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MRL GUIDE

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Prepared by the
Joint Defense Manufacturing Technology Panel
Manufacturing Readiness Level
Working Group

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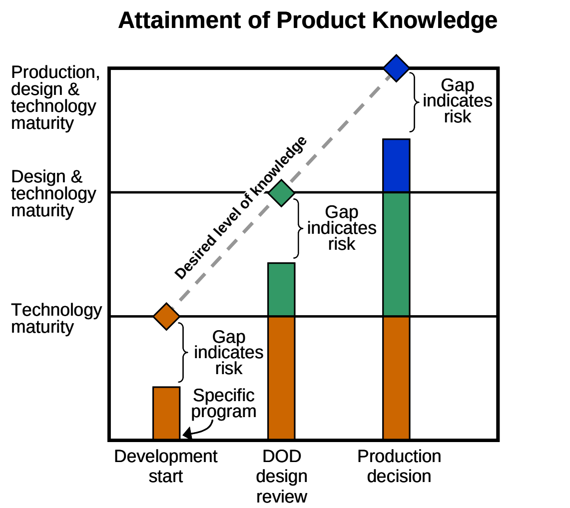
Executive Summary

The Government Accounting Office's (GAO's) report on Defense Acquisitions: Assessments of Selected Major Weapon Programs (GAO-05-301) assessed 54 major weapon programs. The GAO used a knowledge-based approach to product development that reflected the best practices of successful programs. The knowledge-based approach centers on programs attaining a high level of knowledge at key junctures of a new product or weapon development effort:

- ➢ Technology maturity
- ➢ Design maturity
- ➢ Production maturity



Source: GAO-05-301 "Defense Acquisitions: Assessments of Selected Major Programs"

Programs that do not attain these levels of knowledge incur increased technical problems, increased cost and increased schedule slippage. Programs that fail to achieve one element, like technology maturity, find it much harder to attain the requisite amount of knowledge to proceed to succeeding elements.

Twenty-six of the fifty-four programs the GAO assessed cost more and took longer to develop than planned. Those 26 programs showed an average cost increase of 42 percent and schedule increase of 20 percent. The GAO found that these programs proceeded with less knowledge at critical junctures than suggested by best practices. For example, the **technology** and **design** for the F/A-22 matured late in the program contributing to large cost growth and schedule delays. The Joint Air-to-Surface Standoff Missile (JASSM) program, in contrast, achieved a high level of knowledge at all of the critical junctures and experienced minimal cost increases or schedule delays.

Successful product developers, like JASSM, following best practices, ensured that a high level of knowledge was achieved at key junctures in development characterized as knowledge points. These knowledge points and associated indicators are defined as follows:

- ➢ **Technology is mature**. This means that technologies need to meet essential product requirements and have been demonstrated to work in their intended environment. This requires a close matching of customer requirements and resources.

- **Product design is stable**. This means that the design is stable at the system-level critical design review (midway through development). Best practices should have 90 percent of the drawings at the system-level completed.
- **Production processes are mature**. This means that all key manufacturing processes are in statistical control (repeatable, sustainable and capable) at the start of production.

Program and other functional managers can use the Technology Readiness Levels (TRLs) that NASA developed as a tool for assessing technology risks. TRLs can provide significant insights into potential program problems and risks with technology maturity and design stability as identified in the GAO report. There is not, however, a corollary assessment tool to measure manufacturing readiness. Additionally, the GAO report only focused on one factor of manufacturing (statistical process control) as an indicator of readiness. And there are many other manufacturing factors that contribute to the success or failure of a program.

The Joint Defense Manufacturing Technology Panel (JDMTP) Manufacturing Readiness Level (MRL) Working Group (with representatives from government, industrial, and academic) worked on the development of MRL definitions and Manufacturing Readiness Assessments (MRAs) and on reconciling the MRL definitions with TRL definitions.

The development of Manufacturing Readiness Levels and the deployment of Manufacturing Readiness Assessments will go a long way in providing program managers and other managers the necessary tools to help them evaluate their programs and manage their risks prior to production.

This guide was developed to provide an introduction to the major factors impacting manufacturing readiness and a discussion on the tools that are now available to managers to help them identify manufacturing risks so that they can then concentrate on risk mitigation and risk management.

Chapter 1
The Environment for Manufacturing Readiness

1.1 Introduction

Matters of manufacturing readiness and producibility are as important to the successful development of a system as those of readiness and capabilities of the technologies intended for the system. Their importance has long been recognized in Department of Defense (DoD) acquisition, and are reflected in current DoD acquisition policies.

This chapter defines key terms associated with manufacturing readiness. It introduces the notion of Manufacturing Readiness Levels (MRLs). It then describes the goals of manufacturing management and the elements of the manufacturing management process. It also defines current mandatory/statutory requirements and DoD policy guidance. Finally, the chapter describes the objectives of DoD manufacturing management.

1.2 Defining Manufacturing Readiness

Manufacturing Readiness is the ability to harness the manufacturing, production, quality assurance, and industrial functions to achieve an operational capability that satisfies mission needs—in the quantity and quality needed by the war-fighter to carry out assigned missions at the "best value" as measured by the warfighter. *Best value* refers to increased performance as well as reduced cost for developing, producing, acquiring, and operating systems throughout their life cycle. [1]

Timeliness also is important. Our warfighters must maintain a technological advantage over their adversaries. This requires compressed development and acquisition cycles for rapidly advancing technologies.

Manufacturing readiness begins before, continues during the development of systems, and continues even after a system has been in the field for a number of years. The ability to transition technology smoothly and efficiently from the labs, onto the factory floor, and into the field is a critical enabler for evolutionary acquisition.

[1] Definitions in this paragraph are adapted from Deputy Under Secretary of Defense (Science and Technology), *Technology Transition for Affordability: A Guide for S&T Program Managers.* April 2001.

Manufacturing Readiness Levels (MRLs) are designed to be measures used to assess the maturity of a given technology from a manufacturing prospective. The purpose of MRLs are to provide decision makers (at all levels) with a common understanding of the relative maturity (and attendant risks) associated with manufacturing technologies, products, and processes being considered to meet DoD requirements.

1.3 The Goals of Manufacturing Management

The purpose of the manufacturing management function is to ensure that the Acquisition, Technology, and Logistics (AT&L) team has sufficiently identified and managed risks associated with the production of the system. Goals include determining the extent to which the National Technology and Industrial Base (NTIB) can support the intended system, influencing the design for producibility, executing the manufacturing plan, and delivering a consistently uniform and defect-free product to the warfighter.

Central to accomplishing acquisition Program Management goals is an understanding of the risks associated with the industrial process in DoD acquisition, and developing risk mitigation plans and actions. These risk elements are both discrete (are embedded in each phase), and are comprised of nine (9) threads. These threads begin at discovery and invention, go through engineering and development, through production and deployment, and end with operations and support. These nine threads include:

1. **Technology and Industrial Base Thread:** Requires an analysis of the capabilities of the national technology and industrial base to support the design, development, production, operation, uninterrupted maintenance support of the system, and eventual disposal (including environmentally conscious).

Key issues include:

1. Technology base maturity (TRLs)
2. Technology leadership (domestic vs. foreign, and commercial vs. government)
3. Dual Use versus. Spin-On/Off
4. Materials science
5. Manufacturing technology voids

Industrial sector structure and trends (including potential Subcontractors, Suppliers, and Vendors) capabilities/capacities

2. **Design Thread:** Requires an analysis of the degree to which the identified, evolving or system design will meet user requirements and the degree to which the design is new and unproven.

Key issues include:

1. Design approach
2. Design maturity (percentage of design that is new)
3. Design stability
4. Design analyses and tools
5. Use of multifunctional IPTs (includes manufacturing considerations as trade-offs)
6. Configuration and block change management
7. DFX (producibility engineering, design for manufacturing and assembly, and other planning efforts)
8. Manufacturing testability
9. Methods improvement
10. Inclusion of manufacturing management issues in design reviews is key, as well as manufacturing-specific reviews (including Manufacturing Feasibility Reviews, Manufacturing Capability Risk Reviews, Producibility Trade Studies and Reviews, and Production Readiness Reviews)

3. **Materials Thread:** Requires and analysis of the risks associated with materials (including basic/raw materials, components, semi-finished, parts, and subassemblies).

Key issues include:

1. Understanding of materials' basic properties,
2. Availability
3. Environmental considerations
4. Scale-up challenges
5. Characterization in a manufacturing environment
6. Costs
7. Lead times
8. Capacity constraints
9. Sources (domestic/foreign/single/sole/diminishing)
10. Make/Buy Plan
11. Use of COTS/NDI
12. Degree of competition,
13. Storage and handling
14. Parts control

4. **Cost and Funding Thread:** Requires an analysis of the risk that the system development and deployment will not meet the DoD cost and funding goals.

Key issues include:

1. Early manufacturing involvement in technology development and selection

2. Establishment of Design-to-Cost (DTC) and manufacturing cost goals
3. Cost reduction activities
4. Progress toward meeting goals
5. Availability of necessary funding
6. Plans for cost mitigation

5. **Process Capability and Control Thread:** Requires an analysis of the risk that the manufacturing processes may not be able to reflect the design intent (repeatability and affordability) of key characteristics.

Key issues include:

1. Process characterization
2. Variation and variability reduction
3. Identification of key characteristics and process capability indexes
4. Sigma levels

6. **Quality Management Thread:** Requires an analysis of the risk and management efforts to control quality, and foster continuous quality improvement.

Key issues include:

1. Planning for quality
2. Having quality organization and strategy
3. Developing Prime Contractor quality management plan
4. Creating Key Supply Chain Quality Management Structures
5. Understanding the contractor's quality model
6. Writing deployment of risks into contract language
7. Coordinating with Defense Contracts Management Agency (DCMA) resources

7. **Personnel Thread:** Requires the assessment of the required skills and availability in required numbers of personnel to support the manufacturing effort.

Key issues include:

1. Getting involved with the S&T and Manufacturing Technology Programs
2. Manufacturing involvement in the Systems Engineering and IPPD processes
3. Identifying manufacturing planners, schedulers, and control personnel
4. Identifying Tooling and industrial engineers
5. Training Process operators (including training plans and required certifications)

8. **Facilities Thread:** Requires an analysis of the capabilities and capacity (Prime, Subcontractor, Supplier, Vendor, and Maintenance Repair) that are key risks in manufacturing.

Key issues include:

1. Location (domestic or foreign)
2. New or existing lines
3. Dedicated or shared
4. Commercial or traditionally defense
5. Government or contractor owned/operated (organic, commercial, or core)
6. Local environmental laws and regulations
7. Labor unions
8. Capacity utilization
9. Use of manufacturing development centers/pilot lines

9. **Manufacturing Planning, Scheduling, and Control Thread:** Requires an analysis of the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting Program goals for affordability and availability).

Key issues include:

1. Adequacy of the Manufacturing Strategy
2. Integration with the Acquisition Strategy
3. Maturity of the Manufacturing Plan
4. Integration with the Risk Management Plan
5. Scheduling tooling
6. Capital equipment installation and maintenance
7. Personnel
8. Deliveries (i.e.; materiel management)
9. Product flow and test equipment
10. Supply chain management

1.4 MANDATORY/STATUTORY REQUIREMENTS AND DOD POLICY GUIDANCE

DoD Directive (DoDD) 5000.1 specifies:

E.1.14 *Knowledge-Based Acquisition. Program Managers (PMs) shall provide knowledge about key aspects of a system at key points in the acquisition process. PMs shall reduce technology risk, demonstrate technologies in a relevant environment, and identify technology alternatives, prior to program initiation. They shall reduce integration risk and demonstrate product design prior to the design* *readiness review. They shall reduce manufacturing risk and demonstrate producibility prior to full-rate production.*

DODI 5000.2 specifies the requirements for assessing and demonstrating the manufacturing readiness of a system at various stages of its development. In addition to mandatory/statutory requirements, the DoD 5000.2 provides guidance on addressing manufacturing and production-related risks to a Program. These sections provide the acquisition manager with practical guidelines to implement the laws and policies relative to industrial capabilities. They also provide steps a manager should follow to effectively integrate defense industrial capabilities considerations into the acquisition process, and effectively employ industry in acquisition programs. Key intersects for production, quality, manufacturing, and industrial capabilities-related acquisition policy issues within DODI 5000.2 include:

3.4.2. Technology Opportunities
3.7.1.1. Purpose of the SDD Phase
3.7.4. Proceeding Beyond the Design Readiness Review
3.7.5. System Demonstration
3.8.2. Entrance Criteria
3.8.3. LRIP
3.8.4. Full-Rate Production Criteria
E5.1.5.10. DT&E
Table E3.T1. Statutory Information Requirements, Industrial Capabilities.

As part of the Acquisition Strategy, PMs shall perform an analysis of the capabilities of the National Technology and Industrial Base to support the design, development, sustained production, and uninterrupted maintenance of the system. Industrial Capabilities Assessments (ICAs) are mandatory requirements (at Milestones B and C). Specific contents of the ICA are outlined in the Defense Federal Acquisition Regulations Supplement (DFARS) 207.105 (b)(19), including:

> (1) The availability of essential raw materials, special alloys, composite materials, components, tooling, and production test equipment for the sustained production of systems fully capable of meeting performance objectives established for those systems; the uninterrupted maintenance and repair of such systems; and the sustained operation of such systems.
>
> (2) Consideration of requirements for efficient manufacture during the design and production of the systems to be procured under the program.
>
> (3) The use of advanced manufacturing technology, processes, and systems during the research and development phase and the production phase of the program.

The acquisition strategy needs to address the ability to cost effectively design, develop, produce, maintain, support, and restart the program. For applicable products:

— as defined by the Defense Planning Guidance — the acquisition strategy also needs to address the approach to making production rate and quantity changes in response to contingency support objectives. Analysis should address critical sub-tier, as well as prime, planning and infrastructure considerations. Overall industrial assessment elements should include:

(1) New and unique capabilities that must be developed or used to meet program needs. Identify DoD investments needed to create new industrial capabilities. This includes any new capability (e.g. skills, facilities, equipment, etc).

- Identify new manufacturing processes or tooling required for new technology. Funding profiles must provide for up front development of manufacturing process/tooling and verification that new components can be produced at production rates and target unit costs.

- Identify exceptions to FAR Part 45, which requires contractors to provide all property (equipment, etc) necessary to perform the contract.

(2) Program context in overall prime system and major subsystem level industry sector and market.

(3) Strategies to address any suppliers considered to be vulnerable.

(4) Risks of industry being unable to provide new program performance capabilities at planned cost and schedule.

(5) Alternations in program requirements or acquisition procedures that would allow increased use of non-developmental or commercial capabilities.

(6) Strategies dealing with product or component obsolescence, given DoD planned acquisition schedule and product life.

The Defense Acquisition Guidebook (DAG) provides policy guidance on production, quality, manufacturing, and industrial capabilities functional topics, as well as their integration with acquisition critical processes. A listing of these key intersects can be found in Table I-1:

Chapter	**Subject**
2.3.7.	Systems Engineering Plan
2.3.16.1.4.	Potential Sources
2.3.16.3.	Contract Approach
2.3.17.	Accounting Review
2.3.19.	Additional Acquisition Strategy Topics
3.1.4.	Implications of Evolutionary Acquisition
3.2.4.	Cost As an Independent Variable
3.7.4.2.	Assess Risk and Sensitivity
3.7.5.	System Demonstration

4.1.1.	Systems Engineering
4.1.5.	The Integrated Product and Process Development (IPPD) Framework and Systems Engineering
4.2.3.2.	Systems Engineering
4.2.3.6.	Risk Management
4.2.4.4.	Configuration Management
4.2.5.1.	Implementation
4.2.5.2.	The Use of Standards versus Capability and Maturity Models
4.3.3.	Capability Reviews
4.3.3.4.5.	System Development and Demonstration Phase
4.3.3.5.	Critical Design Review (CDR)
4.3.3.6.	Outputs of the Systems Engineering Process/Inputs to the DRR
4.3.3.8.4.	Purpose of Systems Engineering in System Demonstration
4.3.3.9.2.	Combined Developmental Test and Evaluation, Operational Test & Evaluation System Verification Review (SVR)
4.3.3.9.3.	Production Readiness Review (PRR)
4.3.3.9.4.	Technology Readiness Assessment (TRA)
4.3.4.1.	Purpose of Systems Engineering in Production and Deployment
4.3.4.4.3.	Physical Configuration Audit (PCA)
4.3.5.1.	Purpose of Systems Engineering in Operations and Support
4.4.4.	Software
4.4.6.	Manufacturing Capability
4.4.6.2.	Manufacturing Readiness Levels
4.4.7.	Quality
4.4.8.	Reliability, Availability, and Maintainability (RAM)
4.5.6.	Trade Studies
4.5.7.3.	Modeling and Simulation (M&S) in Systems Development and Demonstra-
4.5.7.4.	tion in Production and Development
5.2.1.5.	Continuous Technology Refreshment and Obsolescence
5.2.2.	Pre-Acquisition and Acquisition (Design for Support)
5.4.1.1.2.	Lower Control Limit (LCL) Considerations During Concept Refinement
5.4.2.1.	System Development and Demonstration leading to Milestone C
6.4.1.	Integrated Product and Process Development and Integrated Product Teams
6.4.5.2.	Technology Development and System Development and Demonstration
7.8.3.3.	Redesigning the Processes that the Acquisition Supports
8.4.4.1.	Risk Management in Systems Engineering
8.4.5.1	Critical Program Information (CPI)
9.3.	Developmental Test and Evaluation
9.9.5.	Test and Evaluation Management Plan (TEMP) Recommended Format
9.13.3.	Capability Production Document (CPD)
11.2.1.1.	International Considerations and Program Strategy
11.3.5.	Quality
11.5.	Knowledge-Based Acquisition
11.8.	Integrated Process and Product Development (IPPD)
11.13.	Simulation-Based Acquisition (SBA) and Modeling and Simulation (M&S)

1.5 THE OBJECTIVES OF DOD MANUFACTURING MANAGEMENT

The objectives of DoD manufacturing management are to:

1. Ensure that proper manufacturing planning has been accomplished early in a program so that the manufacturing effort will be performed smoothly.
2. Ensure that the system design will lead to efficient and economical quality manufacture.
3. Assess the status of the program at any point during the production/deployment phase to determine if schedule, costs, and quality standards are being met.
4. Conduct assessments and reviews of the manufacturing effort required to meet decision points at each phase of a defense systems acquisition program.

The overall objective of Manufacturing is to provide a uniform, defect-free product with consistent performance, and a lower cost in terms of both time and money.

Chapter 2
Manufacturing Readiness Levels and Their Application

2.1 Introduction

This chapter provides in-depth discussion of Manufacturing Readiness Levels (MRLs), their ties to Technology Readiness Levels, and ways to roll-up Manufacturing Readiness Assessments from lower level assessments of assemblies to a subsystem or component level. Acquisition managers can benefit from technology transition agreements or plans to quantify manufacturing risk in concert with technology readiness levels. MRLs are important to acquisition managers because they facilitate risk management tools that will assist meeting schedule, cost, and performance requirements.

Measures are also important for S&T managers for Science and Technology Objectives (STOs), ATOs (Army Technology Objectives), ACTDs (Advanced Concept Technology Demonstrations), and ATDs (Advanced Technology Demonstrations). The vision is for these Research & Development managers to use Manufacturing measures in their Technology Transition Agreements or Plans to manage the transition process from the producibility and manufacturability standpoint. S&T managers will have a basis for developing a more thorough technology transition by successfully identifying manufacturing risks.

Technology Readiness Levels (TRLs) provide a systematic metric/measurement system to assess the maturity of a particular technology. TRLs allow and the consistent comparison of maturity between different types of technology. The TRL approach has been used for many years in NASA and is the preferred approach for all new DoD programs. As part of the MRL assessment, the evaluator must determine the current TRL level of the entities within the work breakdown structure (WBS) to assure they have reached the proper maturity levels to meet MRL exit criteria. Their use has been primarily as a tool to assist in the tracking of technologies in development and transition into production. The nine TRLs are defined as follows:

- **TRL 1**: Basic principles observed and reported
- **TRL 2**: Technology concept or application formulated
- **TRL 3**: Experimental and analytical critical function and characteristic proof of concept
- **TRL 4**: Component or breadboard validation in a laboratory environment

- **TRL 5**: Component or breadboard validation in a relevant environment
- **TRL 6**: System or subsystem model or prototype demonstrated in a relevant environment
- **TRL 7**: System prototype demonstration in an operational environment
- **TRL 8**: Actual system completed and "flight qualified" through test and demonstration
- **TRL 9**: Actual system "flight proven" through successful mission operations.

Primary approaches to the implementation of MRLs for new technologies are found in the *Technology Readiness Assessment Guidebook*. This Acquisition Guidebook will expand the application of MRLs for acquisition system managers as well as S&T managers. Manufacturing Readiness Levels (MRLs), analogous to TRLs, are key measures that define risk as a technology or process is matured and transitioned to a system.

Technology Readiness Levels are used in conjunction with MRLs in Army Manufacturing Technology Objectives (MTOs). Within MTOs, TRLs track technical maturity of pacing and associated technologies, while MRLs track the production maturity of those technologies. Both the TRLs and MRLS assists in the determination of how close the technologies are to production, once transitioned to a weapon system.

2.2 MANUFACTURING READINESS LEVELS

MRLs operate within the Integrated Defense Acquisition, Technology, and Logistics Lifecycle Management Framework. There are ten (10) MRLs. These levels directly relate to the nine Technology Readiness Levels that are in use with an additional MRL 10 that is equal to a program in full rate production. The first three levels are discussed as a single level, which is equal to TRLs 1 through 3. Below are definitions of each MRL and a description of the criteria necessary to each level and the associated acquisition phase:

MRL 1-3

The organization has identified manufacturing concepts. This is the Pre-Concept Refinement phase. Identification of current manufacturing concepts or producibility needs has occurred and is based on laboratory studies.

MRL 4

The organization has validated the system, component, or item in laboratory environment. This is the lowest level of production readiness. The Concept Refinement (CR) phase leads to a Milestone A decision. Technologies must have matured to at least TRL 4. At this point few requirements have been validated and there are large numbers of engineering/design changes. The organization has not defined component physical and functional interfaces. Materials, machines and tooling have been demonstrated in a laboratory environment. Inspection and test equipment have been demonstrated in a laboratory environment. DTC & Production drivers identified. Producibility assessments have been initiated.

MRL 5

The organization has validated component or item in an initial relevant environment. Engineering application/bread board, brass board development is occurring. This is the first half of the Technology Development (TD) phase and merges with the second half when we begin system validation leading to a Milestone B decision. Technologies must have matured to at least TRL 5. At this point all requirements have not been validated and there are significant engineering/design changes. Industrial Base analysis has been accomplished to identify potential sources. Initial producibility of component technology has been completed. Form, Fit & Function constraints identified and allocated at component level. Key Performance Parameters allocated at component level and initial evaluation of Key Characteristics accomplished. Subsystem and major component level DTC goals established. Manufacturing cost considerations affect technology choices. Manufacturing cost drivers/goals identified. DTC/Production costs estimated and tracked. Required Manufacturing Technology (ManTech) efforts initiated. Yield/rate issues identified. Key Quality Characteristics identified. Science and Technology/ Special Test Equipment (ST/STE) requirements identified. Initial Manufacturing Plan is developed.

MRL 6

The organization has validated the system in an initial relevant environment. Engineering application/bread board, brass board development is occurring. This is the 2nd half of the Technology Development (TD) phase and leads to a Milestone B decision. Technologies must have matured to at least TRL 6. All requirements have not been validated and there are significant engineering/design changes. Component physical and functional interfaces have not been defined. Materials, machines and tooling have been demonstrated in a relevant environment but most manufacturing processes are in development (e.g. ManTech initiatives). Inspection/test equipment has been demonstrated in a laboratory environment. Producibility assessments are ongoing initial improvements begun. Production cost drivers and goals are being analyzed and set. DTC goals have been set.

MRL 7

The System, component or item is in advanced development. This is the System Development & Demonstration Phase (pre DRR). All technologies have matured to at least TRL 7. At this point engineering/design changes should be decreasing. Physical and functional interfaces should be clearly defined. All raw materials are in production and available to meet the planned LRIP schedule. Pilot line manufacturing processes have been set-up and are under test. Processes and procedures have been demonstrated in a production relevant environment. During this phase the producibility improvements should be underway. DTC estimates are within 125% of the DTC goals. Production estimates are being established.

MRL 8

The system is in System Development & Demonstration leading to a Milestone C decision. Component or item is in advanced development and ready for low rate initial production. Technologies must have matured to at least TRL 8. Engineering/design changes should be decreasing significantly. There must be very few changes at the end of this phase. Physical and functional interfaces should be clearly defined. All raw materials are in production and are available to meet the planned LRIP schedule. Manufacturing processes and procedures have been proven on the pilot line, under control and ready for low rate initial production. During this phase producibility risk assessments should be completed. The DTC goals should have been met. Production estimates meet production goals.

MRL 9

The system, component or item has been previously produced or is in production. Or, the system, component or item is in low rate initial production. This phase is Low Rate Production & Deployment leading to a Full Rate Production Decision (FRP). During low rate initial production all systems engineering/design requirements should be met and there should be minimal system engineering/design changes. Technologies must have matured to at least TRL 9. All materials are in production and available to meet planned production schedules. All manufacturing processes are established and controlled in production to three-sigma or some other appropriate quality level. Machines, tooling and inspection and test equipment deliver three-sigma or some other appropriate quality level in production. Production risk monitoring is ongoing. LRIP costs meet production goals.

MRL 10

The system, component or item previously produced or in production. Or, the system, component or item is in full rate production. This is the Full Rate Production or Sustainment phase. This is the highest level of production readiness. There are minimal engineering/design changes. System, component or item is in production or has been produced and meets all engineering, performance, quality and reliability requirements. All materials, manufacturing processes and procedures, inspection and test equipment, controlled in production to six-sigma or some other appropriate quality level in production. A proven, affordable product able to meet required schedule. Production goals meet actuals.

2.3 PROGRAM LEVEL MRLS

In addition to performance, other factors must be considered by an S&T manager with respect to transition of technology. While a technology demonstration project may meet its performance objectives, the transition of that system will require delivery of multiple units to the warfighter at an affordable cost. The application of MRLs by an acquisition program manager to reduce manufacturing risks of systems in development or nearing production will allow that PM to deliver the system on-time.

As a case example, the Program Manager Unit of Action (UA) has conducted roll-up of manufacturing risk assessments at the systems level. They used Engineering MRL (EMRL) definitions that were developed and published by the Missile Defense Agency (MDA). Attached is a figure that shows the EMRL rollup. The application of these roll-up EMRL measures can provide the program manger with a risk identification, which that PM was able to use to leverage ManTech investments to address pervasive manufacturing issues that reduced risk for those critical technologies.

2.4 SUBSYSTEM/COMPONENT ROLLUP

EMRLs can be used to assess risks within systems. A bottoms-up assessment of the relative manufacturing maturity of a technology against DoD Program goals and objectives must be accomplished at the sub-system level. As sub-systems are put together, their inter-relationship with other sub-systems will add up into an overall system MRL. Below that, component/subcomponent items can be evaluated using MRLs. Findings for lower lever components can be fit into a format for analysis and decision making at higher levels of the Program. Each MRL (at any level) should be identified at the appropriate risk level (i.e.; low, medium, or high). The MRL criteria can be used to evaluate the entire supply chain for manufacturing readiness and will provide insight into specific material risks. Figure 2-1 below provides a suggested format.

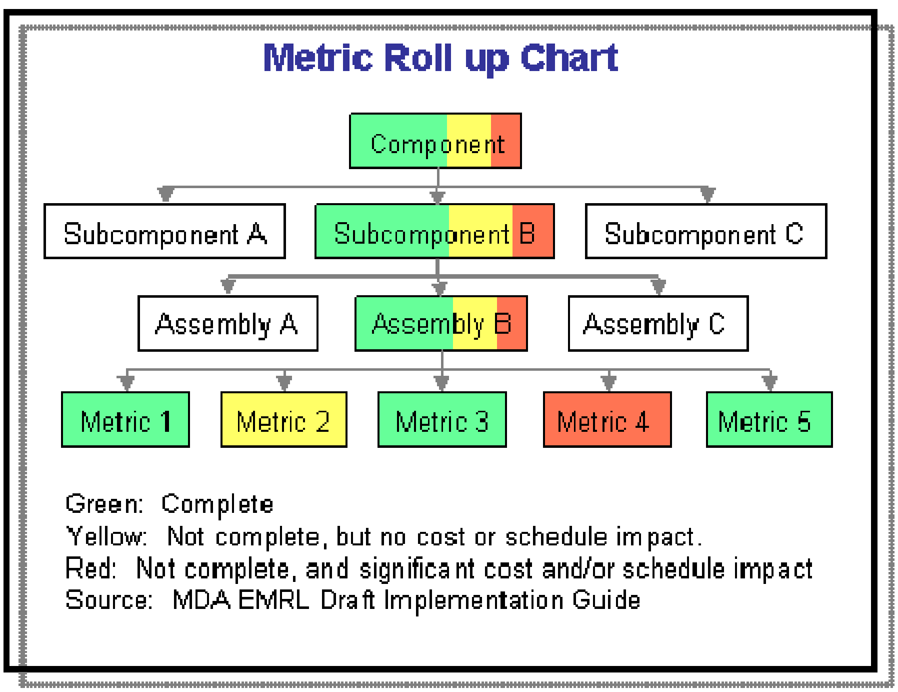


Figure 2-1

- During the second phase of MRL assessments, Program Management should assess the risks of lower-tier MRLs (i.e.; components and parts) for subsequent (i.e.; higher-order) risk mitigation efforts (Figure 2-1). Please note that there is no magic formula for rolling up the effects of components, assemblies, subsystems into one system-level metric. One of the options that make the most sense is to establish weighted guidelines to take into account the criticality of an emerging high risk technology. It is critically important to understand that a single high risk technology could be a program show stopper.

- For MRLs not meeting phase goals, a status should be developed and reviewed by Program Management, including:
  - System Element (i.e.; Component)
  - Problem (i.e.; baseline component yields and failure rates during testing)
  - Program Impacts (i.e.; Cost, Schedule, and Technical Risks)
  - Alternative Solutions (i.e.; technical, cost, schedule, or business). In Figure 2-2, you can see where the SEEKER program used the ManTech Program to help mature an immature technology.

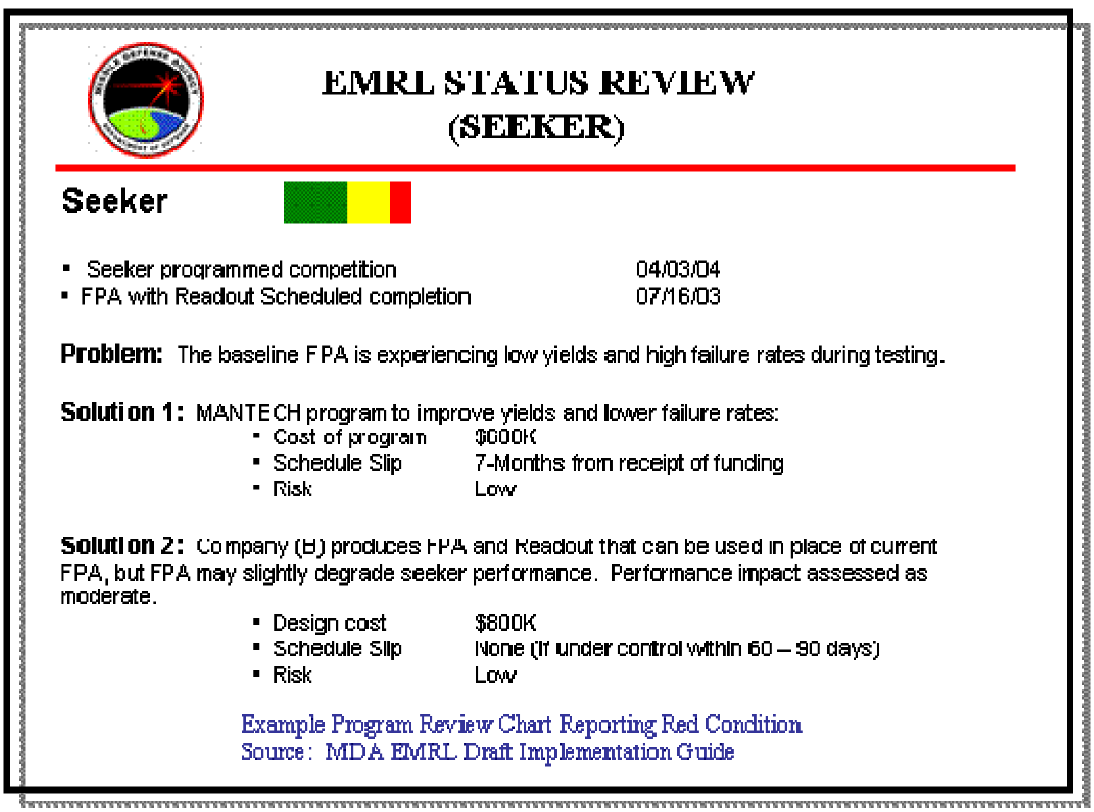


Figure 2-2

- This evaluation should consider Industrial Engineering and QA Manuals for that system

- ➢ As an example, PM. Unit of Action (PM UA) uses Manufacturing Readiness Levels to manage risk of technologies that have Army ManTech investments. The expectation of the PM is that ManTech will mature that technology to MRL level 8 as exit criteria for the MTO (Manufacturing Technology Objective). The U.S. Army Future Combat System (FCS) use of the TRL/EMRL evolution is depicted in Figure 2-3.

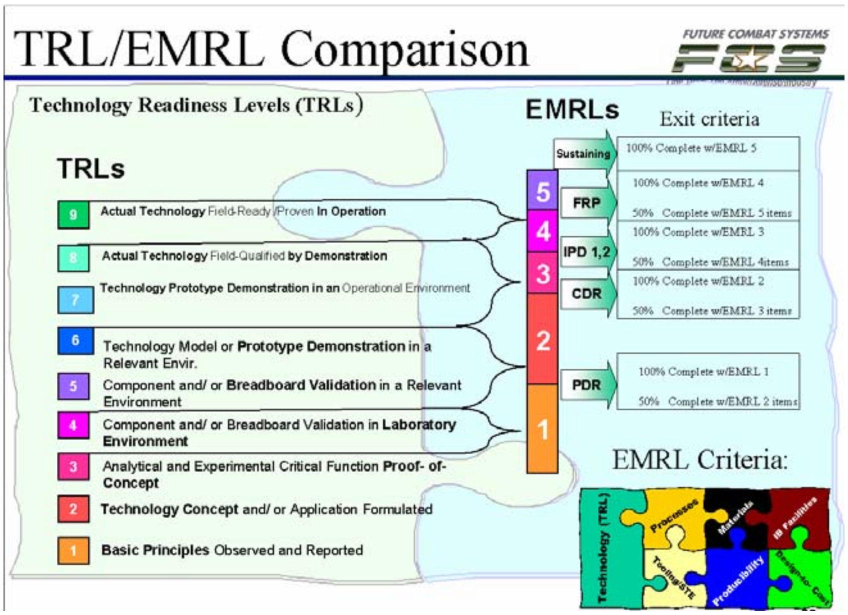


Figure 2-3

i) Program Sustainment MRL Applications

"After production" is the primary consideration for the MRL 10 application. At this point, the system is well into the "Life Cycle" but other factors need to be monitored to address the maintaining of a manufacturing capability. These factors include:

- Training
- Human Factors
- Disposal

ii) Manufacturing Management Exit/Entry Criteria

The central objective of the Manufacturing Readiness levels is to evaluate the risk of transition for technologies into defense systems based upon the maturity of manufacturing and production processes. This transition comes from Industry R&D programs, DoD S&T programs, and early acquisition phases such as technology development. Both DoD and industry acquisition program managers are charged with constructing a system design and development program, including an assessment of the risk in applying advanced technologies. This risk is based upon understanding the specific delivery of technologies from the S&T programs into the Acquisition program. One of the most critical elements of a successful technology transition is the matching of S&T program exit criteria and Acquisition program entrance criteria. The two communities of S&T and acquisition often do not possess enough of a common language to adequately describe this juncture. Measures such as TRLs and MRLs can be used to characterize the maturity of the technology and associated manufacturing processes. The scales for TRLs and MRLs are based upon demonstrated capabilities within development programs, and represent a small number of logistical steps. These metrics can be used as companion measures to establish both exit and entrance criteria.

However, there are other measures than are used within industry to evaluate the readiness of technologies and associated manufacturing processes. These include centrally defined measures such as unit cost and span time or mathematically defined Manufacturing Maturity Index. Since these measures are usually defined for use within a particular company, they can vary a great deal. However, the basic categories that are used to measure the maturity of manufacturing include:

- Step function of demonstrated performance (MRLs)
- Unit production cost and risk
- Estimated time for transition and risk
- Batch process descriptors
- Combination of Yield Rate, Cycle time, defect rate, cost, and process sigma

In each case, the measures are used within fairly controlled circumstances, such as a project or a company. Furthermore, the acceptable levels for transition are not standardized among the industry or among programs.

Two examples:

- Rockwell Collins MMI (presentation at DMC) Jim Lorenz
- Lockheed Martin's Unit Cost and Sigma. (Proprietary on detail)

However, the Department is seeking to establish a readiness measure that can be used across multiple companies and multiple programs. In this way, the manner of measurement and the acceptable level of maturity can be standardized so that an effective comparison of potential technologies can be made during system development.

The core tenet in the implementation of MRLs across DoD and industry is the standardization of the measurement scale and visibility into the assessment process. Since industry and DoD have been using different and sometimes separate processes to measure the manufacturing maturity, MRLs provide a common method of evaluating risks, and should be used in both DoD and industry seamlessly. The implementation cannot be of the nature that organizations continue to use their present, proprietary processes, and then "translate" the results into MRLs before a review. Each organization should transition to using the common definition of manufacturing risk and maturity assessment. This reduces both waste and errors in translation.

The Joint Defense Manufacturing Technology Panel (JDMTP) created the MRLs to be implemented across multiple technical domains, and so that they can be customized for a particular application. For instance, the factors for metal assembly will be different than an electronics factory, or a chemical batch process. However, while the particular measurement process is tailored, the scale and evaluation of risk is held constant by applying MRLs.

Program Managers can use MRLs throughout the risk management and mitigation process as defined within the DoD S&T and Acquisition process. In general, risks associated with performance, cost, and schedule are comprehensively listed, evaluated and a mitigation plan with multiple mid-term checks is developed. Use MRLs within the process to evaluate and check on progress. Use factors within the MRL descriptions and master matrix for entrance criteria for both acquisition phases and system increments.

Chapter 3
Manufacturing Readiness Planning and Tools

3.1 INTRODUCTION:

In this chapter we will discuss the:

- Current State of Manufacturing Readiness
- Risk Management and Management Oversight
- Manufacturing Readiness Assessments
- When to Assess

As the state-of-practice evolves, the ability to assess, identify and manage risks is directly tied to government and industry best practices and the availability of readily assessable tools to help you identify and manage risks. This chapter discusses the development and deployment of a Manufacturing Readiness Assessment tool.

3.2 CURRENT STATE OF MANUFACTURING READINESS:

In 2002 the GAO performed an analysis of several DoD Programs that were successful and not as successful in transitioning from the development phases of the acquisition process into production. Their findings were published in July 2002 in GAO Report 02-701. The findings are summarized below.

Critical elements in successful new product development programs:

1. Requirements are clearly defined / resourced.
2. Product's design is determined to be capable of meeting requirements.
3. Reliable product can be produced repeatedly within established cost, schedule and quality targets.
4. Increased costs, delays, and degradation are in performance / quality when products designed <u>without early manufacturing consideration.</u>
5. Timely manufacturing knowledge is critical to program success.
6. Knowledge that design can be manufactured affordably and with consistent high quality <u>prior to making a production decision</u> ensures cost and schedule targets met.

The GAO recommendation was for the SecDef to improve DoD's acquisition process by incorporating best practices to capture and use manufacturing knowledge as a basis for decisions to commit to system production.

In a follow-up study the subsequent year, the GAO again published findings critical of the transition into production process. Their findings were published in GAO Report 03-476, May 2003. Their findings are summarized below.

Knowledge-based approach can lead to better acquisition outcomes:

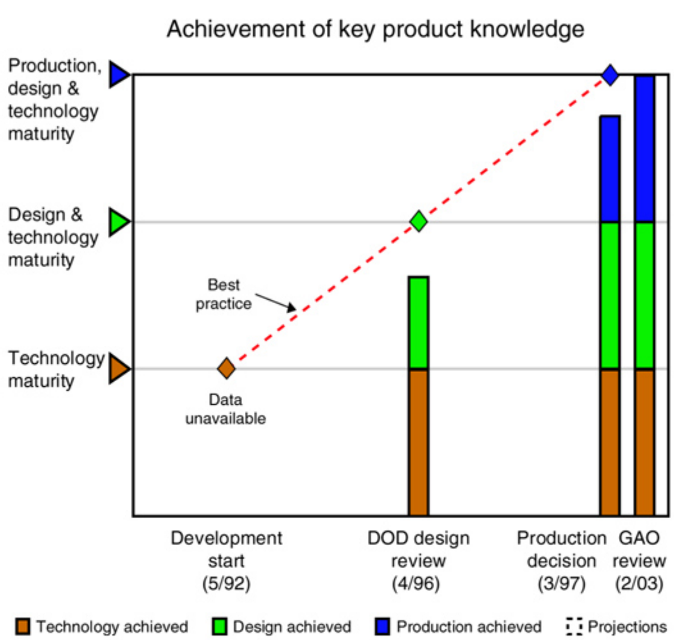
1. Resources and needs are matched.

2. The product design is stable

3. Production processes are mature

GAO reviewed 26 defense programs and had the following findings:

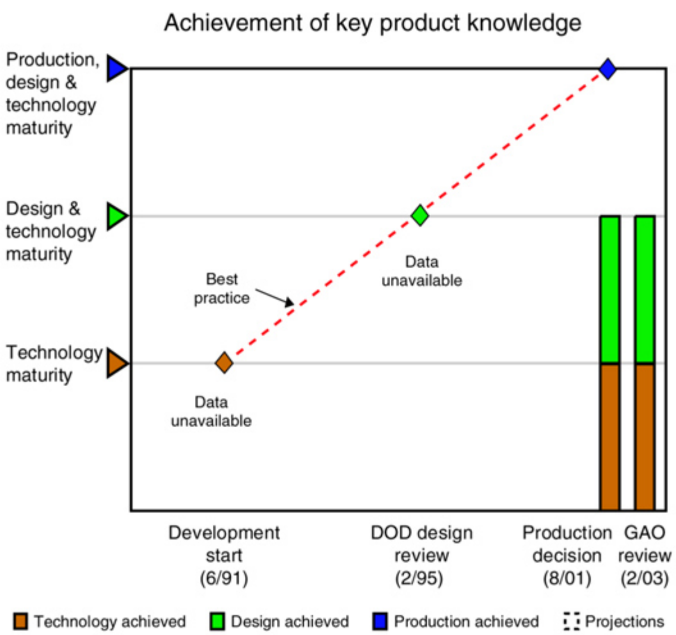
1. **F/A-18E/F**: Labor efficiency rates have steadily improved & aircraft delivered ahead of schedule because design and manufacturing knowledge attained early on.



The F/A-18E/F went into full-rate production in June 2000. Although the program proceeded without obtaining full product knowledge at key decision points, it embraced the concepts of attaining design and manufacturing knowledge early in development. The program released just over half of its engineering drawings by its design review. When low-rate production began, nearly all of the drawings were released and about 75 percent of the manufacturing processes were in control. The Navy reduced some program risk because aviation electronics from an earlier version of the F/A-18 were incorporated into the baseline F/A-18E/F. Furthermore, focus was placed on commonality between the F/A-18 C/D and the F/A-18 E/F, which further reduced risk.

Figure 3.1

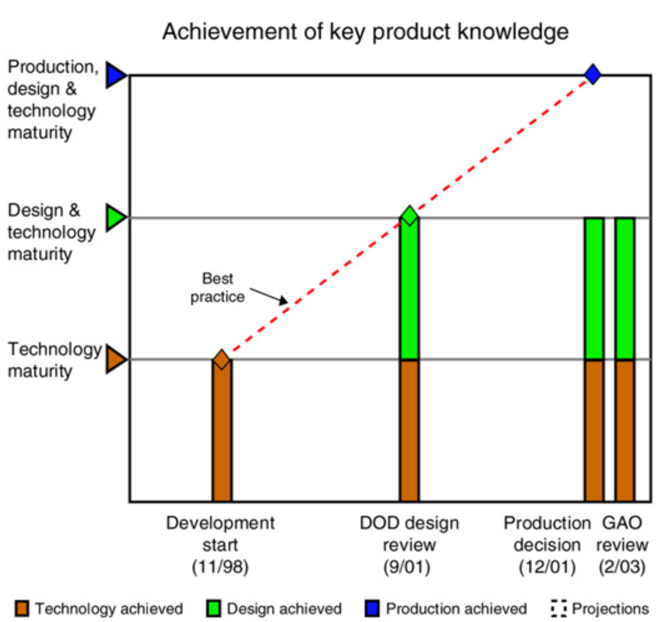
2. **F/A-22**: In September 2001, the Air Force acknowledged production cost increase of more than $5.4 billion over congressional cost limit because of delays in design and production knowledge. See Figure 3.2.



Because the F/A-22 Program Office stopped collecting process control data in 2000, the program began production in 2001 with no proof that processes were in control, as defined by best practice standards. Technology appears mature and the design appears stable; however, problems with the vertical tail and the avionics have been discovered recently, which require design modifications. Delays in capturing technology, design, and production knowledge and these latest problems contributed to cost increases and schedule delays. The potential exists for further cost increases and schedule delays as a significant amount of the test program remains, including operational tests. Also, the latest production cost estimate is likely to increase because of several factors, and the estimate assumes over $25 billion in offsets from cost reduction plans.

Figure 3.2

3. **JASSM**: The contractor will produce first LRIP lot on schedule because design was stable at critical points in development and production processes were demonstrated; However, key production processes that have cost implications will have to be addressed prior to FRP in order to achieve FRP capacity. See below.



The JASSM program entered production in December 2001 without ensuring that production processes were in control, according to best practice standards. However, program officials indicated that they have demonstrated the production processes and that they sample statistical data at the subsystem level. The program ensured that the technology was mature and that the design was stable at critical points in development, closely tracking best practice standards. Redesign remains one area of concern because recent test failures have led to the delay of operational tests. The program has identified fixes to the problems, and a retrofit plan is in progress. The contractor's ability to attain a higher production rate is another area of concern.

Figure 3.3

The GAO recommended establishing cost, schedule and quality targets for product manufacturing early on in order to obtain process maturity. In response to the GAO recommendations, the JDMTP developed MRLs and the associated threads.

So why use MRLs? Because…

- Current Technology Readiness Level (TRL) approach does not require prototype components to be producible, reliable, or affordable.
- Successful products require the capture of design and manufacturing knowledge early in product development.
- MRLs provide a more complete evaluation of a system by addressing producibility earlier in development.

What are MRLs? They are a tool that…..

- Evaluates "manufacturing readiness" of a product.
- Supplements existing TRLs.
- Assesses maturity of a technology's main manufacturing processes.
- Enables rapid, affordable transition to acquisition programs.
- Identifies potential risk areas.

3.3 Risk Management

Effective risk management depends on the knowledge gleaned from all aspects of the program. ***Knowledge reduces risk.*** Risk management is a principal factor in the renewed and increased emphasis on *demonstration* evident in DoD Instruction 5000.2.

Risk management in systems engineering examines the risks of deviating from the program plan. It examines all aspects of the program, from conception to disposal, early in the program and in relation to each other. Most risk management approaches have in common the practice of integrating design (performance) requirements with other Lifecycle issues such as manufacturing, operations, and support.

The concept of MRLs is founded in risk mitigation. The purpose of the MRL tool is to identify manufacturing/production risk. Identifying risk for the PM allows him to create a plan or options to remove/reduce the risk. The tool also allows others to see a program's manufacturing risk and to see what is being done about it. Identifying risk causes risk mitigation efforts making a program stronger and better able to move forward. Not pointing out risk or ignoring risk raises the specter of failure.

HOW DOES A PROGRAM MANAGER MANAGE RISK IN A TECHNOLOGY RISKY PROGRAM?

The program manager establishes a risk management process, including planning, assessment (identification and analysis), handling, and monitoring, to be integrated and continuously applied throughout the program, including, but not limited to, the design process. The risk management effort addresses:

- Risk planning.
- Risk assessment.
- Risk handling and mitigation strategies.
- Risk monitoring approaches.

Risk assessment includes identification and analysis of potential sources of risk to the program plan, including, but not limited to, cost, performance, and schedule risks based on such factors as:

- The technology being used and its related design
- Manufacturing capabilities
- Potential industry sources
- Test and support processes

The overall risk management effort interfaces with technology transition planning, including the establishment of transition criteria for such technologies.

More specifically, technology transfer risk management is a systematic methodology to identify, evaluate, rank, and control inadvertent technology transfer. It is based on a three-dimensional model: the *probability* of occurrence, the *consequence* if realized, and *countermeasure cost* to mitigate the occurrence. This is a key element of a program manager's executive decision-making - maintaining awareness of technology alternatives and their potential sensitivity while making trade-off assessments to translate desired capabilities into actionable engineering specifications. To successfully manage the risk of technology transfer, the program manager should:

- Identify contract vehicles which involve the transfer of sensitive data and technology to partner suppliers.
- Evaluate the risks that unfavorable export of certain technologies could pose for the program.
- Develop alternatives to mitigate those risks.

More information can be found in the *DoD Risk Management Guide.*

3.4 Program Decision Points

There are two types of decision points in DoD Acquisition: milestone decisions and decision reviews. Each decision point results in a decision to initiate, continue, advance, or terminate a project or program work effort or phase. The review associated with each decision point typically addresses program progress and risk, affordability, program trade-offs, acquisition strategy updates, and the development of exit criteria for the next phase or effort. The type and number of decision points should be tailored to program needs. The Milestone Decision Authority approves the program structure, including the type and number of decision points, as part of the acquisition strategy.

Milestones:

Milestone decision points initiate programs and authorize entry into the major acquisition process phases:

- Milestone A: Technology Development
- Milestone B: System Development and Demonstration
- Milestone C: Production and Deployment

The statutory and regulatory information requirements specified in DoD Instruction 5000.2 support milestone decisions.

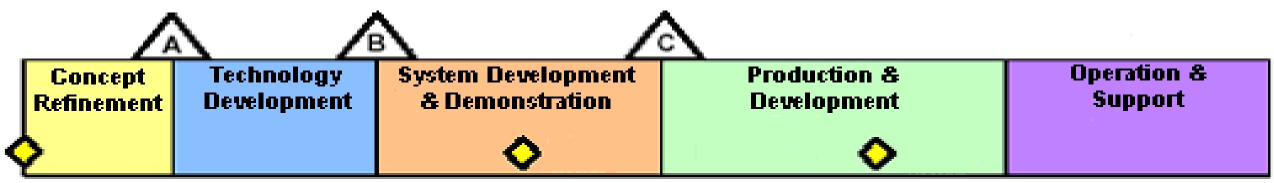


Figure 3.4

Reviews and Audits:

The *Defense Acquisition Guidebook*, Chapter 4.5.8 Summary of Technical Reviews, provides an excellent starting point for identifying some of the important reviews and audits that may be taking place on a program. Technical reviews and audits are an important oversight tool that program managers and other functional managers can use to review and evaluate the state of the program (system, subsystem or component), and then re-direct activity if risks are found. The commonly used reviews and audits accomplished on acquisition programs include:

- Initial Technical Review (ITR)
- Alternative Systems Review (ASR)

- System Requirements Review (SRR)
- System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Test Readiness Review (TRR)
- Production Readiness Review (PRR)
- System Verification Review (SVR)
- Operational Test Readiness Review (OTRR)

Decision reviews assess progress and authorize (or halt) further program activity. The Concept Decision authorizes Concept Refinement; the Design Readiness Review assesses program progress within the System Development and Demonstration phase; and the Full-Rate Production Decision Review occurs during the Production and Deployment phase.

The information required to support both milestone decision points and decision reviews should be tailored to support the review, but must be consistent with (and not exceed) the requirements specified in DoD Instruction 5000.2.

Many of these reviews and audits are also identified as activities within the Systems Engineering "Vee" Diagrams and provide opportunities for program and other managers to evaluate the state-of-manufacturing readiness using the Manufacturing Readiness Assessment process and tools.

3.5 Executive Reviews

The following paragraphs address DoD assessment reviews associated with major decision points.

Defense Acquisition Board Review:

The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)) is the Defense Acquisition Executive (DAE), and conducts Defense Acquisition Board reviews for Acquisition Category ID programs at major program milestones (and at the Full-Rate Production Decision Review if not delegated) and at other times, as necessary. Whenever possible, these reviews should take place in the context of the existing Integrated Product Team and acquisition milestone decision review processes. An Acquisition Decision Memorandum documents the decision(s) resulting from the review.

The Defense Acquisition Board advises the USD(AT&L)/DAE on critical acquisition decisions. The USD(AT&L) chairs the Defense Acquisition Board, and the Vice Chairman of the Joint Chiefs of Staff serves as co-chair. Defense Acquisition Board members are the following executives:

Under Secretary of Defense (Comptroller)	Under Secretary of Defense (Policy)	Under Secretary of Defense (Personnel & Readiness)
Under Secretary of Defense (Intelligence)	Assistant Secretary of Defense for Networks and Information Integration/DoD Chief Information Officer	Director, Operational Test & Evaluation
Chairman, Program Analysis and Evaluation	Secretaries of the Army, the Navy, and the Air Force	Director, Acquisition Resources & Analysis (as the DAB Executive Secretary)

The Defense Acquisition Board advisors include:

Principal Deputy USD(AT&L);	Deputy Under Secretary of Defense (Logistics & Material Readiness)	Director, Defense Research & Engineering
Relevant OIPT Leader(s)	Program Executive Officer	Program Manager
Chairmen, Cost Analysis Improvement Group	Director, Defense Procurement and Acquisition Policy	DoD General Counsel
Deputy Under Secretary of Defense (Industrial Policy)	DoD Component Acquisition Executives	Commander, United States Joint Forces Command
Chair, Functional Capabilities Board(s)		

The USD(AT&L)/DAE may ask other department officials to participate in reviews, as required.

ROLE OF INTEGRATED PRODUCT TEAMS (IPTS):

Defense acquisition works best when all of the DoD Components work together. Cooperation and empowerment are essential to program success. Per DoD Directive 5000.1, the Department's acquisition community shall implement the concepts of Integrated Product and Process Development (IPPD) and IPTs as extensively as possible.(*See Rules of the Road: A Guide for Leading Successful Integrated Product Teams*)

IPTs are an integral part of the Defense acquisition oversight and review process. For Acquisition Category ID and IAM programs, there are generally two levels of IPT: the Overarching Integrated Product Team and the Working-level Integrated Product Team(s). Each program should have an OIPT and at least one WIPT. WIPTs should focus on a particular topic such as cost/performance, test, or contracting. An Integrating Integrated Product Team (IIPT), which is itself a WIPT, should coordinate WIPT efforts and cover all topics not otherwise assigned to another IPT. IPT participation is the primary way for any organization to participate in the acquisition program.

ROLE OF EXIT CRITERIA:

Milestone Decision Authorities should use exit criteria, when appropriate, to establish goals for Acquisition Category I and Acquisition Category IA programs during an acquisition phase. At each milestone decision point and at each decision review, the program manager, in collaboration with the IPT, will develop and propose exit criteria appropriate to the next phase or effort of the program. The OIPT will review the proposed exit criteria and make a recommendation to the Milestone Decision Authority. Exit criteria approved by the Milestone Decision Authority will be published in the ADM.

The MRL concept extensively uses exit criteria. The MRL Matrix is essentially a matrix of exit criteria for each manufacturing thread and sub-thread at each MRL and acquisition phase. To leave one MRL or phase for the next the exit criteria associated with that MRL or phase should be completed. If it is not completed (if you cannot answer "yes" to the criteria) you have identified manufacturing or program risk that needs to be resolved. Answering "yes" to the MRL exit criteria will go along way to answering the DAB and other review questions and move the program forward.

System-specific exit criteria normally track progress in important technical, schedule, or management risk areas. Unless waived, or modified by the Milestone Decision Authority, exit criteria must be substantially satisfied for the program to continue with additional activities within an acquisition phase or to proceed into the next acquisition phase (depending on the decision with which they are associated). Exit criteria should not be part of the APB and are not intended to repeat or replace APB requirements or the phase-specific entrance criteria specified in DoD Instruction 5000.2. They should not cause program deviations. Status of approved exit criteria will be reported in the Defense Acquisition Executive Summary.

3.6 MANUFACTURING READINESS ASSESSMENTS

Manufacturing Readiness Levels (MRLs) are outlined in Chapter 2. Now we will identify tools and resources that you can use to help you assess the manufacturing maturity of your program, sub-system, component or technology.

DoD acquisition policy does not require the capture of design and manufacturing knowledge or sufficiently specify criteria/metrics to enter System Development and Demonstration, or Production and Deployment phases. MRLs provide the baseline metrics for identifying a manufacturing maturity level. The JDMTP has developed Manufacturing Readiness Assessments (MRAs) that provide a framework with specific criteria and metrics to capture the design and manufacturing knowledge for system development, demonstration, production and deployment.

The MRA is a new program management tool developed by and for Manufacturing Personnel to assess the maturity of acquisition and development programs. The process for conducting these assessments is new and therefore guidance is required (see Chapter 6 for more information). The approach outlined in this document will allow program managers and other managers to evaluate the production readiness of the product and process technologies (hardware and software) that they are developing and producing under their management. The MRAs will provide a systematic measurement metrics that supports assessments of the system engineering process, design maturity, and production processes that are critical to success.

RPOSE:

The purpose of this section is to introduce Manufacturing Readiness Assessment (MRA) and outline the steps necessary to use this new program management tool for assessing the maturity of and identification of potential risk areas to the Department of Defense (DoD) Programs and Technologies. This document describes the methodology for accomplishing a program assessment and reporting a program's MRL status during Milestone Reviews and other reviews. The purpose of these assessments is not to stop a program from moving through the acquisition process but to identify manufacturing risk and deal with the risk before it becomes a problem.

TRODUCTION:

The Joint Directors Manufacturing Technology Panel (JDMTP) directed the development and implementation of MRLs and MRAs to assess the maturity of DoD development programs and to report "readiness for production" in a standard format throughout the acquisition cycle. This tool is designed as a program management aid and is applicable at all levels of the Work Breakdown Structure (WBS). The MRA metrics developed are derived from the Acquisition Program Best Practices. When applied, MRAs will aid the program manager in developing a logical roadmap allowing the transition of a technology development program into a program that is ready to transition into production. A manufacturing readiness assessment evaluates both the level of technology development and maturity, as well as, the level of product and process development and maturity. The application of the assessment process will help to facilitate an end result of producible, affordable products.

MRAs operate within the Integrated Defense Acquisition, Technology, and Logistics Lifecycle Management Framework. There are ten (10) MRLs. These levels directly relate to the nine Technology Readiness Levels that are in use with an additional MRL 10 that is equal to a program in full rate production. The first three levels are discussed as a single level which is equal to TRL 1 through 3. The JDMTP has also developed assessment questions for MRLs 4-10. These assessment questions provide for assessments at three different levels of the organization:

1. Program Executive Officer (PEO)
2. Program Manager (PM)
3. Manufacturing/QA Director

The Executive-level questions are very top level but pointed. They ask one or two questions per thread. For example, the PEO may ask "Has the industrial base supporting this effort been characterized?" In order to answer that question, the Program Manager may need to ask three or four questions:

1. Have the potential contractors, subcontractors, and suppliers been identified?
2. Are they foreign or domestic sources?
3. Are they sole source or is this competitive?

Then the next level manager (often the Director of Manufacturing/QA on that program) may need to ask 6-10 questions in order to be able to say "yes" to the Program Managers questions.

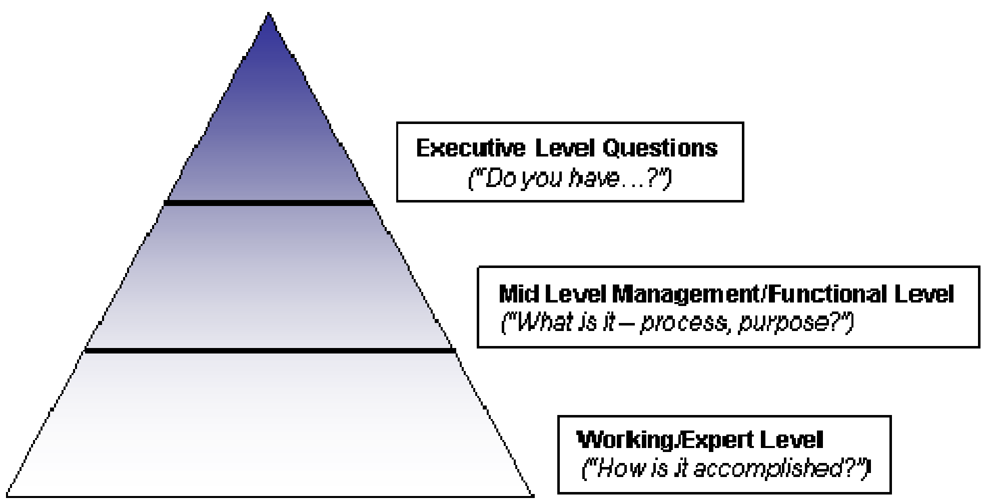


Figure 3.5

3.7 IDENTIFYING MANUFACTURING RISKS.

The MRL concept defines readiness using manufacturing threads which transcend each of the levels. Chapter 1 has in-depth description of the criteria for each thread. These nine threads contain progressively more refined criteria at each level and describe what we mean by readiness at each MRL. The nine threads are:

1. Technology & the Industrial Base
2. Design
3. Materials
4. Cost & Funding
5. Process Capability and Control
6. Quality Management
7. Manufacturing Personnel
8. Facilities
9. Manufacturing Planning

Under many of the threads are sub-threads that also can be used to describe the different levels. As an example, under the thread **Materials** the sub-threads are: Maturity, Availability, Sources, Materials Planning, and Special Handling. Appendix x contains a table of the relationship of MRLs, Threads/Sub-Threads, TRLs and the various criteria/descriptions.

For each thread or sub-thread, 24 in total, there are a series of questions that can be asked at each level to assess manufacturing readiness. The questions are stated such that the "proper" answer is a "yes". If the answer is "no" it would indicate that for the thread or sub-thread associated is a risk that the system, sub-system, component, or part is not at the ascribed MRL.

As an example for the thread "Design", sub-thread "Key Characteristics" at "MRL 6", there is a question about whether the tolerances have been established for key characteristics. If you have established the tolerances then the answer is “yes” so for that particular point there is no associated manufacturing risk. If the response is “no” it would indicate a level of risk. Identifying a level of risk is not in itself bad. It indicates a potential problem. If you know that this is a problem area and have been working to fix or have a risk mitigation process in place, you can alleviate the risk and you could still be at an MRL 6. But the no answer would be visible at a milestone review and would need to be explained.

Technology Readiness Levels (TRL) provides a systematic metric/measurement system to assess the maturity of a particular technology. TRLs allow and the consistent comparison of maturity between different types of technology. The TRL approach has been used for many years in NASA space technology planning and is the preferred approach for all new DoD programs. As part of the MRL assessment the evaluator must determine the current TRL level of the entities within the WBS to assure they have reached the proper maturity levels to meet MRL exit criteria requirements. Use of TRLs is explained in the TRL Deskbook.

MRLs will help a Program Manager in two distinct ways.

1. Provide a standardized method for assessing a program’s manufacturing maturity.

2. Provide a standardized method for reporting on a program's manufacturing maturity during Program Reviews and Milestone Reviews.

The MRL tool relates to both of these areas. The tool contains a network hundreds of questions that relate to the various threads/sub-threads and MRLs. For a single MRL the list of questions is around 700 in total. There are approximately 30 possible questions at each of the thread levels. Of these 30 questions approximately 1/2 would be discarded as not applicable . Of the 15 questions that are left some are at the lowest level of specificity and some are at a much higher level.

As an example, MRL 7 at the Process Capability and Control Thread starts with a high level executive type question that could be asked during a Milestone Review.

- Does the Program have a Variation and Variability Reduction Plan?

To be able to effectively answer that executive level question, a PM might want to have asked the following mid level questions.

- Have all critical manufacturing processes been characterized in a factory environment?
- Have key characteristics and process capability indexes been documented?
- Have initial Sigma levels and variation/variability efforts been documented?
- Have yield improvements been initiated as necessary?
- Will yield data be gathered on the pilot line build?

To be able to answer the PM level questions above, the Manufacturing Managers on a program would want to ask the following questions.

- Have initial production line simulation models been developed?
- Will simulation models be used to determine bottlenecks and improve processes?
- Have analyses of assembly methods been performed in a relevant manufacturing environment?
- Will all assembly methods be developed, documented and verified on the pilot line?

- Have process requirements been proven and validated in a relevant manufacturing environment?
- Have required Manufacturing Technology initiatives been developed?
- Has the plan been completed to implement tooling?
- Will the pilot line be developed and proven out using hard tooling?
- Has the automated STE implementation plan been completed?
- Will the pilot line be developed and proven out with STE?

A "no" answer to any of the above questions would point out a manufacturing risk and require further explanation.

MRLs will aid managers in identifying potential risk areas as a program progresses through development. From this risk identification, the program manager can formulate and execute mitigation plans before the risks become showstoppers.

3.8 HOW DOES IT WORK?

Based on your program schedule, determine what acquisition phase you are in and MRL level you should be at. If you are getting ready for a Milestone B you should be working on achieving the MRL 5 criteria. If you are getting ready for a Milestone C Review you should be working on MRL 8 criteria.

MRL questions can be found in two locations. To access a paper-based version go to https://acc.dau.mil/CommunityBrowser.aspx?id=18231 . To access a web-based version go to the MRL Assist tool at https://www.mrlassist.bmpcoe.org/mrlassist/ .

The questions are broken down to level 1 questions for the decision makers, level 2 questions for intermediate or program level reviewers, and level 3 questions for functional managers and subject matter experts.

The questions are structured such that a yes answer is appropriate for a typical program at that point in the acquisition schedule. You may need to tailor the questions to your particular program. Some questions will be not applicable. Some questions will need to be modified if you use specialized terminology in your program. Some questions may need to be prioritized. The typical list of questions starts with the higher level or more important questions. Those questions will have a higher priority or rating. If these ratings are not appropriate for your program, you need to change the ratings. After you have tailored the questions/tool and everyone within the program office is satisfied those questions, the tool is ready for use. This includes satisfying the second level of managers who would use the level 2 questions. You don't want to tailor out a level 3 question that is necessary to answer a level 2 question later on.

After you have tailored and rated the questions, select someone to serve as the keeper of the final version to ensure multiple documents don't create a problem later on. Divide the list of questions into the thread categories and send out to various persons within your program office who have the appropriate expertise.

The questions get asked or answered and necessary documentation is gathered and attached to the questions. For example, in accordance with question 5 above, just saying that: "Yes, process requirements been proven and validated in a relevant manufacturing environment." Is not enough without some documentation that shows what process requirements have been proven and how many of the process requirements have not been proven vice have been proven. Documentation should be attached to the question to show that a yes answer is appropriate.

The questions, answers and documentation would be gathered up by threads and passed back to the keeper of the final version who would incorporate all questions and threads into a final report. This report would go forward to the next level and to the final reviewers.

One final note: The homepage for the MRL Assist Tool looks like the following graphic.

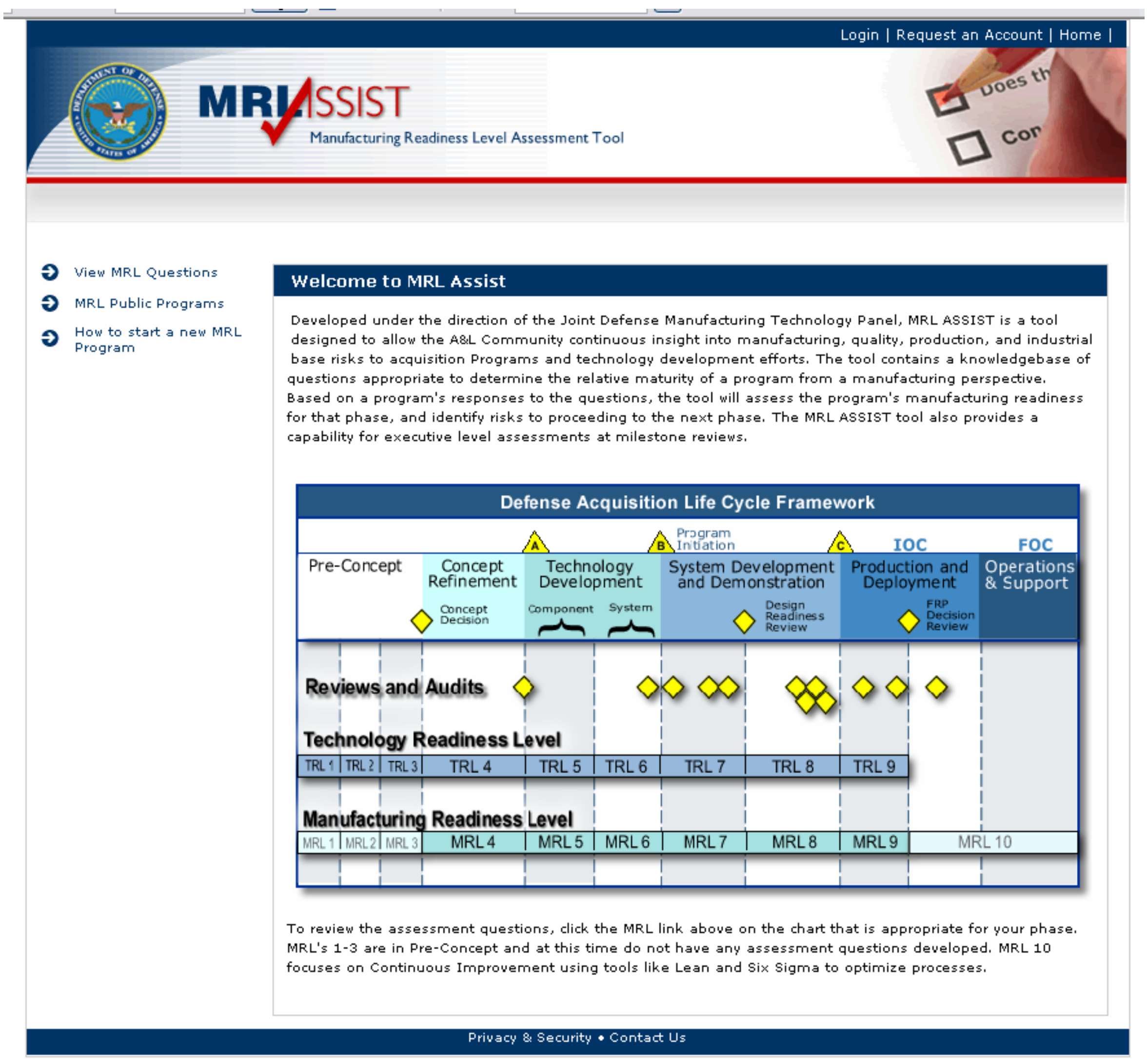


Figure 3.5

3.9 When Should You Assess?

Based on your program schedule determine what acquisition phase you should be in. Then look at the Integrated Framework Chart and the Vee Diagrams and determine if any reviews, audits or trade studies are scheduled to be completed. Any event or activity could be used to plan for and conduct an assessment. The following are a few of these opportunities:

ASR: Alternative Systems Review

SRR: System Requirements Review

SFR: System Functional Review

PDR: Preliminary Design Review

CDR: Critical Design Review

TRR: Test Readiness Review

PRR: Production Readiness Review

SVR: System Verification Review

OTRR: Operational Test Readiness Review

Once you have identified risks at any of these points, you should then identify ways to mitigate those risks using one of the programs that facilitate manufacturing readiness (see Chapter 4).

Chapter 4
Programs That Facilitate Manufacturing Readiness

4.1 INTRODUCTION

Transitioning technology so that it facilitates both technology readiness and manufacturing readiness does not come naturally and can be very difficult to accomplish. To transition technology and mature manufacturing successfully requires positive actions by people interacting throughout the system. A marketplace for the technology and manufacturing processes and appropriate applications for those technologies and processes is a necessary ingredient draw interest in investing in technology and manufacturing transition programs. The following programs were specifically designed to assist the community with developing new technologies and maturing the manufacturing processes that could lead to a successful program. In some cases, the programs offer another source of funds, in addition to the specific program that supports manufacturing readiness. These following programs will be discussed in greater detail:

- Advanced Technology Demonstrations (ATDs)
- Advanced Concept Technology Demonstration Program (ACTDs)
- Defense Acquisition Challenge Program
- Defense Production Act Title III Program
- Dual-Use Science and Technology Program (DUST)
- Joint Experimentation Program
- Manufacturing Technology Program (ManTech)
- Quick Reaction Special Projects
- Small Business Innovation Research Program (SBIR)
- Small Business Technology Transfer Program (STTR)
- Technology Transition Initiative
- Value Engineering (VE)

4.2 Advanced Technology Demonstrations (ATDs)

What is it?

An ATD is a process for managing selected high-priority S&T programs. ATDs are reviewed and approved by the services, and funded with service S&T funds. ATDs are intended to evolve and demonstrate new technologies. Technology development benefits when the communities work as a team, beginning early in the process. This could include the S&T, Acquisition and Operations communities. ATDs are a process for managing S&T programs that brings the team together early, and demonstrates a military capability in either:

- Joint warfighting experiment
- Battle lab experiment
- Demonstration
- Field test, or simulation

What is the value?

ATDs are used to accelerate the maturation of technology needed by warfighters for either next-generation systems or upgrades to existing legacy systems. ATDs use the IPPD process to ensure collaboration between the communities—S&T, requirements/warfighter, R&D, Test and Evaluation (T&E), sustainment, and industry resulting in early interaction and exchange between the communities, permit experimenting with technology-driven operational issues, weed out unattainable technologies as early as possible, and result in more focused requirements and capability documents.

ATDs require planning, review, and approval at the service or agency level. ATDs have a finite program duration, agreed-upon exit criteria, and typically require transition plans. Accordingly, ATDs require technologies and manufacturing processes that are mature enough to provide a capability that can be used or demonstrated during the demonstration period. Services and agencies must provide full funding for ATDs because no source of external funding exists for this process. Most ATDs are funded with 6.3 funds, respond to high-priority user needs, and have a funded target program. ATDs also are reviewed to ensure that they do not duplicate other programs.

The ATD team evaluates technical feasibility, affordability, and compliance with operational and technical architectures, operation and support issues, and user needs as early as possible. This fully integrated approach and focus on operationally-sound capabilities ensures that militarily significant capabilities can be developed, evaluated, and transitioned to the warfighter rapidly.

Success Story:

Program Solution: Multi-Function Staring Sensor Suite
Contract: 48 month ATD
PO: US Army CECOM, Night Vision & Electronic Sensors Directorate
User: Fort Knox
Prime: Raytheon Electronic Systems
Goal: Demonstrate an increased resolution and identify performance of mid-wave staring technology in a field environment.
Success: Achieve a TRL 6 in 2004

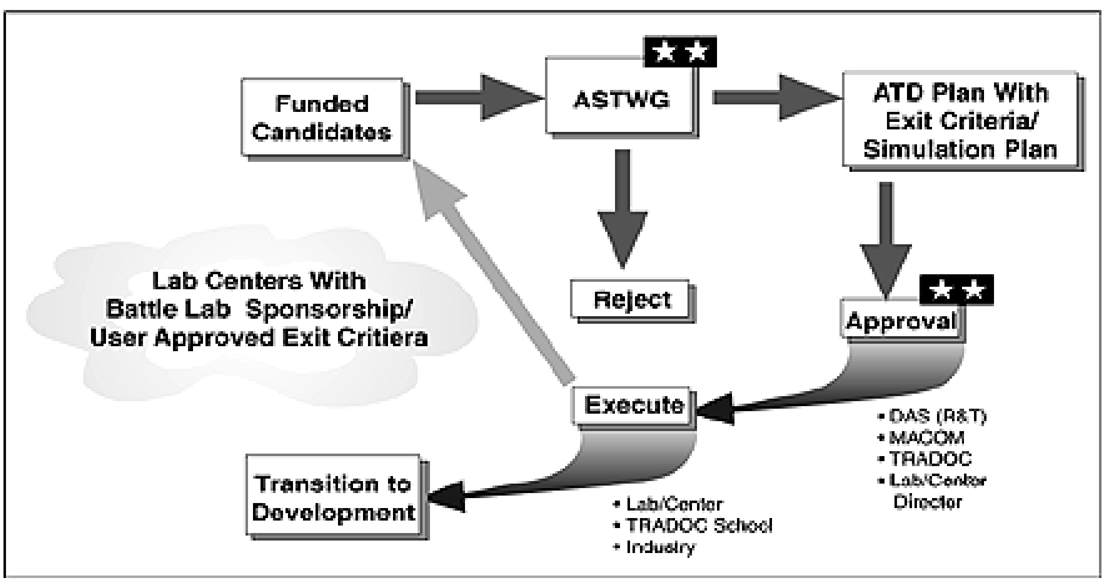
How do I participate?

Services and agencies have processes for nominating and approving ATDs (see Army Process below) and have plans for managing ATDs. In general, the senior research and technology manager in the organization manages ATDs. Typical requirements for participating in the program are the following:

- A concept that addresses established S&T objectives, and could provide a significant new or enhanced military capability or more cost-effective approach to providing the capability.

- A fully planned and funded program which has a limited duration (usually less than 5 years, with shorter durations being better).

- Exit criteria and a transition plan that is supported by the user representative and the systems developer.



Army ATD Process (Figure 4.1)

4.3 ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION PROGRAM (ACTDS)

What is it?

A program designed to help expedite the transition of mature or nearly mature technologies from the developers to the users. The ACTD program was developed to help adapt the DoD acquisition process to today's economic and threat environments. ACTDs emphasize assessing, maturing, and integrating technology rather than developing it. The goal is to give the warfighter a prototype capability and to support the warfighter in evaluating the capability. These capabilities must be affordable, interoperable, sustainable, and capable of being evolved at the technologies and threats change. The evolutionary acquisition approach is an integral part of the ACTD concept. The warfighters evaluate the capabilities in real military exercises and at a scale sufficient to fully assess military usefulness.

What is the value?

ACTDs are designed to enable users to understand the proposed new capabilities for which there is no user experience by giving the warfighter opportunities to:

- Develop and refine the warfighter's concept of operations to fully exploit the capability of the technology being evaluated.
- Evolve the warfighter's operational requirements as the warfighter gains experience and understanding of the capability.
- Operate militarily useful quantities of prototype systems in realistic military demonstrations and, on that basis, assess the military usefulness of the proposed capability.

There are three possible outcomes. (1) The user sponsor may recommend acquiring the technology and fielding the residual capability that remains after the demonstration phase of the ACTD to provide an interim and limited operational capability; (2) The project is terminated or returned to the technology base if the capability or system does not demonstrate military usefulness;. (3) The user's need is fully satisfied by fielding the capability that remains when the ACTD is concluded, and no additional units need to be acquired.

There are several major differences between ACTDs and ATDs. ACTDs are programs, usually employing multiple technologies, which are reviewed by Office of the Secretary of Defense (OSD) and the Joint Requirements Oversight Council (JROC), and funded (in part) with OSD ACTD funds. An ATD is actually a process for managing selected high-priority S&T programs. ATDs are reviewed and approved by the services, and funded with service S&T funds.

ACTDs should work with relatively mature technologies to improve the probability of success and the likelihood of transitioning the technology into programs. A recent GAO report addresses this and other factors affecting ACTDs' success.[2] This GAO report concludes that the OSD can improve ACTD outcomes, while noting that the majority of the ACTDs examined did transition some technologies to the user. The GAO found that:

- Some technology was too immature to be effectively demonstrated in the hands of the warfighter, leading to cancellations of demonstrations.
- Services did not provide follow-on funding for some successful ACTD technologies;
- Military utility assessments required in ACTDs have not been conducted consistently.

ACTDs should consider manufacturing and sustainment issues as a part of their program. Historically, manufacturing and sustainment issues have not received a high priority in ACTDs. The long-term success of ACTD initiatives can be improved by considering all of the manufacturing, sustainment, and operational and support issues.

Success Story:

Problem: The U.S. Transportation Command (USTRANSCOM) was activated at Scott AFB in 1987 to manage the Defense Transportation System efficiently and effectively and needed to optimize its' decision-making across the entire transportation system and provide asset visibility using commercial technologies.
Program Solution: Agile Transportation for the 21st Century
PMO: USTRANSCOM/DISA
Users: Transportation Offices
Prime: Northrop Grumman (others)
Goal: Demonstrate the ability to enable USTRANSCOM to efficiently and effectively manage transportation assets and resources to support the war fighting commander in parallel and continuous operations.
Success: In progress.

How do I participate?

The Deputy Under Secretary of Defense for Advanced Systems and Concepts (DUSD [AS&C]) is responsible for selecting and approving ACTDs. Ideally, a user-developer team, having combined a critical operational need with maturing technology, will develop an ACTD candidate for consideration. The Advanced Systems and Concepts (AS&C) staff is available to assist the team with develop-

[2] GAO Report GAO-03-52, *Defense Acquisitions: Factors Affecting Outcomes of Advanced Concept Technology Demonstrations*, December 2, 2002.

ing and refining the concept and clarifying the ACTD's basic criteria and attributes. When the details of the concept are defined, a briefing is presented to the DUSD (AS&C). If accepted, a briefing is presented to an advisory group of senior acquisition and operational executives, for their review and assessment. The candidate ACTDs then are presented to the Joint Staff, through the Joint Warfare Capabilities Assessment and the Joint Requirements Oversight Council, for their review and recommended priority. Based on these assessments, the DUSD (AS&C) makes the final funding decisions about the ACTDs.

According to an October 30, 2001 memorandum from the DUSD (AS&C), "*ACTD proposals should address the Department's most pressing and urgent military issues. Additionally, they should support the Department's transformation goals and objectives. All proposals should begin with a statement of the problem they intend to solve and the proposed capabilities addressing this problem.*"[3]

Additional Information/Contacts:

The ACTD website at http://www.acq.osd.mil/actd/ is another source of information about ACTDs.

4.4 Defense Acquisition Challenge Program

What is it?

The Defense Acquisition Challenge Program is required by the FY03 National Defense Authorization Act.[4] The Secretary of Defense, acting through the Under Secretary of Defense (Acquisition, Technology, and Logistics) USD (AT&L), will establish a program for providing opportunities for increasing the introduction of innovative and cost-saving technology in DoD's acquisition programs.

What is the value?

The Defense Acquisition Challenge Program will give people or organizations inside or outside DoD the opportunity to propose alternatives, known as challenge proposals, at the component, subsystem, or system level of an existing DoD acquisition program. Challenge alternatives should improve the performance, affordability, manufacturability, or operational capability of the program. The challenge proposal will be evaluated to determine whether the proposal:

- Has merit; and is likely to improve performance, affordability, manufacturability, or operational capability at the component, subsystem, or system level of an acquisition program.

[3] DUSD(AS&C), "Fiscal Year 2003 Advanced Concept Technology Demonstration (ACTD) Proposals," Office of the Under Secretary of Defense, October 30, 2001.

[4] See the Defense Acquisition Challenge Program, Section 243, National Defense Authorization Act for FY 2003.

- Could be implemented in the acquisition program rapidly, at an acceptable cost, and without unacceptable disruption to the program.

The OSD Defense Acquisition Challenge Program (DACP) provides oversight and funds to the Military Services for the Test and Evaluation of technologies that have potential to meet the Services requirements.

Success Story:

Problem: M249 Squad Automatic Weapon (Light Machine Gun) wear-out
Program Solution: Apply a Nickel Boron coating to produce a lubrication-free version
PMO: US Army Picatinny Arsenal
Prime: Universal Chemical Technology Defense
Goal: Extended useful life, increased reliability and reduced maintenance
Success: Potential O&S cost savings of $1.39M annually

How do I participate?

Defense Acquisition Challenge Program Legislated Process

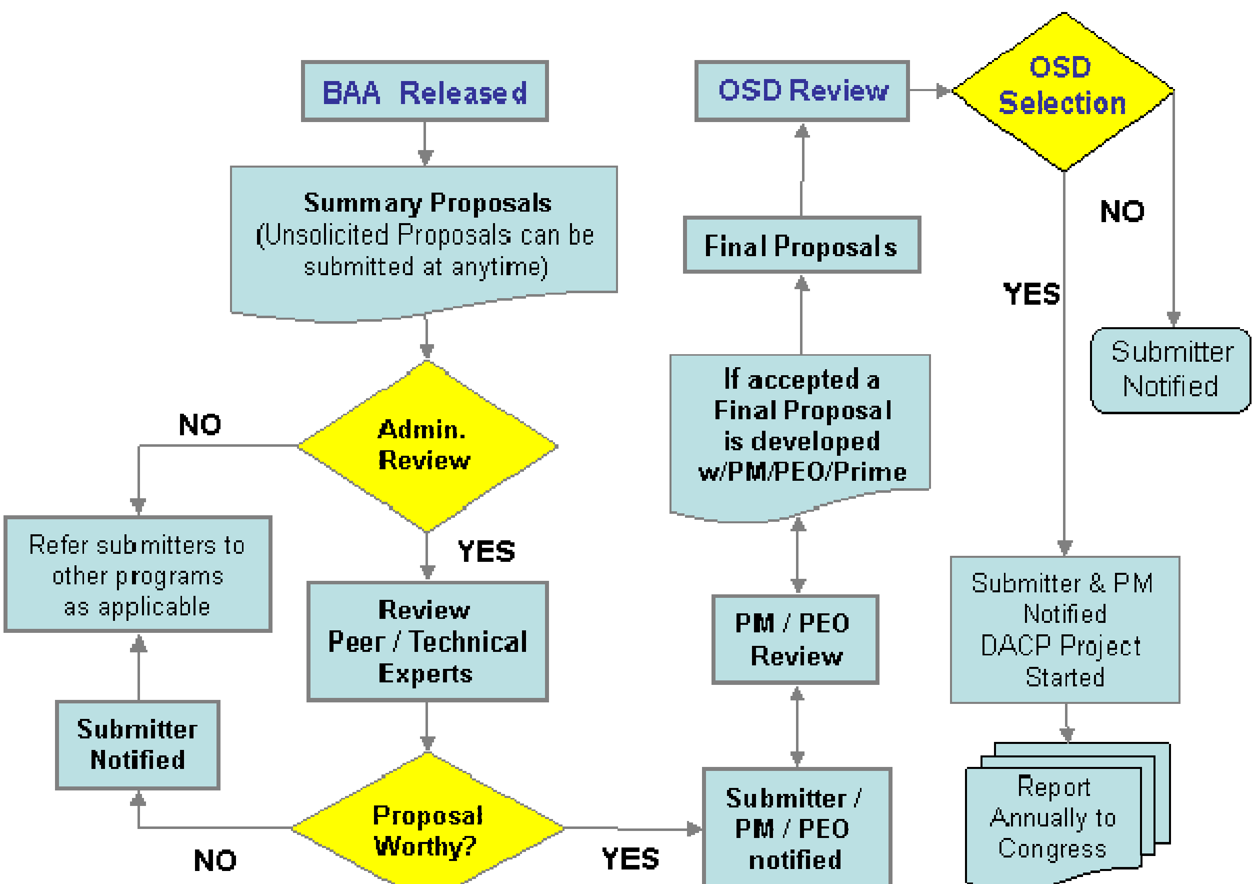


Figure 4.2

Additional Information/Contacts:

The Comparative Testing Office's website is at http://www.acq.osd.mil/cto/

4.5 Defense Production Act Title III Program

What is it?

The mission of the Defense Production Act Title III Program (Title III) is to create assured, affordable, and commercially viable production capabilities and capacities for items that are essential to the national defense. By stimulating private investment in key production resources, Title III helps to

- Increase the supply, improve the quality, and reduce the cost of advanced materials and technologies needed for the national defense.
- Reduce U.S. dependence on foreign sources of supply for critical materials and technologies.
- Strengthen the economic and technological competitiveness of the U.S. defense industrial base.

Title III activities lower defense acquisition and life-cycle costs and increase defense system readiness and performance by using higher quality, lower cost, and technologically superior materials and technologies.

What is the value?

Title III authority can be used to address the following:

- Technological obsolescence, i.e., when a newer technology replaces an older one and the capability to produce the older technology falls into disuse and is gradually lost. By using Title III authority, flexible manufacturing capabilities can be created to produce aging technologies efficiently and affordably. Alternatively, the authority can be used to consolidate and maintain production capabilities that otherwise would be lost because of changing market conditions, even though such capabilities are still needed for defense and still can be operated efficiently and profitably.
- Low or irregular demand (i.e., when the demand for an item is inadequate to support continuous production), so the delivery of the item is delayed because of the time needed to obtain materials for producing the item or for the time needed by the production queuing. Title III purchase commitments can be made to consolidate and level demand for key production capabilities, which gives suppliers incentives to maintaining and upgrade these capabilities, and to respond to defense acquisition needs in time.

Purchase commitments can also be used to reserve production time to ensure timely access to production resources for fabricating critical defense items.

- Producers exiting the business, i.e., when companies go out of business or drop product lines that no longer fit their business plans. Title III authority can be used to support transferring production capabilities to new sources.

Success Story:

Problem: Foreign firms dominated SI GaAs wafer production with a 70% share of U.S. and world markets.
Program Solution: Phase II emphasized market development and customer support.
Contract: $23.1M (government share)
User: Numerous
Prime: Numerous
Goal: Develop a competitive domestic capability to produce semi-insulating gallium arsenide (SI GaAs) wafers.
Success: With the help of Title III Program, the U.S. SI GaAs wafer industry now dominates this market with a 60% share. Savings are expected to total over $300M.

How do I participate?

Virtually all Title III projects promote integrating commercial and military production to lower defense costs and enable earlier defense access to, and use of, emerging technologies. The production for both military and civilian markets represents a new thrust for the Title III program, and is referred to as "dual produce." A government–industry working group identifies dual-produce projects, develops a list of general project areas, and publishes a Broad Area Announcement (BAA) based on the list to solicit proposals from industry and DoD organizations. Projects are selected according to potential cost savings—both direct savings from the projects themselves and indirect savings from the broader application of demonstrated capabilities to other defense items.

The Title III program is a DoD-wide initiative under the Director, Defense Research and Engineering (DDR&E). Management responsibilities include program oversight and guidance, strategic planning and legislative proposals, approval of new projects, and liaison with other federal agencies and Congress.

The Air Force is the executive agent for the program in DoD. The Title III program office, at Wright-Patterson Air Force Base, Ohio, is a component of the Manufacturing Technology Division of the Air Force Research Lab. The program office identifies and evaluates prospective Title III projects, submits projects for DDR&E's approval, structures approved projects, implements contracting and other business actions for the projects, oversees active projects, provides for selling and using materials acquired through Title III contracts, and does the planning and programming support for DDR&E.

Additional Information/Contacts:

For further information about the DoD Title III program, visit http://www.acq.osd.mil/ott/dpatitle3/.

4.6 DUAL-USE SCIENCE AND TECHNOLOGY PROGRAM (DUST)

What is it?

A *dual-use technology* is one that has both military utility and sufficient commercial potential to support a viable industrial base. Funding for this program has shifted from OSD to the services. The government's objectives of the Dual-Use Science and Technology (DUST) program are the following:

- Partnering with industry to jointly fund the development of dual-use technologies needed to maintain DoD's technological superiority on the battlefield and industry's competitiveness in the marketplace.
- Making the dual-use development of technologies with industry a normal way of doing business in the services.

What is the value?

These objectives are met by using streamlined contracting procedures and cost sharing between OSD, the services, and industry.

The industry objective for the program is to achieve the following benefits:

- Leverage scarce S&T funding.
- Be a vehicle for forming beneficial partnerships with other firms, defense labs, or universities.
- Gain access to advanced technology.
- Increase the potential for transitioning technologies to defense systems, which can lead to increased markets.

Success Story:

Problem: The current manufacturing methods require that the compressor section of the Tomahawk F107 engine be milled from a forging of solid titanium al-

loy. A single cutting tool (ball mill end) can not be used to fabricate a complete compressor section. The balls must be changed frequently which increases manufacturing costs.
Program Solution: High Rate Machining of Ti Blisks and Disks
Contract: Several
Prime: Penn State iMAST
Goal: Manufacture prototype machine tools using nanocrystalline powder. Fully dense, nonagrained cemented carbide cutting tools have been fabricated.
Success: Machining results have shown that the prototype cutting tools have up to 40 times the longevity of conventional cutting tools in machining titanium alloys.

How do I participate?

The Military Services issue a joint BAA and projects that meet the minimum requirements identified below are evaluated based on the following selection criteria:

- Quantity and quality of industry cost share
- Military benefit
- Commercial viability of technology
- Technical and management approach

The minimum requirements for DUST&T projects include:

- Project is developing a dual use technology.
- At least 50% of project cost is paid by non-federal participants, one of which is a for- profit company.
- Award must be based on competitive procedures.
- Projects must be awarded using non-procurement agreements.

Additional Information/Contacts:

The DoD guide to developing dual-use technology highlights the advantages of fostering these kinds of relationships.[5] For further information about the Dual-Use Science and Technology program, visit http://www.acq.osd.mil/ott/dust/.

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[5] Deputy Under Secretary of Defense (Science and Technology), Office of Technology Transition, *Dual-Use Science and Technology Process: Why Should Your Program Be Involved? What Strategies Do You Need to Be Successful?* July 2001. Available on line at http://www.dtic.mil/dust.

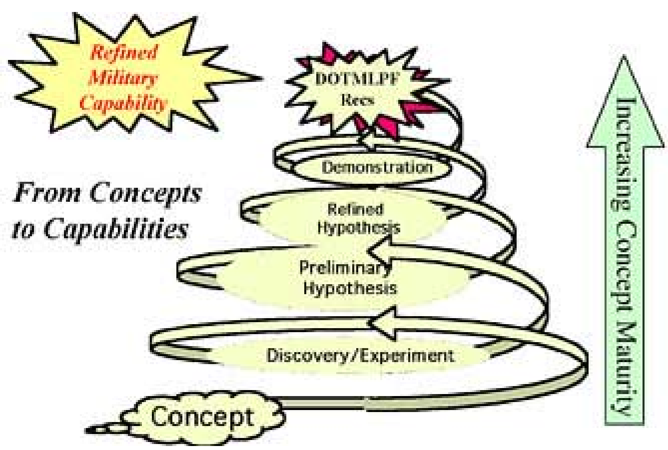
4.7 Joint Experimentation Program

What is it?

Joint experimentation is defined as the application of scientific experimentation procedures to assess the effectiveness of proposed (hypothesized) joint warfighting concept elements to ascertain if elements of a joint warfighting concept change military effectiveness.[6] The U.S. Joint Forces Command (USJFCOM) leads the Joint Experimentation program, with support from the Joint Staff, other combatant commands, services, and defense agencies. The Joint Experimentation program examines new warfighting concepts and techniques, either by modeling and simulation or through exercises with actual forces. The results of the experiments are used to shape the concepts, doctrine, and materiel systems requirements for the future joint force. One of the focus areas is joint interoperability to ensure that our service capabilities operate as one unified force during future conflicts. Selected high-payoff technologies may be examined during the joint experimentation. This program works closely with the ACTD program, assisting with improving and demonstrating ACTD products. A Defense Science Board report on the program is available at http://www.acq.osd.mil/dsb/reports/jointx.pdf.pdf .

What is the value?

The Joint Experimentation Program is one of the key ingredients for the Joint Integration role of USJFCOM. The joint concepts being developed and explored by the Joint Experimentation Program offer the potential to significantly transform the way future U.S. forces accomplish their missions.



Nature of "spiral" experimentation (Figure 4.3).

[6] U.S. Joint Forces Command, "Joint Forces Command Glossary," accessed August 4, 2002, at http://www.jfcom.mil/about/glossary.htm#JE.

How do I participate?

The Joint Experimentation program has limited funding. The majority of the funding is used to get the military units involved to participate and support the events. In general, candidate technologies must address major future joint force capability shortfalls. The technology must be sufficiently mature to demonstrate in an actual exercise. In certain cases, surrogate capabilities may be used, or the system may be represented in computer simulations. Entry is easiest for contractors that submit a fully-funded proposal.

The J-9 (Joint Experimentation) staff at USJFCOM, Norfolk, Virginia, has more information about opportunities and needed capabilities. Each service has its own experimentation programs and participates in the Joint Experimentation program. The relevant service experimentation point of contact (e.g., U.S. Army Training and Doctrine Command) can provide information about opportunities.

Additional Information/Contacts:

The Joint Experimentation Directorate's (J9) website is http://www.jfcom.mil/about/abt_j9.htm .

4.8 MANUFACTURING TECHNOLOGY PROGRAM (MANTECH)

What is it?

The DoD Manufacturing Technology (ManTech) program focuses on the need of weapons system programs for affordable, low-risk development and production. The program is the crucial link between technology invention and development, and industrial applications. The program matures and validates emerging manufacturing technologies to support low-risk implementation in industry and DoD facilities, e.g., depots and shipyards. The program addresses production issues, beginning during the development of the technology. The program continues to support the system during the transition into its production and sustainment phases. By identifying production issues early and providing timely solutions, the ManTech program reduces risk and improves affordability by addressing potential manufacturing problems before they occur. The program vision is to realize a responsive, world-class manufacturing capability to affordably meet the warfighters' needs throughout the defense system life cycle.

What is the value?

The ManTech program uses technology created throughout the S&T base and works with performance technology demonstrations; weapons system development, production, and support; and acquisition reforms, including those for defense use of commercial items and specifications. The ManTech program collaborates with many DoD activities. Collaborative efforts also include non-DoD organizations, such as the National Aeronautics and Space Administration (NASA), Department of Commerce, Department of Energy, and the National Science Foundation (NSF). The three military departments (Army, Navy, and Air Force), the Defense Logistics Agency (DLA), and Defense Advanced Research Projects Agency (DARPA) execute the program. The Deputy Under Secretary of Defense for Science and Technology (DUSD[S&T]) manages the program.

Success Story:

Problem: Develop processes for weight savings on aircraft programs.
Program Solution: Using a Design of Experiment (DoE) approach the program identified manufacturing process parameters and allowed for changes and improvements on parts.
Contract: $1M Army ManTech and .3M Honeywell
PMO: US Army Aviation and Missile Research, Development and Engineering Center
User: Army Aviation Commands
Prime: Honeywell
Goal: Develop and demonstrate advanced manufacturing capability for producing thin wall engine structures.
Success: A cost avoidance of $10.9M is projected for the RAH-66 Comanche T800 engine.

How do I Participate?

A unified planning process is used to identify and prioritize weapon system requirements and the pervasive needs of the industrial base to support those requirements. The Joint Defense Manufacturing Technology Panel, its four sub panels, and its two ad-hoc working groups coordinate the planning. The National Center for Advanced Technologies facilitates the panel's interaction with industry. By analyzing the requirements and technology base efforts, technological opportunities (projects) with direct application to DoD needs are identified for potential ManTech program investment.

For component-unique projects (i.e., those affecting the needs of only one service), the individual component executes and implements the project. For more pervasive or joint projects, DARPA, one of the services, or DLA is designated as the lead depending on internal capability or ownership of the first demonstration application. A variety of activities are used for doing ManTech projects. These include centers of excellence, consortia, private industry, academia, and government facilities.

Additional Information/Contacts:

For more information about the ManTech program, visit https://www.dodmantech.com/ . For service specific programs visit:

Army: http://www.armymantech.com/

Navy: http://www.onr.navy.mil/sci_tech/industrial/mantech/

Air Force: http://www.ml.afrl.af.mil/mlm/default.html

4.9 QUICK REACTION SPECIAL PROJECTS

What is it?

The USD (AT&L), established a team of highly qualified acquisition professionals to advise the Under Secretary on actions that can be taken to expedite the acquisition of needed systems. This requirement was addressed in Conference Report 107-772, House Report 107-436, and in H.R. 4546 House Bill, Sec. 809. Quick-Reaction Special Projects Acquisition Team. The duties of the team shall include advice on:

- Industrial base issues, including the limited availability of suppliers
- Technology development and technology transition issues
- Issues of acquisition policy, including the length of the acquisition cycle,
- Issues of testing policy and ensuring that weapons systems perform properly in combat situations
- Issues of procurement policy, including the impact of socio-economic requirements
- Issues relating to compliance with environmental requirements

What is the value?

Quick Reaction Special Projects provides flexibility to respond to emergent DoD needs within budget cycle. It takes advantage of technology breakthroughs in rapidly evolving technologies. Completion of projects is to be within six to twelve months.

How do I participate?

The program calls for proposals released in October.

Additional Information/Contacts:

There is no single program office or point of contact. Go to http://www.acq.osd.mil/qrsp/qrsp_background.html for background information on this program.

4.10 Small Business Innovation Research Program (SBIR)

What is it?

Congress created the SBIR program in 1982 to help small businesses participate more in federal R&D. Each year, ten federal departments and agencies are required to reserve part of their R&D funds for awarding to small businesses under the SBIR program. Participating departments and agencies include: Agriculture, Commerce, Defense, Education, Energy, Health and Human Services, Transportation, the Environmental Protection Agency, NASA, and NSF.

DoD's SBIR program funds early-stage R&D projects at small technology companies—projects that serve a DoD need and could be commercialized in the private-sector or military markets. The program, funded at approximately $773 million in FY02, is part of the larger ($1.5 billion) federal SBIR program.

The Small Business Innovation Research Program Act of 2000[7] extended the SBIR program's authorization to September 30, 2008. According to Congressional findings reported in the act, "the SBIR program made the cost-effective and unique research and development capabilities possessed by the small businesses of the nation available to federal agencies and departments," and "the innovative goods and services developed by small businesses that participated in the SBIR program have produced innovations of critical importance in a wide variety of high-technology fields, including biology, medicine, education, and defense."[8]

Congress further states "the SBIR program is a catalyst in the promotion of research and development, the commercialization of innovative technology, the development of new products and services, and the continued excellence of this nation's high-technology industries… The continuation of the SBIR program will provide expanded opportunities for one of the nation's vital resources, its small businesses, will foster invention, research, and technology, will create jobs, and will increase this nation's competitiveness in international markets."[9]

[7] P.L. 106-554, Appendix 1—HR 5667, Title 1, accessed at http://www.acq.osd.mil/sadbu/sbir/pl106-554.pdf on August 1, 2002.
[8] Ibid., Section 102.
[9] Ibid.

What is the value?

As part of its SBIR program, the DoD issues an SBIR solicitation twice a year, describing its R&D needs and inviting R&D proposals from small companies, i.e., firms organized for profit with 500 or fewer employees, including all affiliated firms. Companies apply first for a six-month Phase I award of $60,000 to $100,000 to test the scientific, technical, and commercial merit and feasibility of a particular concept. If Phase I is successful, the company may be invited to apply for a two-year Phase II award of $500,000 to $750,000 to further develop the concept, usually to the prototype stage. Proposals are judged competitively on the basis of their scientific, technical, and commercial merit. After Phase II is completed, companies are expected to obtain further funding from the private-sector or non-SBIR government sources (in Phase III) to develop the concept into a product for sale in private-sector or military markets.

How do I participate?

Eligible companies must have no more than 500 employees and must be the primary place of employment of the principal investigator. In addition, the companies must be American-owned and independently operated, and a for-profit entity.

Each of the ten federal departments and agencies accept proposals and select their own R&D topics for the SBIR program. The Small Business Administration (SBA) collects solicitation information from all participating agencies and publishes it quarterly in a pre-solicitation announcement at http://www.sba.gov/sbir/indexprograms.html.

After proposals are submitted, agencies make SBIR awards according to the small business' qualification, degree of innovation, technical merit, and future market potential. Small businesses that receive awards or grants then begin the three-phase program.

Additional Information/Contacts:

Appendix C describes a number of successes achieved by small business participants in the SBIR program. For more information about the program, visit http://www.sba.gov/sbir/ .

4.11 Small Business Technology Transfer Program (STTR)

What is it?

The Small Business Technology Transfer (STTR) program is a small business program that expands funding opportunities for federal innovation R&D. Central to the program is the expansion of the public- and private-sector partnership, including joint venture opportunities for small businesses and the nation's premier nonprofit research institutions. The program's most important role is to foster the innovation necessary to meet the nation's S&T challenges.

What is the value?

Small business has long been where innovation and innovators thrive, but the risk and expense of doing serious R&D can be beyond the means of many small businesses. Conversely, nonprofit research laboratories are instrumental in developing high-tech innovations, but frequently, their innovation is confined to the theoretical rather than the practical. STTR combines the strengths of both entities by introducing entrepreneurial skills to high-tech research.

Each year, five federal departments and agencies (the Departments of Defense, Energy, Health and Human Services; along with NASA and NSF), are required under the STTR program to reserve part of their R&D funds for award to partnerships between small businesses and nonprofit research institutions.

How do I participate?

Small businesses must meet certain eligibility criteria to participate in the STTR program. They must:

- Be American-owned and independently operated.
- Be a for-profit organization.
- Have no more than 500 employees.

A nonprofit research institution also must meet certain eligibility criteria. Although there is no size limit, it must

- Be based in the United States.
- Meet one of three definitions: (1) nonprofit college or university, (2) domestic nonprofit research organization, or (3) federally funded R&D center (FFRDC).

Each of the five participating federal departments and agencies accepts proposals and designates its own R&D topics for the STTR program. The SBA collects solicitation information from the participating agencies and publishes it periodically in a pre-solicitation announcement. The SBA's pre-solicitation announcements, available at http://www.sba.gov/sbir/indexprograms.html are the single source for the topics and anticipated release and closing dates for each agency's solicitations.

After proposals are submitted, the agencies make STTR awards based on the qualifications of the small business or nonprofit research institution, degree of innovation, and future market potential. Small businesses that receive awards or grants then begin a three-phase program.

Phase I is the startup phase. Awards of as much as $100,000, for approximately one year, fund the exploration of the scientific, technical, and commercial feasibility of an idea or technology. Phase II awards of as much as $500,000, for as long as two years, expand Phase I results. During this period, the R&D is done and the developer begins to consider commercial potential. Only Phase I award winners are considered for Phase II. Phase III is the period during which Phase II innovation moves from the laboratory into the marketplace. No STTR funds support Phase III. The small business must find funding from the private sector or a non-STTR federal agency.

Additional Information/Contacts:

For more information about the STTR program, visit http://www.sba.gov/sbir/.

4.12 TECHNOLOGY TRANSITION INITIATIVE

What is it?

The Technology Transition Initiative is a new program, called for in the FY 2003 National Defense Authorization Act, which will provide limited funding for selected technology transition projects. The objectives of the Technology transition Initiative are to accelerate the transition of new technologies into operational capabilities within the armed forces; and to successfully demonstrate new technologies in relevant environments.

What is the value?

The Technology Transition Initiative will be administered by a "Manager", designated by the USD(AT&L). The services and defense agencies will nominate projects for implementation under this Initiative. If the projects are selected, the Initiative will fund 50 percent or more of the cost of the project for up to four years.

The Manager will select the projects to be funded, based on the advice and assistance of a Technology Transition Council. The service Acquisition Executives, the Joint Requirements Oversight Council, and the science and technology executives from the services and defense agencies will be members of the Council.

The funding for this program will be limited. The Technology Transition Initiative will be a way for a relatively small number of programs to receive funding to accelerate a transition needed to get a product to the field. This program will supplement, rather than replace, existing service and defense agency technology transition programs.

Success Story:

Problem: Improved safety from small arms.
Program Solution: Advanced Lightweight Ceramic-Based Armor
Success: Achieve a 20-30% cost savings

How do I participate?

The Technology Transition Initiative is a new program. Details on participation in the program will be provided by the USD(AT&L) as the program is implemented. The Technology Transition Council members prioritize and nominate projects. Evaluation criteria based on:

- Supporting IRAQ Lessons Learned
- TTI funding accelerating product transition.
- Project being from the S&T Base.
- Encouraging cost sharing to leverage funding
- Duration is less than four years
- Ideally a Joint Project, technology mature (TRL 6 or 7) and commitment to transition path (POM dollars)

Additional Information/Contacts:

The Technology Transition Initiative website is http://www.acq.osd.mil/ott/tti/.

4.13 VALUE ENGINEERING (VE)

What is it?

Value Engineering (VE) has two aspects: a financial incentive to get contractors and subcontractors to reduce the cost of our systems, supplies, and services and a rigorous method for maximizing cost savings. Contractors who participate in VE share in net savings on the basis of their financial risk.

What is the value?

If, for example, a contractor funds the cost for developing a VE idea, the share is normally 50 percent; if the government funds the idea development cost initially, the contractor receives 25 percent of net savings. Exact shares are defined in the FAR. VE is unique because it maintains essential functions and lowers overall cost without degrading performance, reliability, maintenance, or safety. To qualify as VE, an idea must, at a minimum, result in a change in a support contract that, when implemented, saves money. A VE incentive clause is required in non-R&D contracts of more than $100,000 and can be requested in smaller ones.

After the contract is awarded, the contractors have little reason to reduce acquisition or life-cycle cost. In fact, without VE, contractors lose money by reducing costs. Because profits are derived from cost, reducing cost without VE reduces profits. With VE, however, the situation is reversed. Contractors keep their original profit and share in net savings in four areas: their existing contract, concurrent contracts (such as foreign military sales), future contracts (normally for three years), and collateral (operations and support) savings.

How do I participate?

Contractors are encouraged to participate in the VE program by submitting cost-reduction ideas as value engineering change proposals (VECPs) pursuant to FAR 52.248-1. Contractors who voluntarily use their own resources to develop and submit VECPs gain the most, sharing 50 percent of the savings. If a VECP is not approved, however, the government does not reimburse a contractor's development cost. This was added to the FAR to ensure that only high-quality VE ideas are proposed. VE savings typically are shared for three years after acceptable implementation. Contractors share *net* savings on their existing contract, concurrent contracts, and on future collateral savings. Collateral savings are measurable net reductions in an agency's overall projected operations, maintenance, logistics support, or government-furnished property costs. Because collateral savings are auxiliary savings, and at best a prediction of future possibilities, the share is smaller—20 percent of a typical year's operations and support savings, not to exceed the price of the existing contract price or $100,000, whichever is more. VE sharing is limited to contracts issued by the procuring office or its successor. Each buying activity funds its own VECPs and may not buy a VECP unless funds are available to develop and implement the idea. Similarly, the government may not disapprove a VECP and then use the idea. When a contractor is unfamiliar with VE, or cannot afford to voluntarily do VE, the government may choose to require a mandatory VE program. When this occurs, the government funds the entire VE process from idea generation to implementation. Because the government is accepting the full financial risk for mandatory VE, contractors share at a lower rate of 25 percent of net savings per FAR 52.248-1.

Additional Information/Contacts:

The DoD Value Engineering homepage is located at http://www.acq.osd.mil/sadbu/resources/ve.htm.

Chapter 5

Challenges and Considerations

5.1 TECHNOLOGY TRANSITION

The environment:

- The weapon system evolutionary acquisition approach currently in use only incorporates technologies with manageable risk (known risk that can be mitigated) in each development increment.

- The acquisition community's expectations are that laboratories will provide technology mature enough to transition smoothly into product designs. That is that they have: known/reproducible performance; known/acceptable costs and cost risks; and are practical for sustainment in service.

- As a result of the use of performance-based specifications and other acquisition reform measures, decisions about which technologies will transition into weapons systems applications are increasingly made by original equipment manufacturers (OEMs). However, contract features, acquisition strategies and military customer involvement can and do influence these decisions.

- Most companies don't make one-dimensional decisions about technology transition. Technology readiness measures that are widely used include: costs; manufacturing process capability; availability of materials and components; in addition to performance maturity and risk. If companies use MRLs, they will address these and related factors.

- Acquisition managers must ensure that their contractors are using a management approach to technology selection that balances manufacturing cost and risk with performance considerations to assure technology transitions with manageable risk. MRLs can be a valuable tool in this process.

- Technology managers must be aware that simply proving that their technology meets threshold performance requirements when tested in a representative environment (i.e. achieving at specific TRL level) does not assure a low-risk for technology transition since technology transition decisions are not one-dimensional. They must seek to understand and mitigate manufacturing risks associated with their technology to have the greatest chance for a successful transition. MRLs are a valuable tool in this process.

Issue 1-A: Inserting Enabling Technology

Evolutionary Acquisition – This approach to weapon system development was intended to shorten and reduce the risk of getting new capability into the field and often affords multiple opportunities for technology insertion into a specific weapon system. Instead of designing a new system to have all of it's ultimate capability in the first items fielded, evolutionary acquisition provides for designing, testing and fielding a basic capability quickly in a first increment with the intent to add additional capability incrementally by designing and testing capability additions in subsequent increments as the technologies that will make the additional capabilities possible mature and are proven.

The purpose of the Technology Development phase of acquisition is to reduce technology risk and to determine the appropriate set of technologies to be integrated into a full system. Technology Development is a continuous technology discovery and development process reflecting close collaboration between the S&T community, the user, and the system developer. It is an iterative process designed to assess the viability of technologies while simultaneously refining user requirements. During this phase of acquisition, a program will expend significant effort in sorting through technology alternatives and then, based on a balancing of risks and resources will arrive at a plan for which some capabilities will be included in the first systems fielded and which other capabilities will be deferred to subsequent increments. Each subsequent increment will be initiated with a separate B review that will specify desired capabilities and associated proven technologies. Where desired capabilities are not available with low-risk technology alternatives, programs will create risk-mitigation plans to increase the odds that the desired capability can be made available with acceptable performance and costs and on an acceptable schedule. These plans can range from monitoring existing tech maturation efforts to active support for technology maturation but almost always will include consideration of competing technology approaches for a given capability that is desired.

In evolutionary acquisition, the identification and development of the technologies necessary for follow-on increments continues in parallel with the acquisition of preceding increments, allowing the mature technologies to more rapidly proceed into System Development and Demonstration (SDD). According to policy within DoDI 5000.2, for a program or increment to exit Technology Development, it must include an affordable increment of militarily-useful capability with technology demonstrated in a relevant environment and describe a system that can be developed for production (SDD) within a short timeframe. TRLs can be used to evaluate the former, and MRLs may be used to evaluate the latter.

SDD has two major efforts: System Integration and System Demonstration. The purpose of the SDD phase is to develop a system or an increment of capability; reduce integration and manufacturing risk; and ensure operational supportability. SDD is where specific technologies transition into a weapon system design and are further matured for transition into production. In the design process alternative approaches are evaluated and "trades" are made to optimize the design – the most common of these is in trading capability for cost. A technology with high cost or perceived high cost risk (costs unknown, but manufacturing very immature) is likely to be deferred if there is not time or resources available to mitigate the cost problems or risks even if the technology performance is desirable and proven. A system may not proceed past system integration and into system demonstration without an assessment of design maturity, including identification of key system characteristics and critical manufacturing processes.

- First Increment - The most significant of these opportunities for inserting enabling technology is the first increment of development where the weapon system baseline capabilities are established. Significant qualification testing is performed on most aspects of the system thus creating opportunities for new technologies to get the qualification testing essential to transition if they are seen to be ready (known, manageable risks) for this level of commitment. While evolutionary acquisition philosophy dictates that design flexibility is to be maintained to the maximum practical extent (e.g. flexible electronics/software architectures) during this initial increment, design decisions will be made that can erect barriers to the introduction of new technologies in subsequent increments of development unless they are explicitly described and planned for. The introduction of new structural technologies, for instance, is very difficult after the initial increment because of the typically large associated qualification expense – expense that is not likely to be undertaken unless a significant problem is discovered that a new technology is needed to solve.

Issue 1-B: Identifying and Selecting Available Technology

<u>For the technology manager:</u>

- Be aware of DoD capability needs that you could meet and weapon system developments that could benefit from the technology you are developing.
- Make OEMs and DoD acquisition managers aware of your technology; the potential military capability benefits associated with it; and the level of maturity or risk associated with the technology.
- Seek to understand the actions you could take to make your technology more attractive to weapons programs (e.g. understanding and working to mitigate technical and manufacturing risks).
- Develop a detailed understanding of what the windows of opportunity are for your technology to transition into a specific weapon system design.

    1. What are the specific requirements that you have to meet and by when?
    2. What data do you have to have available and when?
    3. When do you conduct qualification testing and what are the requirements for the inclusion of your technology?

For the acquisition manager and OEMs

- Work with DoD laboratories to identify promising technologies to provide capabilities needed for your system.
- Use TRLs and MRLs to understand current level of maturity of technologies under consideration.
- Use TRLs and MRLs to plan the maturation/risk reduction of key technologies and to track progress.
- Use TRLs and MRLs as key inputs in deciding which technologies become baselined into designs.
- Ensure that technology managers understand the system requirements that their technology must meet to be competitive.
- Collaborate with technology managers to ensure that technology maturation plans are effective in maximizing the potential for the technology to transition to your weapon system
- When feasible, evaluate or support multiple technology candidates for a given capability need in order to reduce risk

Issue 1-C: Accessing/Using DoD Technology Development Programs

- **Issue:** U,S, producers for a specific product are too costly; cannot produce at acceptable quality; cannot meet schedules; or do not have sufficient production capacity
  Approach: Evaluate the DoD Manufacturing Technology Program as a potential source of assistance. Army, Navy, Air Force and DLA all have active programs. Point of Contacts (POCs) and ManTech orientation materials are provided at www.dodmantech.com.

- **Issue:** Current US producers for critical items on the verge of going out of business or dropping the critical items as an unprofitable.
  Approaches: TIII and ManTech

- **Issue:** Critical items available only from a foreign source
  Approach: TIII

- **Issue:** No industrial base manufacturing capability for a critical item
  Approaches: SBIR, ManTech, TIII, and Diminishing Manufacturing Sources and Material Shortages Center of Excellence (DMSMS)

- **Issue:** A promising technology is available for increased capability or affordability, but no funds are available for qualification testing
  Approach: Defense Challenge Program

- **Issue:** A technology for materials or components with both military and commercial potential needs development support
  Approach: DUST http://www.dtic.mil/dust/index.htm

- **Issue:** Innovative technology approaches are needed to provide military capabilities
  Approaches: SBIR or STTR

- **Issue:** Innovative technology approaches are required to solve manufacturing or inspection issues associated with military products
  Approaches: SBIR or STTR

- **Issue:** Development funds are needed to enable the rapid transition of a technology that
  Approach: Technology Transition Initiative

- **Issue:** Development funds are needed to support the development of prototypes to be fielded to meet a military need.
  Approach: ACTD

Issue 1-D: Planning for Manufacturing Risk Management

<u>For the Technology Manager</u>

- Identify the manufacturing issues associated with your technology
  1. Perform a manufacturing readiness evaluation prior to launching an ADP or ManTech program to establish the current MRL level of your technology and related issues.
  2. Know if the key materials or components are readily available at an acceptable price.
  3. Understand which dimensions or other key design characteristics must be controlled to assure the performance of your technology.
  4. Know if current manufacturing processes are capable of reliably producing the key design characteristics of your technology.
  5. Know if your key manufacturing processes are being used or developed to support a commercial base.
  6. Have credible estimates of the cost of producing items that embody your technology and know which elements drive the cost.

- Understand and manage the manufacturing risks associated with your technology.
  1. Do a risk analysis of the key manufacturing processes related to your technology to identify potential risks; the severity of the impact if the risk event actually occurs; and the probability the event will occur. Some companies have used a formal process called Failure Modes Effects and Analysis (FMEA) methodology with success.
  2. Discuss manufacturing risk items with OEMs and potential military customers to understand their concerns and requirements and, where needed, set goals for improvement of manufacturing-related metrics (MRLs, costs, quality, manufacturing process capability, etc.)

- Create and follow a plan for reducing manufacturing risks. Collaborate with military customers, OEMs, suppliers, and DoD ManTech programs to create a time-phased risk-reduction plan that integrates efforts and resources and focuses on achieving specific targets for MRLs and other manufacturing-related metrics.

- In collaboration with the customers for your technology, create a formal plan for the transition of the technology into the target weapon system application. The plan should identify the key goals and threshold values a technology must meet in order to be accepted for transition. The plan should also identify funding commitments for transition expenses such as qualification testing and tooling and identify key dates (upcoming qualification test windows, design freeze dates, etc.) or other information that describe or place limits on the technology transition opportunity.

<u>For the Acquisition Manager or OEM</u>

- Assess maturity of manufacturing processes and systems at each stage of the acquisition process using MRLs as a tool. Place special emphasis on new technologies that will transition into the system you are managing.

- As immature manufacturing processes are identified, assess the level of risk represented by each area of immaturity and develop risk mitigation plans where the risk is significant.

- Apply normal risk assessment approaches, such as FMEA, that are well established as formal risk management methodologies.

- Develop a manufacturing risk mitigation plan, including the identification of funding for prototypes or experiments. Investigate associated programs (See chapter 4) for outside funding of these activities.

- Develop a detailed cost estimate for the transition of the technology and assure that your program has identified funding to cover those costs.

- Track the implications to schedule and unit cost, benchmarking against a backup option. The benchmark should compare effects of cost, schedule and performance for the entire system.

- Conduct independent assessments of manufacturing maturity, capability and risk in each phase of acquisition. Use the results to create risk mitigation plans and track progress. Government acquisition managers should not rely completely on the effectiveness of contractor manufacturing management efforts.

- Include coverage of manufacturing status and progress as a regular subject in program management reviews with the contractor and internally within the Government program management chain.

Service/Agency-Specific Practices

- The Air Force has a formal process for enhancing the transition of Advanced Development Program (ADP) and selected ManTech Program technologies out of the laboratory and into weapons systems applications. The Applied Technology Council concept (described in Air Force Materiel Command (AFMC) Instruction 61-102 which is managed by AFRL (Air Force Research Laboratory /XPP) engages military customers (acquisition program and warfighting customers) in the evaluation and tracking of ADPs. Formal transition funding commitments are made by military customers for those technologies of greatest interest to the warfighter and the progress of the technology efforts and the stability of both technology and transition funding commitments are reviewed regularly at the flag officer level. The process requires that a formal transition plan be developed for most programs. A producibility risk assessment is required, but the use of MRLs is not currently a formal requirement of this process. The council is currently considering mandating the use of MRLs.

- The AFRL identifies their ADPs and other high-visibility programs as "baseline programs". These programs have a baseline established which is essentially an agreement that establishes program objectives, budget, schedule and technology deliverables for semi-annual review by top management. The requirements of this process are described in AFRL Instruction 61-108 which is managed by AFRL/XPP. Use of MRLs is not currently a formal part of this process but such a requirement is under consideration.

Issue 1-E: Teaming and Partnering

- Integrated Product Teams (IPT) have become widely accepted as a method for incorporating necessary breadth of expertise and viewpoints in both technology development and systems acquisition.

- Technology Managers should form an IPT that includes both initial and final customers for their technology to assure that everyone understands requirements and that technology transition planning is effective. Final customers are warfighting commands within the DoD. Initial customers can be acquisition management offices and, in some cases, industry.

- Acquisition program managers and OEMs should seek to include manufacturing expertise within each level of their IPT structure and should encourage that practice among their contractors. Since manufacturing expertise has become relatively rare within the DoD acquisition workforce, the use of support contractors may be required.

Issue 1-F: Making Manufacturing Ready (Acquisition Mangers and OEM's)

- Assure that both the government and contractor elements of the acquisition program have adequate depth of experience in manufacturing.

- Require detailed manufacturing planning at all levels of the supply chain.

- Use prototypes or experiments whenever possible to validate the manufacturing process and production cost models.

- Do independent assessments of manufacturing maturity, capability and risk in each phase of acquisition. Use the results to create risk mitigation plans and track progress. Government acquisition managers should not depend entirely on the effectiveness of contractor manufacturing management efforts. Include coverage of manufacturing status and progress as a regular subject in program management reviews with the contractor and internally within the Government program management chain.

Issue 1-H: Changing Contractual Relationships – Motivation, requirements, funding profile

The acquisition contracting environment has changed within the past generation of technology development and will continue to adapt to the Evolutionary Acquisition Strategy. These changes have tended to shift control over system design and integration decisions, including technology transition efforts, from the DoD program office to the industry contractor. Most contracts now focus on functional specifications instead of system specifications, allowing greater flexibility for industry contractors to develop innovative system designs and increasing opportunities for advanced technology transition. Generally, this translates into the DoD stating what the system should do, and not what the system should look like. Because of this shift, systems engineering expertise has been steadily decreasing within DoD technical communities. In accordance with contracting for functional capability, performance based contracting has been developed to allow greater flexibility to the contractors while providing the contractor incentives to meet the DoD's desired objectives.

In combination with the adoption of Evolutionary acquisition strategies, these contracting approaches have significantly changed the contractual relationship between DoD and industry, shifting roles, responsibility, and motivation. The core role of the prime contractor is system integration, with responsibility for decisions on which technologies to transition into the system design. This responsibility requires the management of advanced technologies to meet the triad goals of performance, cost and schedule. Since contractors are given incentives to meet these goals, the contractor community must develop an effective model for categorizing and measuring the risk in meeting each of the objectives.

- The role of DoD includes oversight of all contracting activities and operating as a member of the development team. As a team member, DoD must ensure effective communication of the final capability requirements, including description of operating concepts and development options. DoD members often have visibility, but not total authority, into design tradeoffs that rely on technology maturity evaluation.

- Within an evolutionary acquisition strategy, system design decisions may include trade-offs between performance and the risk of meeting program cost and schedule metrics. Using traditional contracting structures, detailed measures of system performance has been of primary importance, resulting in designs with significant manufacturing risk. These usually led to cost and schedule growth. New contractual structures featuring a minimum number of KPPs (Key Performance Metrics), has resulted in opportunities to modify system designs with more proven technologies, limiting some performance but also significantly reducing risk.

- These conditions make the use of MRLs critical to communicate the level of risk during transition of a technology to a system design. Assessment of MRLs will promote the early investigation of manufacturing and production issues. The MRL assessment is a key factor in determining cost and schedule risks, and should be discussed during milestone reviews. Additionally, MRLs can be used to track the progress of a system design, reducing the communication problems between DoD and contractor during system trade-offs. Finally, MRLs may be used as metric to set minimum requirements for performance based contracts.

- To manage manufacturing risk effectively, acquisition contracts should include requirements that:

    1. Set minimum MRL levels for all developmental hardware.

    2. Require assessments of current MRL levels.

    3. Provide for the identification and mitigation of manufacturing risks.

    4. Provide for the development of manufacturing plans for all significant manufacturing activities that identify key activities, approaches and milestones required to support program cost, schedule and performance requirements.

    5. Provide for the support of independent manufacturing reviews by the Government.

    6. Provide for the regular reporting of progress in executing manufacturing plans and manufacturing risk mitigation efforts.

7. Provide incentives for cost control and manufacturing capability improvement and risk reduction.

5.2 CULTURAL BARRIERS

Issue 2-A: Identifying Manufacturing and Production Risk

Emphasis within DoD acquisition on assessing and managing manufacturing risk has declined in recent years. As a result, manufacturing expertise within the DoD acquisition workforce has become rare. Managers may have to seek the support of outside consultants in order to get an independent assessment of manufacturing maturity and risk. Service and Agency ManTech Programs have access to manufacturing expertise and may be able to provide assistance.

Issue 2-B: Relationships and perspectives – getting all the players to work together (Technology manger perspective)

- Effective technology transition requires an effective and continuing dialogue between technology managers, technology developers and technology customers. It usually falls to the technology manager to find customers for their technology and engage them in a dialogue to clarify customer requirements. Identify transition windows and obtain commitments for transition funding.
- People move, thus requiring continual reeducation and reselling of customers. Formal plans and agreements with technology customers help to promote continuity of commitments in the face of personnel changes.
- Acquisition program requirements, funding profiles and schedules change, thus requiring frequent communication to keep technology development efforts aligned with customers.

Issue 2-C: Program Strategies

- Programs sometimes emphasize achieving technical performance as the single most important value. In these cases, assuring some balanced concern for manufacturing issues is essential since products that cannot be produced with consistent quality will not perform and items that are too expensive or cannot be produced in sufficient quantities cannot be fielded in sufficient quantities to meet mission needs.
- Acquisition strategies and source selections can be blind to a number of issues that are key to successful manufacturing:
  1. The need to motivate contractors to control product costs.
  2. The need to assure that the industrial base can provide the needed materials and components.
  3. The need to include manufacturing capability risk management as an important focus to avoid negative impacts to costs, schedule and performance.

Issue 2-D: Contract Strategies

- In the absence of current competition, the basic structure of many acquisition contracts do not adequately encourage cost control. If profits are ultimately computed/negotiated as a percentage of costs, cost will rise and getting the contractor's attention for manufacturing process improvement and cost control efforts will be difficult. This can necessitate the development of special incentives or funding to try to overcome this powerful fundamental inhibitor to cost-effective manufacturing.

Issue 2-E: Traditional Responsibilities

- Laboratory R&D managers often think that their program is successful if all of the performance testing is completed successfully and customer performance threshold requirements have been met. They see manufacturing readiness as the responsibility of "someone else" – Acquisition programs or Service ManTech programs or Industry. DoD-funded advanced technology development efforts that do not lead to a timely transition into a DoD application cannot reasonably be considered successful. A technology manager's being aware of manufacturing risks and issues associated with their technology and working to address them greatly increases the chances of a timely and successful transition of a technology into a weapon system application.
- Acquisition managers often have little understanding of manufacturing risks and issues. Some view these areas as the exclusive responsibility of industry and do not apply management attention on manufacturing until a major problem arises. Manufacturing risks can be very significant and failure to manage them can obviously lead to problems that are discovered too late to avoid a crisis.

Issue 2-F: Design/Capability Dominance in decision-making

- Traditionally source selection decisions are dominated by weapon system performance considerations. The ability of the contractor to produce at good quality levels and at an acceptable price and schedule are usually secondary in importance in the decision-making process. As a result, the amount of effort that contractors put into manufacturing planning and risk reduction prior to source selection is often at the minimum acceptable level.
- Design changes often continue long past target design completion dates, but manufacturing schedules and cost estimates are rarely adjusted to reflect this. This practice usually results in major manufacturing inefficiencies and schedule slips.
- The voice of manufacturing in design decision-making is often weak or non-existent resulting in the creation of designs that are difficult or impossible to produce.

Issue 2-E: Warfighters don't care about manufacturing. They do care about capability and getting it quickly.

- This viewpoint makes it hard for DoD acquisition managers to focus on manufacturing issues, since they are seemingly peripheral (taken for granted) by their customers.

5.3 Knowledge Management

Issue 3-A: Information Access

- Contracts (ADP and acquisition contracts) should require:
  1. The development of manufacturing plans at all levels of suppliers.
  2. The development of manufacturing maturity and risk assessments.
  3. The development of manufacturing risk reduction plans and progress reporting.
  4. The support of independent assessments of manufacturing maturity and risk.

- Defense Contract Management Agency has information on the capability and past performance of many contractors and suppliers.

- Service and agency Manufacturing Technology Programs can often provide information on manufacturing state of the art; expertise in assessing manufacturing maturity and risk; and/or referrals to other DoD or contractor sources of information or assistance.

- Some service acquisition centers maintain a small cadre of manufacturing specialists who can be sought out for information and assistance.

Issue 3-A: Making Contact

- Contacts for DoD ManTech Programs are available on www.dodmatech.com.

DCMA maintains a website with contact information at www.dcma.mil.

Chapter 6
Key Responsibilities and Activities

6.1 Introduction

Manufacturing readiness is a continuous and on-going process that should begin with Concept Refinement and continue through program disposal (Operations and Support). Programs, systems, sub-systems, and components that demonstrate appropriate levels of manufacturing maturity should be allowed to move forward. Programs that fail to demonstrate the appropriate level of manufacturing maturity should develop risk management and mitigation strategies prior to being allowed to move forward.

In the Senate Report (109-254) accompanying the recently passed 2007 Defense Authorization bill (S-2766) directs the Department to report to the congressional defense committees no later than March 1, 2007, on the feasibility of incorporating MRL's into DOD Instruction 5000.2 as explicit criteria for milestone decisions."

Many individuals and groups have some direct or oversight responsibility into the decision-making process to include:

- Program Manager (PM)
- Functional Managers (PQM, S&T, SE, etc.)
- Program Executive Officers (PEOs)
- Component S&T and AT&L Executives
- DUSD (DDR&E)
- DUSD (A&T)

Interim guidance suggests that it is the Program Manager’s responsibility for directing Manufacturing Readiness activities and assessments, and for certifying a program is mature from a manufacturing perspective.

6.2 Key Responsibilities

Program Managers:

The PM is perhaps the most important person when it comes to the development of defense systems. It is their responsibility to transform a need into a reality. The PM normally reports to a Program Executive Officer (PEO), who oversees several PMs. The PEO reports directly to the Component Acquisition Executive (CAE), who then reports through the Component Secretary to the USD (AT&L).

Another very important individual is the Component S&T Executive. They report to the CAE and are responsible for the developing the noncommercial technologies that the Component will need to meet future operational requirements. DUSD(S&T) has an oversight responsibility for Technology Development programs as part of managing the overall S&T program within DoD. Finally, the Program Manager can turn to their staff of functional managers to assist them in managing their program and risks.

What is required? DoDI 5000.1 notes that the PM is the "*designated individual with responsibility for and authority to accomplish program objectives for development, production, and sustainment to meet the user's operational needs. The PM shall be accountable for credible cost, schedule, and performance reporting to the MDA.*" In addition, DoDI 5000.1 notes *"DoD Instruction 5000.2 provides a partial listing of the types of knowledge, based on demonstrated accomplishments, which enable accurate assessment of technology and design maturity and production readiness."* Finally, the Defense Acquisition Guidebook (DAG), Chapter 4.4.6.2 Manufacturing Readiness Levels states *"Engineering and Manufacturing Readiness Levels (EMRLs) are a means of communicating the degree to which a technology is producible, reliable, and affordable. Their use is consistent with efforts to include the consideration of engineering, manufacturing, and sustainment issues early in a program. More information can be found in the Manager's Guide to Technology Transition in an Evolutionary Acquisition Environment. Application of EMRLs should be tightly integrated with the technical reviews detailed in Section 4.3."*

Program Managers should be asking probing questions regarding the readiness of manufacturing to move forward. The answers to their questions should be based on a rigorous manufacturing assessment. These questions could be used to support Milestone Decisions or Program Reviews and Audits. The MRL database of questions (MRL Assist tool) can be used to provide PMs with the top-level questions that they can ask of their functional managers. The database will provide the PM insight into manufacturing readiness risks. It is up to the PM at that time to show that the manufacturing is mature or that the risks have been identified and mitigated.

Program Managers must:

- Identify their target MRL.
- Assess their current MRL.
- Identify programs, plans and investment strategies to achieve the target MRL.
- Certify the MRL at appropriate Milestone Decisions and during significant reviews and audits. Programs should target MRLs as follows:
    - Milestone A: MRL 4
    - Milestone B: MRL 6
    - Milestone C: MRL 8

- Full Rate Production (FRP) Decision: MRL 9

Functional Managers:

Functional Managers support the PM with day-to-day oversight of their functional areas of responsibility. Often there is overlap as risks in one area spill over into other areas. For example, a design that is not producible because it has more parts than an optimal design might have, will cost more to fabricate and assemble, and will be less reliable and cost more to maintain as there are more parts to break or lose. Thus if you are having problems making it on the factory floor, chances are that you will have problems with it in the field and in the maintenance shops keeping it operational. Therefore it is important that functional managers work together to identify related design and production issues that provide additional risks. MRLs and TRLs should be closely linked and jointly evaluated using the Integrated Product Team (IPT) approach. The DAG states that the application of EMRLs should be tightly integrated with technical reviews (and audits) as outlined in Section 4.3 (of the DAG). Please note that EMRLs and MRLs accomplish essentially the same thing.

Rigorous manufacturing assessments should be conducted on a regular basis. The technical reviews and audits outlined in the DAG are excellent assessment points. The MRL database of questions can be used to provide functional managers with the mid-level management questions that can be asked to support those reviews and audits and to support requests for information by their PM. The database will provide the functional managers with insight into manufacturing readiness risks and to provide the PM with an assurance that the manufacturing is mature or that the risks have been identified and mitigated. One way to mitigate risks is to provide funding for maturing the manufacturing processes.

Program Executive Officers:

PEOs typically have primary responsibility for directing several major defense acquisition programs and for assigned major system acquisition programs. The PEO has oversight responsibilities over acquisition program managers and their programs under them. PEOs report to the Component Acquisition Executive. As a part of their responsibilities PEOs need to be able to ensure that manufacturing readiness is addressed and appropriate. For the PEO this means at the Milestone Decision points. But it could also include requests for information from other reviews and audits. The MRL database of questions can be used to provide PEOs with the executive-level questions that they can ask of PMs. PMs in turn, can look up in the MRL database and see what kinds of questions the PEO should be asking.

Component S&T and AT&L Executives:

The Component Acquisition Executives are in the decision-making loop at the Milestone Decision points. They should be using manufacturing assessments to ensure that the program is ready to move forward and those risks have been identified and mitigated. It will be up to the Component S&T or AT&L executives to certify that the program is ready to move forward based on the assessment and risk mitigation strategies and plans. The certifier (S&T or AT&L) will be dependent upon the phase and funding for the manufacture maturing program.

DUSD (DDR&E):

Has oversight for technology policy and is responsible for ensuring that manufacturing readiness is an important factor in Milestone Decisions and in all Technical Reviews and Audits from and manufacturing technology development perspective. They own the MRL definitions and overall MRL and MRA process. They are responsible for ensuring that policy, guidance and training is developed to support these requirements. Provide manufacturing readiness assessment tools and identify and promulgate government and industry best practices and communicate those best practices through the Defense Acquisition University's Communities of Practice for Science and Technology (S&T) and for Production, Quality and Manufacturing (PQM).

DUSD (A&T):

Has oversight for acquisition policy and is responsible for ensuring that manufacturing readiness is an important factor in Milestone Decisions and in all Technical Reviews and Audits from and acquisition perspective.

Milestone Decision Authority (MDA):

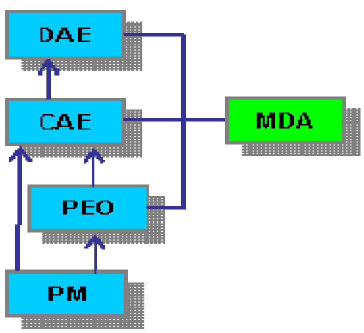


Figure 6.1

The Milestone Decision Authority varies depending on the size and importance of a program. No matter what level is, the Milestone Decision is being made at, the Program Manager must certify to the MDA that the program has achieved the requisite Manufacturing Readiness Level and is prepared to move to the next phase. In addition during the course of the program, program and/or manufacturing technology managers must certify during the appropriate review or audit that the manufacturing readiness is appropriate for the phase of the program. It is important to understand that the Manufacturing Readiness Assessment process is not looking to invent new reporting procedures. We are looking at using the existing framework to add emphasis to a somewhat neglected area. At this time there is no requirement for an independent certification.

6.3 Key Activities/Timing

Interim Guidance suggests that the manufacturing readiness is an on-going activity that begins very early in a programs life and does not end until disposal. Throughout the life cycle there are many opportunities to assess manufacturing readiness to include Milestone Decisions and technical reviews and audits. In addition, the Defense Acquisition Life Cycle Framework can provide for a graphic way to assess and compare technology readiness with manufacturing readiness.

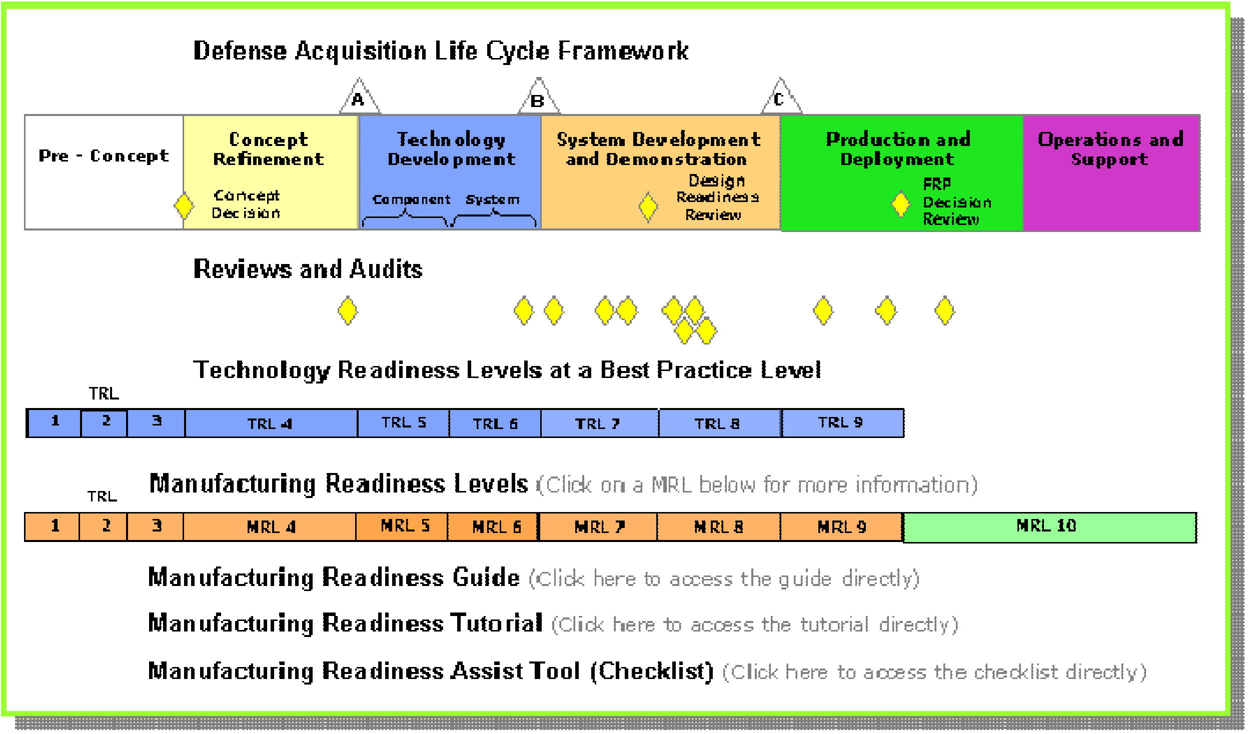


Figure 6.2

Manufacturing readiness begins before systems development, continues during systems development, and continues even after a system has been deployed for a number of years. The ability to transition technology smoothly and efficiently from the labs, on to the factory floor, and into the field is a critical enabler for evolutionary acquisition. One of the critical success factors is the ability to plan for and fund manufacturing and technology investment programs. Typically these programs are funded as follows:

- 6.1 for Basic Research
- 6.2 for Advanced Research
- 6.3 for Advanced Technology Development
- 6.4 for Technology Development
- 6.5 for Technology Transition

We recommend that program managers develop a step-by-step implementation approach to identifying and assessing manufacturing risks. While there is no mandatory implementation process, you could consider using the approach currently used by the Air Force ManTech community:

1. Introduce program office to manufacturing readiness (levels and assessments) and develop a tailored approach for your program with your IPT members.

2. Train your implementers and assessors on manufacturing readiness (begin by looking at the MRL tutorial on the PQM Community of Practice).
3. Define your program goals and identify/prioritize risks.
4. Assess your manufacturing readiness (use the MRL Assist Tool, the questions from the PQM CoP in the MRL folder, or any other appropriate methodologies to include EMRL checklists or assessment tools).
5. Identify budget and funding requirements, capture and fence the funding.
6. Manage the overall manufacturing readiness process, continue to monitor and identify risks. And update the program as necessary.

6.4 POLICY, DIRECTION AND GUIDANCE

DUSD(S&T) will be responsible for ensuring that Manufacturing Readiness is addressed in:

- DoDD 5000.1
- DoDI 5000.2
- Defense Acquisition Guidebook
- Any other documentation, as appropriate

DUSD(S&T) will be responsible for communicating current best practices and approaches to manufacturing readiness at conferences, symposia and other venues.