate of error discovery which rapidly decreases as corrections are made. These relationships are shown in Figure 12-6.

Because of the ease of changing software, as opposed to hardware, software changes are frequently used to effect mission changes and to correct deficiencies in other subsystem areas. Excessive requirement changes in software can indicate potential hardware problems and a lack of maturity in the system requirements. Figure 12-6 depicts the normal behavior pattern for Engineering Change Orders issued against the Design Specification. This experience curve is analogous to the engineering traffic curve for hardware, in that it follows a downward trend, and then experiences smaller and smaller peaks as each successive level of testing is undertaken. Significant deviations from this general form should be identified as to cause. Engineering Change Orders issued against the Design Specification may cause the revision level of the software to be changed, and thus the rate of change of revision level can also be used as an indicator of program development maturity.

If a program is approaching the point where it is time to address readiness issues, it is worthwhile to review the current position of the DOD as to what elements describe the status of readiness for production. The PMO,

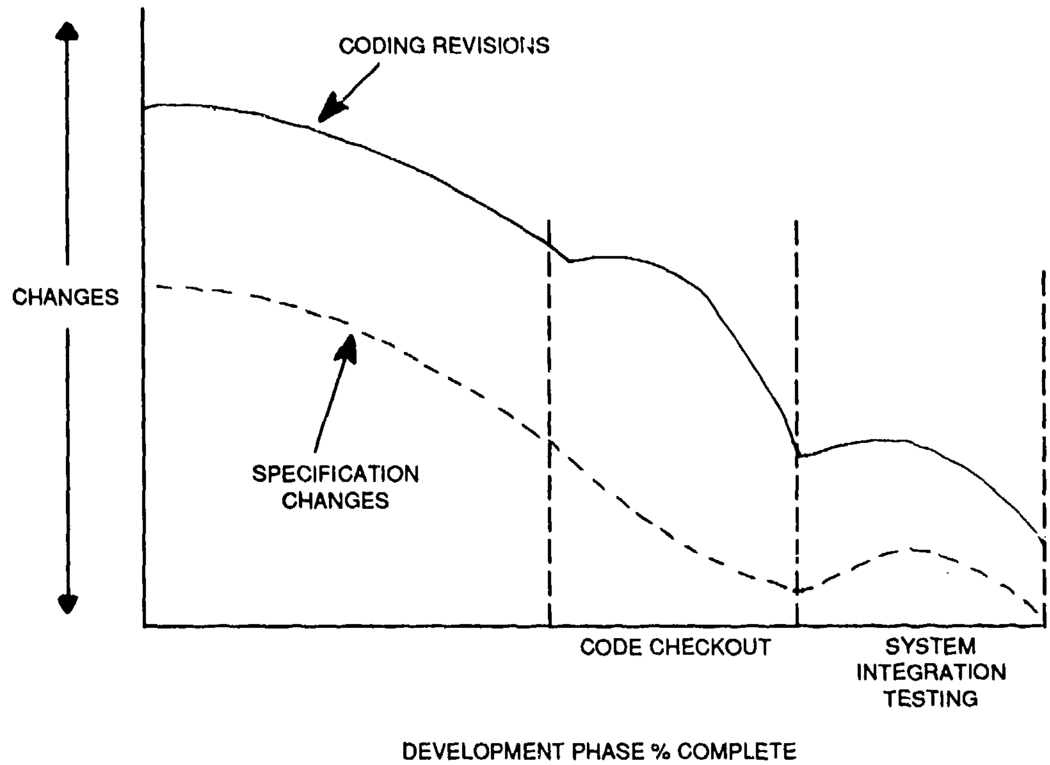


Figure 12-6 Projected Profile for Requirements Changes, Error Discovery, and Coding Revisions

when it goes to the Service Source Acquisition Review Council (S)SARC) or Defense Acquisition Board (DAB) for release for production, must cover production readiness findings in its advocacy paper. DOD may perform an independent assessment of the readiness of programs that go before the DAB. Also PESOs in the Services and at DOD are charged with the responsibility of independent assessments of production readiness, submitting information separately to the decision making organization. It is generally beneficial to have the DOD PESO and the Service PESO involved with planning and executing the PRR and with determining the method and style of presenting production readiness issues. That leads to the question, "How do we achieve the requirements for production readiness reviews?"

CONTRACTING FOR THE PRODUCTION READINESS REVIEW REQUIREMENT

Since there is a certain amount of necessary contractor cost associated with supporting a Production Readiness Review, it is important to assure that appropriate requirements are included in the Statement of Work (SOW) covering PRR support. The success of the PRR is dependent upon a proper environment being created through appropriate contract language. The specific SOW terms need to be tailored to reflect the program objectives, the funds available for accomplishing the PRR task, and the prime and subcontract structure of the program. The language should be as specific as possible to minimize future conflict in the understanding of the requirement. Whenever possible, the types of contractor preparation required for PRR team visits, the PRR team size, number of planned visits and their duration should be specified.

SURVEY ISSUES FOR PRODUCTION READINESS REVIEWS

In identifying the specific areas to be evaluated, the focus should be on those areas which could have the maximum impact on readiness. Developing this focus can be started with identification of the high value or critical items. In most cases, a large portion of the cost and risk is in a small percentage of the items. These are the items on which to focus effort. The review should explore the production implications of the design. Given the details of the design, how can it be built? What are the limitations on the productive processes? What process limits the production capacity? What kind of fabrication approaches can be used? What will it cost to do it? Given a pre-existing unit production cost goal and a breakdown of that goal through the work breakdown structure, the current subsystem and part estimates can be compared to the goals and an engineering trade-off study can be conducted. If the design is not acceptable from either a cost and/or performance standpoint, it will be necessary to go back and look at alternative designs. What design alternatives might yield the same or improved performance? The design needs to be evaluated in terms of the three basic parameters of cost, schedule and quality. (As used here, the quality of the design is the broader term including performance, reliability and maintainability.) After this evaluation, there is a need to define actions such as design changes or process changes. The design cannot be forced to meet the constraints of a specific contractor's production environment nor can the government force this production environment to meet a noncompatible design. Often trades must be made, so both the design and the production process selection must be somewhat flexible during the design evolution. The survey team should see evidence of contractor trade studies which compare alternative approaches to the fabrication and production tasks. The specific issues addressed during the product design evaluation are shown in Figure 12-7.

ROLE OF THE CONTRACT ADMINISTRATION OFFICE

The Contract Administration Office (CAO) can make a significant contribution to most, if not all, of the manufacturing reviews and surveys which are accomplished during the life cycle of a system acquisition. With respect to one of these reviews, the preaward survey, the CAO is the action office for the assessment of contractor capability.

The CAO, as a result of its continuing involvement with the specific contractors, can make major contributions to the successful accomplishment of the PRR. Where the specific Service has plant cognizance, the CAO organization, Air Force Plant Representative Office (AFPRO), Navy Plant Representative Office (NAVPRO) or Army Plant Activity will normally have developed procedures for supporting the survey effort. For the purposes of this guide, the focus will be on the support available from the Defense Contract Administration Services (DCAS). This will provide a framework for cooperation similar to that which would be involved in a situation involving service plant cognizance.

With proper notice of the requirement for a PRR or other survey, the Program Manager can expect DCAS personnel to be on-site and ready to assist the survey team when it arrives. He can expect an in-briefing from the assigned DCAS engineer on the strengths and weaknesses of the contractor involved. The DCAS Engineers, Industrial Specialists and Quality Assurance Specialists will be prepared to answer questions pertaining to the topics listed in Figure 12-8.

In most cases, the personnel assigned to DCAS are highly trained and experienced professionals. They constitute a considerable body of technical expertise familiar with the capacity and capability of the contractors involved in acquisition programs. They represent a substantial resource to program managers which should be utilized to get the most effective use of our limited Defense Budget. In many cases, these resources can be used to offset the problems of finding sufficient numbers of qualified personnel at the PM or buying activity.

When utilizing CAO personnel, it is incumbent on the PM to provide to the CAO personnel an understanding of the specific objectives and risks inherent in the acquisition program. This will provide the necessary "program focus" to the review. It should also be noted that the CAO personnel can provide

Design Simplicity
Standardized Parts
Early Design Confirmation
Use of Efficient, Proven Manufacturing Technology
Process Repeatability and Inspectability
Safe Work Environment
Lead Times
Critical Processes
Special Tooling
Personnel Skills
Minimum Design Change Activity
Availability

Figure 12-7 Product Design Evaluation Issues

Plant Resources/Facilities
- Adequacy for Rate
- Timely Acquisition/Installation
- Automated Production Techniques

Contractor Personnel
- Personnel Levels
- Skills Development/Training
- Certification

Production Engineering/Planning
- Schedule Compatibility
- Cost Reduction
- Alternative Capacities
- Configuration Management
- Handling of Engineering Changes
- Management Information System Adequacy

Materials/Purchased Parts
- Long Lead Items
- Procurement Plan
- Selection of Subcontractors
- Visibility of Subcontractors

Quality Assurance
- Integration with Production Planning Corrective Action

Contract Administration
- Attitudes
- Character
- Working Relationships

Figure 12-8 Contract Administration Office Expertise significant value in the post review time period. Since they continue in residence at the contractor's facility, they can make major contributions to the surveillance of status on action items and periodic reporting of contractor progress.

CHAPTER THIRTEEN

MANUFACTURING CONTROLS

CONTENTS

MANUFACTURING CONTROLS

OBJECTIVE

Throughout this guide, the manufacturing management functions are discussed within the context of the defense systems acquisition process. Government policies, requirements, and guidance are described to ensure that the program managers, and their support personnel, are aware of the many interrelations involved in this important discipline.

This chapter concentrates on the manufacturing controls necessary to ensure that the type of problems listed in Figure 13-1, which are symptomatic of the complex manufacturing environment, do not disrupt the acquisition program. While Figure 13-1 is far from exhaustive, these problems exist in many manufacturing plants. Thus, manufacturing surveillance can assist the program manager in determining progress in meeting milestones and delivery schedules, and identifying factors that may adversely impact delivery, performance or cost.

INTRODUCTION

Control of the manufacturing system is critical to ensuring that high quality products are produced on-time and at reasonable cost. A well defined management system needs to be established and implemented within the factory and supporting organizations. As the manufacturing system is accomplishing the production task, control systems must exist to identify variances from plans or targeted performance. These variances alert management to take action to correct the causes of the problems before major program impact results.

MANUFACTURING MANAGEMENT SYSTEM EVALUATION

Manufacturing resources consist of facilities in which equipment, human resources, and capital convert raw materials and component parts into end products for internal or external users. Contractors must have an effective combination of people and systems in order to plan and control these manufacturing resources. The government, in recognition of this objective, requires contractors to implement proven manufacturing control systems which, when properly implemented and managed, lead to successful manufacturing management.

Scope and Functions

The degree of program management involvement with manufacturing operations is predicated upon the importance of the specific product. Manufacturing directly impacts both cost and DOD capability. Unnecessarily high cost due to manufacturing inefficiency may be reflected in the reduction of vitally needed weapons and equipment. Acquisition programs often are constrained to a specific total expenditure. If manufacturing costs increase, typically the expenditure constraint causes a reduction in the number of systems acquired, which results in a negative impact on DOD capability to achieve its operational objectives. Manufacturing inefficiency also reduces the capability of the industrial base to respond to basic DOD needs as well as surge and mobilization. Regardless of the type of contract involved, the manufacturing management effort including program office, contract administration, and contractor involvement, must be structured to meet defined program objectives related to efficiency, capacity and capability.

Government manufacturing engineers and industrial specialists are the individuals primarily concerned with surveillance of the contractor's accomplishment of the manufacturing objectives and with the efficiency and economy of manufacturing operations. This requires the consideration of a wide range of issues involving manufacturing planning and control, personnel and equipment scheduling and loading, production equipment maintenance, in-process inventory control, analysis of manufacturing operations, scrap prevention, and manufacturing management techniques.

Manufacturing Operations

Manufacturing management involves planning for, controlling and executing manufacturing operations. Accomplishing manufacturing objectives requires that the contractor establish basic manufacturing policies, implement those policies through manufacturing procedures, and develop

- INVENTORY INVESTMENT IS EXCESSIVE, YET THERE ARE SHORTAGES OF NEEDED MATERIAL
- CRASH PROGRAMS TO REDUCE INVENTORY INVESTMENT TO SOME ARBITRARY LEVEL OCCUR FREQUENTLY AND ARE BASED ON EDICTS
- DELIVERY DATES ARE OFTEN MISSED AND OVERTIME IS USED TO MEET NEW NEED DATES
- PRODUCTION CONTROL, PURCHASING, PLANT SUPERVISORY PERSONNEL AND OTHERS ARE IN CONSTANT MODE OF EXPEDITING
- MANY MANUFACTURING AND PURCHASE ORDERS ARE PAST DUE BUT ARE NEEDED TO FILL CURRENT SHORTAGES
- WORK IN PROGRESS IS CLOGGING THE SHOP FLOOR AND MANUFACTURING ORDERS ARE SOMETIMES LOST, ALBEIT TEMPORARILY
- REJECTED MATERIAL ACCUMULATES AND ITS DISPOSITION IS USUALLY MADE WHEN A PART IS SHORT ON THE ASSEMBLY FLOOR
- THERE IS A LACK OF RAPPORT AND COMMUNICATION AMONG PRODUCTION CONTROL, INVENTORY CONTROL, PURCHASING, SALES, ENGINEERING, DATA PROCESSING, ACCOUNTING, AND SHOP FLOOR PERSONNEL
- BILLS OF MATERIAL AND ROUTING AND INVENTORY RECORDS ARE INACCURATE OR INCOMPLETE
- OVERHEAD COST LEVELS ARE EXCESSIVE BECAUSE CURRENT PLANNING AND CONTROL SYSTEMS ARE NOT TIMELY
- PRODUCTIVITY IS LOW BECAUSE OF EXCESSIVE SHORTAGES, CAUSING IDLE TIME AND FREQUENT EQUIPMENT CHANGEOVERS
- DATES ON WHICH ENGINEERING CHANGES BECOME EFFECTIVE ARE NOT HIGHLY VISIBLE TO EVERYONE AND CONFIGURATION CONTROL IS LOST
- THE MAJORITY OF SHIPMENTS ARE MADE DURING THE LAST WEEK OF THE MONTH

Figure 13-1 Typical Manufacturing Problem Areas

detailed work instructions. In evaluating the contractor's ability to attain such objectives, the following questions can serve as a basis for the DOD evaluation:

a. Are the contractor's manufacturing objectives and assignment of responsibilities satisfactorily described in policies and implementing procedures?

b. Does the contractor have a system for establishing functional performance goals, measuring performance against goals and identifying causes for failures to achieve goals?

c. Are manufacturing plans and procedures designed so that personnel requirements can be determined by number, skills, and training?

d. Are the contractor's internal audit practices and procedures designed to identify manufacturing management deficiencies and is there a requirement for prompt corrective action?

It must be emphasized that manufacturing management evaluation is system oriented. While each of the parts comprising the manufacturing operations system may be individually acceptable, contractor integration of the parts is critical to overall success.

PERFORMANCE EVALUATION

Performance evaluation includes the periodic examination of the contractor's efforts to perform the contract; appraisal of the extent to which these efforts have moved forward toward completion of the total effort; and a judgment of the probability of the total effort being completed as required by the agreement (the contract).

The kind of performance evaluation, and the depth and extent of the evaluation, depend upon a variety of considerations. The program office must assess these variables in order to determine the actions necessary and appropriate to enhance the probability of successful contract performance.

The evaluator must determine the importance of the contract activities being evaluated in order to arrive at an order of magnitude of surveillance effort and the priority of that effort. This decision should be influenced by:

a. The size of the program in terms of:

- -- length of time
- -- estimated cost
- -- extent of the effort involved.

b. The significance of the effort in relation to overall organization objectives.

c. The nature and complexity of the work.

d. The type of contractual relationship.

The kind and degree of surveillance and evaluation will also depend upon the degree of certainty or uncertainty associated with the extent of the contract work. Associated with this is the confidence that the government and the contractor have in the estimate of the amount of effort that is necessary to accomplish the contract task within the time and technical constraints.

Progress Evaluation

Most of the effort in performance evaluation focuses on the technical aspects of the work to identify foreseeable technical problems as they bear on the extent of work. In research and development work, the contract effort itself is concerned with the advancing of the state of knowledge. A clear statement of what is to be accomplished, expressed in terms that can be measured, is a necessary requirement for planning a research or development program. When the objective is explicitly expressed the technical or internal uncertainty of a program can be identified; experimental procedures, scientific or engineering skills determined; and work plan developed with subtasks identified which will be most effective in achieving the R&D objective. In research and development, measuring the achievement against a standard of performance for the technical objective is possible when each of the subtasks is identified and the program objective clearly stated.

The status of study and experiment for a research contract is often hard to gauge before completion. Objective scheduling criteria may be minimal; parameters may be broad and flexible. Researchers may encounter breakthroughs or setbacks that negate earlier progress data. Research or development program difficulties of this nature cannot be eliminated but can be significantly reduced with a well developed work plan. In research contracts, monitoring consists largely of evaluation of the technical aspects of a program along with planned schedules. The other main progress controls are costs incurred and the contractor's level of effort and accomplishment.

Progress measurement becomes easier in the developmental phase of acquisition. Though the work is not yet repetitive and detailed specifications are still not completely formulated, much of the indefiniteness of research is gone. The experience gained on earlier contracts should provide some standard for comparison. However, success still depends on the contractor's ability to cope with obstacles not met before. Thus, technical evaluation is still very important in determining the status of development work.

On production contracts, the end item design is reasonably firm. The manufacturing process and a manufacturing schedule are established at the outset of the procurement. Technical evaluation is not paramount since the product design is relatively fixed. The emphasis shifts to the more usual production control and financial status data.

Monitoring Contractor Progress

The purpose of monitoring progress is to obtain the information the government needs about a particular procurement. Monitoring may disclose defects in the contractor's system and, in turn, show the need for monitoring subcontract performance. Monitoring provides a variety of information serving many purposes:

- o Providing up-to-date delivery information;
- o Helping determine the adequacy of the contractor's own monitoring system;
- o Helping to identify and isolate contractor performance problems;
- o Generating data on cost of specific areas of performance (these data are often needed for cost analysis of change orders, or approval of progress payments in certain type contracts);
- o Identifying the need to allocate government property to various programs requiring it;
- o Aiding in making an early decision about when to incorporate new components in major equipment;
- o Determining the government's rights under the contract -- for instance, when questions of default arise;
- o Determining future funding requirements by comparing actual cost with accomplishments.

Progress information comes from many sources; however, the primary ones are: schedules, monthly cumulative progress reports, material inspection and receiving reports, special progress reports, and cost performance reports or cost/schedule status reports.

The contractor may be required to submit a phased schedule for review by the government. This requirement appears in the Statement of Work and the Contract Data Requirements List (CDRL). These schedules usually show the time required to perform the fabrication cycle of planning, purchasing, plant rearrangements, tooling, component manufacture, subassembly and final assembly, testing, and shipping. The degree to which each function is subdivided depends on considerations of the nature of the end item, the type of fabrication process, the size and complexity of the contractor's organization, and the established schedule. The approved schedule serves as a basis for reporting and measuring contract performance.

The monthly progress report is used to obtain performance progress information from contractors. On this report the contractor shows actual and forecast deliveries (as compared with the contract schedule); delay factors, if any; and the status of prefabrication work (design and engineering facilities, tooling; receipt of government furnished property (GFP) and construction of prototypes. These data are shown in terms of scheduled and estimated starting and completion dates and percentage of completion. The report form should also contain narrative sections. The contractor uses these sections to explain any difficulties, or delay factors, action taken or proposed to overcome these difficulties, and any assistance required from the government.

Financial Progress Information

For other than FFP contracts, effective program management depends on receiving cost information and ensuring that the contractor's system is capable of generating timely and accurate cost information. The financial data furnished by the contractor normally includes: cumulative expenditures on the contract, forecasts of future expenditures and commitments, and an estimate of the total costs at contract completion. This information helps in forecasting cost underruns or overruns on cost reimbursement and fixed-price-incentive contracts. Cost performance reports (CPR) and the cost/schedule status report (C/SSR) provide the bases for measuring the contractor's overall performance on the contract.

In evaluating cost information, the rate of expenditure can be compared with the percent completion. On cost reimbursement contracts, costs should, as a rule, be assessed against individual work elements, even though the cost limitation applies to the entire job. Looking at progress from this standpoint should give a picture of the status of the work and indicate any special problems that might exist.

CONFIGURATION MANAGEMENT

The configuration management (CM) discipline spans the product life cycle and contributes toward ensuring sustained system performance, minimizing the effects of design changes -- functional or physical -- reducing the incidence of system incompatibility, and avoiding the procurement of obsolete spare parts during the provisioning process. In order to relate configuration management to manufacturing management, a number of definitions are provided.

Configuration means the physical and/or functional characteristics of hardware and software as set forth in technical documentation and achieved in a system or component. Configura on management, then, can be defined as a discipline applying technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a configuration item; to control changes to those characteristics, and to record and report change processing and implementation status. These simple words describe a complex process essential to the successful management of a production program and highlight three major areas of effort -- identification, control, and status accounting --- comprising the configuration management discipline. Figure 13-2 shows the relationship between configuration management and the product development cycle.

Two other concepts should be mentioned - configuration items and baselines. The basic unit of configuration management is the configuration item (CI) which is defined as an aggregate of hardware/computer programs, or any of their discrete portions, which satisfy end-use functions.

This breakdown of CIs is critical to successful application of the configuration management discipline and impacts performance and functional compatibility of the weapon system sub-elements. Specifications must be prepared to document the characteristics of each CI; design reviews and audits must be performed for each CI; engineering change proposals are prepared individually for each CI; and status accounting tracks the implementation of changes to each CI.

The second concept -- baselines -- refers to the authorized and documented technical description specifying the functional and physical characteristics of a system/component. Functional characteristics describe the performance requirements the item is expected to meet. Physical characteristics relate to the material composition and dimensions of the

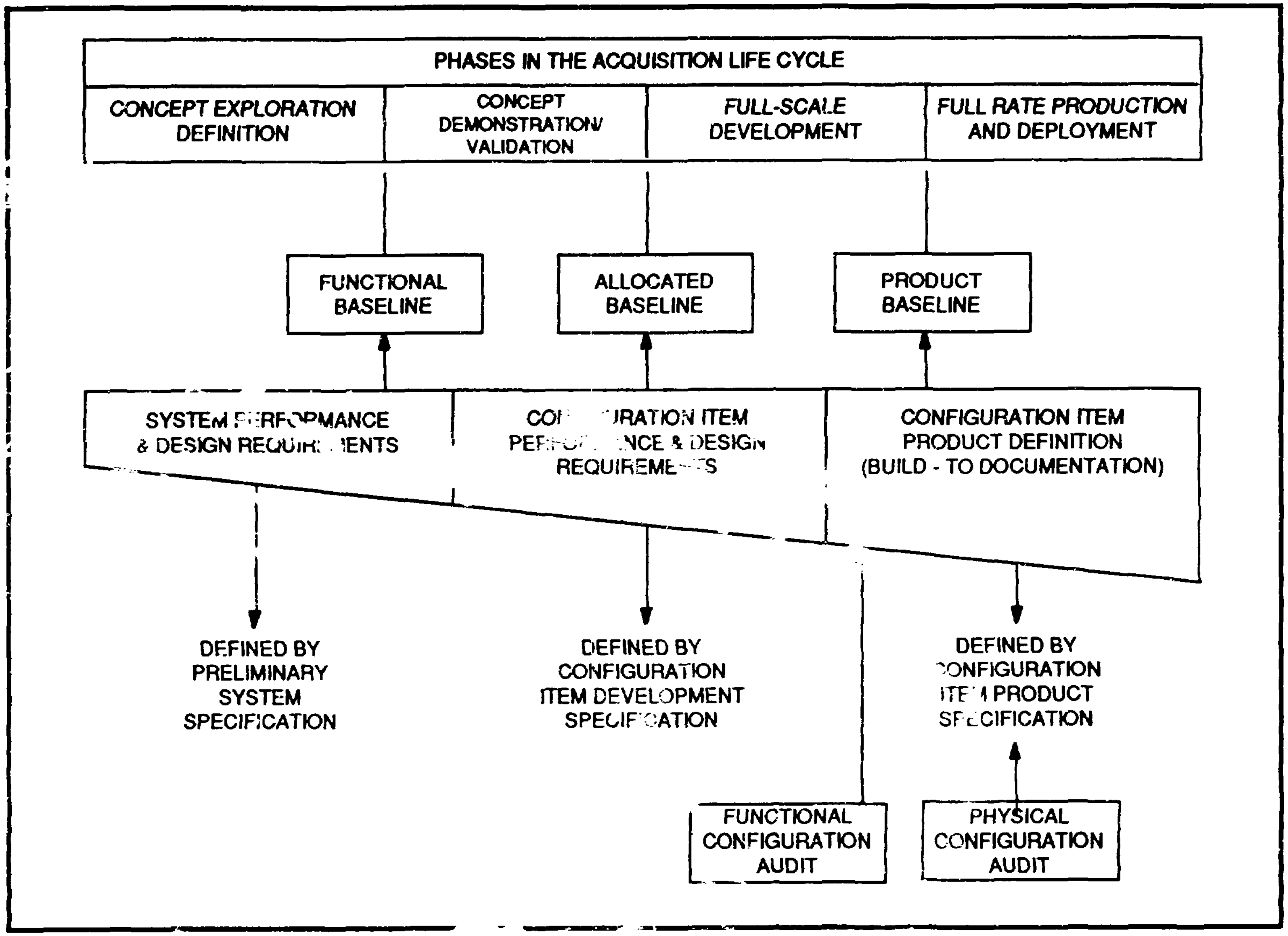


Figure 13-2 Configuration Management by Baselines

manufactured item. An item is governed primarily by the intended functional characteristics during development. As the item enters production, it should be defined in terms of its physical characteristics with full consideration for material requirements, part tolerancing, quantities to be produced and delivery schedule. It becomes obvious that the configuration management process must be tailored to a number of configuration item factors -- program size, complexity, life cycle state -- and the fact that no single set of management procedures will meet every program need. Since the physical design evolves from the system performance design requirements, it is necessary to control both the functional and the physical configuration. This is accomplished through configuration baseline management.

Baseline management deals with defining and documenting, for each configuration item, the system requirements and the requirements for each CI. These baselines reflect the development status and are intended to control the implementation of system changes while retaining design and development flexibility. The translation of technical requirements in a baseline management function permits contracting for needed engineering and production support (producibility, risk analyses, process development, tool design, testing, inspection) in a clearly definable, priceable and manageable progression.

Three baselines are generally considered in configuration management. These are the functional, allocated, and product base lines. The functional baseline is the initial baseline and is defined by the system specification prepared during the concept exploration phase. As the system specification is expanded and refined, contractor specifications are prepared for all new configuration items comprising the total system configuration. These development specifications define the allocated baseline for the system CIs. As the program proceeds through full-scale development, system as well as CI design and development continues and results in item product specifications. The product specification then becomes the product baseline for use during production.

Figure 13-2 is intended to summarize visually those configuration management areas of specific interest to the program manager. During each phase, configuration management decisions will be required. These decisions impact both the weapons system and manufacturing process designs and are critical to the attainment of program objectives.

Policies and Objectives

DOD has established policies and guidance governing the configuration management of systems/components. MIL-STD-490 covers specification practices (configuration identification). DOD-STD-480A and MIL-STD-481 cover configuration control and establish requirements for submitting engineering change proposals (ECPs) deviations, and waivers, as well as the amount and type of information that should be included in the submittals. Finally, MIL-STD-482 provides guidance on configuration management status accounting. In addition to these primary standards, there are numerous DOD and Service documents highlighting associated areas including contractual requirements for those areas not included in the basic standards.

Configuration Identification

Configuration Identification (CI) is defined as the current or conditionally approved technical documentation of an item as set forth in specifications, drawings and associated lists, and documents referenced therein. Configuration identification is established by baseline configuration identification documents and all affected changes. Configuration identification documents include all those necessary to provide a full technical description of the characteristics of the item that require control at the time that the baseline is established.

Functional Configuration Identification (FCI) (functional baseline and approved changes) will normally include a Type A, system specification, or a Type B, product specification supplemented by other specification types as necessary to specify: (1) all essential system functional characteristics; (2) necessary interface characteristics; (3) specific designation of the functional characteristics of key configuration items; and (4) all of the tests required to demonstrate achievement of each specified characteristic.

Allocated Configuration Identification (ACI) (allocated base line and approved changes) normally consists of a series of Type B specifications defining the functional requirements for each major configuration item. These may be supplemented by other types of specifications, engineering drawings and related data, as necessary, to specify: (1) all of the essential configuration item functional characteristics, including delineation of interfaces; (2) physical characteristics necessary to assure compatibility with associated systems, configuration items and inventory items; and (3) all of the tests required to demonstrate achievement of each specified functional characteristic.

Configuration Audits

Two kinds of configuration audits are performed -- functional and physical. Functional configuration audits represent the formal examination of the CI's functional test data, before acceptance of the development effort, to verify that the item has achieved the performance specified in its functional or allocated configuration identification. The functional configuration audit also verifies that the CI's technical documentation accurately reflects the CI's functional characteristics and the documentation of the physical configuration from which the test data was obtained. This is necessary for determining the adequacy of production acceptance tests.

The physical configuration audit represents the formal examination of the "as built" configuration of a CI against its technical documentation. The physical configuration audit helps ensure that the production acceptance testing requirements are adequate and includes a detailed audit of engineering drawings, specifications, computer program listings, flow charts, and other technical data used in producing hardware and computer program CIs. This audit typically occurs at selected points after the development phase and involves first production items, new production after a long break in production, contractors producing a CI for the first time and first production units of a significantly changed CI. It should be recognized that the product specification must be available to the program office in sufficient time to plan the audit.

Configuration audits and system engineering design reviews are complementary. The purpose of the configuration audits and engineering design reviews is to validate the contractor's system design and test engineering efforts while progressive increments of the configuration identification and test documentation are being generated.

Configuration Control

Configuration control is the systematic evaluation, coordination, approval, and implementation or disapproval of all changes in the configuration of a system or end product after formal establishment of its configuration identification. Simply stated, configuration control maintains the functional, allocated, and product CI baselines and regulates all changes thereto. Change control prevents unnecessary or marginal engineering changes while expediting the approval and implementation of those that are necessary or offer significant benefits.

Both DOD-STD-480A and MIL-STD-481 delineate configuration control requirements and provide instructions for preparing and submitting proposed engineering changes and related information. One of the two standards, DOD-STD-480A, covers the broader area and requires a more complete analysis of the impact if the engineering change described by an engineering change proposal (ECP) were implemented. DOD-STD-480A requires that the data package submitted with an ECP contain a description of all known interface effects and information concerning changes required in the functional, allocated and product configuration identification (FCI/ACI/PCI). It is intended that DOD-STD-480A be imposed on prime contractors who (1) have participated or are participating in the engineering or operational systems development of a system or high level CI, or (2) are being supplied with copies of the system specification and/or development specification(s), or (3) have extensive experience in the preparation of ECPs relative to high level CIs. Such contractors have the capability of providing to the government the majority of the information needed to properly evaluate the merits of a complex engineering change, possibly involving interrelated changes in other CIs. DOD-STD-480A also covers requirements for submittal of deviations, waivers and notices of revision (NORs).

MIL-STD-481 is intended for use in contracts involving either multi-application items not peculiar to specific systems or procurement from a contractor who cannot reasonably be expected to know all of the consequences of an engineering change. An example of such a contractor is one who is required to fabricate an item to a PCI which he did not prepare, or one who did not participate in engineering development and hence is not familiar with requirements of the system or higher level CI. When MIL-STD-481 rather that DOD-STD-480A is prescribed, the major portion of the analysis of the impact of an ECP on associated items is transferred from the contractor to the procuring activity.

Configuration Status Accounting

Configuration status accounting is defined as the recording and reporting of the information that is needed to manage configuration effectively, including a listing of the approved configuration identification, the status of proposed changes to configuration, and the implementation status of approved changes.

Configuration status accounting represents the process of recording the documented changes to an approved baseline and results in the maintaining of a continuous record of the configuration status of the individual CIs comprising the system. Additionally, valuable management information concerning both required and completed actions resulting from approved engineering changes is provided. Status accounting information includes an index consisting of the approved configuration and a status report detailing the current configuration. All items of the initially approved configuration are identified and tracked as authorized changes to the baseline occur.

MEASURES OF CONTRACTOR EFFECTIVENESS

During the production phase of the product life cycle, some measures of the effectiveness of the manufacturing organization should be established. The objective of this phase is to produce, in a timely fashion, systems and equipment which conform to the technical documentation at a minimum cost. Measures of effectiveness for each of these areas should be established, and performance tracked against the measure to identify opportunities for improvement for the manufacturing organization.

Time Measures

When a delivery schedule has been established, the effectiveness of the manufacturing organization to meet that schedule should be evaluated. In most DOD acquisitions, the delivery schedule is integrated with deployment and training schedules and failure of the manufacturing organization to achieve and maintain schedule can have significant impact on the operational forces. Schedule attainment also tends to be a rather visible program element and is often used as a measure of program status by the DOD and Service Headquarters as well as Congress and the public. In evaluating schedule performance, the fundamental issue is on-time delivery of acceptable end items to the government. In many cases, the program office will be unwilling to measure only past or current performance against the end item delivery schedule. Generally, the PM should establish, or have the contractor establish, some system which will support projections of schedule attainment in future periods. This provides an opportunity to take actions to minimize the impact of delays on the deployment process. A very useful tool for this future perspective is the Line of Balance (LOB) technique which is discussed in detail later in this chapter.

Conformance Measures

When systems or equipments are presented for customer acceptance, it is generally assumed that they meet the technical requirements. Many times, this assumption does not reflect reality. Equipment is presented accompanied by waiver and/or deviation requests (or approved waivers or deviations). There are also departures from technical documentation below the level of the government's configuration control which are handled by Material Review Board (MRB) action. Reducing the number of these occurrences is a basic element of a strong Total Quality Management (TQM) program.

Cost Measures

Manufacturing cost estimates are normally based on the assumption that the design is fully specified and that the manufacturing process will be relatively straightforward with operations being successfully accomplished as planned. Consequently, any deviation from this plan indicates the potential for cost problems. As such, time and conformance measures can give some indication of cost aberrations since there is normally a direct correlation between late delivery or conformance problems and cost. In addition, the following measures may also indicate the existence of cost problems:

1) Scrap and rework rates,

2) Percentage of out-of-station work,

3) Engineering change volume,

4) Yield rates on manufacturing operations, and

5) Reliability growth profiles.

These indicators do not replace normal management control systems but can be used as supplementary information or aids in predicting and isolating causative factors. They are also valuable measures in assessing the effectiveness of the contractor's TQM program.

WORK MEASUREMENT

Work measurement is an important tool which can be of great value in cost estimating, production planning, and contract management. A work measurement system uses engineered labor standards in most phases of the manufacturing operation. A labor standard describes the time allowed for a normally skilled operator following a prescribed method, working at a normal all-day level of effort, to complete a defined task with acceptable quality. An engineered standard is one established using a recognized technique, such as time study, predetermined time system, standard data, or work sampling to derive at least 90% of the total time associated with the labor effort covered by the standard. Non-engineered standards are those not meeting the above criteria and are usually determined by estimates or based on historical data.

DOD Policy

The use of approved work measurement systems (WMS) is required for all production contracts for major weapon systems and subsystems costing more than $20 million annually or a total of $100 million. WMS may also be required on full-scale development contracts over $100 million.

WMS should be tailored to the requirements of individual programs. Several categories of contracts are specifically exempted from the requirement. These include contracts that:

1) Procure commercial or non-developmental items;

2) Have low volume, non-repetitive production runs, such as ship construction and ship systems;

3) Do not require the submission of certified cost or pricing data; or

4) Will not realize a cost benefit as a result of WMSs; however, the cost-benefit decision must be documented and approved.

In addition, the WMS should be compatible with existing contractor technical and management processes and procedures, such as the principle of continous improvement of the total quality management process. If WMS is required, DOD policy also requires that established WMS be actively used in contract and program management.

1) WMS data must be considered in contract pricing objectives and contract negotiation.

2) WMS must be used to provide data for use in planning, cost estimating, and monitoring contract performance in all appropriate contracts.

Objectives

Experience has shown that excess personnel and lost time can be identified and reduced through WMS application. Furthermore, continued method improvements can be more easily identified and implemented.

Work measurement and the reporting of labor performance are not considered ends in themselves, but a means to more effective management. When properly understood and used by management, the benefits described in Figure 13-3 typically accrue from an effective WMS.

- GREATER OUTPUT FROM A GIVEN AMOUNT OF RESOURCES
- LOWER UNIT COSTS BECAUSE PRODUCTION IS MORE EFFICIENT AT ALL LEVELS
- REDUCING WASTED TIME IN PERFORMING OPERATIONS
- CONTINUED ATTENTION TO METHODS AND PROCESS ANALYSIS BECAUSE OF THE NECESSITY FOR ACHIEVING IMPROVED PERFORMANCE
- IMPROVED BUDGETING AND COST ESTIMATING
- IMPROVED BASIS FOR PLANNING FOR LONG-TERM PERSONNEL, EQUIPMENT, AND CAPITAL REQUIREMENTS
- CONTINUAL CONTROL ACTIVITIES AND DELIVERY TIME ESTIMATES
- HELP IN SOLVING LAYOUT AND MATERIAL HANDLING PROBLEMS BY PROVIDING ACCURATE FIGURES FOR PLANNING AND UTILIZATION OF SUCH EQUIPMENT

Figure 13-3 Benefits of Work Measurement Systems

Measurement System

Current contracting regulations do not require the specific use of MIL-STD-1567A. Defense Acquisition Circular (DAC) 88-5 states that either the military standard or a contractor's own WMS may be used, provided the latter is acceptable to the government. However, MIL-STD-1567A is frequently cited as an example of an acceptable WMS. MIL-STD-1567A establishes certain requirements which must be met for a contractor's work measurement system to be considered acceptable. These requirements are intended to permit maximum contractor flexibility in the application to the standard, rather than providing rigid methodology by which work measurement should be accomplished. The contractor's WMS must be documented and include the elements described in Figure 13-4.

Specific MIL-STD-1567A requirements set goals for coverage, accuracy, allowance development, realization factor development, and WMS review. Realization factor development and analysis are particularly important, because it is the realization factor that is used to compare the WMS ideal to what is actually happening on that plant floor. Identification and elimination of inefficiencies is a vital element of WMS application.

MIL-STD-1567A also covers the use of trade-off analyses relating savings attainable through improved productivity and simplification of work methods to the cost of developing engineered standards, schedules for conversion of non-engineered to engineered standards, use of touch labor standards in the development of price proposals, contractor generated change order proposals or for estimating the prices of initial spares and replenishment spares, and production count methods to ensure accurate measurement of the work completed.

COST/SCHEDULE CONTROL SYSTEM CRITERIA

The Cost/Schedule Control Systems Criteria (C/SCSC), are a set of criteria which describe the capabilities which must be present for a contractor's cost and schedule control systems to be acceptable for use on contractors for major programs. The objectives of C/SCSC are twofold:

For contractors to use effective internal cost and schedule management control systems, and

- **WORK MEASUREMENT PLAN AND SUPPORTING PROCEDURES**
- **CLEAR DESIGNATION OF THE ORGANIZATION AND PERSONNEL RESPONSIBLE FOR EXECUTING THE SYSTEM**
- **PLAN TO ESTABLISH AND MAINTAIN ENGINEERED LABOR STANDARDS OF A KNOWN ACCURACY**
- **PLAN OF CONTINUED IMPROVED WORK METHODS IN CONNECTION WITH THE ESTABLISHED LABOR STANDARDS**
- **PLAN FOR THE USE OF LABOR STANDARDS AS AN INPUT TO BUDGETING, ESTIMATING, PRODUCTION, PLANNING, AND TOUCH LABOR PERFORMANCE EVALUATION**

Figure 13-4 Elements of a Contractor's Work Measurement System

For the Government to be able to rely on timely and auditable data produced by those systems for determining product oriented contract status.

The C/SCSC are not a management control or an accounting system. Due to variations in organizations, products, and working relationships, it is not feasible or prescribe a universal system for cost and schedule controls. Therefore, the DOD adopted an approach to identify general criteria that contractor's management control systems must meet.

The criteria are intended to be general enough to allow their use in evaluating development, construction and production contracts. Since these contracts differ significantly, it is unwise to specify detailed guidance applicable in every circumstance. Use of the criteria must be based upon common sense and practical interpretations that maintain the capabilities for adequate performance measurement.

Uniform implementation of the criteria will avoid imposing multiple cost and schedule systems on contractors. Application of management control systems acceptable to both the DOD and contractor to contracts at a given contractor's facility, will provide a common source of information for all management levels.

DOD Requirements and Guidelines

DODI 7000.2, first issued in 1967, requires that on major contracts, contractors use management control systems that comply with the C/SCSC. Major contracts are defined jointly by the Military Departments as: $40 million or more or R&D, $160 million or greater for procurement; and subcontractors that exceed $25 million for R&D, $60 million for procurement. This dollar amount is expressed in current/then year figures and includes the "full" planned value of the contract, including options.

The C/SCSC will not be construed as requiring the use of specific systems or changes in accounting systems that will adversely affect: the equitable distribution of cost to all contracts, or compliance with the standards, rules and regulations issued by the Cost Accounting Standards Board. Further, it is not intended to affect the basis on which contract funding or cost reimbursements are paid.

The contractor's management control system must provide data that: (a) relate time phased budgets to specific contract tasks and/or statements of work; (b) indicate work progress; (c) properly relate cost, schedule and technical accomplishment; (d) are valid, timely and auditable; (e) supply managers with information at a practicable level of summarization; (f) are derived from the same internal management control systems used by the contractor to manage the contract.

C/SCSC improves on the budget vs. actuals (spend plan) management technique by requiring that work progress be quantified through "earned value", an objective measure of how much work has been accomplished on the contract. The C/SCSC require the contractor to plan, budget, and schedule authorized effort in time phased increments that form a performance measurement baseline (time-phased budget). As work is accomplished, the earned value concept allows comparisons to be made against the plan which identifies schedule and cost variances.

The schedule variance (SV), compares the budgeted value of work accomplished (earned value) to the budgeted value of the work scheduled to be done, i.e., a difference from the plan expressed in budget ($) terms. Likewise, a comparison of earned value against the actual costs generated to do the work provides a measure of the cost variances, i.e., the amount of cost under or overrun from the plan for the work accomplished. Planned or scheduled value of work, earned value, and the actual cost of work performed provide an objective measure of performance, thus enabling a performance trend analysis to be done and cost estimates at completion to be developed at various levels of the contract.

In addition to emphasizing the concept of earned value, the C/SCSC requires thorough integrated contract planning, realistic baseline establishment and control, performance information to be segregated by both product and performing organization, and that measurement of accomplishment at relatively low levels within the contract be summarized and provided to higher management.

Work Breakdown Structure

The task of defining the contract work is accomplished through the use of a work breakdown structure which is essentially a "family tree" subdivision of work to successively lower levels of detail. Figure 13-5, extracted from MIL-STD-881A, Work Breakdown Structures for Defense Material Items defines three levels of identification. The PMO, in conjunction with the contractor, determines the upper levels of this WBS, which serve as the summary level for reporting purpose.

The contractor extends this structure to the cost account and work package levels (Figure 13-6). At that level, organizational elements are actually assigned to do the work. The work package must have discrete starting and completion points which are compatible with upper level schedules. The work package must be the responsibility of a single organizational unit.

Relationship to Contractual Schedules

The C/SCSC performance measurement baseline represents the contractor's internal work plan, the time-phased schedule expressed in dollars for performing the contract. This internal plan generally provides some cushion or slack calendar time with respect to the contract deliveries and milestones and anticipates typical problems such as late vendor deliveries and/or time required for rework of materials. If not understood, setback schedules can cause confusion. Negative (unfavorable) schedule variance may not affect contract delivery if sufficient slack is available in the schedule to absorb the delay. Schedule variance is expressed in dollars worth of work ahead or behind the plan and must be analyzed in conjunction with other schedule information such as network, Gantt, and line-of-balance charts. By itself, the C/SCSC schedule variance reveals no critical path information and may be misleading because unfavorable accomplishment in some contract WBS areas my be offset by favorable accomplishment in other areas.

Implementation

Implementation of the C/SCSC begins with the requirement being placed in the Request for Proposal (RFP) using DFAR 52.234-7000, Notice of Cost/Schedule Control Systems. The offeror's proposal is then evaluated in terms of its ability to meet the criteria. The contractor either offers to use a previously accepted system or to make changes in the existing system to attain compliance with the criteria. The negotiated contract will contain DFAR 52.234.7001, Cost/Schedule Control Systems.

When a contract is awarded to a contractor that has not previously demonstrated an acceptable management

Level 1. **Level 1 is the entire defense materiel item; for example, the Minuteman ICBM System, the LHA Ship System, or the M-109A1 Self-Propelled Howitzer System. Level 1 is usually directly identified in the DOD programming/budget system either as an integral program element or as a project within an aggregated program element.**

Level 2. **Level 2 elements are major elements of the defense materiel item; for example, a ship, an air vehicle, a tracked vehicle, or aggregations of service, (e.g., systems test and evaluation), and data.**

Level 3. **Level 3 elements are elements subordinate to Level 2 major elements; for example, an electric plant, an airframe, the power package/drive train, or type of service (e.g., development test and evaluation); or item of data (e.g., technical publications).**

Figure 13-5 Work Breakdown Structure Level Identification

control system, the contractor's system is reviewed by the Government to ensure that it meets the criteria. Successful demonstration of the contractor's management control system generally results in a tri-service acceptance that remains in effect as long as the system continues to met the criteria. In the case above, wherein the contractor had a previously accepted management control system and proposed to use it on the contract, the Government performs a Subsequent Application Review (SAR). The purpose of the SAR is to determine whether the contractor is properly and effectively using this accepted system for the new contract. It is not a redemonstration of the previously accepted system.

Typical points of contention between the Government and Industry concerning C/SCSC implementation include: time required to implement, levels designated for management and reporting, variance thresholds, and system discipline requirements. These sensitive areas can affect the cost of implementing and operating a C/SCSC compliant system. The cost of C/SCSC, sometimes alleged to be excessive, has defied quantification. However, there is no dispute that improper implementation and excessive reporting requirements impose an unnecessary burden and additional cost on the contract. Knowledgeable C/SCSC personnel should be consulted during the preparation of the RFP, the data call and during negotiations.

Reporting

There are no explicit external reporting requirements in the C/SCSC. The criteria require that contractors have and use effective internal control systems. Summary data from the internal systems are reported to the Government through the Cost Performance Report (CPR) as specified on the Contract Data Requirements List (CDRL).

C/SCSC Summary

C/SCSC is the best tool available to assure that contractors have and use adequate cost and schedule management control systems. It provides better overall planning and control discipline on defense contracts. The associated reports summarize objective data from the contractor's internal system for both contractor and government managers to use. Improvements in contract management can be achieved by management attention to developing and using good cost and schedule management control systems and taking timely actions when problems are identified from the data generated.

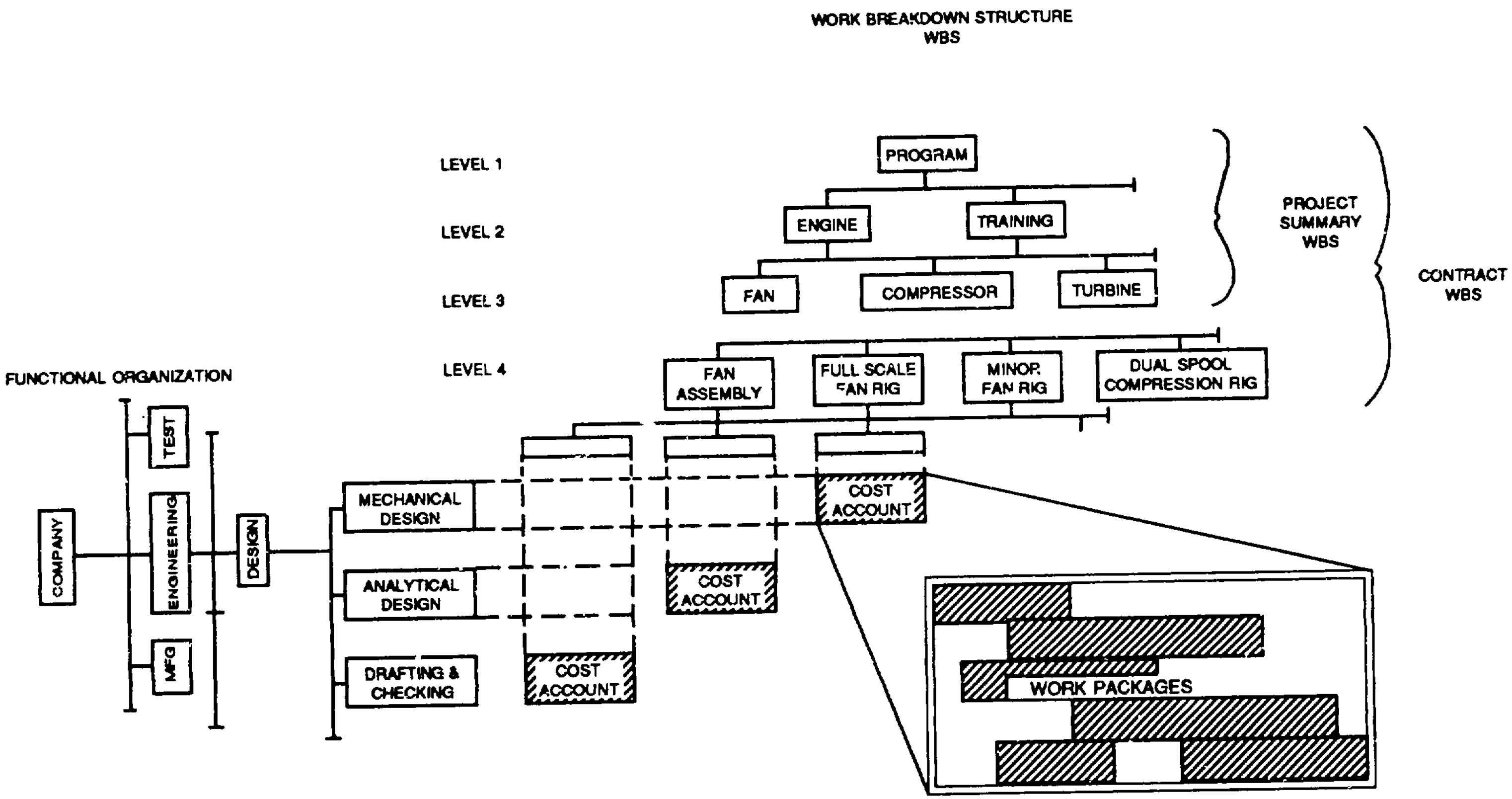


Figure 13-6 Work Breakdown Structure Extended to Cost Account and Work Package Levels

LINE OF BALANCE

Line of Balance (LOB) is a production control technique which combines features from a critical path scheduling time chart with a required delivery schedule, and presents in graphic form information relating to time and accomplishment of production. It shows the delivery objective, sequence and duration of all activities required to produce a product, a progress chart of the current status of production items, and, from these charts, an LOB to show the relationship of actual component production to schedule.

LOB is most appropriate for assembly operations involving a number of discrete components and has proven most useful in production programs from the point when raw materials or incoming parts arrive, to the shipment of the end product.

Without a computer controlled production process, Line of Balance does not lend itself readily to day-by-day updating, but a weekly or monthly check is usually frequent enough to keep the process on schedule. If the project falls behind schedule, management will know it, and know why, far enough in advance to make smooth adjustments.

Reporting to customers or top management is quick, inexpensive and graphic. The charts used for analysis and trouble shooting are suitable for at-a-glance status reporting. A set of clear, simple charts is easier to understand than a list of facts and figures, and charts are faster and more reliable than oral reports.

A Line of Balance study has four elements: (1) the objectives of the program; (2) the production plan, and a schedule for achieving it; (3) the current program status; and (4) a comparison between where the program is and where it's supposed to be. The first step in using LOB is to gather and organize the needed material for the three charts which comprise an LOB report. Once this is done you can "strike the line of balance" whenever necessary to keep track of the program.

Objective Chart

The objective chart is designed to display planned and actual deliveries in cumulative and items per unit of time. In Figure 13-7, for example, the delivery schedule calls for three items in December, five in January, seven more in February and five each month thereafter through June. The delivery schedule should realistically reflect attainable production capability taking into account learning associated with a new product (if this is an initial production activity) anticipated methods improvements, or other factors expected to influence productivity.

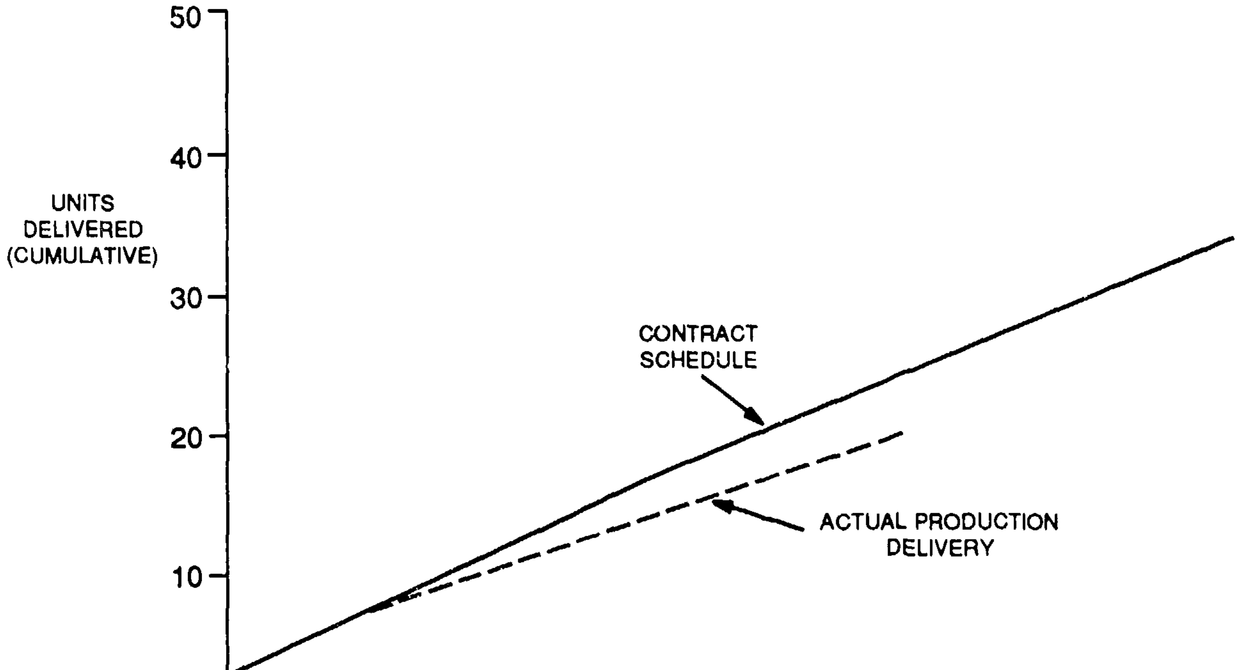
The other curve on the Objective Chart shows actual delivery of parts. The horizontal difference shows how far actual deliveries lag scheduled deliveries in terms of time, the vertical difference shows the variance, in numbers of units, from schedule.

The Production Plan

Following the development of the objectives, the second step is to chart the planned process of production. The production plan is a graphic flow chart of the operations required to complete a unit. Selected production activities are plotted against the lead time required before shipment. For example, Figure 13-8 illustrates the key plant operations in the manufacturing sequence of a rocket.

The production plan is developed by setting down the selected events and operations in their proper sequence, commencing at the point of delivery and moving backward through the entire production process. The control points are numbered from left to right and from top to bottom as shown in Figure 13-8. This will usually result in four or more general sequential phases as follows: the final assembly process, preceded by major subassembly work, preceded by manufacture of parts, preceded by acquisition and preparation of raw materials and purchased parts.

In Figure 13-8, the receipt of purchased parts identified as event 1 must start 24 working days in advance of final delivery for that unit. The gyro components must enter the production stream at control point 2 on day 22, as must the guidance and control components at control point 3 in order to assure start of the assembly of the guidance section (event 5) on day 16. If the required material or number of parts is not at each control point or any critical event in the production flow of a unit is not started on time (or completed on schedule), the delay is



MONTH	DEC	JAN	FEB	MAR	APR	MAY	JUN
SCH CUM	3	8	15	20	25	30	35
ACT. DEL	3	5	10	15	20		

DATE OF STUDY

Figure 13-7 Objective Chart

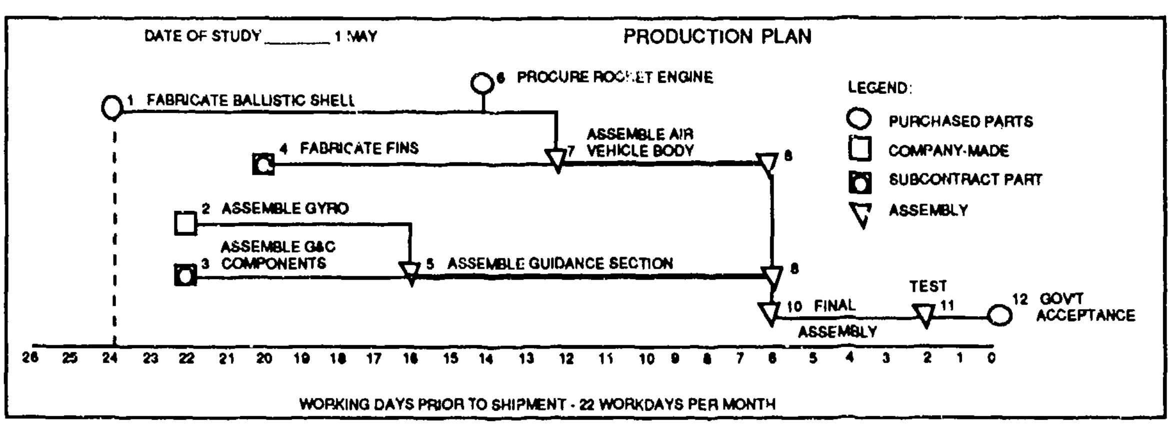


Figure 13-8 Production Plan

symptomatic of a problem which should be investigated; corrective action should be taken to forestall continuing delays and late deliveries.

The Progress Chart

The progress chart, example shown in Figure 13-9, pertains to the status of actual performance and comprise a bar chart which shows the quantities of materials, parts, and subassemblies available at the control points at a given time.

Production progress is depicted in terms of quantities of materials, parts, and subassemblies which have passed through the individual check points or control points of the production plan, including those contained in end items already completed. This information is derived from production records or accumulated by a physical inventory for each control point.

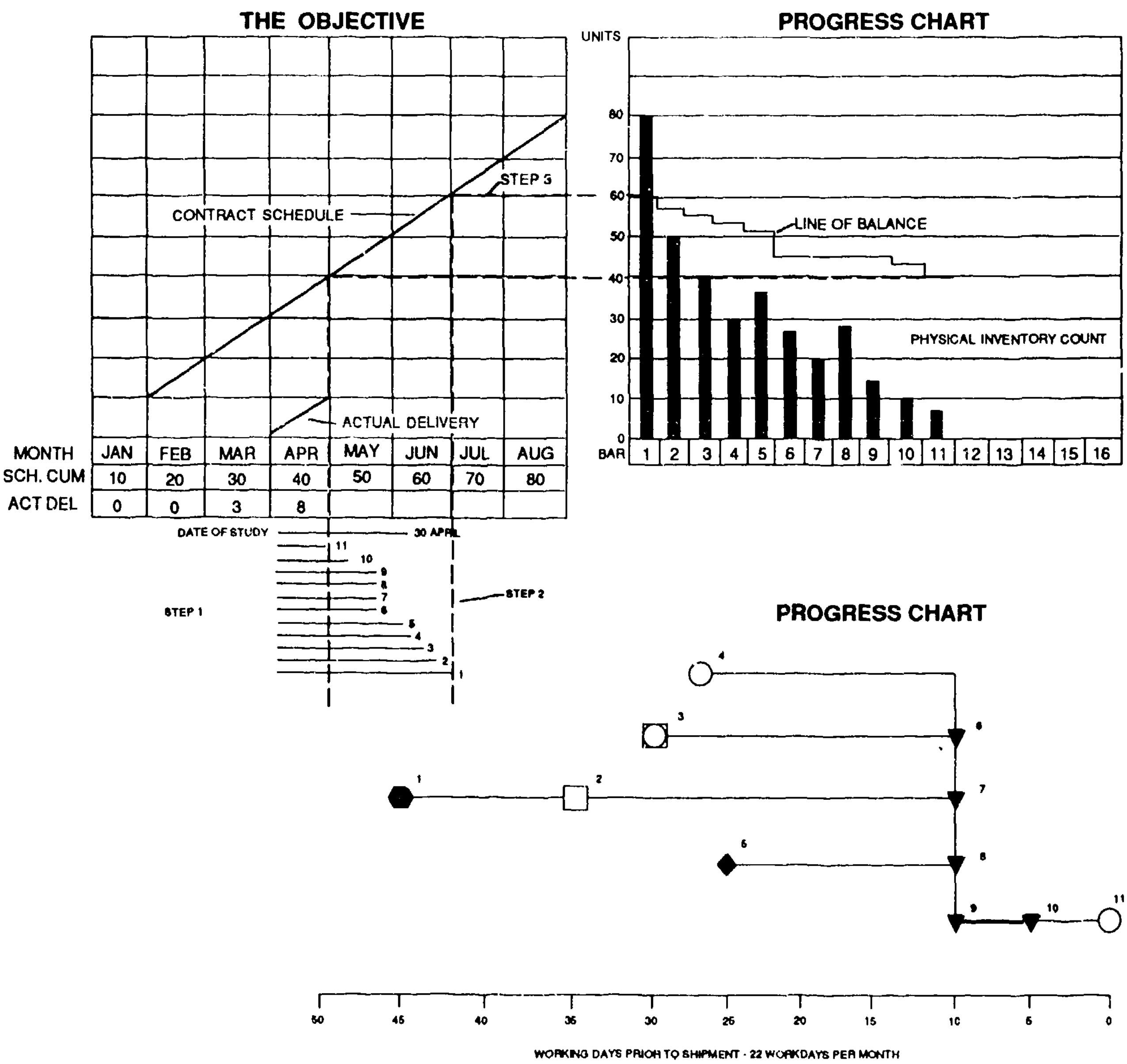


Figure 13-9 Line-of-Balance Chart

Comparison of Program Progress to Objective

Development of the objective chart, the production plan, and program progress chart completes the accumulation of physical information. There remains the task of relating the facts already gathered. This is accomplished by striking a "Line of Balance, (LOB)" which is the basis to be used for comparing the program progress to the objective.

The balance line quantity depicts the quantities of end item sets for each control point which must be available as of the date of the study to support the delivery schedule. In different words, it specifies the quantities of end item sets for each control point which must be available in order for progress on the program to remain in phase with the objective. Figure 13-9 is illustrative of the procedure for striking the LOB.

The balance line quantity depicts the quantities of end item sets for each control point which must be available at the end of the reporting period to support the delivery schedule. The required quantities are then compared with the actual completions by control point. Where the actual completions are less than the required quantity, this would indicate that there is a strong probability that deliveries will not be met at some future point. The timing of the potential delivery shortfall can be determined from the lead time data displayed in the LOB. If the behind schedule control point is 20 weeks flow time prior to final delivery, we would expect to see the impact in 20 weeks if corrective action is not taken.

Two final points should be noted. While the LOB technique offers insight into future delivery problems, the technique shows only where the problem is and does not characterize its nature. It is necessary for contractor or government management action to be taken to identify the causes and initiate appropriate corrective action. The second point deals with manner of presentation of the output products of the technique. For expository purposes we have emphasized the graphic mode utilizing charts. For large acquisitions it is often more appropriate to have the data provided in tabular form (particularly when the contractor utilizes computer analysis for preparation of the data). The key is to find the most cost-effective manner of portraying information for management action.

CHAPTER FOURTEEN

FACTORY OF THE FUTURE

CONTENTS

FACTORY OF THE FUTURE

OBJECTIVE

Planning for system production is driven primarily by the existing and expected near term (less than 5 year) improvements in factory technology. Consideration of the longer term factory technologies may be necessary especially for those programs in Concept Exploration /Definition or Concept Demonstration/Validation. This chapter describes the environment and major influences operating to change the nature and role of the factory. The primary areas of change in the factory of the future are described and a brief summary of the current status is discussed.

INTRODUCTION

The transition from hand crafted products to mechanization of the factory was seen as a significant industrial accomplishment during World War II. Since then, more and better machines have contributed to improved precision and a better quality, lower cost product. Mechanization has continued to play a leading role in the industrial economy but "modernization" has had an even greater impact as the emerging computer technology has been applied to industrial equipment. For instance, mechanical tool control devices, such as special cams for automatic lathes, have been replaced by direct numerical controls which eliminate the need for a special set of cams for each new part configuration. This innovation not only eliminated a costly tool component but drastically reduced set-up time for each new part. While maintaining the same capability to accurately reproduce many parts, greater freedom for part variation was provided. With machine control centered in a computer program, a relatively minor computer program change is needed to affect a change in part configuration compared to two to three hours previously required to change cams.

Similar examples can be cited for equipment used in a variety of industrial processes where computer control or computer aided control systems have been incorporated in new equipment designs for more efficient performance.

No single technological advance will have as great an impact on industry during the 20th Century as computer aided design/computer aided manufacturing (CAD/CAM). The National Science Foundation has stated that, "CAD/CAM has more potential to improve productivity than any technological development since electricity."

The factory of the future will be a totally integrated business and manufacturing system. The system will include modular subsystems for managing all functions from marketing to product shipment. A fully integrated system will provide business planning and support including customer order processing, finished goods inventory management; engineering design including computer assisted drafting, design and simulation; manufacturing planning including process planning, materials planning, inventory record control, order scheduling, dispatching and machine loading control, and computer controlled machine operation, testing and process automation.

Technologically we are at the dawn of another industrial revolution brought about by the inexpensive computing power available through today's electronic technology. Computer aided design (CAD) and computer aided manufacturing (CAM) are the applications of this computing power to manufacturing and the selection of manufacturing processes driven by this technology.

To date, no one has implemented a completely integrated CAD/CAM system. However, each of the elements and cells which collectively make up a plant and the communication and control system modules for directing plant operation have been successfully implemented in today's industry. Even though a completely automated factory does not now exist, all the essential components exist and we can describe the factory of the future as a collection of computerized or computer aided subsystems capable of ially no direct labor operation.

FACTORY TECHNOLOGY

The extent of automation will vary widely from individually automated numerical control (NC) machine tools to a completely integrated computer aided manufacturing (ICAM) system. The size and type of the business, the manufacturing methods employed, and the economic state of affairs are some of the factors that dictate the level of automation appropriate for each industry or company. The trend of manufacturing in this country is "written on the wall" when we see machine tools which operate entirely free of operator intervention. And, what is more amazing, perform a great variety of tasks taking their instructions from computer generated design specifications.

Factory automation includes the use of such equipment as: 1) numerical control machines, 2) transfer machines, 3) robots, 4) automated warehouse systems, and 5) material handling devices (hardware systems for processing, handling, or storing factory products). Japan leads the world today in the use of automated manufacturing.

In order to visualize the factory of the future, let's examine each of the components of automation, the element, the cell, and automation at the plant level:

The elemental level or work center is the basic unit of automation and involves two components. These are the process mechanization component and its corresponding information component. A computer-based automation element always includes both the process mechanization component and the informational component.

The next higher level of automation is a cell. The cell provides automation for a functional segment of a plant consisting of a group of machines or work stations which perform similar operations or a series of operations.

The highest order of automation is at the plant level. Automation at the plant level includes computerized management of any number of automated cells.

Automated Factory Structure

The element level is where the basic concept of automation begins. When a machine control unit does electronically what an operator has been doing visually, then machine instructions can be computer directed. At the cell level, full machine control has been achieved for a wide range of machines, enabling them to be controlled and monitored much closer than by human control. For instance, adaptive control units (for which fixed speeds and feeds are not programmed) utilize feedback sensors to optimize operational conditions by sensing pressure conditions at a cutting tool position and automatically adjusting feeds and speeds within a desired range. The control will also reduce feeds and speeds if adverse conditions are met. This permits operation to optimize cutter life and/or lower machining cost. Adaptive controls can be applied to sense loads, temperature or other phenomena. Control systems are not limited in the number of control actions which can be managed. They are used to: turn on a machine, check initial condition, through to even signaling a malfunction and indicating the location of the problem. In turn, a number of elements can be interconnected (i.e.. work centers) to form a cell where many machines perform a variety of operations.

The cell arrangement may be sequential, where parts flow along in the manner of an assembly line; complementary machines, performing similar operations on a variety of parts; or machine groups dedicated to processing a special material, such as in a plastic molding shop. Work flow to, through and from the cells, and a continuous monitoring of parts for each order is maintained according to a predetermined schedule. A cell can be utilized to produce a specific part in a dedicated operation or to produce several different parts. A family of parts or similarly shaped parts can be grouped for effective machine utilization. Radically different shape parts also can be produced, but maximum productivity and operating efficiency are obtained when similar parts are collected on a job order to minimize set-ups and tooling changeovers.

Interconnecting a number of cells through a computer network will provide the highest level of automation. Support services such as inventory control, quality control records, special test requirements and performance records for any and all work stations will be available as a record of the automated factory's operation.

Every part of the factory of the future is here now. An example of a computer integrated manufacturing system illustrates the versatility of automation. Computer control of one plant's gear machining cell has, for over ten years, been used to monitor machine operations with an outstanding record of machine utilization. One important feature is the diagnostic capability designed into the system. In the event of a machine malfunction, which requires operator attention, the maintenance operator (not a machine operator) is alerted and a video screen display in the area indicates the difficulty and displays the appropriate maintenance procedure for corrective action. The result has been more efficient maintenance and an outstanding record of machine utilization.

Flexible Manufacturing Systems

Flexible manufacturing systems (FMS) started with attempts to combine several numerically controlled machine tools with an automated materials handling system all operating under computer control. More current applications of FMS handle palletized workpieces of different types which randomly travel among and are processed by a group of programmable, multi purpose machine tools and work stations. Many of these applications include automated inspection, adaptive control systems, sensors and vision or other tactile information processing equipment.

As the integration of FMS continues, future applications will feature a number of cells operating under a general command computer, buffered but some intermediate work in process inventory by operating with a high degree of synchronization among the cells. While the introduction of FMS in the US has been slow (estimate of 4 in 1975 to 46 in 1985), a recent forecast by the Yankee Group estimates that this could grow to 280 installations by 1990.

Expert Systems

Expert systems are computer based decision or analysis aids which apply rules developed by drawing on the knowledge base of experts in a specific field. The knowledge base is structured in rules or representations which can assist the designer in developing and specifying a design which will be well adapted to the manufacturing environment. Current research is focusing on the development of a theory and practice for mechanical and electrical design and selection of manufacturing processes. Some of this research is being fostered under the AF Concurrent Design program, but the majority of it is sponsored by the commercial industry. Some of the major objectives of the research are to develop expert systems to:

- Do on-line evaluation of designs for manufacturing demands
- Support manufacturing process planning
- Utilize new languages for the representation of manufacturing knowledge.

These systems are also being explored to develop the capability to analyze the logistics implications of the design and support the design of the logistics support elements.

Machine Vision and Tactile Sensing

Current applications of vision systems are primarily for the control of manipulation tasks such as sorting, assembly, welding and riveting. Machine vision has also been applied to inspection, evaluating characteristics such as dimensions, color, and orientation. Research is currently being pursued to expand the capability of vision system primarily in the speed of pattern discrimination and the ability to discriminate shading, texture, color and motion. The keys improved performance of vision systems appear to be in parallel processing and application of Very Large Scale Integrated Circuit (VHSIC) technologies to this task. The development and economic application of machine vision may well be the prerequisite to achieving the full benefits of truly computer integrated fifth generation factory automation.

Communication Links

Communication links are essential in an automated plant to assure that coordinated operations run according to an overall plan. Equally important are the communications which link manufacturing with its related business functions. Examination of the factory of the future by its functions (Figure 14-1) illustrates the variety of information processing activities which must be provided to successfully implement a fully integrated production system. The traditional distinction between product design and manufacturing engineering will be minimal or no longer exist. The truly computer integrated factory of the future will provide for the output of one system to serve as the input to another. For example, the business planning and support provided by the sales force relating to product descriptions serves as an input to the engineering design function. If the product contains previously designed components, a computer assisted drafting system would output the engineering drawing information to the Bill of Materials Processor and to Manufacturing Process Planning for Order Scheduling. If the product description contains new features or new components, the description would serve as input to a CAD system where interactive graphics could be used as a design technique to produce engineering and manufacturing information. A CAM system interacting with CAD would provide the full compliment of functions to process the ordered product through the system.

Changing Role of the Manufacturing Engineer

In 1988, A.T. Kearney, Inc. conducted a study commissioned by the Society of Manufacturing Engineers to explore the future role of the manufacturing engineer. This study concluded that the manufacturing engineer of the year 2000 will be faced with a new set of challenges in the form of:

- An environment exploding in scope
- Multiple roles
- Advanced tools
- Changed work emphasis

The dominant causes of the changes in the challenges faced by the manufacturing engineer arise from:

- Increased product sophistication and variation
- A global manufacturing environment
- A multitude of social and economic changes

The role of the manufacturing engineer will also change dramatically. The A.T. Kearney study indicates that the three primary roles that manufacturing engineers will play by the year 2000 are:

- Operations integrator
- Manufacturing strategist
- Technical specialist

To meet these roles, the manufacturing engineer will have at their disposal much more advanced tools including communications devices, expert systems and other software. The emphasis on how work will be accomplished will be far different with more importance being placed on the human aspects of production and less on the technical. Teamwork rather than individual effort will be the key to success.

Major changes in the basic and continuing education of the manufacturing engineer will be required to respond effectively to these major challenges.

Future Expectations

In the future, the truly integrated manufacturing system will provide assistance to all business functions from order entry to product shipment. Productivity in developing and producing affordable and supportable weapons is the "New Era" of the 1990s and beyond. CAD and CAM have taken the first steps. The advancing computer and data systems technologies (data base management, data distributed networks, distributed processing) afford the means to move toward the integrated system with its attendant benefits. The DOD and its supporting industry have taken some initial steps but there is still a long way to go.

A market study published late in 1988 by Automation Research Corp of Medfield, MA forecasts that the price of factory automation systems is reducing. The study, titled Factory Management Systems: Cell, Area, and Factory Levels, reports that the number of manufacturing software tools available today is on the rise, making it more cost effective for software developers and end-users to develop specialized manufacturing software. As a result we can expect to see more new and affordable manufacturing packages over the next few years.

According to this study, the trend has already begun to have an impact. For example, while the US market for factory management software was worth more than $475 million 1987, these shipments are projected to grow at an average annual rate of

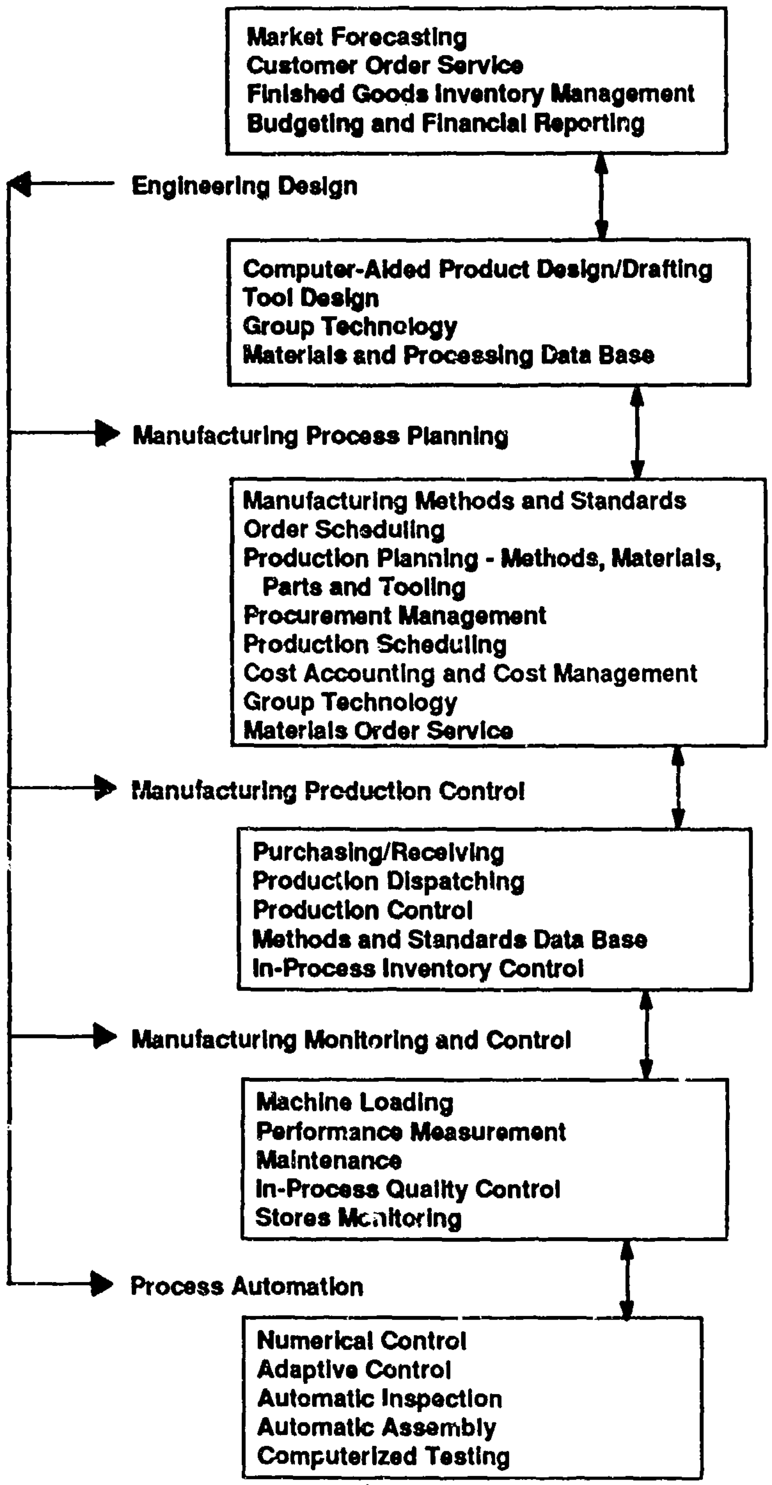


Figure 14-1 Integrated Manufacturing System

nearly 12% through 1992, when they will rise to more than $830 million. About $525 millionworth of factory management software is expected to be shipped this year alone.

The study also groups manufacturing software into seven categories and predicts growth rates for each. Some of these are:

O Cell Control: About $16 million worth was shipped in 1987, and more than $80 million worth will be shipped in 1992.

O Quality Control: About $21 million worth was shipped in 1987, and more than $34 million worth will be shipped 1992.

O Production Management and Scheduling: Around $35 million worth was shipped in 1987, and nearly $120 million worth will be shipped in 1992.

O Factory Simulation: About $25 million worth was published in 1987, and $90 million worth will be shipped in 1992.

Significant US Government effort is being applied to developing manufacturing communications tools and systems.

THE HUMAN ELEMENT

A major environmental characteristic of the factory of the future is the changing nature and role of the workforce. As the "baby boom" of the 50's and 60's is replaced by the "baby bust" generation of the 70's, the supply of new workers entering the job market will drop substantially. This employee shortage is already impacting the fast food industry with its heavy reliance on part time high school and college age employees. As this shortage begins to impact the industrial entry process, major changes in the role of the employee will follow. In addition to the obvious impact of increasing wages and salaries as industry competes for a decreasing pool of talent, the relationship of the firm and the worker will change. Greater emphasis will be placed by industry on developing long term employment relationships. Education and training will be provided by industry.

The need for this education and training will be driven by two forces. First, success in the future factory will be driven by industry's success in harnessing the creative power of the worker. As John Naisbit describes it in "Megatrends" "The more technology around us, the more the need for human touch." Technology raises the level of knowledge required. In addition, the world class competitors have learned that providing all employees the opportunity to contribute to decision making is critical to success. Mr. Rene McPherson, Chairman of the Dana Corporation, has said: "Until we believe that the expert in any particular job is most often the person performing it, we shall forever limit the potential of that person in terms of both his contribution to the organization and his personal development . . . Within a 25 square foot area, nobody knows more about how to operate a machine, maximize its output, improve its quality, optimize the material flow, and keep it operating efficiently than to the machine operators, material handlers and maintenance people responsible for it." This philosophy is the basis for employee involvement programs such as quality circles, one of the major contributors to the success of Japanese industry.

The second force motivating industry to increase education and training is the perceived performance of American schools. As reported in the July 4, 1988 issue of Fortune, "In the United States, 30 percent of all high school students - one million teenagers each year - drop out before graduating. Most are virtually unemployable. And of those who do graduate, many do not have the problem-solving skills necessary to function in an increasingly complex information society." Industry is reacting by increasing support to and involvement in public education and by adding education to their internal employee development programs.

The forces of much management attention in the factory of the future will be on the human contribution to progress. Motivating, educating and empowering the full work force combined with application of new manufacturing and information technologies will be critical elements in factory success.

FACTORY NETWORKS

Digital Equipment Corporation was one of the first computer vendors to perceive then need for enterprise-wide communications in corporate America. To communicate this perception Digital came up with the slogan "The network is the system." At about the same time, Sun Microsystems announced that it too saw a networked future and, further, that in its vision, "The network is the computer." IBM has adapted its System Network Architecture (SNA) design into the peer-to-peer System Application Architecture (SAA) system. Chairman John Akers has stated that "transparent access to remote data" is now required, and is among the company's top three R&D priorities.

A key question currently being addressed is whether the order-entry and control systems are the end point of networking for corporate America? What will all the new networks of the 1990s connect to, and what will they do?

Manufacturing managers have come to realize that one of the key sources of their productivity woes is not with their inability to automate the manufacturing process but with their link between what's designed and what's manufactured. Getting 10% improvement our of a machining station may cost a lot more than motivating engineers to design components using common parts and getting engineers to design parts that are easy to manufacture, assemble, and service.

This is no easy task. The design that feeds manufacturing has traditionally been a stand-alone function, discrete even from the engineering analysis that determines whether a part will actually work. And that's a traditionally separate activity from the engineering that determines who the manufacturing floor should tool up to make the parts.

The ENE 88i (Enterprise Networking Event '88 International) conference strongly indicated that the next generation of networks-the open generation built on Open Systems Interconnection (OSI) standards will revolutionize the production of goods worldwide. These networks will lead to and from all factory floor around the world.

The factory floor is where the big payoffs will be, the places where more human knowledge will be turned into more useful products than anywhere else. But the factory floors will not be where they used to be; in fact, they won't even be what they used to be. Manufacturing Automation Protocol/Technical and Office Protocol (MAP/TOP) will change everything. From now on, economic value will be added in the MAP/TOP networks themselves, not on any traditional factory floors.

The MAP/TOP duo is the heart of all preproduction technologies in the next industrial age now taking shape worldwide, the so-called CIM (computer-integrated manufacturing) age. MAP and TOP are two distinct networking schemes, but, by deliberate design, they work together and share five layers (layers 6, 5, 4, 3, and 2) of the seven-layer OSI architecture. (See Figure 14-2).

TOP is aimed at engineering and business activities; its CIM partner, MAP, is designed to tie into and control activities on the factory floor. To best perform their diverse roles, MAP and TOP remain distinct and specialized at OSI layers 7 (the application layer) and 1 (the physical layer).

Already, Boeing, one of the prime movers behind TOP, uses integrated design/build teams instead of design and build teams as before. Boeing refers to its MAP/TOP networks as "enhanced information systems" and places them at the core of its CIM effort. General Motors, a major supporter of MAP, currently has 20 facilities under or going under MAP.

Worldwide, there are now about 100 known installations using MAP and about a dozen using TOP. Virtually all these installations are world-class competitors, including the likes of BMW, Deere & Company, British Aerospace, Ford, Eastman Kodak, Du Pont and Lockheed. In addition, the U.S. Government has issued its Government OSI Profile (GOSIP) requiring OSI standards in the 1990s. In GOSIP, the government has virtually committed its $300 billion per year defense procurement budgets to companies that favor MAP/TOP systems.

The major CIM leaders in Europe are one or two years ahead of their U.S. counterparts. And the Japanese are somewhere in between the leaders in Europe and the United States.

ENE 88i provided demonstrations of MAP/TOP 3.0, the latest version of that combined preproduction technology.

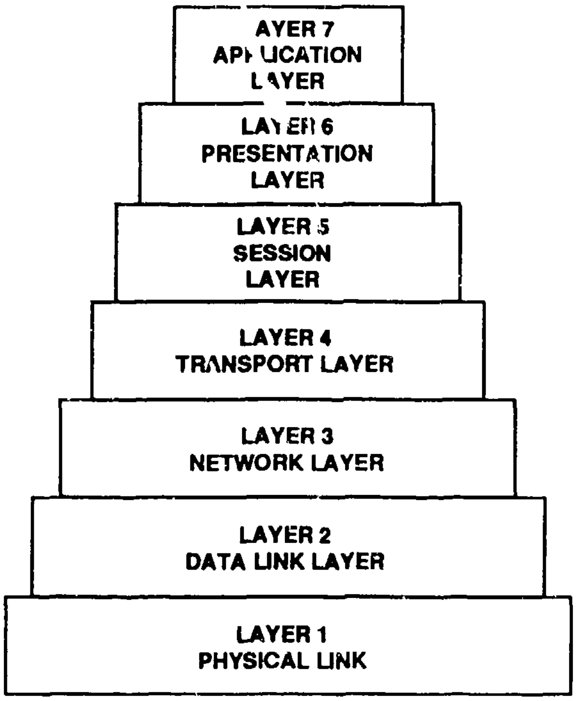


Figure 14-2 Open Systems Interconnection Model

Applications had been previously tested in the United States or in Europe, and they all worked. Many were more flexible and more powerful than proprietary networks. There is now a six-year compatibility freeze on MAP/TOP; all applications and improvements for the next six years will be compatible with MAP/TOP 3.0 today.

MAP 3.0 incorporates a technology called Manufacturing Message Specification (MMS). MMS is a very robust manufacturing description language (MDL) with the power to revolutionize factory floors. MMS can be described as an industrialized and networked variant of the PostScript page-description language (PDL). Whereas PostScript describes images for publishing, MMS is an MDL that describes the handling and shaping of products in manufacturing. No matter what the devices are on the factory floor, robots, machining devices, or assembly devices, and no matter which vendors made them, a product designer can interface all of them using MMS.

MMS can have potentially significant impact on manufacturing. First, TOP creates and shares design information in a multi vendor environment; MAP takes the electronic information onto the factory floor within one enhanced information stream. With MMS, the same software can drive similar industrial devices from any manufacturer. In CIM, the computer is used to design and manufacture products with machines anywhere around the world.

The use of networks in the future can be a significant change. The handful of leaders in each industry in each country will not only adopt MAP/TOP 3.0, they may also use it in building extensive private communications networks to tie together their customers and suppliers. These networks will utilize fiber optics and will be based on OSI standards. To get maximum effectiveness, the industry leaders will require that suppliers and customers adopt MAP/TOP technology.

The Air Force has developed a Product Definition Data Interface (PDDI), which is a standard format for adding parts information to CAD designs. A common encoding technique would allow better intersystem communication of design and manufacturing information. The Air Force has used PDDI to electronically transmit CAD and manufacturing data directly to the factory floors of manufacturing subcontractors. The National Institute of Standards and Technology (NIST) and the Initial Graphics Exchange Standard (IGES) organizations are working on a more universal Product Data Exchange Standard (PDES) less focused on aerospace manufacturing than PDDI.

The Air Force and major suppliers are working on an extension of PDDI - a Geometric Modeling Application Program (GMAP) - that will be sufficient to describe a part all the way through its life cycle. Design data will automatically generate test sequences, for instance, under GMAP. In addition, the DOD Computer Aided Acquisition and Logistics Support (CALS) program will substantially impact communications standards.

CONCURRENT ENGINEERING

Concurrent engineering is a systematic approach to product design that considers all the elements of the product life cycle during the design process.

The traditional development process is based on a serial approach. Design engineers complete a design and analyze it. Then, they pass the details to manufacturing engineers. Processing, routing, tool fixture design, shop floor control and quality programming steps are completed in a series prior to the start of production.

This serial process generally results in engineering change traffic well into the production phase. It also introduces penalties and limitations in that the design does not reflect the realities and constraints of the manufacturing environment resulting in expensive design changes.

The goal of Concurrent Engineering, also referred to as Concurrent Product/Process Development is to move design iterations forward in the development cycle. A multi-functional development team made up of Marketing, Engineering, Manufacturing, and Finance people looks at all of the product and process alternatives. They then simulate and model product and related process alternatives in the computer. Simulation helps develop a fundamental understanding of each alternative and allows the various functions to be involved in the design process before detailed drawings are released.

Companies must learn this new way of developing products. In the future, engineers will need to have a fundamental understanding of a broader scope of product and process development. The prototype "proof of concept" tools used on early Concurrent Engineering projects have defined a new generation of integrated tools. These tools span the spectrum of functions from Marketing to Quality while providing the engineer with a common, user-friendly interface. Relieved of the burden of learning a myriad of tool interfaces and interface quirks, the new engineer will have time to spend finding solutions to actual product and process development problems.

Mr. Del Lucas, Vice President of International Techne Group Inc. has modeled this process as shown in Figure 14-3.

This integrated process includes:

- o Developing product alternatives and then using computers to simulate them
- o Developing manufacturing alternatives and the manufacturing analysis and simulation of those alternatives
- o Identifying what the customer wants and how many. Will it be profitable to supply what he wants?
- o The multi-functional team
- o Next-generation tools

Product alternative evaluation involves the creation of concepts which are then analyzed, and simulated. Selective testing is performed to validate the simulation models. A comparison of predicted results versus requirements is made for each concept.

Process alternative methods include the creation of manufacturing and assembly concepts. Analysis and simulation of these concepts and validation of simulation models by selective testing allow comparison of predicted results vs. cost, production flexibility, and investment requirements. Each product concept is analyzed for its potential to be grouped with similar parts across families within each concept application.

The manufacturing and assembly layouts and process simulation provide the

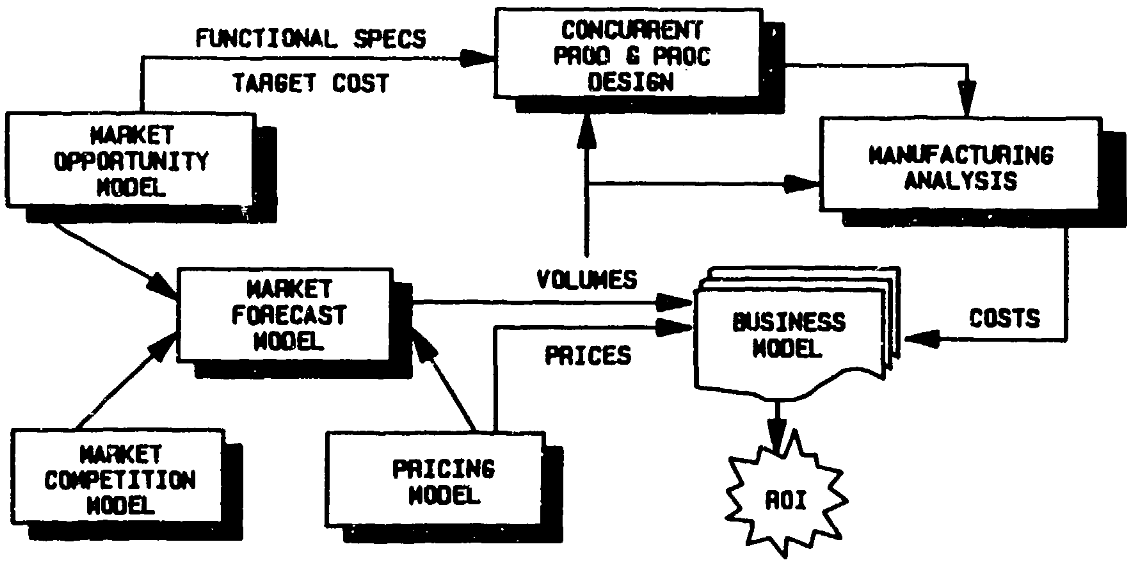


Figure 14-3 Concurrent Engineering Model

Exploded views of a concept applied to a family of applications to a common scale provide a good way to scope the size range of the application family. A common type of automation which makes sense for the application family is the primary criterion for scoping the limits of rationalization.

Simulation and analysis of each product concept and each volume and automation alternative produces estimates of product costs and capital requirements. The system which must be integrated to produce the necessary simulation and analysis is shown in Figure 14-4.

Additionally for each concept, alternative CIM interfaces are considered. These include Networks and Controllers, Real-Time Scheduling and Monitoring, Support Systems, and Quality. The need for consistency with corporate systems must be considered at this stage of the development process. Supplier links to access statistical process control and other types of information, including graphics, must be included. Links to customers are an even more important consideration because different customers may dictate different types of interface needs.

team with feedback on how relatively difficult it is to produce a given product concept alternative. They also provide an early look at the types of manufacturing and assembly automation that the product must be "designed for."

Projects using Concurrent Product/Process Development Methodology have produced very favorable results. However, these results have not been won easily. Each functional area requires its own specialist to interface with the computer aid. Even within functional area, the engineer who models on one software package may not be able to simulate a system on another software package. The two programs may interface differently and may not be "user-friendly."

With the advent of next-generation tools, interfaces between different functional models will become easier. These tools will provide a common interface to different functional models. Interface requirements of the different functional tools will be transparent to the user. As a result, users need to understand little of the mechanics of the individual functional tools. For example, an engineer can go from building a solids model to building a manufacturing cell using a "part flow analysis" model and then to finding a forecast volume niche from the market model at the same terminal. The same interface

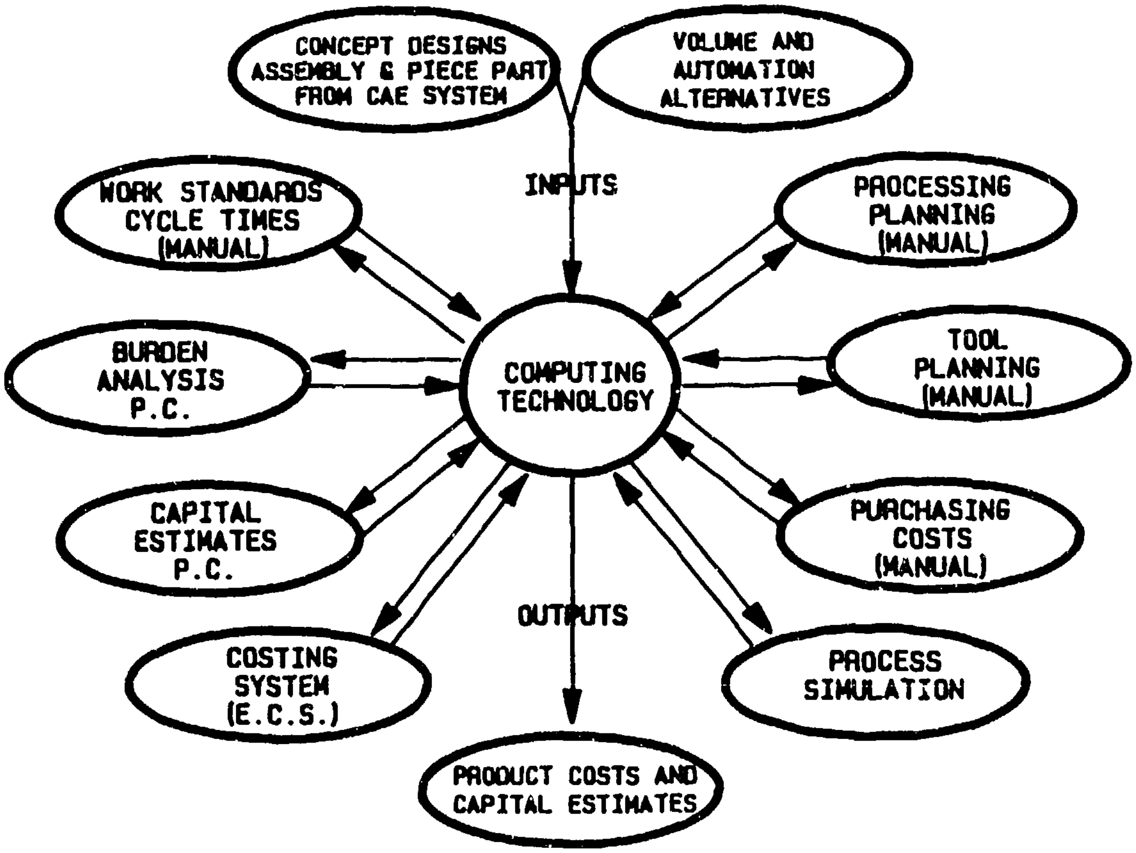


Figure 14-4 System Integration in Concurrent Engineering

format will be used and there will be outward indication that the engineer is switching from one system to another.

COMPUTER AIDED ACQUISITION AND LOGISTICS SUPPORT

Computer Aided Acquisition and Logistics Support (CALS) is a DOD strategy to accomplish the transition form the current paper intensive design, manufacturing and support processes to a highly automated, integrated mode of operations for future weapon systems.

Objectives

The CALS program has three broad objectives as outlined in a policy memorandum by the Deputy Secretary of Defense, William H. Taft, IV, in September 1985:

O To accelerate the integration of reliability and maintainability design tools into contractor CAD systems. The payoff will be more reliable, supportable weapon systems with a lower life cycle cost.

O To encourage the automation and integration of contractor processes for generating weapon system technical information. The payoff is more consistent data, less duplication of effort, and ultimately lower data costs.

O To rapidly increase DOD capabilities to receive, store distribute, and use technical information in digital form.

The DOD and industry have established and effective organization for planning and implementing CALS. Key organizational entities and functional area assignments are depicted in Figure 14-5. Information to DOD Components and industry throughout the lifetime of a weapon system.

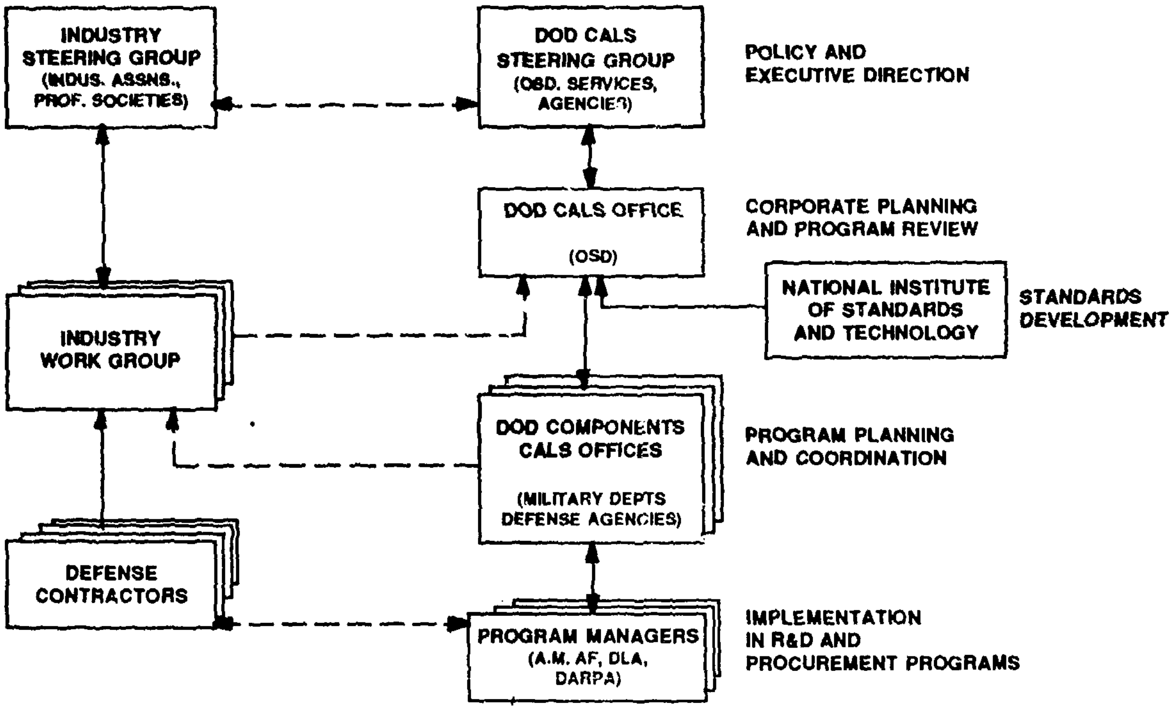


Figure 14-5 CALS Management Organization

<u>Organization</u>

CALS, of course, is not a system, but rather a strategy to link together a system of systems in DOD and industry to achieve the objectives and payoffs described. The target system for CALS integration is one whose primary purpose is to process (create, modify, store, distribute, or use) weapon system technical information in digital form.

<u>Integrated Weapon System Data Base Concept</u>

The long term goal of CALS is the development of an Integrated Weapon System Data Base (IWSDB) which incorporates digital engineering product data and logistic support data into a shared, distributed data base. The IWSDB will provide rapid availability of

The two major components of the IWSDB data base are product data and support data. Their planned transition phases and ultimate culmination in the IWSDB are illustrated in Figure 14-6. This distributed data base will support a full range of life cycle applications shown in Figure 14-7.

CALS provides a unique opportunity to achieve major productivity and quality improvements through carefully planned and managed investment by both Government and industry. As the cumulative impact of CALS implementation is experienced through the process of infrastructure modernization in DOD and industry, major savings will occur as DOD and industry incorporate more far-reaching functional changes made possible by

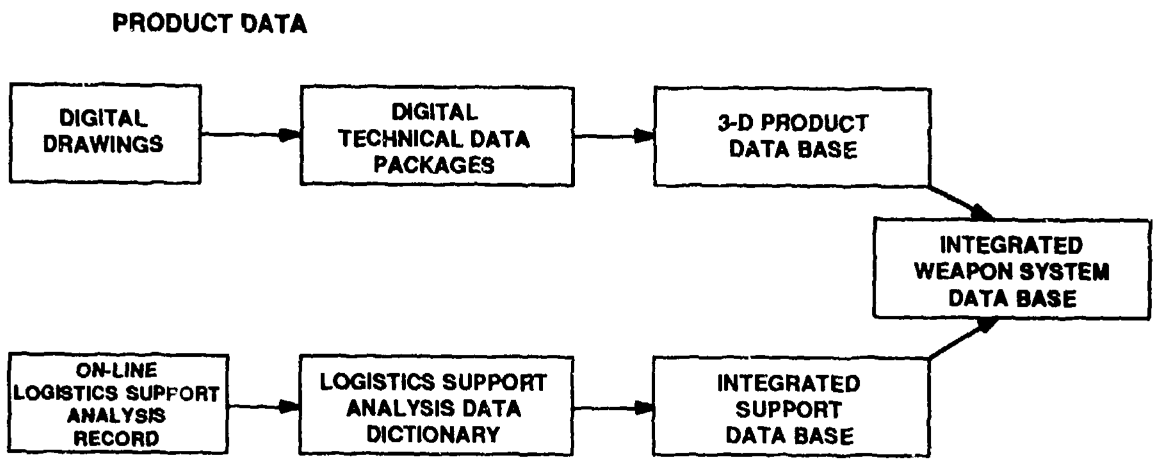


Figure 14-6 Transitional Plan for the IWSDB

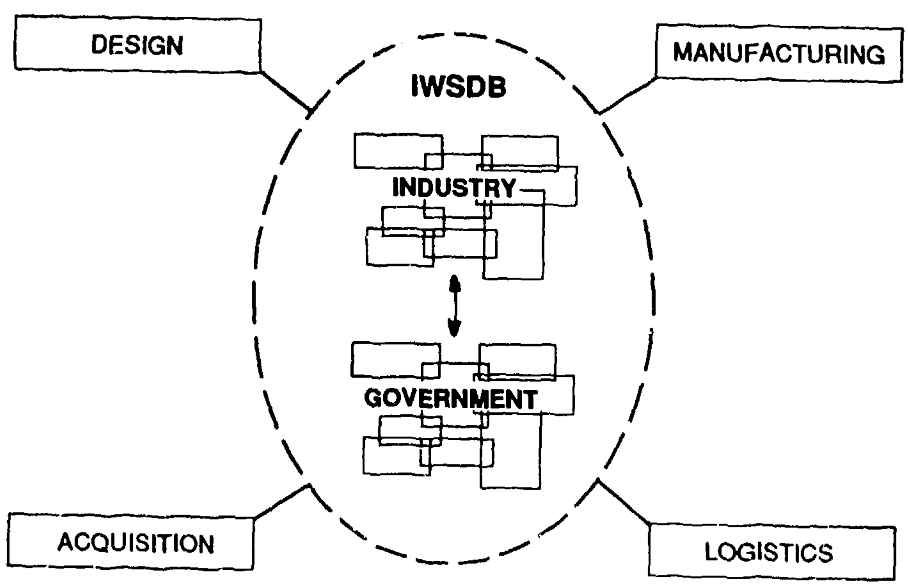


Figure 14-7 Integrated Weapon System Data Base

weapon system life cycle cost, shortened acquisition times, and improvements in reliability, maintainability and readiness.

Figure 14-8 illustrates the current flow of logistics support information. While much progress has been made in CAD/CAE and CIM systems, data must still be converted to hard copy (paper, vellum, aperture cards) for use in the DOD logistics systems.

portion of the life cycle. The technical issues (communications, distributed database information integration. These changes represent the ultimate goal of CALS implementation and will result in a lower technology), the legal and policy issues (rights to data, security, competition), and the cultural changes (realignment of some current functions) combine to make achievement to this target system a challenging goal indeed.

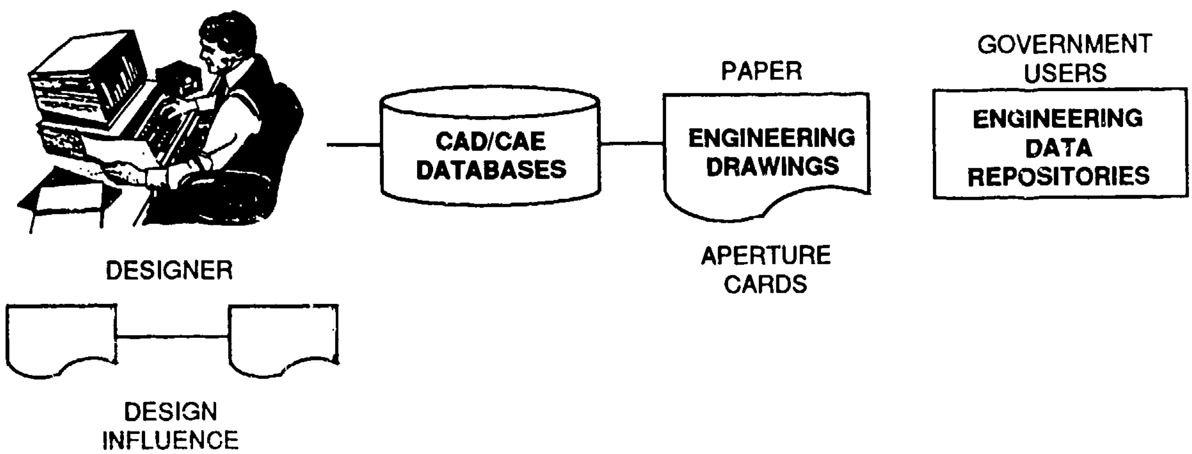


Figure 14-8 Current Data Transfer

The evolutionary part to effective communication sought by CALS is shown in Figures 14-9 and 14-10. Already some prime contractors are starting to integrate some of their stand-alone data systems, eliminating redundant data and making timely information more accessible to users. This reduces the number of paths for data transmission to the government, thereby simplifying the translation problem. In the longer term, the goal is an environment of distributed databases connected by local area and wide area networks that provide DOD and industry users with direct access to the information they need. This scenario opens the possibility of relying on specified government access to the contractor's database rather than delivering data to a DOD repository, at least for a

The CALS program is committed to establishing a unified interface with industry for digital data exchange. The mechanism for this unified interface will be a set of private sector data exchange standards and DOD applications subsets. The same standards will be used to ensure the compatibility of systems within DOD for technical data interchange.

Due to the importance of this standardized interface, DOD has obtained the support of the National Institute for Standards and Technology (NIST) of Gaithersburg, MD, in the selection and implementation of CALS standards. In 1987, the NIST effort is focused on developing tightly defined application subsets and compliance testing approaches in the following areas :

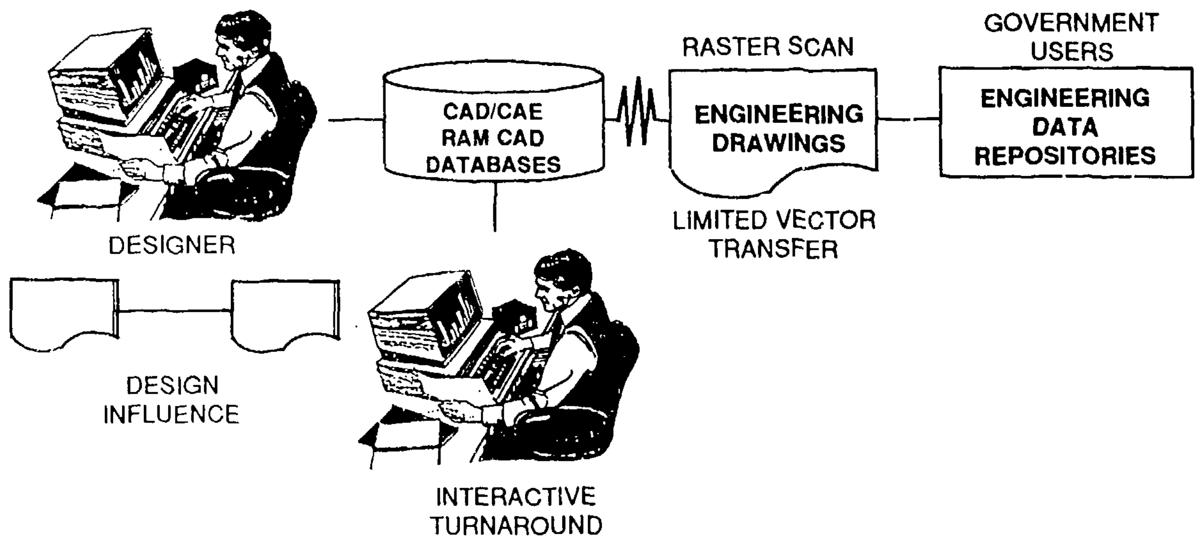


Figure 14-9 Near Term Improvements

Product definition data. The primary standards involved are the Initial Graphics Exchange Specification IGES and the Product Data Exchange Specification (PDES). IGES will be used as a near-term mechanism for transferring data among CAD systems. Early difficulties in the completeness of transfer are being addressed by narrowly defining DOD application subsets and establishing validation tests. For the longer term, CALS will make a substantial commitment to the development of PDES. Product data is the common ground for CALS and CIM, and coordination with the CIM community will be essential.

Computer graphics. The primary data exchange standards are the International Consultative Committee for Telephone and Telegraph Group 4 raster scan standard and Computer Graphics Metafile. Also of interest to achieve device-independent graphics presentation capabilities are Computer Graphics Interface, Graphical Kernel System, and Programmers Hierarchical Interactive Graphics Standard.

Text processing. The primary near term standards in this area is Standardized Generalized Markup Language. Other standards, such as Office Document Architecture/Office Document Interchange Format, Text Composition Language, and Text Presentation Metafile, are being considered for longer-term implementation.

Database management. To support the goal of neutral access of distributed databases, CALS applications of the Information Resource Dictionary Standard, Structured Query Language, and Network Data Language are being examined.

FUTURE OF ROBOTICS

The U.S. industry and the government should foster more widespread use of industrial robots. The application of robots was one of the keys to the remarkably high levels of productivity achieved by the Japanese in the 1970's. The Robot Institute of America (RIA) suggests that U.S. industry

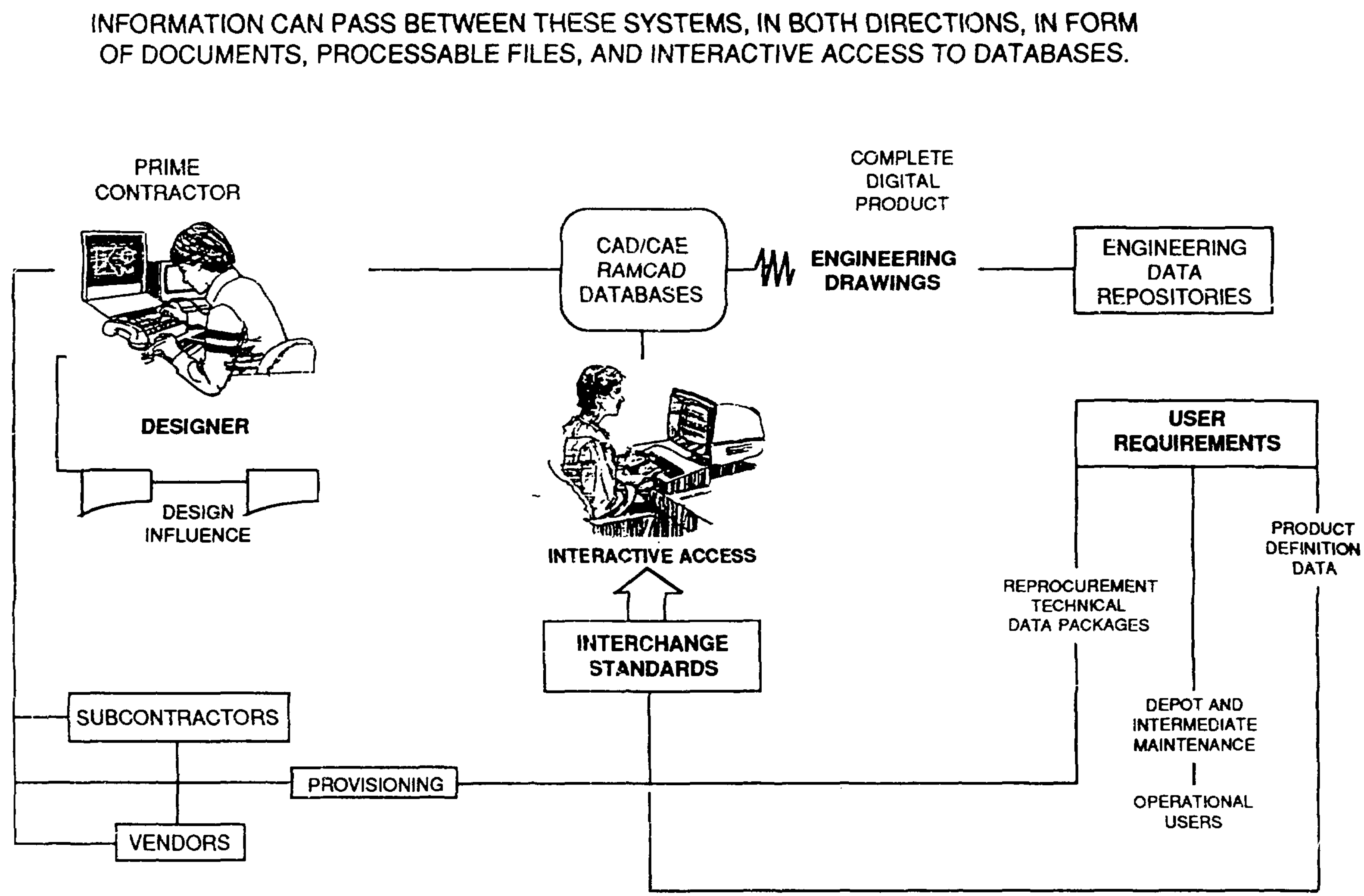


Figure 14-10 Computer-Aided Logistics Support

assign high priority to the installation of robots, especially in dangerous, dirty, and dull jobs, "recognizing that robots are one of the quickest and cheapest ways to increase productivity." Also, industry must accept the responsibility for retraining workers who are displaced by robots. Industry managers will have to communicate with the work force and help the workers to understand the advantages of using robots. Further, industrial managers will have to develop plans so workers will share in the benefits of increased productivity.

Someone has said that "if robots are becoming the tireless arms and eyes of production, then computers are their minds." The versatility of the computer has made it one of the principal elements leading to the automation of the factory. According to the National Institute of Standards and Technology, computer-aided design (CAD), computer-aided manufacturing (CAM) and computer-aided testing (CAT) have more potential to radically increase productivity.

The new flexible manufacturing systems in which several numerically controlled production machines are grouped, along with a transport system, under a control of a main computer, are impacting productivity substantially. Using this type of manufacturing system, machine tool utilization has increased as much as 45 percent in some companies.

Robot manufacturers have been reluctant to talk about "smart" robots - those capable of decision-making -- because, for the most part, industry has only started to utilize the capabilities of existing robots. If industry's interest in robots grows as expected, smart robots will be used in many U.S. factories in the 1990s. The smart robots will be able to understand spoken commands, or they will be able to convert printed language into operating commands. Also, the elementary intelligence available in some robot programs will be able to give the robot the ability to change a program on its own, or to modify a program to cope with a new situation. Fortunately, the more sophisticated robot designs will not make the earlier designs obsolete. The new robot designs will be capable of performing more demanding tasks, and older robots will continue to perform their previously assigned tasks.

The robots of the late 1980s and early 1990s will be more economical, reliable, and versatile (as well as programmable) than those in use today. They will continue to provide a solution to the problems that are encountered when manufacturing takes place in hazardous, unpleasant, or monotonous environment. Robot qualities and benefits will exert a positive influence on the robot market, a market that may reach $3 to $4 billion in sales by the mid-1990s, with the heaviest demands coming from the electronics, automobiles and aerospace/defense industries. Because the benefits available through the application of robots within specific ranges, industrial managers will find ways to accommodate them in the factories. Products will be designed for robot handling. Massive shifts in the nature of factory skills will be made with little, if any, loss in the work force. These events, of course, will increase the size of the market for educational robots . . . robots that tend to mimic their industrial counterparts.

Other advances in robots on the horizon are those with the following characteristics:

1. Higher speeds, better stability, and improved controls.
2. Multiple-armed configurations.
3. Off-line programming in a nigh-order language.

The potential advances show great promise. However, the greatest advance in robot use may come about as a result of more effective manufacturing management techniques. For example, "group technology" will be a boom to robots. This technique involves classifying parts to be manufactured into families. Parts are never placed in bins for storage or transferred to other areas. The parts maintain their orientation throughout the entire manufacturing process. In addition to group technology applications, robots will be used in CAM, product assurance systems, and automatic-warehousing.

As we prepare for the coming age of robots, it is important to keep the following points in mind. First, the initial cost and possible benefits of using robots may be difficult to establish. Second, there may be surprises and setbacks along the way. Third, a structured environment and thoughtful approach to robot applications will usually ensure success.

Forward-looking industrial managers recognize that the introduction of robots will bring about major changes in manufacturing operations. These managers are looking beyond the simple one-for-one replacement of workers and toward understanding the interactions within the manufacturing operations so they can identify those applications where robots can be applied successfully. Further, these forward-looking managers are calling for a systems approach to conceive, define, and build robotic cells. Such an approach will ensure that three goals for successful manufacturing operations efficiency, flexibility, and effectiveness will be met.

Robotic technology will be integrated into flexible manufacturing systems. In the production of products, there will be a movement back to the concept of a general purpose robot with many human-like attributes. In the final analysis, robots will continue to present industrial management with a tremendous challenge. The industrial firms in which management meets the challenge successfully will prosper; the firms in which management fails to meet the challenge head-on may fall by the wayside.

APPENDIX A

LIST OF ACRONYMS

A & P	-Analysis and Production
A & T	-Assembly and Transport
ACI	-Allocated Configuration Identification
ACM	-Authorized Controlled Material
ACO	-Administrative Contracting Officer
ACWP	-Actual Cost of Work Performed
ADM	-Acquisition Decision Memorandum
ADP	-Automated Data Processing
AE	-Acquisition Executive
AFPRO	-Air Force Plant Representative Office
AFSARC	-Air Force System Acquisition Review Council
AGE	-Aerospace Ground Equipment
AI	-Artificial Intelligence
AIP	-Acquisition Improvement Program
AMC	-Army Material Command
	-Acquisition Method Code
AMSDL	-Acquisition Management System and Data Requirements Control List
AQAP	-Allied Quality Assurance Provision
AQL	-Acceptable Quality Level
ASARC	-Army System Acquisition Review Council
ASPPO	-Armed Services Production Planning Officer
ATE	-Automatic Test Equipment
BA	-Budget Authorization
BCE	-Baseline Cost Estimate
BCWP	-Budgeted Cost of Work Performed
BCWS	-Budgeted Cost of Work Scheduled
BES	-Budget Estimate Submission
BOM	-Bill of Material
BPAC	-Budget Program Account Code
C-V-P	-Cost-Volume-Profit
C/SCSC	-Cost/Schedule Control Systems Criteria
CAD	-Computer Aided Design
CAIG	-Cost Analysis Improvement Group
CALS	-Computer Aided Acquisition and Logistics Support
CAM	-Computer Aided Manufacturing
CAMP	-Computer Aided Manufacturing Planning
CAMPP	-Computer Aided Material Planning & Processing
CAO	-Contract Administration Office
CAP	-Cost Account Package, Contractor Acquired Property
CAPP	-Computer Aided Process Planning
CAPS	-Computer Aided Planning System
CAS	-Cost Accounting Standard,
	-Contract Administration Service
CASB	-Cost Accounting Standards Board
CAT	-Computer Aided Testing
CATM	-Computer Aided Technical Management
CCB	-Configuration Control Board
CCDR	-Contractor Cost Data Report
CCN	-Contract Change Notice
CDR	-Critical Design Review
CDRL	-Contract Data Requirements List
CEO	-Chief Executive Officer
CER	-Cost Estimating Relationship

CFC	-Cost of Facilities Capital
CFE	-Contractor Furnished Equipment
CFM	-Contractor-Furnished Material
CFSR	-Contract Funds Status Report
CI	-Configuration Item
CIL	-Critical Item List
CIM	-Computer Integrated Manufacturing
CIMS	-Computer Integrated Manufacturing System
CINC	-Commander in Chief
CLIN	-Contract Line Item Number
CM	-Configuration Management
CMF	-Cost of Money Factor
CNC	-Computer Numerical Control
CO	-Change Order
COQ	-Cost of Quality
CPAF	-Cost Plus Award Fee
CPCI	-Computer Program Configuration Item
CPFF	-Cost Plus Fixed Fee
CPIF	-Cost Plus Incentive Fee
CPM	-Critical Path Method, -Contract Performance Measurement
CPR	-Cost Performance Report
CPSR	-Contractor Purchasing System Review
CR	-Cost Reimbursement
CSCI	-Computer Software Configuration Item
C/SSR	-Cost Schedule Status Report
CWBS	-Contract Work Breakdown Structure
CY	-Calendar Year
DAB	-Defense Acquisition Board
DAC	-Defense Acquisition Circular
DAE	-Defense Acquisition Executive
DAL	-Data Accession List
DAR	-Defense Acquisition Regulation
DARPA	-Defense Advanced Research Projects Agency
DCAA	-Defense Contract Audit Agency
DCAS	-Defense Contract Administration Services
DCASMA	-DCAS Management Area
DCASPRO	-DCAS Plant Representative Office
DCASR	-Defense Contract Administration Services Region
DCN	-Design Change Notice
DCP	-Decision Coordinating Paper
DCPR	-Defense Contractor Planning Report
DEFCON	-Defense Condition
DEMVAL	-Demonstration/Demonstration
DG	-Defense Guidance
DIB	-Defense Industrial Base
DIBA	-Domestic and International Business Administration
DIBP	-Direct Industrial Base Planning
DID	-Data Item Description
DIDS	-Data Item Description System
DIN	-Deutschland Industrial Norm
DIPEC	-Defense Industrial Plant Equipment Center
DLA	-Defense Logistics Agency
DLACAS	-Defense Logistics Agency, Contract Admin. Services
DMB	-Defense Manufacturing Board
DMO	-Defense Mobilization Order
DMS	-Defense Materials System

DMSMS	-Diminishing Mfg. Sources and Material Shortages
DNC	-Direct Numerical Control
DOD	-Department of Defense
DODD	-Department of Defense Directive
DODI	-Department of Defense Instruction
DOE	-Department of Energy
DP	-Development Plan
DPA	-Defense Production Act
DPCCP	-Defective Parts & Components Control Program
DPESO	-DOD Product Engineering Services Office
DPS	-Defense Priorities System
DR	-Deficiency Report
DSARC	-Defense System Acquisition Review Council
DSB	-Defense Science Board
DT&E	-Development Test & Evaluation
DTIC	-Defense Technical Information Center
DT/OT	-Development Testing/Operational Testing
DTC	-Design to Cost
DTLCC	-Design to Life Cycle Cost
DTUPC	-Design to Unit Production Cost
EB	-Electron Beam
ECN	-Engineering Change Notice
ECP	-Engineering Change Proposal
EIA	-Environmental Impact Assessment
EIS	-Environmental Impact Statement
ELS	-Engineered Labor Standards
EOQ	-Economic Order Quantity
EPA	-Economic Price Adjustment
EPA	-Extended Planning Annex
EPR	-Emergency Production Requirements
	-Economic Production Rate
ER	-Estimating Relationship
ERDA	-Energy Research and Development Agency
FAB	-Fabrication
FAR	-Federal Acquisition Regulation
FCA	-Functional Configuration Audit
FCI	-Functional Configuration Identification
FEMA	-Federal Emergency Management Agency
FFP	-Firm Fixed Price
FIFO	-First In - First Out
FMC	-Flexible Manufacturing Cell
FMS	-Flexible Manufacturing System
FOT&E	-Follow-On Test & Evaluation
FP	-Fixed Price
FPAF	-Fixed Price-Award Fee
FPIF	-Fixed Price Incentive Fee
FPR	-Federal Procurement Regulation
FQR	-Functional Qualification Review
FRACAS	-Failure Recording and Corrective Action System
FSD	-Full-Scale Development
FSTE	-Factory Support Test Equipment
FTBO	-Flow Time Between Orders
FTE	-Factory Test Equipment
FY	-Fiscal Year
FYDP	-Five-Year Defense Program
G&A	-General and Administrative
GAO	-General Accounting Office

GAQA	-Government Acquisition Quality Assurance
GBL	-Government Bill of Lading
GDB	-Geometric Data Base
GFE	-Government Furnished Equipment
GFF	-Government Furnished Facilities
GFI	-Government Furnished Information
GFM	-Government Furnished Material
GFP	-Government Furnished Property
GIDEP	-Government Industry Data Exchange Program
GMAP	-Geometric Modeling Application Program
GMR	-Graduated Mobilization Response
GOCO	-Government Owned, Contractor Operated (facilities)
GOGO	-Government Owned, Government Operated (facilities)
GOSIP	-Government Open Systems Interconnection Profile
GPQA	-Government Procurement Quality Assurance
I&A	-Integration and Assembly
I&CO	-Integration and Checkout
IAC	-Information Analysis Center
ICAM	-Integrated Computer Aided Manufacturing
I&SC	-Integration and System Checkout
I/WS	-Item/Weapon System
IB	-Industrial Base
IC	-Integrated Circuit
ICA	-Independent Cost Analysis
ICD	-Interface Control Document
ICE	-Independent Cost Estimate
ICG	-Interactive Computerized Graphics
IDWA	-Inter-Divisional Work Authorization
IE	-Industrial Engineer
IEB	-Industry Evaluation Board
IER	-Industry Equipment Reserve
IES	-Industrial Engineering Standard
IFAC	-Integrated Flexible Automation Center
IGES	-Initial Graphics Exchange Standard
IL	-International Logistics
ILS	-Integrated Logistics Support
ILSP	-Integrated Logistics Support Plan
IMIP	-Industrial Modernization Incentives Program
IMS	-Integrated Manufacturing System
IOC	-Initial Operational Capability
IOT&E	-Initial Operational Test & Evaluation
IP	-Industrial Preparedness
IPB	-Illustrated Parts Breakdown
IPE	-Industrial Plant Equipment
IPF	-Initial Production Facilities
IPL	-Indentured Parts List
IPM	-Industrial Preparedness Measures
IPP	-Industrial Preparedness Program
IPPL	-Industrial Preparedness Planning List
IPPP	-Industrial Preparedness Program Planning
IPPS	-Industrial Preparedness Program Planning System
IPR	-Industrial Plant Representative
IPSG	-Investment Policy Study Group
IR&D	-Independent Research and Development
ISO	-International Standardization Organization
JAMAC	-Joint Aeronautical Materials Activity
JIT	-Just In Time

JMPAB	-Joint Materials Priorities and Allocations Board
JMSNS	-Justification for Major System New Start
KFL	-Key Facilities List
LCC	-Life Cycle Cost
LIFO	-Last In - First Out
LLTI	-Long Lead Time Items
LOA	-Letter of Offer and Acceptance
LOB	-Line of Balance
LOE	-Level of Effort
LRIP	-Low Rate Initial Production
LRU	-Line Replaceable Unit
LSA	-Logistics Support Analysis
LSAR	-Logistic Support Analysis Record
LSI	-Large Scale Integrated (Circuit)
LTPD	-Lot Tolerance Percent Defective
MAA	-Mission Area Analysis
MAP	-Manufacturing Automation Protocol
MANTECH	-Manufacturing Technology
MDL	-Manufacturing Description Language
ME	-Manufacturing Engineering
	-Mission Element
MEL	-Master Equipment List
MIPR	-Military Interdepartmental Purchase Request
MITI	-Ministry of International Trade and Industry
MM/PCR	-Manufacturing Management/Production Capability Review
MMS	-Manufacturing Message Specification
MNS	-Mission Need Statement
MOA	-Memorandum of Agreement
MOU	-Memorandum of Understanding
MRB	-Material Review Board
MRP	-Materials Requirement Planning
MRP II	-Manufacturing Resource Planning
MS	-Milestone
MSC	-Major Subordinate Command
MSR	-Minimum Sustaining Rate
MTAG	-Manufacturing Technology Advisory Group
MTBF	-Mean Time Between Failure
MTIAC	-Manufacturing Technology Information Analysis Center
MTP	-Master Tooling Plan
MTTF	-Mean Time to Failure
MTTR	-Mean Time to Repair
MUL	-Master Urgency List
MVT	-Module Verification Test
MYP	-Multi-Year Procurement
NADIBO	-North American Defense Industrial Base Organization
NATO	-North Atlantic Treaty Organization
NC	-Numerical Control
NIST	-National Institute for Standards and Technology
NMTBA	-National Machine Tool Builders Association
NOR	-Notice of Revision
NSARC	-Navy System Acquisition Review Council
NSC	-National Security Command
NSN	-National Stock Number
NTIS	-National Technical Information Service
O&O	-Organizational and Operational
O&S	-Operation and Support
ODC	-Other Direct Costs

OFPP	-Office of Federal Procurement Policy
OIM	-Office of Industrial Mobilization
OJT	-On-the-Job Training
OMB	-Office of Management and Budget
OPE	-Other Plant Equipment
OR	-Operational Requirement
ORLA	-Optimum Repair Level Analysis
OSD	-Office of the Secretary of Defense
OSHA	-Occupational Safety and Health Act
OSI	-Open Systems Interconnection
OT&E	-Operational Test and Evaluation
P&A	-Price & Availability
PA	-Product Assurance
PBA	-Production Base Analysis
PCA	-Physical Configuration Audit
PCC	-Primary Controller Card
PCDA	-Plan, Do, Check, Act
PCI	-Product Configuration Identification
PCO	-Principal Contracting Officer
PCR	-Production Control Records
PCWBS	-Preliminary Contract Work Breakdown Structure
PDES	-Product Data Exchange Standard
PDDI	-Product Data Definition Interface
PDL	-Post-script Page Description Language
PDM	-Program Decision Memorandum
	-Programmed Depot Maintenance
PDP	-Procurement Data Package
PDR	-Preliminary Design Review
PEP	-Plant Equipment Package
	-Producibility Engineering and Planning
PERT	-Performance Evaluation and Review Technique
PESO	-Product Engineering Services Office
PIDS	-Prime Item Development Specification
PIECOST	-Probability of Incurring Estimated Cost
PIF	-Provision of Industrial Facilities
PIN	-Plant Index Number
PIP	-Product Improvement Plan/Proposal/Program
PL	-Public Law
PM	-Program Manager
PMC	-Procurement Method Code
PMD	-Program Management Directive
PMO	-Program Management Office
POM	-Program Objective Memorandum
POM/BES	-Program Objective Memorandum/Budget Est. Submission
PPBS	-Planning, Programming and Budgeting System
PPE	-Preproduction Proposal Evaluation
PPPI or P3I	-Pre-Planned Product Improvement
PPR	-Production Progress Report
	-Production Plan Review
PR	-Purchase Request
PRAM	-Production Risk Assessing Methodology
PRAT	-Production Reliability Acceptance Testing
PROC	-Procurement
PROD	-Production
PRR	-Production Readiness Review
PRVT	-Production Reliability Verification Test
PVT	-Product Validation Test

QA	-Quality Assurance
QAR	-Quality Assurance Representative
QFD	-Quality Function Deployment
Q/T	-Qualification Test
R&D	-Research and Development
RAM	-Reliability, Availability, and Maintainability
RD&E	-Research, Development & Engineering
RDT	-Reliability Development Testing
RDT&E	-Reliability Development, Test & Evaluation
RFP	-Request for Proposal
RIA	-Robot Institute of America
RIW	-Reliability Improvement Warranty
R&M	-Reliability and Maintainability
ROC	-Required Operational Capability
ROI	-Return on Investment
RPEP	-Register of Planned Emergency Producers
S/M	-Surge/Mobilization
SAA	-System Application Architecture
SAE	-Service Acquisition Executive
SAIE	-Special Acceptance and Inspection Equipment
SAR	-Selected Acquisition Report
SAR	-Subsequent Application Review
SARC	-Service Acquisition Review Council
SCN	-Specification Change Notice
SCP	-System Concept Paper
SDL	-Software Development Laboratory
SDR	-System Design Review
SDTR	-Supportability to Design Requirement
SECDEF	-Secretary of Defense
SEMP	-Systems Engineering Master Plan
SERD	-Support Equipment Requirements Document
SF	-Standard Forms
SNA	-System Network Architecture
SON	-Statement of Need
SOW	-Statement of Work
SPC	-Statistical Process Control
SRR	-System Requirements Review
SSA	-Source Selection Authority
SSAC	-Source Selection Advisory Council
(S)SARC	-Service Source Acquisition Review Council
SSEB	-Source Selection Evaluation Board
ST	-Special Tooling
STE	-Special Test Equipment
SV	-Schedule Variance
SVT	-Software Verification Test
T&E	-Test and Evaluation
TAAF	-Test, Analyze and Fix
TACP	-Technical Analysis of Cost Proposal
TCO	-Termination Contracting Officer
TDP	-Technical Data Package
TECHMOD	-Technology Modernization
TEMP	-Test and Evaluation Master Plan
TMU	-Time Measurement Unit
TOP	-Technical and Office Protocol
TPMR	-Transfer of Program Management Responsibility
T&PP	-Tool and Production Planning
TQC	-Total Quality Control

TQM	-Total Quality Management
TRACE-P	-Total Risk Assessing Cost Estimate, Production
TRR	-Test Requirements Review
TSE	-Test Support Equipment
TTF&T	-Technology Transfer, Fabrication & Test
UBO	-Unit Buy Off
V&V	-Verification and Validation
VE	-Value Engineering
VECP	-Value Engineering Change Proposal
VRP	-Variability Reduction Program
WBS	-Work Breakdown Structure
WIP	-Work In Progress
WMS	-Work Measurement System
WP	-Work Package
WRM	-War Reserve Materials

APPENDIX B

GLOSSARY OF TERMS

ACCEPTANCE -- The act of an authorized representative of the government by which the government assumes for itself, or as agent of another, ownership of existing and identified supplies tendered or approves specific services rendered, as partial or complete performance of the contract on the part of the contractor.

ACQUISITION PLAN -- A document which records program decisions, contains the requirement, provides appropriate analysis of technical options and the life cycle plans for development, production, training and support of materiel items.

ACTUAL COST -- The sum of the allowable direct and indirect costs (allocable) incurred as a result of producing a part, product, or service.

ACTUAL TIME -- The time taken by a worker to complete a task or an element of a task.

ADVANCE BUY DOLLARS -- The time lapse between ordering key defense components and their delivery (lead time) has increased dramatically in recent years. The direct effect of this is that obligation authority, to finance long lead items in advance of the end item buy year, is required earlier and in greater amounts. This obligation authority is normally referred to as "advance buy dollars."

ADVANCE BUY FUNDING -- Advance buy funding is funding obligated/expended to procure long lead material/components in advance of the fiscal year in which the related procurement action is initiated.

ADVANCED DEVELOPMENT -- Includes all projects which have moved into the development of hardware for experimental or operational test.

ADVANCED ENGINEERING MODEL -- A prototype.

ALLOCATED CONFIGURATION IDENTIFICATION (ACI) -- Currently approved performance oriented specifications governing the development of configuration items that are a part of a higher level configuration item (CI) in which each specification; 1) defines the functional characteristics that are allocated from those of the higher level CI, 2) establishes the tests required to demonstrate achievement of its allocated functional
characteristics, 3) delineates necessary interface requirements with other CIs, and 4) establishes design constraints, if any,such as component/part standardization, use of inventory items and integrated logistic support requirements.

ALLOWANCE -- A time increment included in the standard time for an operation to compensate the worker for production lost due to fatigue and normally expected interruptions, such as personal and unavoidable delays. It is usually applied as a percentage of the normal or leveled time.

ANALYSIS OF MANUFACTURING OPERATIONS -- The review and evaluation of assembly and fabrication processes to determine how effectively and efficiently the contractor's manufacturing operations have been planned or accomplished.

ASSEMBLY -- Two or more parts or subassemblies joined together to form a complete unit, structure, or other article.

ASSEMBLY CHART -- Portrays the proposed sequence of assembly operations constituting the assembly process in the production of goods that are composed of many components.

ASSESSMENT REPORT -- The report generated by an independent assessment of a major system during any phase of the acquisition and support process to provide an examination and evaluation of technical requirements, status toward achievement of those requirements, identify problems and problem causes and make recommendations for correction of the problems or to improve either the requirements or the actions to achieve the requirements.

ATTRITION -- The loss of a resource due to natural causes in the normal course of events such as a turnover of employees or spoilage and obsolescence of material.

AVAILABILITY -- A measure of the degree to which an item is in the operable and committable state at the start of the mission,when the mission is called for at an unknown (random) point in time (MIL-STD-721).

AVOIDABLE DELAY -- Any time during an assigned work period which is within the control of the worker for idle time or for doing things unnecessary to the performance of the operation. Such time does not include allowance for personal requirements,fatigue, and unavoidable delays.

BALANCED LINE -- A series of progressive related operations with approximately equal standard times for each, arranged so that work flows at a steady rate from one operation to the next.

BANK -- A planned accumulation of work-in-process to permit reasonable fluctuations in performance times of coordinated or associated operations.

BARCHART -- The detailed graphical working plan of a part providing sequence and time for the job scheduled ahead and progress to date.

BASELINE COST ESTIMATE (BCE) -- A document which provides a detailed estimate of acquisition and ownership costs.

BRASSBOARD -- An experimental device used to determine feasibility and to develop technical and operational data, sufficiently hardened for use outside the laboratory for use in demonstrating the technical and operational principles of immediate interest.

BREADBOARD -- An experimental device used to determine feasibility and to develop technical data, normally only configured for laboratory use to demonstrate the technical principles of immediate interest.

BUDGET -- A planned program for fiscal periods in terms of estimated costs, obligations, expenditures, source of funds for financing, reimbursements anticipated and other resources to be applied.

BUDGETING -- The process of translating approved resource requirements into time-phased financial requirements.

CALIBRATION -- The comparison of a measurement system or device of unverified accuracy to a measurement system or device of known or greater accuracy to detect and correct any variation from required performance specifications of the unverified measurement system or device.

CAPACITY ANALYSIS -- An analysis most frequently employed in a machine or process area to project the ability to absorb additional business.

CONCEPT DEMONSTRATION/VALIDATION -- The period when major program characteristics are refined through extensive study and analysis, hardware development, test and evaluations. The objective is to validate the choice of alternatives and to provide the basis for determining whether or not to proceed into full-scale development.

CONCEPT DEVELOPMENT -- The initial period when the technical,military, and economic bases for acquisition programs are established through comprehensive studies and experimental hardware development and evaluation. The outputs are alternative concepts and their characteristics (estimated operational,schedule, procurement, costs, and support parameters) which serve as inputs to the System Concept Paper (SCP) on major systems, Program Memoranda (PM) on smaller systems/equipment, and to Service decision documents (Program Management Directives) for programs that do not require OSD decisions.

CONCURRENT ENGINEERING -- A method for integrating and design manufacturing.

CONFIGURATION -- The functional and/or physical characteristics of hardware/ computer programs as set forth in technical documentation and achieved in the product.

CONFIGURATION ITEM (CI) -- An aggregation of hardware/computer programs or any of its discrete portions which satisfies an end use function and is designated by the government for configuration management.

CONFIGURATION MANAGEMENT -- A discipline applying technical and administrative direction and surveillance to; 1) identify and document the functional and physical characteristics of a configuration item, 2) control changes to those characteristics,and 3) record and report change processing and implementation status.

CONTRACTOR-ACQUIRED PROPERTY (CAP) -- Property procured or otherwise provided by the contractor for the performance of a contract, title to which is vested in the government.

CONVERGENCE POINT -- The value (on the X-axis) where the experience curve crosses the horizontal line representing the labor standard. The point in time (unit number) when workers, on a learning curve, attain standard performance.

COOPERATIVE DEVELOPMENT -- Cooperative development includes any method by which governments cooperate to make better use of their collective research and development resources to include technical information exchange, harmonizing of requirements, codevelopment, interdependent research and development, and agreement on standards. Many of these elements occur prior to appointment of the program manager or occur outside the program management environment, but their results impact programs which have multinational involvement.

COST ACCOUNTING -- A system of methods and records which organizes and displays the actual costs associated with a given production contract.

COST ANALYSIS IMPROVEMENT GROUP (CAIG) -- An advisory body established to advise the DAB on all matters concerning the estimation, review and presentation of cost analysis of future weapon systems.

COST CENTER -- Any subdivision of an organization comprised of workers, equipment areas, activities, or combination of these that is established for the purpose of assigning or allocating costs. Cost centers are also used as a base for performance standards. Synonym: burden center, cost pool.

COST ESTIMATING RELATIONSHIP (CER) -- The curve of a cost function which relates the cost of a product to some measurable characteristic of its physical characteristics or manufacture and from which extrapolations and interpolations may be extracted for estimating purposes.

COULD COST -- A cooperative government and industry process of eliminating all non-essential (labor, material and other)costs while ensuring at the same time product performance and quality.

CREW LOAD -- The number of workers assigned to complete the work on a defined production component.

CRITICAL DESIGN REVIEW (CDR) -- Determines that the detail design satisfies the performance and engineering specialty requirements of the development specification establishes the detail design compatibility among the item and other items of equipment facilities ... programs and personnel; assesses producibility and risk areas and reviews the preliminary ... specifications.

CRITICAL ITEMS LIST (CIL) -- A prioritized list of en[illegible] essential to sustained combat operations. This list ser[illegible] Industrial Preparedness Planning List, and is used as a g[illegible]

CRITICAL MATERIAL -- A material that has been clas[illegible] There are approximately 40 minerals in this catego[illegible] dependent on foreign sources for over half of these

CRITICAL WEAKNESS RELIABILITY TEST -- This [illegible] equipment is exposed to environments in excess of th[illegible] critical levels can be determined from vibration tempera[illegible] affect the component. In subsequent tests of the tota[illegible] expected limits, an evaluation of the critical weakness [illegible] may have been damaged or what can be expected to [illegible]

CUTTING SPEED -- [illegible] relative velocity usually ex[illegible] tool and the surface of the material from which it is rem[illegible]

CYCLE -- Time required to complete a predetermined [illegible]

DEFENSE ACQUISITION BOARD (DAB) -- An advisor[illegible] SECDEF to appraise the SECDEF of the program sta[illegible] system to proceed to the next phase in the acquisition pro[illegible]

DEFENSE ACQUISITION EXECUTIVE (DAE) -- The [illegible] SECDEF and the focal point in OSD for system acquisitions

DEFENSE CONTRACTOR PLANNING REPORT WEIGHT -- The empty weight [illegible] the airplane less 1) wheels, brakes, tires and tubes, 2) engines, 3) starter, 4) cooling fluid, 5) rubber or nylon fuel cells, 6) instruments, 7)batteries and electric power supply and conversion equipment, 8)electronic equipment, 9) turret mechanism and power operated gunmounts, 10) remote fire mechanism and sighting and scanning equipment, 11) air conditioning units and fluid, 12) auxiliary power plant unit and 13) trapped fuel and oil.

DEFENSE SYSTEM -- See Weapon System

DELAY ALLOWANCE -- A time increment included in a time standard to allow for predictable contingencies and minor delays beyond the control of the workers.

DESIGN TO COST (DTC) -- A process utilizing unit cost goals as thresholds for managers and design parameters for engineers normally in terms of a single cumulative "average flyaway cost."This cost represents what the government has determined it can afford to pay for a unit of military equipment which meets established and measurable performance requirements at a specified production quantity and rate during a specified period of time.

DESIGN TO COST GOAL -- A specific cost established as a goal for a specific configuration, established performance characteristics and a specific number of systems at a defined production rate.

DEVELOPMENTAL TESTING AND EVALUATION (DT&E) -- DT&E is conducted to demonstrate that the engineering design and development process is complete and that the design risks have been minimized, that the system will meet specifications and that the system's military utility when introduced to operating units is estimated.

DIRECT COST -- Those costs which can be traced directly to a specific piece-part, subassembly or product.

DIRECT ENGINEERING -- Engineering effort directly traceable to the design, manufacture, or control of specific end products.

DIRECT LABOR STANDARD -- A specified output or a time allowance established for a direct labor operation.

DIRECT MANUFACTURING LABOR -- Work which alters the composition, condition, conformation, or construction of the product; the cost of which can be identified with and assessed against a particular part, product, or group of parts or products accurately and without undue effort and expense; colloquially called "direct labor."

DIRECT MATERIAL -- All material that enter into and becomes part of the finished product (including waste) the cost of which can be identified with and assessed against a particular part,product, or group of parts or products accurately and without undue effort and expense.

DOD COMPONENTS -- The Military Departments, the Defense Agencies,the Organization of the JCS, and the OSD and activities administratively supported by OSD.

EARNED HOURS -- The time in standard hours credited to a worker or group of workers as a result of their completion of a given task or group of tasks.

ECONOMIC LOT SIZE -- That number of units of material or a manufactured item that can be purchased or produced within the lowest unit cost range. Its determination involves reconciling the decreasing trend in preparation unit costs and the increasing trend in unit costs of storage, interest, insurance,depreciation, and other costs incident to ownership, as the size of the lot is increased.

ECONOMIC ORDER QUANTITY (EOQ) -- EOQ is the most economical quantity of parts to order at one time to support a defined production rate considering the applicable procurement and inventory costs.

EFFICIENCY FACTOR -- The ratio of standard performance time to actual performance time, usually expressed as a percentage.

ENGINEERING DEVELOPMENT -- Includes those development programs being engineered for service use but which have not yet been approved for procurement or operation.

EQUIPMENT -- A major subdivision of a weapon system or subsystem that performs a function impacting the operational capability and readiness of the weapon system/subsystem. It is grouped into two general categories, that is, mission equipment and support equipment. Equipment does not denote bit part pieces or components elements that comprise an equipment entity.

EQUIPMENT SCHEDULING AND LOADING -- The effective and efficient loading of machines according to their capabilities to perform defined operations utilizing their maximum capability to assure attainment of the manufacturing schedule.

EXPLORATORY DEVELOPMENT -- Includes all effort toward the solution of specific military problems, short of major development projects.

FABRICATION -- The construction of a part from raw material.

FACILITIES -- Industrial Property (other than material, special tooling, military property, and special test equipment for production, maintenance, research, development, or test) including real property and rights therein, buildings, structures, improvements and plant equipment.

FAILURE -- The event in which any part of an item does not perform as required by its performance specification.

FATIGUE -- A physical and/or mental weariness, real or imaginary, existing in a person, adversely affecting the ability to perform work.

FATIGUE ALLOWANCE -- Time included in the production standard to allow for decreases or losses in production which might be attributed to fatigue (usually applied as a percentage of the leveled, normal, or adjusted time.)

FINAL ASSEMBLY -- The joining together of the major sections to perform a complete unit.

FIVE-YEAR DEFENSE PROGRAM (FYDP) -- The publication that records, summarizes and displays the decisions that have been approved by the SECDEF as constituting the DOD program.

FIXED COST -- Those costs which remain relatively constant irrespective of volume.

FLOW DIAGRAM -- The paths of movement of workers and/or materials superimposed on a graphical representation of a work area.

FLOW PROCESS CHART -- A graphic representation of the sequence of all operations, transportations, inspections, delays, and storages occurring during a process or procedure.

FLOW TIME -- The time required for a defined amount of work to be completed.

FOLLOW-ON OPERATIONAL TEST AND EVALUATION (FOT&E) -- That T&E which is necessary during and after the production period to refine the estimates made during the IOT&E, to evaluate changes,and to reevaluate the system to ensure that it continues to meet operational needs and retains its effectiveness in a new environment or against a new threat.

FOREIGN MILITARY SALES (FMS) -- An FMS agreement is the document by which the U.S. Government agrees to sell defense articles and services to a foreign government or international organization.

FULL FUNDING POLICY -- This general policy prescribes that the annual appropriation of funds for the total estimated costs to be incurred in the delivery of a given quantity of a usable end item are to be available in the fiscal year in which the procurement action is initiated for that end item.

FULL-SCALE DEVELOPMENT PHASE -- The period when the system/equipment and the principal items necessary for its support are designed, fabricated, tested, and evaluated. the intended output is, as a minimum, a preproduction system which closely approximates the final product, the documentation necessary to enter the production phase, and the test results which demonstrate that the production product will meet stated requirements.

FUNCTIONAL CONFIGURATION AUDIT (FCA) -- The formal examination of functional characteristics test data for configuration item, prior to acceptance, to verify that the item has achieved the performance specified in its functional or allocated configuration identification.

FUNCTIONAL CONFIGURATION IDENTIFICATION (FCI) -- The current approved or conditionally approved technical documentation for a configuration item as set forth in specification, drawing and associated lists and documents referenced therein which prescribes; 1) all the necessary functional characteristics, 2) the tests required to demonstrate the achievement of specified functional characteristics, 3) the necessary interface characteristics with associated configuration items (CIs), 4)CI's key functional characteristics and its key lower level CIs,if any, and 5) design component standardization, use of inventory items and integrated logistic support policies.

GANTT CHART -- A graphic representation of a time scale of the current relationship between actual and planned performance.

GENERAL AND ADMINISTRATIVE (G&A) COSTS -- An overhead cost category for accumulation of such costs as personnel department, accounting, purchasing, etc.

GOVERNMENT ACQUISITION QUALITY ASSURANCE -- The function by which the government determines whether a contractor has fulfilled his contract obligations pertaining to quality and quantity.

GOVERNMENT-FURNISHED MATERIAL (GFM) -- Government property which may be incorporated into or attached to an end item to be delivered under a contract or which may be consumed in the performance of a contract. It includes, but is not limited to; raw and processed material, parts, components, assemblies, and small tools and supplies.

GOVERNMENT-FURNISHED PROPERTY (GFP) -- Property in the possession of or acquired directly by the government, and subsequently delivered to or otherwise made available to the prime contractor.

IDLE TIME -- A time interval during which either the workman, the equipment, or both do not perform useful work.

IN-PROCESS INVENTORY CONTROL -- The process whereby materials and parts are planned and controlled to assure their availability at the required stage of production.

INDUSTRIAL FACILITIES -- Industrial property (other than material, special tooling, military property, and special test equipment) for production, maintenance, research and development, or test, including real property and rights therein, buildings, structures, improvements, and plant equipment.

INDUSTRIAL MODERNIZATION INCENTIVES PROGRAM (IMIP) -- A partnership between DOD agencies and their prime contractors to stimulate industry capital investments implementation of advanced manufacturing technologies, and productivity.

INDUSTRIAL PLANT EQUIPMENT (IPE) -- That part of planned equipment, exceeding defined acquisition cost thresholds, used for the purpose of cutting, abrading, grinding, shaping, forming, joining, testing, measuring, heating, treating, or otherwise altering the physical, electrical or chemical properties of materials, components or end items, entailed in manufacturing, maintenance, supply, processing, assembly, or research and development operations.

INDUSTRIAL PREPAREDNESS (IP) -- The state of preparedness of industry to simultaneously produce essential materiel and support the sustained operational requirements of U.S. and approved Allied Forces.

INDUSTRIAL PREPAREDNESS PROGRAM (IPP) -- A coordinated system of plans, actions, and measures for the transformation of the industrial base, both government-owned and civilian-owned, from its peacetime activity to the emergency program necessary to support the national military objectives. It includes industrial preparedness measures such as modernization, expansion, and preservation of industrial facilities.

INHERENT R&M VALUE -- Any measure of reliability or maintainability that includes only the effects of item design and installation, and assumes an ideal operating and support environment.

INTEGRATED LOGISTICS SUPPORT (ILS) -- A composite of all support considerations necessary to assure the effective and economical support of a system for its life cycle.

INITIAL OPERATIONAL TESTING AND EVALUATION (IOT&E) -- That T&E performed during a development program intended for acquisition.

INSPECTION -- The examination and testing of supplies and services (including, when appropriate, raw materials, components, and intermediate assemblies) to determine whether they conform to specified requirements.

INTERFERENCE TIME -- A period of time during which one or more machines are not operating because the worker or workers assigned to operate them are busy operating other machines in their assignment or are performing necessary duties related to operating machines such as making repairs, cleaning the machines, or inspecting completed work.

JIG -- A device which holds components in a required position for assembly and guides the equipment which performs the necessary operations.

JOB -- A group of contiguous operations related by similarity of functions that can be completed by one or more workers without interference or delay.

JOB ANALYSIS -- A detailed examination of a job to determine the duties, responsibilities and specialized requirements necessary for its performance.

JOB LOT -- A relatively small number of a specific type of part or product that is produced at one time. The part or product maybe a standard item that has been and will again be produced, or it may be a special item destined for a specific customer who has not ordered it before and may not order it again.

JOB ORDER COST SYSTEM -- Direct and overhead cost data are accumulated by each contract or order.

JOB SHOP -- A manufacturing enterprise devoted to producing special or custom made parts or products usually in small quantities for specific customers.

KAIZEN -- A Japanese term for continuous improvement. When properly applied, companies experience significant importance in quality, increased productivity and ultimately, greater profits, without the expense associated with innovation.

LABOR PRODUCTIVITY -- The rate of output of a worker or group of workers per unit of time, compared to an established standard or expected rate of output.

LABOR STANDARDS -- A compilation of standard time for each element of a given type of work. Once element standards have been established, the standards are applied to work containing similar elements without making actual time studies of the work.

LEARNING CURVE -- The learning, or manufacturing improvement, curve is a quantitative technique used to predict resource requirements in a manufacturing operation. The primary application has been the prediction of the direct manufacturing hours required to produce a known quantity of a specific product.

LEVELED TIME -- The average time adjusted to account for the difference in operator performance; such as skill, effort and conditions.

LIFE CYCLE COST (LCC) -- The Life Cycle Cost of a system is the total cost to the government of acquisition and ownership of that system over its full life. It includes the cost of development,acquisition, support and, where applicable, disposal.

LIFE UNITS -- A measure of use duration applicable to the item (such as, operating hours, cycles, distance, rounds fired, attempts to operate).

LINE OF BALANCE (LOB) -- A graphic display of scheduled units versus actual units over a given set of critical schedule control points on a particular day.

LINE PRODUCTION -- A method of plant layout in which the machines and other equipment required, regardless of the operations they perform, are arranged in the order in which they are used in the process (layout by product).

LINE STOCK -- Parts or components (for example, screws, washers, solder, common resistors, etc.) which are physically identifiable with the product, but which are of very low value, and therefore, do not warrant the usual item-by-item costing techniques.

LONG LEAD MATERIAL -- Long lead materials are those material items or components whose lead times are significantly longer than other material items/components of the same end item.

LOT -- Order quantity released for production.

LOT ACCEPTANCE TEST -- This test is based on a sampling procedure to assure that the product retains its quality. A specified number of items from each lot or group are withdrawn, at random, and tested to establish that the functions, tolerances, and materials have not been degraded. No acceptance or installation should be permitted until this test for the lot has been successfully completed.

LOW RATE INITIAL PRODUCTION (LRIP) -- A term describing a low rate of output at the beginning of production to reduce the government's exposure to large retrofit programs and costs.

M-DAY -- Term used to designate the day on which mobilization is to begin.

MACHINE CONTROLLED TIME -- That part of a work cycle that is entirely controlled by a machine and, therefore, is not influenced by the skill or effort of the worker.

MACHINE ELEMENT -- A work cycle subdivision that is distinct, describable and measurable, the time for which is entirely controlled by a machine, and, therefore, not influenced by the skill or effort of the worker.

MAINTAINABILITY -- The ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

MAJOR ASSEMBLY -- An operation in the construction of a section which joins a number of subassemblies.

MAKE OR BUY -- Analysis performed by a contractor to determine whether an item should be made "in house" or purchased from an outside supplier.

MANPOWER SCHEDULING AND LOADING -- The effective and efficient utilization and scheduling of available manpower according to their skills to ensure that required manufacturing operations are properly coordinated and executed.

MANTECH (MANUFACTURING TECHNOLOGY) -- Manufacturing Technology refers to any action which has as its objective, 1) the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs, and 2) the assurance of the ability to produce, reduce lead time, ensure economic availability of end items, reduce costs, increase efficiency, improve reliability, or to enhance safety and anti-pollution measures.

MANUAL ELEMENT -- A distinct, describable, and measurable subdivision of a work cycle or operation performed by one or more human motions that are not controlled by process or machine.

MANUFACTURING ENGINEERING -- Preproduction planning and operation analysis applied to specific projects. Other similar functions include sustaining (on-going) engineering, production engineering, and production planning.

MANUFACTURING MANAGEMENT PRODUCTION/CAPABILITY REVIEW -- A review accomplished by the program office during source selection to determine each competing contractor's existing and planned manufacturing management system and production capability/ capacity to meet all known production requirements of the proposed system considering all current firm and projected business.

MANUFACTURING OVERHEAD -- A form of indirect costs -- accumulated manufacturing costs prorated over all products in process, generally as a percent of direct labor and/or material.

MATERIAL -- Property which may be incorporated into or attached to an end item to be delivered under a contract or which may be consumed or expended in the performance of a contract. It includes, but is not limited to, raw and processed material, parts, components, assemblies, fuels and lubricants and small tool and supplies which may be consumed in normal use in the performance of a contract.

METHODS ENGINEERING -- The technique that subjects each operation of a given piece of work to close analysis in order to eliminate every unnecessary element or operation and in order to approach the quickest and best method of performing each necessary element or operation. It includes the improvement and standardization of methods, equipment, and working conditions; operator training; the determination of standard times; and occasionally devising and administering various incentive plans.

METHODS STUDY -- Systematic recording of all activities performed in a job or position of work including standard times for the work performed. Work simplification notes are written during the study.

METROLOGY -- The science of weights and measures used to determine conformance to technical requirements including the development of standards and systems for absolute and relative measurements.

MILITARY PROPERTY -- Military property is government-owned property designed for military operations. It includes end items and integral components of military weapons systems, along with the related peculiar support equipment which is not readily available as a commercial item. It does not include government material, special test equipment, special tooling or facilities.

MINIMUM BUY -- The purchase of material in standard bulk quantities even though the contract requirement is less than the standard quantity. This is done when price does not increase proportionately for quantities less than the standard quantity.

MISSION AREA ANALYSIS (MAA) -- Continuous analysis of assigned mission responsibilities in the several mission areas to identify deficiencies in the current and projected capabilities to meet essential mission needs and to identify opportunities for the enhancement of capability through more effective systems and less costly methods.

MISSION EQUIPMENT (ME) -- Any item which is a functional part of a system or subsystem and is required to perform mission operations.

MOBILIZATION -- The act of preparing for war or other emergencies through assemblying and organizing national resources; and the process by which the Armed Forces or part of them, are brought to a state of readiness for war or other national emergency. This includes assembling and organizing personnel, supplies, and material for active military service.

MULTI-YEAR PROCUREMENT (MYP) -- A procurement of more units of product than can be funded by the government in a single year. The total purchase is divided into annual segments which are larger buys; however, the contractor is protected from annual cancellations through clauses in the contract.

NATIONAL EMERGENCY -- A condition declared by the President or Congress by virtue of powers previously vested in them which authorizes certain emergency actions to be undertaken in the national interest. Actions to be taken may include partial or total mobilization of national resources.

NONRECURRING -- A descriptive term applied to a type of work, operation, part, or the like that does not recur frequently or in any reasonable regular sequence (also nonrepetitive).

NORMAL PACE -- The work rate usually used by workers performing under capable supervision but without the stimulus of an incentive wage payment plan. This pace can easily be maintained day in and day out without undue physical or mental fatigue and is characterized by the fairly steady exertion of reasonable effort.

NUMERICAL CONTROL (NC) -- Tape controlled machine operation which provides high repeatability for multiple process steps.

OPERATION -- The intentional changing of an object in any of its physical or chemical characteristics; the assembly or disassembly of parts or objects; the preparation of an object for another operation, transportation, inspection or storage; planning, calculating, or the giving or receiving of information.

OPERATION PROCESS CHART -- Identifies the successive operations,in their required sequence, for producing a product.

OPERATIONAL R&M VALUE -- Any measure of reliability or maintainability that includes the combined effects of item design, quality, installation, environment, operation, maintenance, and repair.

OPERATIONAL TEST AND EVALUATION (OT&E) -- T&E participated in or performed by operational personnel focusing on operational effectiveness and suitability.

OTHER PLANT EQUIPMENT (OPE) -- That part of plant equipment, regardless of dollar value, which is used in or in conjunction with the manufacture of components or end items relative to maintenance, supply, processing, assembly or research and development operations; but excluding items categorized as industrial plant equipment.

OUTPUT STANDARD -- Specifies the number of items or amount of services that should be produced in a specific amount of time by a specific method.

PERSONAL ALLOWANCE -- Time included in the production standard to permit the worker to attend the personal necessities such as obtaining drinks of water, making trips to the restroom, and the like. Usually applied as a percentage of the leveled, normal, or adjusted time.

PERT -- PERT (Program Evaluation and Review Technique) is a management tool applied to planning complex and high priority research and development programs.

PHYSICAL CONFIGURATION AUDIT (PCA) -- A technical examination of a designated configuration item to verify that the item "as built" conforms to the technical documentation which defines the item.

PILOT PRODUCTION -- The controlled manufacture of limited numbers of an item for service T&E purposes using manufacturing drawings and specifications which have been developed for quantity production and with tooling that is representative of that to be used in unlimited production.

PLANNED PRODUCER -- An industrial firm/activity which has indicated its willingness to produce military items during a surge or mobilization under industrial preparedness planning procedures by consummating a production planning schedule.

PLANNING ITEM -- Any item/critical component selected for industrial preparedness planning. Critical components of any Industrial Preparedness Planning List (IPPL) end item, which are not separately planned or listed in the IPPL, are considered planning items when they meet all of the following criteria: 1)components are produced in the same plant as the end item which is listed in the IPPL, 2) a list of these components is included as a part of the approved planning data (DID, DD 1519, Sector Study), and 3) the components have been validated by the designated ASPPO and/or acquisition activity as critical for end item production capability.

PLANNING, PROGRAMMING, AND BUDGETING SYSTEM (PPBS) -- An integrated system for the establishment, maintenance and revision of the FYDP and the DOD budget.

PREAWARD SURVEY -- A review accomplished by the Contract Administrative Office of a prospective contractor's physical, financial and managerial capability to accomplish the work included in a specific contract effort.

PRELIMINARY DESIGN REVIEW (PDR) -- Conducted on each configuration item to evaluate the progress, technical adequacy and risk resolution of the selected design approach, determine its compatibility with performance and engineering specialty requirements of the development specification and establish the existence and compatibility of the physical and functional interfaces among the item and other items of equipment, facilities, computer programs and personnel.

PREPRODUCTION MODEL -- An article in final form employing standard parts, representative of articles to be produced subsequently in a production line.

PREPRODUCTION TEST -- This is a test of design qualified hardware that is produced using production tooling and processes which will be used to produce the operational hardware. No production hardware should be accepted prior to satisfactory completion of this test. Test objectives include gaining confidence that production hardware is going to works it will be reliable; it can be maintained and supported by the user and is not over designed.

PRIORITY RATINGS - DO AND DX -- the two types of priority ratings contained in Defense Priorities System Regulation that specify rules relating to the status, placement, acceptance and treatment of priority rated contracts and orders. DO ratings have equal preferential status and take priority over all unrated orders. DX ratings have equal preferential status and take priority overall DO rated and unrated orders.

PROCESS -- 1) A planned series of actions of operations which advances a material or product from one stage of completion to another, and 2) a planned and controlled treatment that subjects materials to the influence of one or more types of energy for the time required to bring about the desired reactions or results.

PROCESS COST SYSTEM -- Total costs for producing a type of unit and the number produced are determined for regular accounting periods. An average unit based on that data is determined.

PROCESS LAYOUT -- A method of plant layout in which the machines,equipment, and areas for performing the same or similar operations are grouped together, i.e., layout by function.

PROCESS SHEET -- A document, originating in manufacturing engineering and sent to the production floor, which describes and illustrates methods and tools to be used in fabricating or assembling specific parts or subassemblies.

PRODUCIBILITY -- The relative ease of producing an item or system which is governed by the characteristics and features of a design that enable economical fabrication, assembly, inspection, and testing using available production technology.

PRODUCIBILITY ENGINEERING AND PLANNING (PEP) -- The production engineering tasks and production planning measures undertaken to ensure a timely and economic transition from development to the production phase of a program.

PRODUCIBILITY REVIEW -- A review of the design of a specific hardware item or system to determine the relative ease of producing it using available production technology considering the elements of fabrication, assembly, inspection and test.

PRODUCTION CAPACITY REVIEW -- A review of a contractor's currently available and planned availability of production resources to determine the resources which could be committed to a proposed program and the expected facility utilization level.

PRODUCT CONFIGURATION IDENTIFICATION -- The current approved technical documentation which defines the configuration of a configuration item (CI) during the production, operation, maintenance and logistic support phases of its life cycle and which prescribes that necessary for: 1) fit and function characteristics of a CI, 2) the selected functional characteristics selected for production acceptance testing, and 3) the production acceptance tests.

PRODUCT MANUFACTURING BREAKDOWN -- The product manufacturing breakdown takes the product physical description and decomposes it into demands for specific types of manufacturing capability. This establishes the baseline for determination of the types of personnel and manufacturing facilities which will be required. It can also serve as the basis for establishing the time requirements for the individual manufacturing operations involved in developing the required schedule relationships.

PRODUCTION CENTER -- The area containing the machine or machines operated by a worker or workers as well as the space required for the storage of materials at the machine and for loading and unloading it; auxiliary tools, benches jigs, and the like; and the free and safe movement of the worker while working which, for administrative and accounting purposes, is considered a unit.

PRODUCTION CONTROL -- The procedure of planning, routing,scheduling, dispatching, and expediting the flow of materials parts, subassemblies, and assemblies within the plant from the raw state to the finished product in an orderly and efficient manner.

PRODUCTION ENGINEERING -- The application of design and analysis techniques to produce a specified product. Included are the functions of planning, specifying, and coordinating the application of required resources; performing analyses of producibility and production operations, processes, and systems; applying new manufacturing methods, tooling, and equipment; controlling the introduction of engineering changes; and employing cost control techniques.

PRODUCTION EQUIPMENT MAINTENANCE -- The task of inspecting, servicing, and adjusting the production equipment to achieve minimum interruption of the manufacturing flow.

PRODUCTION FEASIBILITY -- The likelihood that a system design concept can be produced using existing production technology while simultaneously meeting quality, production rate, and cost requirements.

PRODUCTION FEASIBILITY REVIEW -- A review of a system design concept to estimate the likelihood that the concept.can be produced using existing production technology while simultaneously meeting quality, production rate and cost requirements.

PRODUCTION LINE BALANCING -- Balancing a production line means to plan its operation so that the rate of materials which flow through all the work stations is as nearly uniform as practicable.

PRODUCTION MANAGEMENT -- The effective use of resources to produce on schedule the required number of end items that meet specified quality, performance, and cost. Production management includes but is not limited to industrial resource analysis, producibility assessment, producibility engineering and planning, production engineering, industrial preparedness planning, postproduction planning, and productivity enhancements.

PRODUCTION MANAGEMENT TECHNIQUES -- The technique utilized by the contractor to plan for and determine the progress of the production program.

PRODUCTION PHASE -- The period from production approval until the last system/equipment is delivered and accepted. The objective is to efficiently produce and deliver effective and supportable systems to the operating units. It includes the production and deployment of all principal and support equipment.

PRODUCTION PLAN -- The production plan is the vehicle which describes the employment of the manufacturing resources to produce the required products or systems, on time, and within cost constraints.

PRODUCTION PLAN REVIEW -- A review conducted to approve or disapprove a contractor prepared and submitted production plan.

PRODUCTION PLANNING -- The systematic scheduling of workers, materials, and machines by using lead times, time standards, delivery dates, work loads, and similar data for the purpose of producing products efficiently and economically and meeting desired delivery dates.

PRODUCTION PLANNING AND CONTROL -- The planning of operations that accomplishes coordination of workers, material, and facilities to achieve effective and efficient production goals.

PRODUCTION READINESS -- The state or condition of preparedness of a system program to proceed into production. A system is ready for production when industrial resource capability completeness and producibility of the production design and the managerial and physical preparations necessary for initiating and sustaining aviable production effort have progressed to the point where a production commitment can be made without incurring unacceptable risks that thresholds of schedule, performance, cost, or other established criteria will be breached.

PRODUCTION READINESS REVIEW (PRR) -- A formal examination of a program to determine whether the design is ready for production, production engineering problems have been resolved, and the producer has accomplished adequate planning for the production phase.

PRODUCTION SCHEDULES -- Chronological controls used by management to regulate efficiently and economically the operational sequences of production.

PRODUCTIVITY -- The relationship of the quantity and quality of products, goods and services produced to the quantity of resources (personnel, captial, facilities, machine tools and equipment, materials and information) required to produce them.

PRODUCTIVITY ENHANCEMENT -- The use of contract incentives and other techniques to provide the environment, motivation and management commitment to increase production efficiencies.

PRODUCTS -- All items, materiel, material, data, software, supplies, systems, assemblies, subassemblies, or portions thereof which are produced, purchased, developed or otherwise used by DOD.

PROGRAM DECISION MEMORANDUM (PDM) -- A document which provides decisions of the Secretary of Defense on Program Objective Memoranda (POMs) and Joint Force Memoranda.

PROGRAM EXECUTIVE OFFICER -- Officials responsible for administering a defined number of major and/or non-major acquisition programs who report to and receive direction from a Service Acquisition Executive.

PROGRAM OBJECTIVE MEMORANDUM (POM) -- A memorandum in prescribed format submitted to the Secretary of Defense by the Secretary of a Military Department or the Director of a Defense Agency which recommends the total resource requirements within the parameters of the published Secretary of Defense fiscal guidance.

PROGRAM MANAGEMENT DIRECTIVE -- The official management directive used to provide direction to the implementing and participating commands and satisfy documentation requirements. It will be used during the entire acquisition cycle to state requirements and request studies as well as initiate, approve, change, transition, modify or terminate programs.

PROGRAM MANAGEMENT PLAN -- The document developed and issued by the program manager which shows the integrated time phased actions and resources required to complete the task specified in the program management directive.

PROGRAM MEMORANDUM -- An OSD document prepared with similar format, content and coordinating as the DCP but documents program guidelines and thresholds for those significant development programs which are not subject to specific DCP action.

PROTOTYPE -- An original or model on which a later item is formed or based. Usually built during Concept DEM/VAL and tested prior to the Milestone II decision.

QUALIFICATION TEST -- This test simulates defined environmental conditions with a predetermined safety factor. The results of this test indicate whether a given design can perform its function within the simulated environment of a system; tests at this time are usually not made on models using production tooling and processes.

QUALITY -- The composite of material attributes including performance features and characteristics of a product or service to satisfy a given need.

QUALITY ASSURANCE (QA) -- A planned and systematic pattern of all actions necessary to provide confidence that adequate technical requirements are established; products and services conform to established technical requirements; and satisfactory performance is achieved.

QUALITY AUDIT -- A systematic examination of the acts and decisions with respect to quality in order to independently verify or evaluate the operational requirements of the quality program or the specification or contract requirements for a product or service.

QUALITY OF CONFORMANCE -- The extent to which the product or system conforms to design criteria or requirements.

QUALITY OF DESIGN -- The adequacy of the product or system design to meet the needs of the user.

QUALITY PROGRAM -- A program which is developed, planned, and managed to carry out, cost-effectively, all efforts to effect the quality of materiel and services from concept through validation, full-scale development, production, deployment, and disposal.

R&M ACCOUNTING -- That set of mathematical tasks which establish and allocate quantitative R&M requirements, and predict and measure quantitative R&M achievements.

R&M ENGINEERING -- That set of design, development, and manufacturing tasks by which R&M are achieved.

RATING FACTOR -- That percentage of skill and effort and method displayed by an operator during the period of the study with 100% representing normal skill and effort.

RDT&E ACTIVITIES -- Consists of all effort funded from the RDT&E appropriation regardless of program category.

RDT&E PROGRAM CATEGORIES -- Consists of six divisions that the RDT&E program is divided into, namely; research, exploratory development, advanced development, engineering development, management and support, and operational system development.

REAL PROPERTY -- Real property is land and rights therein, ground improvements, utility distribution systems, buildings, and structures. It excludes foundations and other work necessary for the installation of special tooling, special test equipment and plant equipment.

RELIABILITY -- The duration or probability of failure free performance under stated conditions.

RELIABILITY, MISSION -- The ability of an item to perform its required functions for the duration of a specified mission profile.

REALIZATION FACTOR -- The ratio of actual performance time to standard performance time, usually expressed as a decimal number.

RECURRING EFFORT -- An effort repeated regularly during a contract's duration.

RESEARCH -- Scientific study and experimentation directed towards increasing knowledge and understanding in those fields directly related to explicitly stated long term national security needs.

REWORK -- Any corrections of defective work either before, during or after inspection.

SCHEDULING -- Prescribing when and where each operation necessary to the manufacture of a product is to be performed.

SCRAP -- Residual material resulting from machine or assembly processes, such as machine shavings, unusable lengths of wire, faulty parts.

SCRAP PREVENTION -- The program developed to assure that minimum scrap is generated during the manufacturing process.

SELECTED ACQUISITION REPORT (SAR) -- A document prepared for the SECDEF by a DOD component which summarizes current estimates of technical, schedule, and cost performance in comparison with the original plans and current program.

(SERVICE) SYSTEM ACQUISITION REVIEW COUNCIL ((S)SARC) -- A council established by the Head of a Military Department as an advisory body to and through the Military Department to the SECDEF on major system acquisitions. The (S)SARC is chaired by the Secretary/Under Secretary of the Military Department and is similar in functional composition, responsibilities and operation to the DAB. In application the term (Service) is replaced by the designation of the applicable Military Department, i.e., ASARC.

SETUP -- Making ready or preparing for the performance of a job or operation. Machine setup involves equipping a machine with the appropriate accessories, tools, and fixtures, setting the proper feed, speed, and depth of cut, and so forth. In manual work, setup is the arrangement prior to commencing the work, of the tools, accessories, component parts, and details involved. It also includes the teardown to return the machine or work area to its original or normal condition.

SETUP TIME -- The time required to arrange locating fixtures and equipment in order to begin productive work; including adjustments and take down of the original setup.

SHRINKAGE -- An additional quantity of material added to the quantity listed on the Bill of Material to provide for spoilage, scrap, waste and natural attrition.

SOFTWARE FAILURE -- The inability, due to a fault in the software, to perform an intended logical operation in the presence of the specified/date environment.

SOFTWARE MAINTAINABILITY -- The probability that the software, can be retained in or restored to a specified status in a prescribed period compatible with mission requirements.

SOFTWARE RELIABILITY -- The probability that the required software will perform the intended logical operations for the prescribed mission(s) and period(s) in the specified data/environment, without failure.

SOURCE SELECTION -- The process wherein the requirements, facts, recommendations and government policy relevant to an award decision in a competitive procurement of system/project are examined and the decision made.

SPECIAL TEST EQUIPMENT (STE) -- Single or multipurpose integrated test units engineered, designed, fabricated, or modified to accomplish special purpose testing in the performance of the contract. Such testing units comprise electrical, electronic, hydraulic, pneumatic, mechanical, or other items interconnected so as to become a new function entity, causing the individual item or items to become interdependent and essential in the performance of special purpose testing in the development or production of particular supplies or services. The term "special test equipment" does not include: 1) material, 2) special tooling, 3)buildings and nonseverable structures (except foundations and similar improvements necessary for the installation of special test equipment), and 4) plant equipment items used for general plant testing purposes.

SERVICE ACQUISITION EXECUTIVE -- The senior acquisition executive within each Military Department, designated by the Component Head, responsible for administering acquisition programs in accordance with DOD policies and guidelines.

SPECIAL TIME ALLOWANCE -- A temporary time value applying to an operation in addition to or in place of a standard allowance in order to compensate for a specified, temporary, nonstandard production condition.

SPECIAL TOOLING (ST) -- All jigs, dies, fixtures, molds, patterns, taps, gauges, other equipment and manufacturing aids, and replacements thereof, which are of specialized nature that, without substantial modification or alteration, their use is limited to the development or production of particular services. The term includes all components of such items, but does not include: 1) consumable property, 2) special test equipment, and 3) buildings, nonseverable structures (except foundations and similar improvements necessary for the installation of special tooling), general or special machine tools, or similar capital items.

SPOILAGE -- A form of waste material resulting from misuse of material or errors in workmanship.

STANDARD -- A term applied, in work measurement, to any established or accepted rule, model, or criterion against which comparisons are made.

STANDARD COST -- The normal expected cost of an operation, process, or product including labor, material, and overhead charges, computed on the basis of past performance costs, estimates, or work measurement.

STANDARD TIME -- The time which is determined to be necessary fora qualified worker, working at a pace which is ordinarily used under capable supervision and experiencing normal fatigue and delays, to do a defined amount of work of specified quality when following the prescribed method.

STANDARD TIME DATA -- A compilation of all the elements that are used for performing a given class of work with standard elemental time values for each element. The data is used as a basis for determining time standards on work similar to that from which the data was determined without making actual time studies.

STANDARDIZATION -- The process by which various defense forces achieve the closest practicable cooperation and the most efficient use of research, development and production resources.

SUBASSEMBLY -- Two or more parts joined together to form a unit which is only a part of a complete machine, structure, or other article.

SUPPORT EQUIPMENT -- Includes all equipment required to perform the support function, except that which is an integral part of the mission equipment. Support equipment should be interpreted as including tools, test equipment, automatic test equipment (ATE) (when ATE is accomplishing a support function) organizational, field and depot support equipment, and related computer programs and software.

SURGE -- The accelerated production, maintenance, and repair of selected items, and the expansion of logistics support services, to meet contingencies short of a declared national emergency utilizing existing facilities and equipment. Only existing peacetime program priorities will be available to obtain materials, components, and other industrial resources necessary to support accelerated program requirements; however, increased emphasis may be placed on use of these existing authorities and priorities.

SYNTHETIC TIME STANDARD -- A time standard developed for an operation by utilizing predetermined elemental time data or standard data rather than by making a time study.

SYSTEM AVAILABILITY -- The probability (or proportion of operational time) that the hardware and software is in the required operable and committable state when the mission is required with a specified date/environment.

SYSTEM CAPABILITY -- The probability that the hardware and software can achieve the required mission objectives given the operational conditions, including data environment, during the mission.

SYSTEM DEPENDABILITY -- The probability that the hardware and software will perform successfully during one or more required sequences of a mission, given the hardware and software status at the start of the mission (availability).

SYSTEM DESIGN REVIEW (SDR) -- Evaluates the optimization, correlation, completeness and risks associated with the allocated technical requirements.

SYSTEM EFFECTIVENESS -- The measure of the degree to which the hardware and software achieve the mission requirements in the operational environment as evidenced in system availability, dependability and capability.

SYSTEM R&M PARAMETER -- A measure of reliability or maintainability in which the units of measurement are directly related to operational readiness, mission success, maintenance manpower cost, or logistic support cost.

SYSTEM REQUIREMENT REVIEW (SRR) -- Evaluates the adequacy of the contractor's efforts in defining system requirements.

TECHNICAL DATA PACKAGE -- Those documents, drawings, reports, manuals, revisions, technical orders, or other submissions as set forth as a CDRL line item to be delivered as required by the contract.

TECHNOLOGY MODERNIZATION -- The coupling of modernization with the implementation of advanced manufacturing technology by providing incentives for contractor (and subcontractor) capitalization.

TESTING -- An element of inspection. Generally denotes the determination by technical means of the properties or elements of supplies, or components thereof, including functional operation, and involves the application of established scientific principles and procedures.

TIME PHASED ACTION PLAN -- The time phased action plan represents the schedule for the employment of the manufacturing facilities, processes, and personnel necessary to meet the end item delivery date.

TIME STUDY -- The procedure by which the actual elapsed time for performing an operation or subdivisions or elements thereof is determined by the use of a suitable timing device and recorded. The procedure usually but not always includes the adjustment of the actual time as the result of performance rating to derive the time which should be required to perform the task by a worker at a standard pace and following a standard method under standard conditions.

TOLERANCE -- A measure of the accuracy of the dimensions of a part or the electrical characteristics of an assembly or function.

TOOL STUDY -- An instrument that makes or assists in the production of fabricated parts, other tools and assemblies.

TOUCH LABOR -- Defined as production labor which can be reasonably and consistently related directly to a unit of work being manufactured, processed, or tested. It involves work affecting the composition, condition, or production of a product; it may also be referred to as hands on labor or factory labor. It includes such functions as machining, welding, fabricating, painting, assembling, and functional testing of production articles.

UNAVOIDABLE DELAY -- A production delay that the operator cannot prevent.

UNAVOIDABLE DELAY ALLOWANCE -- Time included in the production standard to allow for time lost which is essentially outside the worker's control; as, interruption by supervision for instruction, waits for crane, or minor adjustments to machines or tools (usually applied as a percentage of the leveled, normal, or adjusted time).

VARIABLE EXPENSE -- Expenditures that vary in proportion to the volume of production, such that an increase/decrease in production causes an increase/decrease in the variable cost.

VARIANCE -- The difference between any standard or expected value and an actual value. For example, the difference between the established standard cost and the cost actually incurred in performing a job or operation.

WEAPON SYSTEM -- Technically complex items such as aircraft, missiles, ships and tanks including not only the major item of equipment itself, but the subsystems, logistical support, software, construction and training needed to operate and support it. Sometimes used interchangeably with "defense system".

WORK AID -- A device such as a pattern, template, or sketch used to enhance worker's ability to learn and perform a task efficiently.

WORK CYCLE -- A pattern of motions and/or processes that is repeated with negligible variation each time an operation is performed.

WORK SAMPLING STUDY -- A statistical sampling technique employed to determine the proportion of delays or other classifications of activity present in the total work cycle.

APPENDIX C

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This guide was designed to provide the user with an understanding of, and a basic working familiarity with, the newest and most effective manufacturing management methods used in defense systems acquisition programs today. It is intended that the guide be particularly useful in preparing for and executing the production phase of a defense system program. The guide includes a discussion of DOD policies, directives, methodologies, and practices - along with a list of acronyms and a glossary of terms - applicable to the management of the manufacturing efforts of defense contractors.

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Comment Sheet
for
Defense Manufacturing Management Guide (3rd Edition)

Because of the dynamic nature of the acquisition process and the management implications of rapidly advancing manufacturing technology, future revisions to this Guide are necessary and expected. A major consideration during the preparation of subsequent editions will be the comments, criticisms, or suggestions of you, the Guide's users. Use the space below to let the editors know how you think this Guide can be improved (e.g., recommended additions, deletions, corrections, or other suggestions). Attach additional sheets as necessary.

Whether or not you have comments or suggestions for future editions, we are very interested in your reaction to our efforts on this Guide. Please take a few moments to identify its strengths and weaknesses. In each box, enter a number rating as follows: 1-Excellent; 2-Good; 3-Fair; 4-Poor.

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