1.0 Manufacturing Readiness Level Introduction

1.1 Addressing Manufacturing Maturity in Acquisition

DoD case studies and GAO reports have demonstrated that the failure to adequately manage manufacturing risk early in a program's life cycle is a root cause of cost and schedule growth. There is near universal agreement that examining manufacturing maturity for the first time just prior to production is a mistake; manufacturing readiness must be addressed early in the acquisition process and some phases of Science and Technology (S&T).

Recognition of the need to address manufacturing readiness earlier in acquisition policy was implemented by Department of Defense Instruction 5000.02, Operation of the Defense Acquisition System, dated 8 December 2008. The policy established maturity criteria for measuring risks associated with manufacturing processes for Milestones A, B, and C and Full Rate Production.

This policy is not enough. It does not explain what to do or how to do assess and measure manufacturing risk. For programs to transition from development to production effectively and efficiently, they must be given clear guidance on how to:

1) Manufacturability and producibility of the product design must be assessed early in the S&T and/or Material Solution Analysis acquisition phases;

2) follow a well-documented roadmap to achieve manufacturing maturity;

3) collect fact-based information on manufacturing maturity to improve the program's understanding of manufacturing risk much earlier than in the past;

4) manage and communicate manufacturing maturity throughout the program's supply chain and customer base; and

5) identify systemic manufacturing problems across programs, contractors, and the industrial base.

The procedures described in the Manufacturing Readiness Level (MRL) Deskbook represent best practices for successfully implementing such guidance. These procedures were developed jointly by government and industry subject matter experts through a rigorous process of collecting best practices, performing extensive literature searches, conducting pilot studies, and convening major workshops. See appendix (a) for the detailed history of MRL development.

1.1.1 Use of an MRL-Based Process to Manage Manufacturing Risk

The GAO and Congress identified MRLs as an important tool for assessing manufacturing maturity and recommend that the DoD acquisition community utilize MRLs to help manage

manufacturing risk in programs. The following are some key examples of the recognition of the importance of using MRL criteria to address this situation:

Add the following:

- The issue of involving all key stakeholders early in the S&T/Material Solution Analysis process was first formally introduced in a joint Government, Industry and Academia task force organized under the National Center for Advanced Technologies (NCAT) which issued major report January 1994 entitled “Technology for Affordability” based on employing Integrated Product/Process Development (IPPD), Simplified Contracting and Dual-use Manufacturing

  Organize the following documents in order of date issued:

- NDIA Manufacturing Division endorsed MRLs in 2009
- DoD ManTech Strategic Plan – March 2009
  - Thrust 3.1: Develop and release effective policies and practices to assess and improve manufacturing readiness to support the implementation of manufacturing readiness as a management criterion in the transition of programs in each phase of development.
- DoDI 5000.02 – Dec 2008
  - Manufacturing considerations introduced earlier in the life cycle.
  - Exit criteria, based upon MRL definitions, required for all phases of acquisition.
- GAO report 10-439 - 22 April 2010
  - Performed an in-depth assessment of MRL practices.
  - Recommended a requirement to use MRLs in DoD acquisition.
- Section 812 of the FY 2011 National Defense Authorization Act in Dec 2010
  - Required MRLs on MDAPs.
- OSD used MRL criteria on some Program Support Reviews (PSRs) in 2009, where results support major milestone decisions.
- An August 2011 update to DAG Chapter 4 on Systems Engineering advocated the use of Manufacturing Risk Assessments starting at MS A in response to Section 812 language.

MRLs are being deployed throughout industry and government because they help improve acquisition performance, from a manufacturing cost, availability, and quality perspective. Based

on their successes, many prime contractors are using MRLs as “Standard Operating Procedure” (e.g. Raytheon, Honeywell, GE, Lockheed, etc.). DoD Components and other government agencies have also implemented MRLs to varying degrees.

- Air Force policy requires the use of MRLs on S&T and acquisition programs.
- The Army requires the use of MRLs on its Manufacturing Technology Programs. It has implemented MRLs on a number of acquisition programs, but there is no overall policy requirement to do so.
- The Navy has no firm requirement for utilizing MRLs but has used them at both NAVSEA and NAVAIR on selected programs.
- MDA, DCMA, DOE, DOC, and NASA have used MRLs at some level
- MRLs are finding their way overseas to EU countries (Great Britain and Germany)

1.2 Purpose and Organization of this Document

The main purpose of this guide is to allow the user to effectively and efficiently implement MRLs. Each chapter is written to be a stand alone for a specific phase and therefore allows the User to concentrate on efforts recommended for their program.. The MRL Deskbook, at http://www.dodmrl.com, describes how to use MRLs to manage manufacturing risk and should be read before using this guide. If possible you should also take the AFIT Web-based training program, SYS 113, available to everyone that has a .gov or .mil site and attend the AFIT course (SYS 213) to get further understanding of the basics of MRLs. The Deskbook and the AFIT course will provide you with the necessary grounding to effectively follow this guide. There are also various DAU courses available that can provide additional guidance in this area. This document is designed to help the user implement MRLs in all Science and Technology, Acquisition, and Deployment Phases of a program. It is organized by phases (e.g. S&T, Materiel Solution Analysis, Technology Development, EMD, etc). Each chapter provides the following for a specific phase:

- the purpose of using MRLs;
- the key activities that benefit from the use MRLs;
- the specific activities and documents take should take MRLs into account;
- and identification of expected results at the end of that phase.

The following chapters will provide guidance on how to use MRLs in the specific phase of their programs. The below will highlight the objective of each chapter in the guide.

- Chapter 2 – Using MRLs to help transition S&T into Acquisition
- Chapter 3 – Using MRLs to assess manufacturing feasibility – IAW DoDI 5000.02

- Chapter 4 – Using MRLs to assess manufacturing capability/risk and demonstrating in a production relevant environment - IAW DoDI 5000.02
- Chapter 5 – Using MRLs to assess manufacturing readiness for production and demonstrating in a pilot production line - IAW DoDI 5000.02
- Chapter 6 – Using MRLs to demonstrate readiness for Full Rate Production
- Chapter 7 – Using MRLs to assess supportability

Every program is different, and it is critical when using this guide that manufacturing Subject Matter Experts (SMEs) assesses program complexity and overall program objectives on cost, schedule and performance to best decide on an implementation strategy that will maximize probability of success. This document is just a guide, and even with the comprehensive process outlined therein, blind implementation, or implementation with inexperienced personnel could result in excess cost. Even when applied correctly, use of this document does not guarantee success, but it will enable earlier program manager understanding and more thorough management of manufacturing maturity issues.

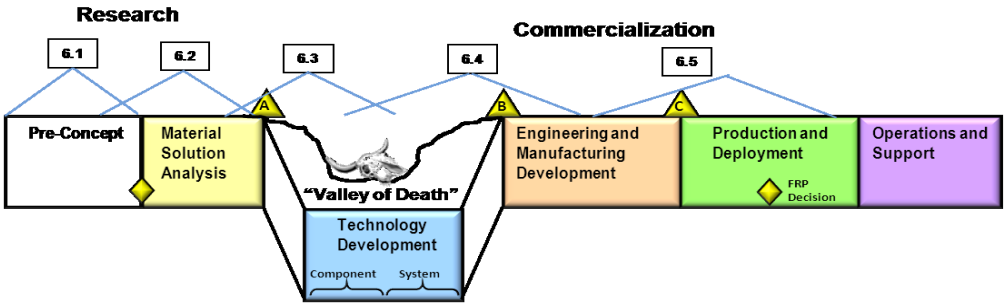
1.3 Summary

The MRL process was developed by SMEs from Industry, Government, and Academia and has been continuously refined and improved by numerous Joint Workshops and Pilot Studies over a ten-year period. The process is well defined in the MRL Deskbook (http://www.dodmrl.com), and it is recognized by Industry, Services, GAO, Congress, and other Government agencies as an excellent process to reduce risk. The process has now been integrated into acquisition and systems engineering processes to allow for a total system approach. This guide will provide specific details on to implement MRLs into your program for evaluating manufacturing readiness at any given point in the acquisition process (e.g. Program Milestones, Technical Reviews, etc.).

2.0 MRLs in the Science and Technology (S&T) Phase

2.1 Purpose

The purpose of MRLs in S&T is to help transition capability to our Warfighters more effectively and efficiently. Within DoD, the S&T and Acquisition communities have been separated organizationally and financially for good reasons (e.g. focusing more on future capabilities versus near-term issues), but one of the problems that has resulted in this separation is a lack of clearly defined roles and responsibilities for each community, to effectively transition



capabilities from S&T into the acquisition process resulting in what is often referred to as the "valley of death". It is essential that **collaboration and coordination** between these communities be achieved, but there is no clear guidance on how to make that happen. One tool available is MRLs. MRLs provide a standard language in addressing manufacturing maturity, by all parties, much like TRLs have provided a standard language for measuring technology maturity. The S&T community clearly understands the role of TRLs in performing studies, trials, experiments and other intellectual activity in the development of prototypes to demonstrate technologies to some readiness level; however, their responsibility for maturing a technology to effectively and efficiently transition to production is not clearly defined. The problem, from a manufacturing perspective, is that in S&T programs we place our focus on building (producing) one item to demonstrate an innovation/technology, but we lack the resources to assess the risk in maturing manufacturing processes that were used to build that one test unit, or the manufacturing processes that may be needed to produce the later defined items in acquisition. The consequence is that S&T products are often transitioned to acquisition without a clear understanding of manufacturing risk. This increases the probability that an acquisition program will not achieve its cost, schedule and performance objectives. Addressing manufacturing maturity in S&T is critical if we wish to deliver the affordable warfighting capability that is demanded by our customers.

2.1.1 Basic Research (6.1)

Basic Research is a systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications

toward processes or products in mind. It includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. It is farsighted high-payoff research that provides the basis for technological progress. It is difficult to visualize how to use MRLs in this early phase where there is no specific application identified for a process or product. Understanding how new knowledge can be used matures over the course of the basic research period so that at its conclusion, application can begin for specific use. For manufacturing, this new knowledge may translate into new or improved manufacturing processes or new manufacturing technology. Researchers at this point may see immediate application to manufacturing, or they may discover side benefits to manufacturing in later phases of S&T.

Purpose of MRLs in Basic Research

The MRL process in Basic Research has limited applicability. The lower MRLs (1-3) are better reserved for characterizing the state of the manufacturing risk of a potential product than assessing manufacturing aspects of the outcome of scientific discovery. Alternatively, assessing manufacturing aspects of new technologies or materials may provide insight into new manufacturing processes that need to be developed to achieve innovative new products.

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Summary of MRLs in Basic Research

In this early stage MRLs should only be used to obtain knowledge that would be useful to leadership to make informed decisions on which future manufacturing risk areas or technologies they may wish to address when proceeding into the Applied Research phase or to define manufacturing areas where more basic research needs to be done.

2.1.2 Applied Research (6.2)

Applied research is a systematic study to gain knowledge, or understanding, necessary in order to determine the means by which a recognized and specific need may be met. From a manufacturing perspective this level is characterized by assessing the application of the manufacturing capabilities, capacities, or materials needed to meet the specific need. Applied research translates basic research into solutions for broadly defined military needs. Typically this level of readiness includes identification, paper studies and analysis of material and process approaches. An understanding of manufacturing feasibility and risk should be emerging at the point when a clear definition of how the technology fits into a military product with a good understanding of the risk at the completion of the product definition,.

Applied Research is taking the knowledge of manufacturing process/science and demonstrating application of the fundamental principles learned in basic research. It is generally performed in a laboratory environment where small samples are developed to allow measurement and observation of process and technique. The resulting item should have materials and processes (limited) that can be assessed. Proof of results on a limited scale is generally the objective.

Upon completion of Applied Research, application of these processes and techniques is ready for demonstration on a prototype.

Purpose of MRLs in Applied Research

The MRL process in Applied Research should use MRLs (1-4) assess the manufacturing feasibility of the S&T results.

Summary of MRLs in Applied Research

Information gained from an identifying manufacturing risks in the Applied Research phase should be used to provide leadership knowledge of potential manufacturing shortfalls that should be addressed in future product development phases..

2.1.3 Advanced Technology Development (ATD) (6.3)

In an ATD program, systematic application of knowledge to produce useful materials, devices, and systems or methods, is considered. This includes design, development, and improvement of prototypes and new processes to meet specific requirements. It encompasses all efforts for the development and integration of hardware for field experiments and tests. However, at this stage it is essential to begin addressing manufacturing maturity on products you anticipate transitioning to acquisition.

The objective of the ATD program is to meet the larger Defense Department enterprise's needs as efficiently and effectively as possible. This phase of S&T requires the greatest degree of collaboration between the S&T and Acquisition communities. ATD programs must demonstrate, apply, and partner in the transition of technologies to enable affordable and decisive military superiority to defeat any adversary on any battlefield.

To effectively transition ATDs one must address the manufacturing maturity of the prototypes being developed! Assessing the maturity of the manufacturing processes in ATDs mandates that the S&T and acquisition community work together. Whenever there is a potential to transition hardware, it is recommended that an agreement or memorandum of understanding be implemented by these two parties. This should be the norm for all ATDs. The agreement should spell out specifically **what** will be done, addressing manufacturing maturity assessments and manufacturing improvements in the ATD. Further, it should spell **who** will accomplish what by spelling out specific roles and responsibilities for providing resources and funds to perform required tasks to implement the agreement. This enables the acquisition customer to better define product maturity and allows for more effective planning for transitioning into the acquisition phase. Finally, the agreement should identify **when** tasks will be done by laying out an integrated schedule. This agreement is important to avoid risk of not achieving cost, schedule, and performance objectives during ATD implementation.

Specifically during an ATD (or Future Naval Capability—FNC for Navy project initiation), communication should begin with the anticipated customers on their requirements and expectations for the completed project. The S&T community, working closely with the acquisition community, should assess these requirements versus their constraints (e.g. funds,

resources, timing, etc). Once this assessment is achieved the S&T community should define the final objectives for assessing and addressing manufacturing maturity issues for the ATD. Finally, before beginning an ATD these final objectives should be agreed to by all parties through some type of Technology Transition Agreement (TTA) or Memorandum of Understanding.

Purpose of MRLs in ATDs

- One of the performance objectives to be achieved in the ATD phase on programs with hardware being transitioned **should be** to gain an understanding of the MRL at the **completion** of the ATD. However where there exist a high probability of transitioning a product, it is recommended, as a best practice, that you need to identify the manufacturing feasibility using the MRL criteria at **initiation** of the ATD to determine the baseline manufacturing maturity on projects and where to go from there. This should be performed and funded by the agreed parties identified in the TTA. This should not be an expensive nor a time consuming activity.

- Performance objectives **should be** established by the potential customer(s) including the MRL criteria necessary at acquisition program initiation. It is important to note at this time that the MRL(s) criteria consist of nine major treads and twenty-two sub-treads. It is essential to decide on specific MRL criteria that should to be demonstrated as part of the ATD.

- At the beginning of ATD, overall objectives/goals for cost, schedule and performance that are planning to be demonstrated should be reviewed with the customer(s) who could jointly resource and execute those manufacturing maturity requirements that are considered appropriate to their objectives. It is especially critical that the cost goals reflect manufacturing cost considerations and capabilities.

Key Documents and Activities in ATD to address MRLs

If the TTA spells out that manufacturing maturity that will be assessed or improved in the ATD you will need to accomplish the following;

- Scope the effort you want performed (e.g. target MRL) - TTA
  - — Define objectives, funding responsibilities, roles of each party, and outline a schedule
- Obtain manpower to manage the effort
  - — Skills
  - — Resource needs (e.g. man-years)
  - — Availability
- Budget the effort
- Develop contractual language to address the activity
- Release proposal
- Award a contract
- Manage the contract

- Provide reports to your customers on progress
- Final Report

Summary of MRLs in ATD

To effectively transition ATD programs there is a need to know the manufacturing maturity and what the manufacturing risks are before transitioning an ATD into the acquisition process.

2.1.4 Other Developmental Non- Acquisition Programs

There are a number of other developmental non-acquisition program efforts where the use of MRLs is more critical than most 6.1, 6.2, and 6.3 projects. These include those efforts that have a primary goal of developing and delivering manufacturing capability to their customer and those programs where there is a high confidence they will be delivered to the Warfighter. In these cases it is strongly recommended that MRLs be part of the management process to ensure transition is done effectively and efficiently. More importantly, an assessment of manufacturing readiness using MRLs is essential to provide the customer with an understanding of the manufacturing maturity of the final result so they have a full understanding of the risk they assume by proceeding to the next phase.

The following are some key programs that develop manufacturing capability for the customer(s).

- Manufacturing Technology Programs
- Title III Projects
- Manufacturing Small Business Independent Research Projects

Programs where there exists a high expectation of delivery capability to the Warfighter.

- Advanced Concept Technology Demonstration (ACTD)
- Joint Capability Technology Demonstration (JCTD)
- Defense Acquisition Challenge (DAC) Programs
- Rapid Fielding Projects

All of these projects should have a TTA which requires the following actions;

- Scope the effort you want performed (e.g. target MRL)
- Obtain manpower to manage the effort
    - Skills
    - Resource needs (e.g. man-years)
    - Availability
- Budget the effort
- Develop contractual language to address the activity
- Release proposal

- Award a contract
- Manage the contract
- Provide reports to your customers on progress
- Final Report

To effectively transition these programs one must know their manufacturing maturity and the risks before transitioning to acquisition.

2.2 Summary

Addressing manufacturing maturity during technology demonstration has historically been a low priority by both the S&T and Acquisition communities. As we look to the future, a conscious decision must be made on whether we should continue as we have in the past or to change. One needed change is to start addressing manufacturing more comprehensively during technology development by both the acquisition and S&T communities. The S&T community probably does not have adequate funding to execute this on their own. The real benefactor of understanding manufacturing maturity and improving it is the acquisition community. Bottom line, addressing manufacturing maturity during S&T is critical to achieving the goal of transitioning capability to our Warfighters more effectively and efficiently.

3.0 MRLs in the Materiel Solution Analysis (MSA) Phase

The process to review available options to support the warfighter requirement starts when the Initial Capability Document (ICD) is released by the Joint Requirements Oversight Council (JROC). A Material Development Decision (MDD) gets released if a new development is necessary to provide the required capability. This begins the MSA phase.

Entrance into this phase depends upon an approved ICD resulting from the analysis of current mission performance and potential concepts across the DoD Components, international systems from allies, and cooperative opportunities. The Materiel Solution Analysis Phase begins with the MDD review. The MDD review is the formal entry point into the acquisition process and is mandatory for all programs….The ICD and the Analysis of Alternatives (AoA) study guidance guides the AoA and MSA Phase activity. The AoA focuses on identification and analysis of alternatives, measures of effectiveness, cost, schedule, concepts of operations, and overall risk. The AoA assesses the critical technology elements (CTEs) associated with each proposed materiel solution, including technology maturity, integration risk, **manufacturing feasibility**, and, where necessary, technology maturation and demonstration needs. To achieve the best possible system solution, emphasis is placed on innovation and competition.

"The purpose of the MSA phase is to assess potential materiel solutions and to satisfy the phase-specific entrance criteria for the next program milestone designated by the Milestone Decision Authority (MDA)."

—DoDI 5000.02 dated 8 December 2008

"The Analysis of Alternatives (AoA) shall assess the critical technology elements (CTEs) associated with each proposed materiel solution, including technology maturity, integration risk, manufacturing feasibility, and, where necessary, technology maturation and demonstration needs."

—DoDI 5000.02 dated 8 December 2008

3.1 Purpose of MRLs in MSA

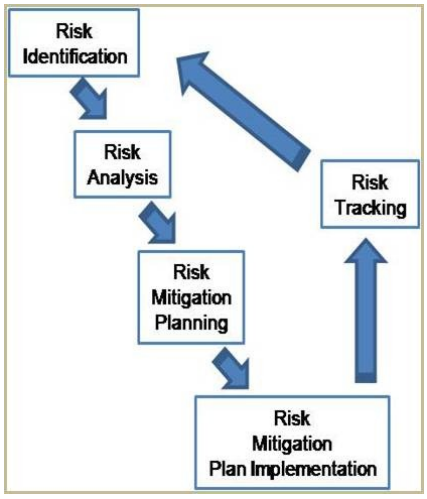
The main purpose of MRLs in this phase is to help assess the manufacturing feasibility of various alternatives being considered in order to understand the risks with proceeding with the selected solution(s). The manufacturing risk identified in this phase needs to be addressed in the Technology Development Phase risk mitigation efforts and reflected in all cost estimates.

According to DoDI 5000.02 the Analysis of Alternatives (AoA) "…shall assess, amongst other things**,** manufacturing feasibility." MRLs (i.e. MRLs 1-4) provide objective criteria for assessing the manufacturing feasibility of the proposed materiel solutions, and the results of this assessment should be used to evaluate the likelihood of the proposed material solutions to

achieve the program's cost, schedule, and performance objectives. This assessment can also be used to address and mitigate manufacturing risk. Manufacturability and Producibility as defined in the MRL Deskbook along with the traditional risk assessment process define what is referred to as "manufacturing feasibility" throughout this chapter.

3.1.1 Assessing Manufacturing Feasibility

Manufacturing feasibility answers the question "can you build it and achieve program objectives?" An assessment of manufacturing feasibility, using MRL criteria, is an examination of the key manufacturing drivers and processes to determine the likelihood of meeting program cost, schedule, and performance objectives using the classic DoD Risk Management process. The assessment of manufacturing feasibility helps a program to: (1) better understand the risk, (2) allow the program to begin risk mitigation efforts, and (3) provide critical information to accurately reflect the financial risk in both the estimating and funding processes. The assessment of manufacturing feasibility provides the foundation for planning efforts necessary to resolve the identified risk.



Manufacturing feasibility assessments are usually associated with the beginning of any project no matter what phase is being entered. However, a risk assessment can be conducted at any time. These assessments should be performed in the conceptual phase, or in acquisition terms, the Materiel Solution Analysis Phase. The key is, before selecting any potential solution, the manufacturing feasibility/ readiness should be evaluated to understand the risk of achieving the cost and schedule for any proposed approach.

Manufacturing feasibility assessments are all about assessing and addressing the risk. Therefore, to use your resources effectively you must decide on the areas to assess based on program/technology/manufacturing complexity. The following criterion provides excellent questions to be asked to help decide where to focus your assessments.

1. Materials: Are there materials which have not been demonstrated in similar products, are not available or have environmental concerns?

2. Cost: Is this item a driver that significantly impacts cost (development, production, or life cycle cost to include operations or support costs)? Is the technology new with a high degree of cost uncertainty?

3. Design: Is the item design new or novel, and have appropriate systems engineering design considerations been evaluated (manufacturability, producibility, reliability and maintainability, obsolescence, safety, human factors, etc.)

4. Manufacturing Process: Will the item require the use of new manufacturing technology, new manufacturing processes, or capabilities that are unproven in the current environment?

5. Quality: Does the item have historical/anticipated yield or quality issues, or require new inspection tools or techniques?

6. Schedule: Does this item have lead time issues, or does it significantly impact schedule?

7. Facilities: Does this item require a new manufacturing facility or scale-up of existing facilities (i.e., new capability or capacity)?

8. Supply Chain Management: Does the item have anticipated or historical sub-tier supplier problems (e.g., cost, quality, delivery), and is the supply chain adequate to meet future needs?

9. Industrial Base: Can the industrial base meet future needs or does the footprint have critical shortfalls, or is this a critical item manufactured by a sole or foreign source?

If you answer "yes" to any of the above questions, there exists a strong possibility that an assessment of manufacturing feasibility will be needed for this approach. The use of manufacturing subject matter experts (SMEs) at this phase is important to ensure that critical factors are addressed and that time is not wasted on irrelevant manufacturing issues.

Once you determine at where to perform the assessment (e.g. Prime, 1st Tier key or critical suppliers, 2nd Tier, etc.), the next step is assessing proposed products and processes using the MRL criteria associated with the phase you are entering (e.g., entering TD phase use MRL criteria 1-4). By using the appropriate MRL criteria you can assess the manufacturing maturity of the proposed product or process against a well-defined path developed by industry and government systems engineering and manufacturing SMEs. **It is important to stress that failing to achieve a targeted MRL may not necessarily be a problem--but it may point to an area that requires further evaluation.**

The figure below outlines the basic approach for performing a manufacturing feasibility assessment. The recommended approach in determining the proposed products/processes to assess is by using the above nine criteria.

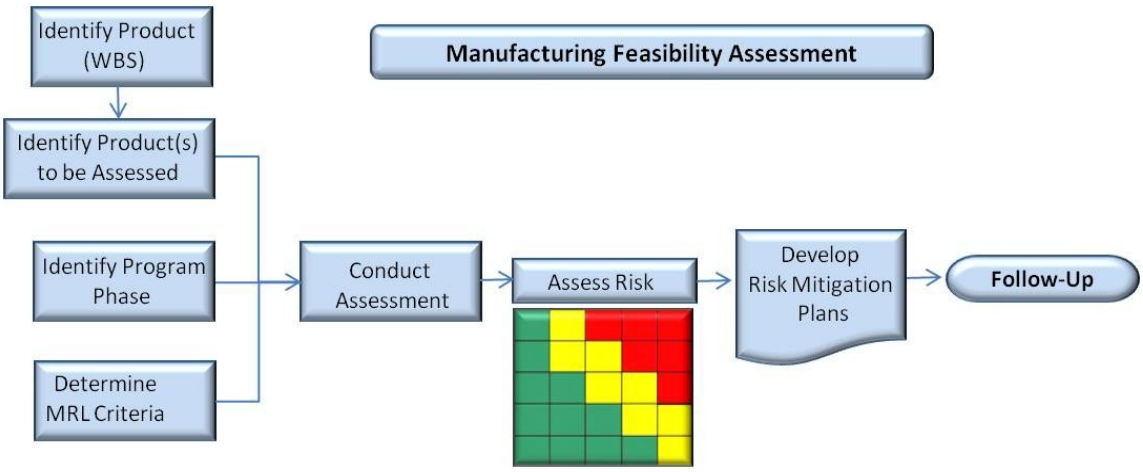


Figure 3-1 A Flow Diagram for the Assessment of Manufacturing Feasibility

The Manufacturing Feasibility Assessment process is comprised of the following eight steps:

1. Identify the product(s) WBS: The AoA identifies a proposed material solution (product). That solution should have an associated work breakdown structure. Capture that WBS!

2. Identify the product(s) to be assessed: From step 1 above, review the WBS to identify the greatest risks and identify within the WBS what sub-products (subsystems and components) contain the highest risks, and identify them as potential candidates for a feasibility assessment.

3. Identify the program phase: The program phase is probably Material Solution Analysis.

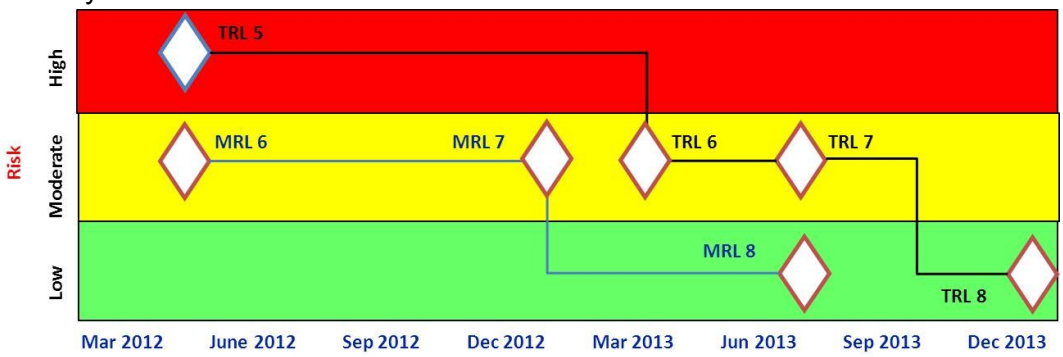
4. Determine the MRL criteria: Since this is the beginning of the MSA phase this will drive you to use the MRL 4 criteria. Once you have the MRL 4 checklist, your team needs to tailor the review to meet the needs of your product's customer. Rate, quantity, producibility and complexity are some of the major factors that drive the production environment. Thus, if you are only building a few items, you will probably want to produce them in a job shop environment. Job shop environments are heavily dependent on skilled labor. If you are producing a high volume, then your production environment may be continuous-flow operation that is more dependent on the use of specialized machines with software controls. Trading on these factors will help you to select MRL questions that better relate to the manufacturing feasibility of the product.

5. Conduct the assessment: Once you have identified all of the criteria and questions, conduct the assessment. At this time your effort is probably a desktop assessment. It may require inputs from other activities. For example, you may want to review any recent industrial base assessments to see if any risks were identified. Once the assessment is performed, the manufacturing maturity level of the proposed product/process is determined. It is essential when performing the assessment that you address the overall

program cost, schedule, and performance objectives. For example, it might be feasible to produce one for 100 million dollars but not feasible to build production units for 10 million per copy, or the industrial base could produce one item, but not thousands.

6. Assess the risk: Any item that receives a negative response identifies a risk that could impact manufacturing feasibility. The impact of that risk needs to be assessed in terms of impact to cost, schedule and performance and resources estimated to mitigate the risk.

7. Develop risk mitigation plans: A plan needs to be developed to “burn-down" the risk. It needs to be time-phased to show how the risks can be managed and reduced in time to meet the next milestone or other major event. The plan also must identify needed resources (dollars, people, etc.) and that budget needs to be fenced to ensure that funds are available to mitigate the risk. This step takes into account a program’s cost, schedule, and performance objectives and assesses them against the manufacturing maturity.



Action Plan	Goals	Cost	Start Date	End Date	Focal Point
TRL actions					
MRL actions					

8. Follow-up: Once the plan has been developed and implemented, it is up to the program office or technology development team to monitor the risk to ensure that the risk mitigation efforts are on track for successful completion.

Note: It is critical to emphasize that the assessment is not to focus on the MRL number. The important thing is to identify and mitigate the risk to achieving program objectives. The MRL number simply points out the activities that should have been completed. The important thing is to realize that it is not about the number; it is about identifying the risk. For example, you could be at the target MRL 4, for leaving the MSA phase, and still have a very high risk in achieving your program’s objectives that will need to be mitigated in the TD phase. The real value of the MRLs is that they make you aware of the risk and provide you an opportunity to develop a roadmap to follow which should increase the probability of successfully achieving your program objectives.

3.2 The use of MRLs in the MSA Phase

MRLs 1-4 are to be used in the MSA phase to assess the **manufacturing feasibility** of the proposed **material solution(s) and provide a roadmap on activities that must be performed in this phase**. The questions that need to be addressed are:

- Are there any new or unique manufacturing processes and materials?
- Does an industrial base exist that can support the program technology requirements?
- Does a manufacturing capability exist that can achieve the cost, schedule, and performance requirements of the program?

This assessment probably will not require a lot of resources, but it does require SMEs in both manufacturing/quality assurance and systems engineering to translate performance requirements into manufacturing capability and capacity requirements. They must then assess manufacturing requirements against the current manufacturing state of the art and capability of the industrial base. One of the key areas to look at in assessing manufacturing capability in these early phases is the projected First Pass Yields (FPY). Any process that is critical in making cost and schedule and has a FPY below 90% should be addressed in the risk assessments. **Key manufacturing considerations include:**

- Identification of manufacturing technologies, materials, capacity and processes not currently available to meet program objectives and mitigate advanced development risks.
- Initial Producibility assessments to achieve cost objectives
- Manufacturing cost and schedule driver analysis to support trade-offs among alternatives
- DoD investments needed to create new industrial capabilities and increased capacity
- Ensure cost estimates reflect the risk of industry not being able to provide new program capabilities at planned cost and schedule

MRLs in this phase are used to identify the manufacturing risk associated with each alternative. Once the risks are identified for each alternative, the information should be used in the cost and schedule estimates for each proposed solution, and then used to begin risk mitigation planning activities for the follow-on phases. In mitigating the manufacturing risk, the following should be considered by the program team:

- Challenge Requirements – If the performance requirements are exceeding the manufacturing capability, it is important to ask the design team and the user to look at relaxing requirements to make the proposed solution more producible. Perhaps even

looking at a phased approach for maturing the capabilities to meet increased performance requirements.

- Use of multiple sources in the next phase to increase the probability of success and create competition.
- Use ManTech and/or other technical funds to explore solutions to solving your risk areas.
- Use Title III funds wherever applicable to address risk areas.
- Look at S&T options wherever applicable to provide a more producible performance option.
- Use SBIR funding wherever applicable to explore solutions to solving the risk areas.

3.3 Key Activities, and Documents in the MSA Phase

The decisions, activities and reviews during this phase are critical in determining whether the final solution will achieve its overall cost, schedule, and performance requirements. It is very difficult to perform detailed manufacturing assessments in this early phase, since there is a likelihood there will be no manufacturing efforts associated with possible alternatives at this time and there really may not be a lot of data or history to review. However, this is the time when a program has the most flexibility to balance cost, schedule, and performance requirements, to conduct trade studies and make trade-off decisions. Therefore, it is strongly recommended that during this phase a through analysis be performed on the manufacturing maturity and risk for each alternative. The purpose of this information is to ensure manufacturing maturity risk issues are reflected in both the program cost estimates and follow-on risk mitigation efforts in the next phase. Historically, both management from the government and industry have spent little, if any, energy assessing the manufacturing feasibility of the alternatives being considered. If there was any manufacturing focus, during this phase, it has been answering the question “Can we produce just one item to get it into testing?” Even though this is a critical question, you must also ask whether a sufficient quantity can be produced to execute the warfighter’s mission. If the manufacturing risk to achieve program target cost and schedule requirements is not addressed here, in all likelihood addressing them later will cost much more with a greater program schedule impact. The focus on manufacturing feasibility must be assessed at a much higher level than the cost to produce one unit. The real questions that must be addressed here are:

- What are the manufacturing risk areas that have a medium to high probability of impacting the program’s cost and schedule estimates? and
- How do you minimize risks and reflect those risks in the cost estimates?

The following will provide some key activities and documents needed to address the planning, execution, or addressing the results of performing an assessment of manufacturing feasibility is this phase.

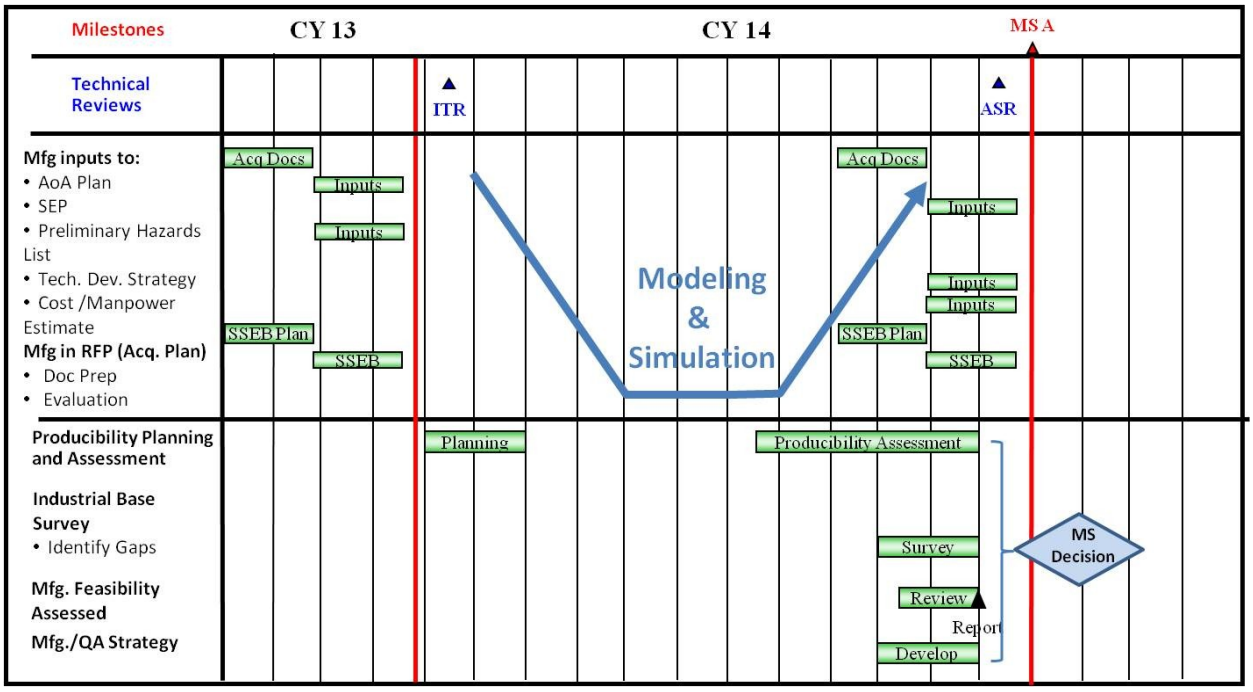


Figure 3-1 Manufacturing Activities During MSA

3.3.1 Key Activities in the MSA Phase

The following activities performed during this phase should assess the manufacturing feasibility using MRLs 1-4, for each of the alternatives being considered.

Analysis of Alternatives (AoA) Assessments

Manufacturing feasibility for each alterative must be assessed by quantifying the risk of the industrial base capability and capacity to achieve the program's cost, schedule and performance objectives. This information will be used to down-select the alternatives and to implement the identified risk reduction activities. – Link to DAG

Lifecycle Cost Estimates

This estimate should be performed on each alternative that is being considered. It is probably the first area where manufacturing feasibility should be adequately addressed. History has proven that we can usually produce one item, but when we need to develop a new manufacturing capability or a new material we do a poor job of reflecting the risk and budget to reduce that risk. We must ensure that projected costs reflect the appropriate manufacturing risk and risk reduction efforts. - Link to DAG

Industrial Base Assessment

For each alternative you should perform a top level assessment to ensure there is adequate industrial base capability available to support overall program requirements. A focus on material availability and unique manufacturing products are crucial in this analysis; however, you should look at any unique demands that push existing capability and capacity beyond

today's industrial base limits. It can take an extraordinarily long time to develop additional capability and capacity, so the earlier that issues are identified and mitigation efforts begin the better. – Link to DAG

Assessments of Manufacturing Readiness

During this phase the assessment will consider new material choices, new manufacturing capability requirements, cost drivers, and industrial base capability. It is a top-level analysis performed by a small number of highly qualified SMEs. The team will use MRL 1-4 criteria to assess the manufacturing maturity of each alternative and its corresponding risk of achieving program cost and schedule objectives. The final step in the MRA process is to begin mitigation efforts for identified risks. – Link to Deskbook

Initial Technical Review (ITR)

The ITR ensures that prospective drivers of system life-cycle cost have been quantified to the maximum extent possible and their range of uncertainty has been reflected in program cost estimates. This will be an essential consideration in addressing manufacturing feasibility concerns for proposed alternatives. Link to DAG

Alternative Systems Review (ASR)

This review assesses preliminary materiel solutions that were identified during the MSA phase and assesses their potential for affordability, suitability, and operational effectiveness. It also answers the question, "can this solution be developed in a timely manner at an acceptable level of risk?" Again, the manufacturing feasibility is of critical importance in this review to increase the probability of meeting the affordability and schedule constraints of each alternative concept. –Link to DAG

Technology Readiness Assessments (TRA)

During this phase the TRA will be focusing on determining the technology maturity of each alternative and assessing the risk of those technologies to achieving program requirements. It is important to understand that there is usually a link to manufacturing feasibility and critical technologies, and further, it is possible that manufacturing processes or materials themselves could be that critical technology. Manufacturing SMEs need to address the manufacturing risk associated with the technology risk areas identified in the TRAs. Link to TRA Deskbook

Budget Process

It is critical that budgets include adequate funding to address the mitigation of manufacturing and critical product technology risks identified in the manufacturing feasibility assessment.

3.3.2 Key Documents in the MSA Phase

To accomplish the above activities manufacturing considerations and feasibility assessments must be addressed in some key documents. The focus of these documents will fall into three areas. The first area will perform the assessment to ensure that the risk is being adequately identified. The next step will ensure that the risk is reflected in the cost estimates. Finally, the

documents will cover the risk mitigation efforts for follow-on phases. The following are those key documents that should be considered, along with a brief explanation on what you should be addressing in each.

System Engineering Plan (SEP)

The government technical lead on the program should explain the approach on how manufacturing considerations will be addressed in the design and how feasibility will be assessed on each option and how the results will be used to mitigate identified cost, schedule, and performance risk. – Link to DAG

Technology Development Strategy (TDS)

This document is developed at the exit of the MSA phase. The TDS should address areas where the program needs to develop or improve manufacturing capability and capacity to achieve its objectives. It should specifically address those manufacturing risk areas identified in the MSA phase and provide an approach to ensure these capabilities are demonstrated in a relevant environment in the next phase. – Link to DAG

Initial Capabilities Document/Capability Development Document (ICD/CDD)

In both of these documents it is important to be able to translate the manufacturing risk, associated with proposed requirements, and be able to provide this information to the Warfighter. The either ICD or CDD or both will include Key Performance Parameters (KPPs) and these should be traced into the design and ensuing manufacturing processes and capabilities. It is critical that they understand what their requirements will cost. It will be even more useful if requirements can be quantified as to their contribution to overall manufacturing risk and cost. Usually the requirements driving manufacturing risk are those that require new materials and/or new manufacturing capability/technology. – Link to DAG

Acquisition Strategy (AS)

Usually in this phase the program should have only one strategy and that should be the TDS; however, if a separate AS is developed it should address how the program will minimize identified manufacturing risk and provide an approach to ensure these risk areas are demonstrated in a relevant environment in the next phase. – Link to DAG

Acquisition Plan (AP)

This document usually does not require outside program approval. It is a tool of the Program Manager (PM) to translate the TDS or AS into specific details needed to accomplish the strategy. This would be an excellent place to identify manufacturing considerations that may be used to impact program planning, the approach to contracting to include the development of source selection criteria, and for the development of manufacturing risk mitigation approaches. – Link to DAG

Request For Proposal (RFP)

One of the principal roles of the manufacturing SME is making an input to the RFP. Once the MSA phase is exited and the Technology Development (TD) Phase is entered, it is essential that the actions expected by the contractor(s) in accomplishing the manufacturing

strategy and planning be called out in the RFP and reflected in the TSD/AS and SEP. The risk areas identified from the above assessments must be evaluated. In addition, the contractor(s) should be required to demonstrate the manufacturing processes in a relevant environment, and he (they) must identify and mitigate manufacturing risk in the TD phase. The RFP should include manufacturing criteria (MRL) to be used to evaluate the pending proposals. - Link to DAG and Deskbook

Integrated Master Plan (IMP)

The IMP is a critical tool to manage the program. The program manager should use event-driven schedules and require manufacturing SMEs to identify all tasks that should be accomplished in a rational and logical order. Necessary entry and exit criteria for each major task should be identified, and no major task should be started or declared complete until all required criteria have been satisfied. When documented in a formal plan and used to manage the overall program, this event-driven approach ensures that all tasks are integrated properly and the management process is based on accomplishment of significant events in the acquisition life cycle--not on arbitrary calendar dates. This planning effort should take documents like the SEP and MRL threads and translate them into defined activities to be performed as part of the IMP during this phase. They will be used to assess manufacturing feasibility and address the risk areas identified. - Link to DAG

Integrated Master Schedule (IMS)

The IMS takes the IMP requirements and defines the requirements in terms of calendar time and resources needed to accomplish the IMP. The IMS also needs to address the resources needed to accomplish the requirements. – Link to DAG

Program Objective Memorandum (POM)/Budget Estimate Submission (BES)

It is critical that these documents identify that there is adequate funding to cover the activities to assess and mitigate manufacturing risks in the next program phase.

3.4 Supporting the Defense Acquisition Board (DAB) at Milestone A

From a manufacturing perspective, the Milestone Decision Authority (MDA) needs to be assured that an adequate assessment of manufacturing feasibility has been performed on each alternative and that the recommended risk mitigation activities coming from the assessment are being implemented and reflected in the cost estimates. The following activities/documents need to address manufacturing feasibility at the DAB.

- Program Support Reviews (PSRs) - The PSR, if performed on the program, will assess the technical progress being made. The PSR should address the program's progress in assessing the manufacturing feasibility of each alternative and the risk mitigation efforts being planned in the program. This information should be used at the DAB. Defense Acquisition Program Support (DAPS) Methodology, Version 2.0, Change 3 *March 20, 2009*

- Milestone Certification Requirements – It is important that this certification states that the manufacturing feasibility of each alternative was addressed, and results were used in the program cost estimates. – Link to DAG

- Overarching Integrated Product Team (OIPT) - An OIPT reviews program planning, facilitates program communications and issue resolution, and supports the MDA for ACAT ID. It will be important that the OIPT is aware of the manufacturing feasibility issues and how these issues will be addressed to ensure the MDA has the required information to make a sound decision on the programs direction.

3.5 Summary

During the MSA Phase, an assessment of manufacturing feasibility is conducted for each competing materiel solution being examined in the AoA. The manufacturing risk of each proposed materiel solution will be assessed to determine whether it can achieve program cost, schedule, and performance objectives. The program can then begin addressing and mitigating any identified risk.

The results of these assessments are key emphasis areas that should be considered at the Milestone A Defense Acquisition Board (DAB) decisions in selecting the preferred approach. Results should be used in the contractual and program planning activities to mitigate the identified risk as the program enters the next phase.

4.0 MRLs in the Technology Development (TD) Phase

Entrance into this phase depends on the completion of the AoA, a proposed materiel solution, and full funding for planned Technology Development Phase activity. At Milestone A, the MDA reviews the proposed materiel solution and the draft Technology Development Strategy (TDS) to determine if ready to proceed. The Technology Development Phase begins when the MDA has approved a materiel solution and the TDS, and has documented the decision in an ADM.

"The purpose of the TD phase is to reduce technology risk, determine and mature the appropriate set of technologies to be integrated into a full system, and to demonstrate CTEs on prototypes. 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."

—DoDI 5000.02 dated 8 December 2008

"The TDS and associated funding shall provide for two or more competing teams producing prototypes of the system and/or key system elements prior to, or through, Milestone B. Prototype systems or appropriate component-level prototyping shall be employed to reduce technical risk, validate designs and cost estimates, ***evaluate manufacturing processes****, and refine requirements. Information technology initiatives shall prototype subsets of overall functionality using one or more teams, with the intention of reducing enterprise architecture risks, prioritizing functionality, and facilitating process redesign."*

—DoDI 5000.02 dated 8 December 2008

"A successful PDR will inform requirements trades; improve cost estimation; and identify remaining design, integration, and ***manufacturing risks****."*

—DoDI 5000.02 dated 8 December 2008

"The project shall exit the Technology Development Phase when an affordable program or increment of militarily useful capability has been identified; the technology and ***manufacturing processes for that program or increment have been assessed and demonstrated in a relevant environment; manufacturing risks have been identified****; a system or increment can be developed for production within a short timeframe (normally less than 5 years for weapon systems)****; or, when the MDA decides to terminate the effort."*

—DoDI 5000.02 dated 8 December 2008

4.1 Purpose of MRLs in TD

The two main purposes of MRLs in this phase are to identify and assess the manufacturing risk of the alternatives being considered and to begin maturing the manufacturing processes to reduce risk. One of the key activities in maturing the manufacturing process in the TD phase is to assess the degree to which the systems being considered has been adequately demonstrated in a relevant environment. The manufacturing risk identified in this phase needs to be addressed in the Engineering Manufacturing Development (EMD) Phase through various risk mitigation efforts. Risk mitigation cost must be reflected in all cost estimates.

4.1.1 Using MRLs for Managing and Assessing Manufacturing Risk in the TD phase

Managing and assessing manufacturing risk using the MRL process is basically a three step operation. The first step is requiring the program to perform critical manufacturing maturity efforts that will not only generate the data necessary to perform an assessment but put into place the activities needed to mature the manufacturing processes. The MRL process, using the criteria of MRLs 5 & 6, defines key activities to be performed to reach a target level of manufacturing maturity during this phase. The next step is to assess the manufacturing maturity of the program using the MRL criteria to ensure the recommended activities have been accomplished. The third and final step, before proceeding into EMD, is to use the data created by the first two steps to assess the manufacturing risk and determine whether the manufacturing processes will fall within the program's cost and schedule objectives. After these risks are assessed, risk mitigation plans need to be developed to minimize manufacturing risk for EMD. The use of MRL criteria is an industry best practice to ensure your program deals with manufacturing risk before proceeding to the next phase. If the program doesn't follow the steps outlined in the MRL process there is likelihood that the program will not capture all the manufacturing risk, thereby carrying that risk over to the next phase of the program. Nevertheless, we must stress that following this process does not necessarily eliminate all risk, but it does increase the likelihood of identifying specific risks much earlier in the programs lifecycle. The use of MRLs provides the program with an excellent to tool to evaluate manufacturing risk before proceeding into EMD, and it takes advantage of the expertise and experience of many SMEs from both industry and government. Some of the advantages of using MRL criteria during this phase are looking at the unit cost goal realism, recognizing the likelihood of achieving the program's EMD schedule, and ensuring that the manufacturing processes have been demonstrated in a relevant environment.

Demonstrating critical manufacturing processes in a production relevant environment before proceeding into the EMD Phase is critical to assessing manufacturing risk and obtaining confidence that you can achieve program cost, schedule and performance requirements for EMD. This level of production realism is well beyond what is seen in a laboratory. The emphasis is on addressing higher risk areas (e.g., more advanced technologies and newer manufacturing capabilities). During this critical junction it is essential that the contractor(s) demonstrate the capability to build the product or a similar product (e.g., considering size, tolerances, quality

levels, processes, and testing) in the facility that will be used during production. A production relevant environment is defined as follows:

Production relevant environment— an environment with some shop floor production realism present (such as facilities, personnel, tooling, processes, materials etc.). There should be minimum reliance on laboratory resources during this phase. Demonstration in a production relevant environment implies that contractor(s) must demonstrate their ability to meet the cost, schedule, and performance requirements of the EMD Phase based on their production of prototypes. The demonstration must provide the program with confidence that these targets will be achieved, but does not require a production line.

Furthermore, there must be an indication of how the contractor(s) intend to achieve the requirements in a production representative and pilot environments.

This definition of a production relevant environment is intended to demonstrate the natural progression of manufacturing maturity throughout the acquisition life cycle. The program office and contractor must reach agreement on the detailed production realism content (equipment, personnel skill levels, processes, etc.) for what they define as the production relevant environment for their specific program. This agreement must be based on the specific system requirements and associated manufacturing risk in order to mitigate that risk in a timely and thorough manner.

Defining those critical manufacturing processes to evaluate in the TD phase is very similar to the process one would use in the MSA phase. If the hardware is using manufacturing capability that is well understood and the design is fairly straight forward where one can easily project the ability of this hardware to make the cost, schedule, and performance requirements then you should not be spending too much time on this. However, the following criteria are provided to determine where you will need to expend resources to address the manufacturing maturity in the TD phase.

1. Materials: Are there materials which have not been demonstrated in similar products or manufacturing processes?
2. Cost: Is this item a driver that significantly impacts life-cycle cost (development, unit, or operations and/or support costs)? Is the technology new with high cost uncertainty?
3. Design: Is the item design novel or does it contain nonstandard dimensions, tolerances or arrangements?
4. Manufacturing Process: Will the item require the use of manufacturing technology, processes, inspection, or capabilities that are unproven in the current environment?
5. Quality: Does the item have historical/anticipated yield or quality issues?
6. Schedule: Does this item have lead time issues or does it significantly impact schedule?

7. Facilities: Does this item require a new manufacturing facility or scale-up of existing facilities (i.e., new capability or capacity)?

8. Supply Chain Management: Does the item have anticipated or historical sub-tier supplier problems (e.g., cost, quality, delivery)?

9. Industrial Base: Does the item have an industrial base footprint with critical shortfalls or is this a critical item manufactured by a sole or foreign source?

If you answer "yes" to any of the above questions there is a high likelihood that an assessment of manufacturing maturity and corresponding manufacturing risk will be needed for this hardware. The use of manufacturing SMEs at this phase is important to ensure that critical factors are addressed and that time is not wasted on irrelevant manufacturing issues. Selecting the right areas to assess for risk is extremely important in this phase, for there is a much higher likelihood that your efforts will have the greatest return on investment now versus later.

4.1.2 Overview of MRLs to mature the manufacturing process in the TD Phase

The MRL process provides what is considered to be a best practice to capture and manage manufacturing risk before proceeding into the next phase. While it is unlikely that contractors would have a complete factory and supply chain established this early in a program, there is still a need to obtain knowledge of critical manufacturing processes, production scale-up efforts, potential supply chain issues, and manufacturing maturity issues. It is essential that a good baseline of the manufacturing maturity and risk be established at the beginning of the TD phase in order to employ the correct risk mitigation efforts. If your program had an MSA phase, the results from that would be a good start in addressing the manufacturing risk, but it is recommended in any case that you conduct a manufacturing assessment early in the TD Phase to establish a baseline for manufacturing maturity and risk. A key goal in this phase is to mature the manufacturing process, but probably even more important, it is to identify, assess, and mitigate manufacturing risk before proceeding into EMD. Some of the key considerations you should be able to address at the end of the TD Phase:

- Probability of meeting the EMD delivery date
- Potential impact of critical and long-lead time material
- Production and test equipment availability
- Production unit cost goal realism
- Design producibility risks areas identified
- Manufacturing capability to achieve cost and schedule requirements
- Demonstrated in a production relevant environment

The use of MRLs is important to ensure your program manufacturing efforts mature in an effective manner and provide you the necessary information to make well-informed decisions before proceeding to EMD.

MRLs in this phase are used to mature the manufacturing processes and identify the manufacturing risk associated with each alternative. Once the risks are identified, the

information should then be used in cost and schedule estimates for the EMD planning effort. Specifically, they should be used to begin risk mitigation planning activities for the selected options in EMD. In mitigating the manufacturing risk, the following should be considered by the program team:

- Challenge Requirements – If the performance requirements exceed manufacturing capability, it is important to ask the design team and user to look at relaxing performance requirements to make the proposed solution more producible.
- Use of multiple sources in the next phase to increase the probability of success.
- Use ManTech and/or other technical funds to explore solutions to solving your risk areas.
- Use Title III funds wherever applicable to address risk areas.
- Look at S&T options wherever applicable to provide a more producible performance option.
- Use SBIR funding wherever applicable to explore solutions to solving the risk areas.

4.2 Key Activities and Documents in the TD Phase

The following activities and supporting documentation during the TD phase are an essential step in assessing the manufacturing risk prior to entering EMD. Basically, you need to focus on three areas. The first step is accomplishing the up-front planning and contractual activities necessary to ensure necessary manufacturing maturity efforts performed in the TD phase are in place and on contract. Key requirements in this phase are to demonstrate your product is produced in a production relevant environment (per DODI 5000.02), and that you will have sufficient data to assess the manufacturing risk before exiting TD (per DODI 5000.02). The next step is to perform a manufacturing assessment to determine current risk status and what must be accomplished before leaving the TD phase (i.e. Risk Mitigation). The final step is managing the necessary activities to achieve desired manufacturing maturity before exiting the TD phase and to identify, assess, and mitigate the manufacturing risk before entering EMD. The focus in this phase is to ensure you have demonstrated the critical products in a relevant environment and that you have a good understanding of the manufacturing risk proceeding into EMD.

The following identified the necessary activities and documents to accomplish the planning and execution of a manufacturing readiness assessment in this phase.

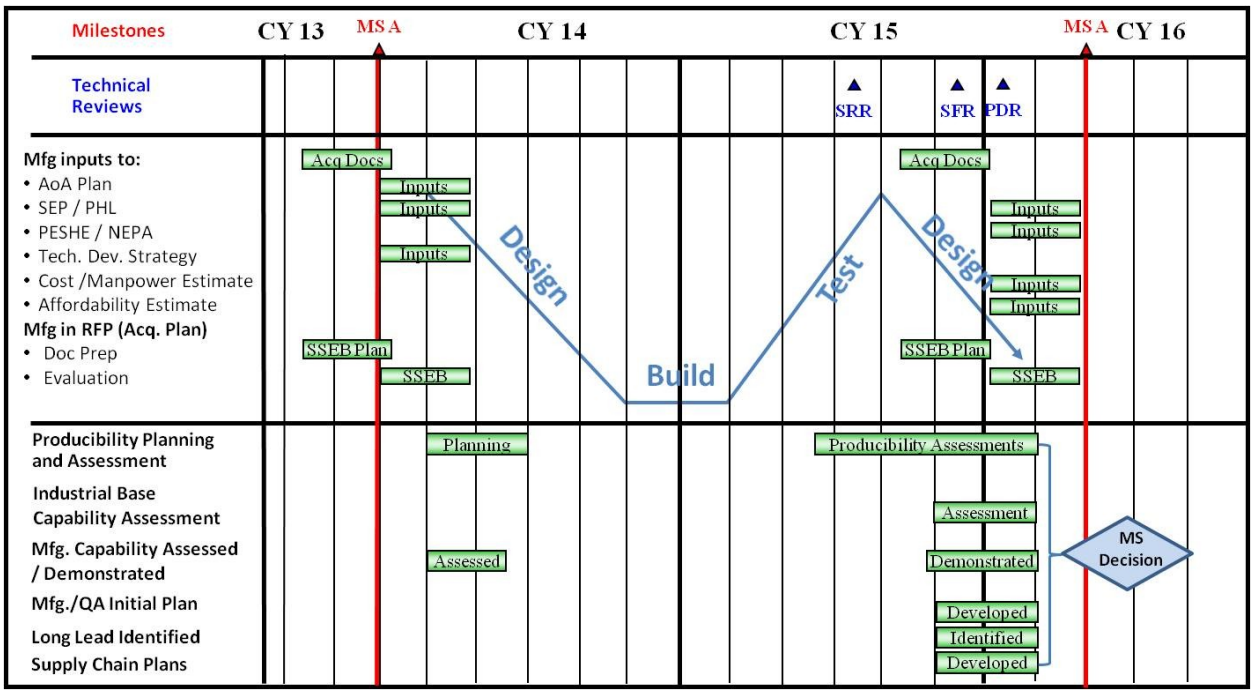


Figure 4-1 Manufacturing Activities During TD

4.2.1 Key Activities in the TD Phase

Lifecycle Cost Estimate

This estimate should be performed on each alternative being considered. This is an area where manufacturing risks need to be adequately addressed. History has proven that we can usually produce one item, but when we need to develop a new manufacturing capability or a new material we do a poor job of reflecting the risk and cost to reduce that risk in our cost estimates. We must ensure that projected costs reflect the appropriate manufacturing risk and risk reduction efforts. - Link to DAG

Industrial Base Assessment

For each alternative you must perform a top level assessment to ensure there is adequate industrial base capability to support overall program requirements. A focus on material availability and unique manufacturing products are crucial in this analysis; however, you should look at any unique demands that push existing capability and capacity beyond today's industrial base limits. It can take an extraordinarily long time to develop additional capability and capacity, so the earlier that issues are identified and mitigation efforts begin the better. – Link to DAG

Assessments of Manufacturing Readiness

During this phase the assessment will consider new material choices, new manufacturing capability requirements, cost drivers, and the industrial base capability, and use that data to begin identifying and assessing manufacturing risks. The MRL Deskbook explains clearly how to perform an assessment and provides the criteria to evaluate readiness (refer to the

MRL Matrix). It is essential in performing this activity in the TD phase to use highly qualified SMEs in each technology area being evaluated. The focus will be on assessing the manufacturing maturity at the MRL 5 and 6 criteria level to determine the manufacturing risk of each alternative. This activity should be performed at least twice on a program, and maybe more often depending on the risk assessments. The first time it should be done as early as practical to get a manufacturing risk baseline established. This will provide needed data to support follow-on design reviews and risk mitigation efforts. The final manufacturing assessment should be timed to support the PDR, if planned for this phase, but in all cases there should be an assessment to support the Milestone B Decision process for going into EMD. Fundamentally, the manufacturing assessment must give the team understanding of the manufacturing maturity of program hardware and the associated manufacturing risk that maturity level presents to achieving program cost, schedule, and performance objectives. – Link to Deskbook and DAG

Systems Requirements Review (SRR)

The SRR is a multi-disciplined technical review to ensure that the system under review can proceed into initial systems development. The review considers whether all system requirements and performance requirements derived from the Initial Capabilities Document or draft Capability Development Document are defined and testable, and are consistent with cost, schedule, risk, technology readiness, and other system constraints. The manufacturing readiness is one of more important areas to address in determining whether the program can achieve its cost and schedule constraints. Analyzing whether manufacturing processes are mature enough is an essential element in determining whether a program will achieve its required performance within budget and schedule targets. A manufacturing readiness assessment results should be used at the SRR to update the program risk assessment, the Cost Analysis Requirements Description (CARD), and the program schedule. –Link to DAG

Systems Functional Review (SFR)

The SFR is a multi-disciplined technical review to ensure that the system's **functional baseline** is established and has a reasonable expectation of satisfying the requirements of the Initial Capabilities Document or draft Capability Development Document within the allocated budget and schedule. Again, analyzing whether manufacturing processes are mature enough is an essential element in determining whether a program will achieve its required performance within budget and schedule targets. A manufacturing readiness assessment results should also be used at the SFR to update the program risk assessment for Engineering and Manufacturing Development (EMD), the Cost Analysis Requirements Description (CARD), and the program schedule.–Link to DAG

Preliminary Design Review (PDR)

The PDR establishes the **allocated baseline** (hardware, software, human/support systems) and underlying architectures to ensure that the system under review has a reasonable expectation of satisfying the requirements within the currently allocated budget and schedule. The maturity of the manufacturing process and associated risk of attaining that maturity is an essential element in determining whether a program will achieve its required

performance within budget and schedule targets. A manufacturing readiness assessment results should also be used at the PDR to update the program risk assessment for Engineering and Manufacturing Development (EMD), the Cost Analysis Requirements Description (CARD), and the program schedule. –Link to DAG

Integrated Business Review (IBR)

An Integrated Baseline Review (IBR) is a joint assessment conducted by the government program manager and the contractor to establish the Performance Measurement Baseline (PMB). Completion of the review should result in the assessment of risk within the program measurement baseline and the degree to which the following have been established:

1. Technical scope of work is fully included and is consistent with authorizing documents,
2. Key project schedule milestones are identified and supporting schedules reflect a logical flow to accomplish the work,
3. Resources (budgets, facilities, infrastructure, personnel, skills, etc.) are available and are adequate for the assigned tasks,
4. Tasks are planned and can be measured objectively relative to the technical progress,
5. Rationales underlying the PMB are reasonable, and
6. Management processes support successful execution of the project.

How manufacturing readiness is to be addressed in determining whether or not the program will achieve its cost and schedule constraints is a key consideration during the IBR. As with the SRR, SFR and PDR, analyzing whether manufacturing processes are mature enough is an essential element in determining whether a program will achieve its required performance within budget and schedule targets. The IBR should spell out how the program resources are performing assessments of manufacturing readiness and how these efforts relate to the System Engineering Plan (SEP) which should spell out how manufacturing risk will be identified and mitigated in the TD phase. –Link to DAG

Technology Readiness Assessments (TRA)

During the TD phase the TRA will be focusing on technology maturity of each alternative and assessing the risk of those critical technologies of achieving program requirements. There is usually a link to manufacturing risk and critical technologies, and it is possible that manufacturing processes or materials could be that critical technology that drives technology readiness. Manufacturing SMEs need to address the manufacturing risk associated with the technology risk areas identified in the TRAs and ensure that manufacturing CTEs are identified and have been incorporated in a relevant environment. Link to TRA Deskbook

Budget Process

It is critical that the budgets provide adequate funding to address the manufacturing risks that have been identified along with the efforts required to minimize those risk areas. Budgets must also allow for demonstration of mature manufacturing processes in the EMD phase.

4.2.2 Key Documents in the TD Phase

To accomplish the above activities, certain documents should address how manufacturing maturity will be implemented in the TD phase. The focus of these documents will fall into three sets. The first set is used to perform the planning and budgeting needed to implement and assess the manufacturing maturity of your program. The second set addresses how you will place this effort on contract. The third set includes documents you will need to update as a result of your assessment to ensure that the risk is being adequately addressed.

System Engineering Plan (SEP)

The SEP is a detailed formulation of actions that should guide all technical aspects of an acquisition program. The SEP describes the program's overall technical approach, including systems engineering processes; resources, and key technical tasks, activities, and events along with their metrics and success criteria. Integration or linkage with other program management control efforts, such as Integrated Master Plans, Integrated Master Schedules, Technical Performance Measures, risk management, and Earned Value Management, is fundamental to successful program execution. The governments technical lead on the program should have the SEP explain how they will integrate the technical approach efforts to identify and mitigate manufacturing risk in the TD phase. – Link to DAG

Capabilities Document/Capability Development Document (CDD)

The CDD is a Milestone B requirement, so program or project offices planning a PDR in the TD Phase must work closely with the requirements and capabilities communities to integrate development schedules. This is a key document required when exiting the TD phase because it spells out requirements that must be achieved in EMD. The CDD is important, because manufacturing personnel can use it to spell out the manufacturing risk associated with any proposed requirements. This is the best time in the program life cycle to perform a manufacturing risk assessment; however, to be most effective, manufacturing personnel need to translate identified risks into quantified costs so the Warfighter understands whether he will need to change his requirements. Usually the requirements that drive manufacturing risk are those that entail the use of new materials or a new manufacturing capability – Link to DAG

Acquisition Strategy (AS)

The Acquisition Strategy is a comprehensive, integrated plan that identifies the acquisition approach, and describes the business, technical, and support strategies that management will follow to handle program risks and meet program objectives. The Acquisition Strategy should define the relationship between the acquisition phases and work efforts, and key program events such as decision points, reviews, contract awards, test activities, production

lot/delivery quantities, and operational deployment objectives. An AS should be linked to the SEP and it should address how the program will identify and mitigate manufacturing risk and provide an approach to ensure these risk areas are demonstrated in a relevant environment in the this phase. – Link to DAG

Acquisition Plan (AP)

This document usually does not require outside program approval. It is a tool of the Program Manager (PM) to translate the AS into specific details needed to accomplish the strategy. This would be an excellent place to identify risk mitigation approaches. – Link to DAG

Request For Proposal (RFP)

As in the MSA phase, one of the principal roles of the manufacturing SME in TD Phase is making an input to the RFP. Once the MSA phase is exited and TD is entered, it is essential that necessary actions by the contractor(s) to identify and mitigate manufacturing risk be put to into contract requirements. The RFP will require this. There must also be a contract requirement for the contractor and government to work together to identify and mitigate manufacturing risk and mature processes in TD phase. The RFP will also require that the contractor(s) demonstrate critical manufacturing processes in a relevant environment. The MRL Deskbook provides suggested RFP language. - Link to DAG and Deskbook

Cost Analysis Requirements Description (CARD)

The CARD formally describes the acquisition program for purposes of preparing both the DoD Component Cost Estimate and the Cost Assessment independent cost estimate. DoD Instruction 5000.02 specifies this for major defense acquisition programs, the CARD will be provided in support of major milestone decision points (Milestone B, Milestone C, or the full-rate production decision review). The manufacturing assessments performed during this phase should be a source document to capture the cost associated with the identified manufacturing risk.

Integrated Master Plan (IMP)

The IMP is a critical tool used to manage the program. The program manager should use event-driven schedules and require manufacturing SMEs to identify all tasks that should be accomplished in a rational and logical order. Necessary entry and exit criteria for each major task should be identified, and no major task should be started or declared complete until all required criteria have been satisfied. When documented in a formal plan and used to manage the overall program, this event-driven approach can help ensure that all tasks are integrated properly and that the management process is based on the accomplishment of significant events in the acquisition life cycle and not on arbitrary calendar dates. This planning effort should take documents like the SEP and MRL threads and translate them into defined activities to be performed as part of the IMP during this phase. They will be used to assess manufacturing capability and address the risk areas identified. - Link to DAG

Integrated Master Schedule (IMS)

The IMS takes the IMP requirements and defines the requirements in terms of calendar time and resources needed to accomplish the IMP. The IMS also addresses the resources needed to accomplish the requirements to identify and mitigate manufacturing risk. – Link to DAG

Program Objective Memorandum (POM)/Budget Estimate Submission (BES)

It is critical that these documents assure that there is adequate funding to cover the activities to mitigate manufacturing risks in the next program phase.

Selected Acquisition Report (SAR)

In accordance with 10 U.S.C. 2432 , the Secretary of Defense will submit a SAR to Congress for all MDAPs. The program manager will use the Defense Acquisition Management Information Retrieval (DAMIR) application to prepare the SAR. The program manager will submit quarterly exception SARs for the quarters ending March 31, June 30, and September 30 not later than 45 days after the quarter ends. Quarterly SARs are reported on an exception basis, as follows:

- The current estimate exceeds the Program Acquisition Unit Cost (PAUC) objective or the Average Procurement Unit Cost (APUC) objective of the currently approved APB in base-year dollars by 15 percent or more;
- The current estimate includes a 6-month or greater delay, for any schedule parameter, that occurred since the current estimate reported in the previous SAR;
- Milestone B or Milestone C approval occurs within the reportable quarter.

Results from the manufacturing assessment should be used in updating the SAR.

4.3 Supporting the Defense Acquisition Board (DAB) at Milestone B

A program should exit the TD Phase when “the technology and manufacturing processes for that program or increment have been assessed and demonstrated in a relevant environment” and “manufacturing risks have been identified.” The activities and documentation identified above will be the source of this information. The following activities/documents need to address manufacturing risk at the DAB.

- Program Support Reviews (PSRs) - The PSR, if performed on the program, will assess the technical progress being made. The PSR should address the program’s progress in assessing the manufacturing risk and the mitigation efforts being planned in the program. This information should be used at the DAB. Defense Acquisition Program Support (DAPS) Methodology, Version 2.0, Change 3
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- Milestone Certification Requirements – It is important that this certification states that the manufacturing risk of each alternative has been identified and addressed, critical manufacturing processes have been demonstrated in a relevant environment and results were used in updating the program cost estimates. – Link to DAG

- Overarching Integrated Product Team (OIPT) - An OIPT reviews program planning, facilitates program communications and issue resolution, and supports the MDA for ACAT ID. It will be important that the OIPT is aware of the manufacturing risk issues and how these issues will be addressed to ensure the MDA has the required information to make a sound decision on the programs direction.

4.4 Summary

MRLs are used in the TD phase to identify and mitigate manufacturing risk before entering EMD. The critical document is the contract, for this is where you require the contractor to perform activities to mature manufacturing processes and establish a means for both government and contractor to assess that maturity against program requirements. The key activity is manufacturing assessments, because it is essential to ensure that manufacturing risk is identified and efforts are in place to mitigate it. You must also use this risk information to update budgeting and funding documents to reflect whether you can achieve program cost, schedule, and performance objectives. Finally, maturing the manufacturing process will increase the likelihood of achieving your program objectives in EMD, but just as important, the data created from that process is essential for assessing your manufacturing risk before proceeding into EMD.

5.0 MRLs in the Engineering and Manufacturing Development (EMD) Phase

Entrance into this phase depends on technology maturity (including software), approved requirements, and full funding. Unless some other factor is overriding in its impact, the maturity of the technology determines the path to be followed. MDA approval of the Acquisition Strategy is a requirement before final RFPs for the EMD Phase (or any succeeding acquisition phase) can be released. Additionally no other action can be taken that would commit the program to a particular contracting strategy, until the MDA has approved the Acquisition Strategy. The PM will include language in the RFP advising offerors that (1) the government will not award a contract to an offeror whose proposal is based on CTEs that have not been demonstrated in a relevant environment, and (2) that offerors will be required to specify the technology readiness level of the CTEs on which their proposal is based and to provide reports documenting how those CTEs have been demonstrated in a relevant environment.

"The purpose of the EMD Phase is to develop a system or an increment of capability; complete full system integration (technology risk reduction occurs during Technology Development); ***develop an affordable and executable manufacturing process****; ensure operational supportability with particular attention to minimizing the logistics footprint; implement human systems integration (HSI);* ***design for producibility****;* ***ensure affordability****; protect CPI by implementing appropriate techniques such as anti-tamper; and demonstrate system integration, interoperability, safety, and utility. The CDD, Acquisition Strategy, SEP, and Test and Evaluation Master Plan (TEMP) shall guide this effort."*

—DoDI 5000.02 dated 8 December 2008

"EMD has two major efforts: Integrated System Design, and ***System Capability and Manufacturing Process Demonstration****."*

—DoDI 5000.02 dated 8 December 2008

"Post-CDR Assessment. The MDA shall conduct a formal program assessment following system-level CDR. The system-level CDR provides an opportunity to assess design maturity as evidenced by measures such as: successful completion of subsystem CDRs; the percentage of hardware and software product build-to specifications and drawings completed and under configuration management; planned corrective actions to hardware/software deficiencies; adequate developmental testing; an assessment of environment, safety and occupational health risks; a completed failure modes and effects analysis; the identification of key system characteristics; ***the maturity of critical manufacturing processes****; and an estimate of system reliability based on demonstrated reliability rates.."*

—DoDI 5000.02 dated 8 December 2008

*"**System Capability and Manufacturing Process Demonstration**. This effort is intended to demonstrate the ability of the system to operate in a useful way consistent with the approved KPPs and **that system production can be supported by demonstrated manufacturing processes**. The program shall enter System Capability and Manufacturing Process Demonstration upon completion of the Post-CDR Assessment and establishment of an initial product baseline. This effort shall end when the system meets approved requirements and is demonstrated in its intended environment using the selected production-representative article; **manufacturing processes have been effectively demonstrated in a pilot line environment; industrial capabilities are reasonably available;** and the system meets or exceeds exit criteria and Milestone C entrance requirements. Successful developmental test and evaluation (DT&E) to assess technical progress against critical technical parameters, early operational assessments, and where proven capabilities exist, the use of modeling and simulation to demonstrate system/system-of-systems integration are critical during this effort. T&E should be used to assess improvements to mission capability and operational support based on user needs and should be reported in terms of operational significance to the user. The completion of this phase is dependent on a decision by the MDA to commit to the program at Milestone C or a decision to end this effort."*

—DoDI 5000.02 dated 8 December 2008

5.1 Purpose of MRLs in EMD

The use of MRLs, in EMD, addresses two major requirements from DODI 5000.02. The First is to ***develop an affordable and executable manufacturing process***, and the second is to ***demonstrate that manufacturing processes can support the system production requirements***. A major effort on the second requirement, that MRLs play a vital role in achieving, is ensuring that ***manufacturing processes have been effectively demonstrated in a pilot line environment and that industrial capabilities are reasonably available***. The MRL time-table to accomplish these two requirements can be broken into two specific time phases within EMD. The first phase includes all the activity being done to support the CDR. In this phase the MRL process is used to trigger the development of affordable and executable manufacturing processes. Then it is used to assess the maturity of critical manufacturing processes to ensure a producible design is created that will meet cost, schedule, and performance objectives. The activities that occur in the first phase provide necessary information to support major decisions at the CDR. The second phase, after CDR, provides the required demonstration that the manufacturing maturity can meet program objectives. During this phase the manufacturing assessments that are performed will demonstrate that the manufacturing processes can support production requirements and are demonstrated in a pilot line (per DODI 5000.02). The use of MRLs in the EMD phase will prove that manufacturing process maturity has progressed enough to ensure a high probability of achieving program cost, schedule, and performance objectives prior to entering Low Rate Initial Production (LRIP). It is essential that the use of MRLs prove that this is the case, or provide Decision Makers with information on the level of risk of proceeding into the next phase along with recommended mitigation efforts.

5.1.1 Using MRLs for Managing, Assessing and Demonstrating Manufacturing Capability in the EMD phase

Managing, assessing and demonstrating manufacturing capability using the MRL criteria is basically a three step process. The first step is to contractually establish a program to require the contractor to mature the manufacturing processes, perform a manufacturing maturity assessment, and then to use the assessment data to establish effective manufacturing process maturation activities. The MRL process does this by defining key activities/criteria to reach a target level of manufacturing maturity during this phase (i.e. MRLs 7 and 8). An essential step in the process is to decide up front which suppliers should implement this effort. As a general rule at this phase of the program it will usually be the prime and most of the major subcontractors, but the major subcontractors may also need to flow this requirement down to some of their key suppliers. Specific criteria are available in the MRL Deskbook to determine where to apply this effort on your program. The second step in the MRL process is to use the MRL criteria to ensure all recommended activities have been completed. This is explained in the MRL Deskbook. The third and final step is to use the data created by the first two steps to determine if the manufacturing capability has been adequately demonstrated (i.e., the manufacturing processes meet the program's cost and schedule objectives) before proceeding into the LRIP Phase. As part of this effort, you must perform a risk assessment where shortfalls are identified. The use of MRL criteria is considered an industry best practice for maturing the manufacturing process so your program managers fully understand the manufacturing risk before proceeding into the next phase. If the program doesn't follow the steps outlined in the MRL process, it is likely that the program will not capture all the manufacturing risk and will only transfer it to the next phase of the program. It must be stressed that following this process does not necessarily eliminate all risk, but it does increase the likelihood that you will be able to identify the manufacturing risk before entering Production. One of the key benefits of applying MRL criteria during EMD is that you can ensure that your manufacturing processes will have been demonstrated in a Pilot Line environment. This will enable you to better identify the risk before proceeding to LRIP.

The final stage of EMD is producing products that look and operate like production units from LRIP. These products need to be built on a pilot line to realistically demonstrate the ability to migrate from EMD to LRIP. Without this realism, it would be very difficult to gain confidence that the production process will meet cost, schedule, and performance (e.g., quality and reliability) requirements in production. The following defines a pilot production line:

Pilot line environment—An environment that incorporates all of the key production realism elements (equipment, personnel skill levels, facilities, materials, components, work instructions, processes, tooling, temperature, cleanliness, lighting etc.) required to manufacture production configuration items, subsystems or systems that meet design requirements in low rate production. To the maximum extent practical, the pilot line should utilize full rate production processes.

A pilot line is intended to demonstrate the natural progression of manufacturing maturity as you exit development and enter production. The program office and contractor must reach agreement on the degree of production realism (equipment, personnel skill levels, processes, etc.) required for a specific program. This agreement will be based on the specific production scenario with its associated manufacturing risk so as to mitigate that risk in a timely and effective manner.

5.1.2 Overview of MRLs for assessing the manufacturing process in the EMD Phase

During EMD, assessments of manufacturing readiness are conducted to demonstrate production capability and to ensure manufacturing maturity risks are completely understood prior to a production decision. These manufacturability assessments should be conducted in concert to support the CDR and Milestone C decision. The assessment should focus on program-wide manufacturing risks such as fabrication, assembly, integration and test operations; supply chain performance; maturity of manufacturing planning; maturity of manufacturing management systems; adequacy of funding for manufacturing risk reduction efforts and other factors defined in MRL thread descriptions. Key considerations include:

- Industrial base viability
- Probability of meeting the delivery date (e.g., for qualification units)
- Design stability
- Process maturity
- Manufacturing costs
- Supply chain management
- Quality management
- Facilities
- Manufacturing skills availability

The output of the assessment at CDR should be included in the CDR Report to the MDA. This assessment assures that adequate progress is being made toward Milestone C targets. The program-level PRR is a Systems Engineering technical review at the end of EMD that determines if a program is ready for production. The PRR historically assesses more than just manufacturing maturity; it looks at the readiness of all the functional areas as they relate to the entire program's readiness to go into production. The manufacturing portion of the PRR will assesses whether the prime contractor and major subcontractors and suppliers have adequately demonstrated that their production capability will support program objectives and that there are no unacceptable risks for schedule, performance, cost, or other objectives. The use of MRLs to assess manufacturing maturity and risk should be a principal area of emphasis during the PRR. The assessment of manufacturing readiness should highlight any areas where manufacturing maturity falls short of requirements. The assessment should discuss the risks that these shortfalls pose to the program and the status of efforts to mitigate these risks. It should also include an estimate of schedule or funding changes required to correct significant shortfalls. If any program manufacturing area is found to fall short at the end of EMD, there are two basic choices available to an acquisition program manager:

• Request a delay in the Milestone C decision point to implement efforts to reduce manufacturing risk before proceeding – NOT VERY LIKELY
• Carry higher manufacturing risk beyond Milestone C – and try to mitigate the risk.

Neither of these options are optimum. This shows the importance of addressing manufacturing earlier in the process. There are some other options available, but due to the timing are less viable as you enter production. Some of these options are:

- Challenge Requirements – If performance requirements exceed manufacturing capability, first ask the design team and user to consider relaxing performance requirements to make the proposed solution more producible.
- Use multiple sources in the next phase to increase the probability of success.
- Use ManTech and/or other technical funds to explore solutions to solving your risk areas.
- Use Title III funds where applicable to address risk areas.
- Look at S&T options to provide a more producible performance option.
- Use SBIR funding where applicable to explore solutions to solving the risk areas.

5.2 Key Activities, and Documents in the EMD Phase

The following activities and supporting documentation during the EMD phase are essential steps in developing an affordable and executable manufacturing process and demonstrating that manufacturing capability can support production requirements prior to entering LRIP. Here you need to focus on three efforts. The first effort is accomplishing the up-front planning and contractual activities necessary to ensure manufacturing maturity efforts required to be performed in the EMD phase are in place and on contract. This step is essential to develop an affordable and executable manufacturing processes and to ensure that system production can be supported by demonstrated manufacturing processes before exiting EMD (per DODI 5000.02). The second effort is managing the necessary activities to achieve desired manufacturing maturity before exiting the EMD phase and to mitigate the manufacturing risk identified while demonstrating manufacturing capability. In this effort you must ensure manufacturing processes have been effectively demonstrated in a pilot line environment and industrial capabilities are reasonably available (per DODI 5000.02). The final effort is ensuring that the manufacturing risk of proceeding to LRIP is clearly presented to decision makers and that it is reflected in cost (budgets), schedule, and performance projections in the production phase.

The following are the necessary activities and documents to accomplish the planning and execution of a manufacturing readiness assessment in EMD. Figure 5.1 outlines these activities.

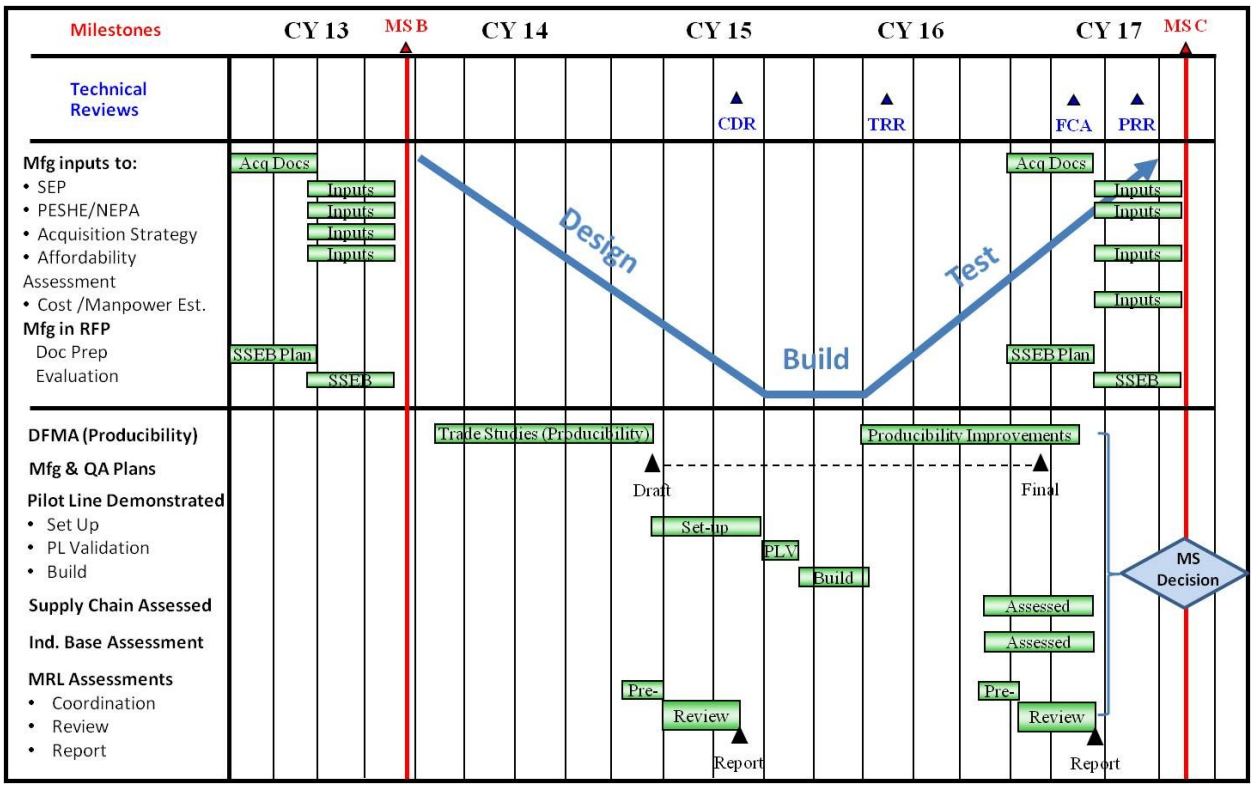

Figure 5-1 Manufacturing Activities During EMD

5.2.1 Key Activities in the EMD Phase

Lifecycle Cost Estimates

This estimate should be performed on each final design. This is an area where manufacturing risks must be adequately addressed. We must ensure that projected costs reflect the appropriate manufacturing risk and risk reduction efforts. - Link to DAG

Industrial Base Assessment

For the final design you need to perform an assessment to ensure that industrial capability can support your program. A focus on material availability and unique manufacturing products are keys in this analysis; however, you should look at any unique demand that may push existing capability and capacity beyond today's industrial base limits.– Link to DAG

Assessments of Manufacturing Readiness

This is the key activity for manufacturing in EMD. During this phase the assessment needs to focus on demonstrating the manufacturing capabilities to meet the cost, schedule, and performance requirements of the program. The MRL Deskbook spells out clearly how to perform an assessment and provides the criteria to evaluate (i.e. MRL Matrix). The focus will be on assessing manufacturing maturity at the MRL 7 and 8 criteria level to ensure you have developed an affordable and executable manufacturing process. The assessment must also demonstrate that manufacturing processes can support the system production requirements

(i.e., manufacturing processes have been proven in a pilot line environment). This assessment activity should be performed at least twice on a program, perhaps more, depending on the assessed risk. The first assessment in EMD needs to be performed in sufficient lead time to obtain manufacturing data/risk assessment to support the CDR. It is essential to understand the manufacturing maturity as it relates to producibility in critical manufacturing processes, before CDR. This will provide you necessary information to impact the decision-making process during CDR. The next critical event is the effort to support the Milestone C Decision process prior to entering LRIP. Fundamentally the manufacturing assessment at this time must be able to ***demonstrate that manufacturing processes can support the system production requirements (i.e., manufacturing processes have been effectively demonstrated in a pilot line environment).*** The manufacturing assessment in this phase probably will be linked to Production Readiness Review activities. In addition to having the data needed to answer these critical questions for the MDA, another key product coming out of these assessments is the risk mitigation plan to minimize shortfalls identified. It is important that results of this assessment be used to update the cost (budget), schedule and performance objectives/projections for LRIP. – Link to Deskbook and DAG

Critical Design Review (CDR)

The CDR is to ensure that the system under review can proceed into system fabrication, demonstration, and test, and can meet the stated performance requirements within cost (program budget), schedule (program schedule), risk, and other system constraints. Results of the manufacturing assessments need to be used specifically in whether or not the system under review can meet cost, schedule, and performance objectives.

Production Readiness Review (PRR)

The PRR examines a program to determine if the design is ready for production and if the prime and major subcontractors have accomplished adequate production planning without incurring unacceptable risks that breach thresholds of schedule, performance, cost, or other established criteria. The review examines risk; it determines if production or production preparations identify unacceptable risks that might breach thresholds of schedule, performance, cost, or other established criteria. The review evaluates the full production-configured system to determine if it correctly and completely implements all system requirements. Since the PRR looks at all system requirements, it will look at more than manufacturing issues (e.g., software, sustainment, operational testing, etc.). The review determines whether traceability of final system requirements to the final production system is maintained. Typical PRR success criteria include affirmative answers to the following exit questions:

1. Has the system product baseline been established and documented to enable hardware fabrication and software coding to proceed with proper configuration management?

2. Are adequate processes and metrics in place for the program to succeed?

3. Are the risks known and manageable?
4. Is the program schedule executable (technical/cost risks)?
5. Is the program properly staffed?
6. Are all technologies mature enough for production?
7. Is the detailed design producible within the production budget?
8. Are the production facilities ready and required workers trained?
9. Is detail design complete and stable enough to enter low rate production?
10. Is the supply chain established and stable with materials available to meet planned low rate production?
11. Have manufacturing processes been demonstrated and proven in a pilot line environment?
12. Have all producibility trade studies and risk assessments been completed?
13. Is the production cost model based upon the stable detailed design and been validated?
14. Are the ESOH residual risks known and manageable?

The manufacturing assessments are certainly a large portion of any PRR and should be performed in conjunction with any PRR to maximize efficiency.

Program Management Review (PMR)

A PMR is conducted at defined intervals (monthly or quarterly) by the Program Manager for the purpose of determining the status of an assigned system. PMRs are designed as tools to report program status, identify issues and problems, discuss risks, and to develop appropriate follow-up actions as required. Typically, the SOW tasks the contractor to participate in the PMR and to capture minutes. During these reviews the progress and concerns about developing the manufacturing maturity of your program should be addressed.

Integrated Business Review (IBR)

An Integrated Baseline Review (IBR) is a joint assessment conducted by the government program manager and the contractor to establish the Performance Measurement Baseline (PMB). Completion of this review should result in the assessment of risk within the program measurement baseline and the degree to which the following have been established:

1. Technical scope of work fully included and is consistent with authorizing documents,

2. Key project schedule milestones identified and supporting schedules reflect a logical flow to accomplish the work,
3. Resources (budgets, facilities, infrastructure, personnel, skills, etc.) available and are adequate for the assigned tasks,
4. Tasks planned and can be measured objectively relative to the technical progress,
5. Rationale underlying the PMB is reasonable, and
6. Management processes support successful execution of the project.

A key consideration during the IBR is how manufacturing readiness is addressed to determine whether the program will achieve its cost and schedule constraints. The maturity of the manufacturing process and associated risk of that maturity is an essential element in a program achieving performance requirements within budget and schedule objectives. Therefore, the IBR should spell out how program resources will support assessments of manufacturing readiness and how these efforts relate to the System Engineering Plan (SEP) which spells out how manufacturing risk will be identified and mitigated in the EMD phase. – Link to DAG

Budget Process

It is critical that the budgets provide adequate funding to address the **manufacturing risk** that has been identified, and that efforts to minimize those risks are in place to demonstrate adequate manufacturing maturity progress in the LRIP phase.

5.2.2 Key Documents in the EMD Phase

To accomplish the above activities certain documents should address how the program will ***develop an affordable and executable manufacturing process*** and ensure that ***manufacturing processes have been effectively demonstrated in a pilot line environment*** in EMD. The following are the key documents that must be considered, along with a brief explanation on what should be addressed in each.

System Engineering Plan (SEP)

The SEP is a detailed formulation of activities that encompass all technical aspects of an acquisition program. The SEP describes the program's overall technical approach, including systems engineering activities, resources, and key technical tasks, along with their metrics and success criteria. Integration or linkage to other program management control efforts, such as Integrated Master Plans, Integrated Master Schedules, Technical Performance Measures, risk management, and Earned Value Management, is fundamental to successful program execution. The manufacturing lead on the program should have the SEP explain how the program will develop affordable and executable manufacturing processes and demonstrate that the manufacturing capability can support production requirements prior to entering LRIP. The SEP should therefore specify how they plan to integrate program manufacturing requirements with all the technical efforts in EMD. – Link to DAG

Capability Production Document (CPD)

The final step in the capabilities refinement process is the CPD development. This document describes the refined operational capabilities and system performance expected for the production articles. The CPD is used by the T&E working-level Integrated Product Team to update the Test and Evaluation Master Plan for the Milestone C decision and for subsequent decision milestones in Production and Deployment, such as the full-rate production decision review. At Milestone C, the technical testing begins to focus on production, including Production Qualification Testing to demonstrate performance of the production system in accordance with the contract. Operational testing focuses on evaluating the Low-Rate Initial Production system's operational effectiveness, suitability, survivability, and mission capability. It is essential that manufacturing personnel use this document to translate manufacturing risks into information the Warfighter understands, so he can possibly change what the requirements will cost.– Link to DAG

Acquisition Strategy (AS)

The Acquisition Strategy is a comprehensive, integrated plan that identifies the acquisition approach and describes the business, technical, and support strategies that management will follow to deal with program risks and meet program objectives. The Acquisition Strategy should define the relationship between the acquisition phases and work efforts, key program events such as decision points, reviews, contract awards, test activities, production lot/delivery quantities, and operational deployment objectives. An AS should be linked to the SEP and should address how the program will develop an affordable and executable manufacturing process. It should ensure manufacturing processes have been effectively demonstrated in a pilot line environment (per DODI 5000.02), and that system production can be supported by demonstrated manufacturing processe***s*** before exiting EMD (per DODI 5000.02).

The PM will prepare, and the MDA will approve an Acquisition Strategy to guide activity during EMD.

(a) The Acquisition Strategy describes how the PM plans to employ contract incentives to achieve required cost, schedule, and performance outcomes.

(b) The strategy includes a time-phased workload assessment identifying the manpower and functional competency requirements for successful program execution and the associated staffing plan, including the roles of government and non-government personnel.

(c) If the program is dependent on the outcome of other acquisition programs or must provide capabilities to other programs, those relationships should be detailed in the acquisition strategy. Similarly, if a program is part of a system-of-systems or family-of-systems, the relationship and associated dependencies with other system elements should be described. – Link to DAG

Acquisition Plan (AP)

This document usually does not require outside program approval since it is a tool of the Program Manager (PM) to translate the AS into specific details needed to accomplish the strategy. This would be an excellent place to identify how the program will implement the tasks necessary to develop affordable and executable manufacturing processes and demonstrate that the manufacturing capability can support production requirements prior to entering LRIP. – Link to DAG

Request For Proposal (RFP)

This is the key document that must be adequately addressed by the manufacturing SME supporting the program. In EMD it is essential to develop affordable and executable manufacturing processes and ensure that these processes have been effectively demonstrated in a pilot line environment (per DODI 5000.02). It is also crucial that system production can be supported by demonstrated manufacturing processes. These requirements must be put to into contractual language within the RFP. The MRL Deskbook will provide suggestions on what might used in the RFP. - Link to DAG and Deskbook

Cost Analysis Requirements Description (CARD)

The CARD is used to formally describe the acquisition program for purposes of preparing both the DoD Component Cost Estimate and the Cost Assessment independent cost estimate. DoD Instruction 5000.02 specifies that for major defense acquisition programs, the CARD will be provided in support of major milestone decision points (Milestone B, Milestone C, or the full-rate production decision review). The manufacturing assessments performed during this phase should be a source document to capture the cost associated with the manufacturing risk identified.

Integrated Master Plan (IMP)

The IMP is a critical tool used to manage the program. The program manager should use event-driven schedules and require manufacturing SMEs to identify all tasks that need to be accomplished in a rational and logical order. Necessary entry and exit criteria for each major task should be identified, and no major task should be started or declared complete until all required criteria have been satisfied. When documented in a formal plan and used to manage the overall program, this event-driven approach can help ensure that all tasks are integrated properly and that the management process is based on the accomplishment of significant events in the acquisition life cycle and not on arbitrary calendar dates. This planning effort should take documents such as the SEP, AS, AP and MRL threads and translate them into defined activities that need to be performed during this phase in order to develop an affordable and executable manufacturing process. Following the IMP will ensure that all manufacturing processes have been effectively demonstrated in a pilot line environment (per DODI 5000.02), and that system production can be supported by these proven processes. - Link to DAG

Integrated Master Schedule (IMS)

The IMS takes the IMP requirements and defines the requirements in terms of calendar time and resources needed to accomplish the IMP. The IMS should address the resources

needed to accomplish the requirements to develop an affordable and executable manufacturing process.

Program Objective Memorandum (POM)/Budget Estimate Submission (BES)

It is critical that this document reflect the manufacturing risk and efforts to develop an affordable and executable manufacturing process and to ensure manufacturing processes have been effectively demonstrated in a pilot line environment (per DODI 5000.02). The BES should include adequate funding to cover the activities to mitigate those risks carried over into LRIP.

CDR Report

The PM shall provide a Post-CDR Report to the MDA that provides an overall assessment of design maturity and a summary of the system-level CDR results which shall include, but not be limited to:

- The names, organizations, and areas of expertise of independent subject matter expert participants and CDR chair,
- A description of the product baseline for the system and the percentage of build-to packages completed for this baseline,
- A summary of the issues and actions identified at the review together with their closure plans,
- An assessment of risk by the participants against the exit criteria for the EMD phase, and
- Identification of those issues/risks that could result in a breach to the program baseline or substantively impact cost, schedule or performance.

Results of the manufacturing maturity assessments should be reflected in the estimate of the probability of achieving program cost, schedule, and performance.

Selected Acquisition Report (SAR)

In accordance with 10 U.S.C. 2432 , the Secretary of Defense will submit a SAR to Congress for all MDAPs. The program manager will use the Defense Acquisition Management Information Retrieval (DAMIR) application to prepare the SAR. The program manager will submit quarterly exception SARs for the quarters ending March 31, June 30, and September 30 not later than 45 days after the quarter ends. Quarterly SARs are reported on an exception basis, as follows:

- The current estimate exceeds the Program Acquisition Unit Cost (PAUC) objective or the Average Procurement Unit Cost (APUC) objective of the currently approved APB in base-year dollars by 15 percent or more;

- The current estimate includes a 6-month or greater delay, for any schedule parameter, that occurred since the current estimate reported in the previous SAR;
- Milestone C approval occurs within the reportable quarter.

Results from the manufacturing assessment should be used in updating the SAR.

Defense Acquisition Executive Summary (DAES) Report

The program manager will report the unit costs of the program to the CAE on a quarterly basis through the electronic Defense Acquisition Executive Summary (DAES) submission process. The program manager should submit updates in accordance with DAES submission procedures. Reporting should begin with submission of the initial SAR, and end with submission of the final SAR. Each report should include the current estimate of the Program Acquisition Unit Cost and the Average Procurement Unit Cost (in base-year dollars), cost and schedule variances for each of the major contracts since entering the contract, and all changes that the program manager knows will occur, or expects to occur, to program schedule or performance parameters as compared to the currently approved Acquisition Program Baseline. Results from the manufacturing assessments should be used to update this information.

Contractor Cost Data Reporting (CCDR)

CCDR reports provide for each contract a display of incurred costs to date and estimated costs at completion by Work Breakdown Structure element, with nonrecurring and recurring costs identified separately. CCDR reports in some cases can display costs by functional category (**manufacturing labor**, engineering, etc.). Where appropriate, a functional category is broken out by direct labor hours, direct material, overhead, and other indirect. The impact of system manufacturing maturity needs to be reflected in this report.

5.3 Supporting the Defense Acquisition Board (DAB) at Milestone C

Entrance into this phase depends on the following criteria: acceptable performance in developmental test and evaluation and operational assessment (OSD OT&E oversight programs); software capability is mature; significant manufacturing risks mitigated; manufacturing processes under control (if Milestone C is full-rate production); an approved ICD (if Milestone C is program initiation); an approved Capability Production Document (CPD); a refined integrated architecture; acceptable interoperability; acceptable operational supportability; and demonstration that the system is affordable throughout the life cycle, fully funded, and properly phased for rapid acquisition. The CPD reflects the operational requirements, informed by EMD results, and details the performance expected of the production system. If Milestone C approves LRIP, a subsequent review and decision shall authorize full-rate production. A program should exit the EMD Phase when ***production of that system can be supported by demonstrated manufacturing processes.*** The activities and documentations identified above will be the source to obtain this information and should be addressed in the following activities.

- Program Support Reviews (PSRs) - The PSR, if performed on the program, will assess the technical progress being made. The PSR should address the program's progress in assessing the manufacturing risk and the mitigation efforts being planned in the program. This information should be used at the DAB. Defense Acquisition Program Support (DAPS) Methodology, Version 2.0, Change 3
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- Milestone Certification Requirements – It is important that this certification states that the manufacturing risk has been identified and mitigated, critical manufacturing processes have been demonstrated in a pilot production line, and the results were used in updating the program cost estimates. – Link to DAG

- Overarching Integrated Product Team (OIPT) - An OIPT reviews program planning, facilitates program communications and issue resolution, and supports the MDA for ACAT ID. It will be important that the OIPT is aware of the manufacturing risk issues and how these issues will be addressed so the MDA has the required information to make a sound decision on the program's direction.

5.4 Summary

The bottom line: The purpose for using MRLs in the EMD phase is to develop an affordable and executable manufacturing process and ensure that system production can be supported by demonstrated manufacturing processes. The key document is the contract. In this document you must require the contractor to perform the activities necessary to mature manufacturing processes. The contract should identify a procedure that lets both government and contractor assess manufacturing maturity against program requirements. The contract is essential to develop affordable, executable manufacturing processes, and a key activity specified in the contract should be the performance of manufacturing assessments. The main purpose of those assessments is to ensure that manufacturing capability has been demonstrated and that all risks are identified, assessed and mitigated. It is also essential to use data obtained from these assessments to update the budgeting and funding documents to show the likelihood of achieving program cost, schedule, and performance objectives. Finally, maturing the manufacturing processes will increase the probability of achieving program objectives in LRIP, but just as important, the data created from the assessment process will be critical to present the manufacturing risk and mitigation efforts to decision makers before proceeding into LRIP.

6.0 MRLs in the Low Rate Initial Production (LRIP) Phase

Entrance into this phase depends on the following criteria: acceptable performance in developmental test and evaluation and operational assessment (OSD OT&E oversight programs); mature software capability; no **significant manufacturing risks**; **manufacturing processes under control (if Milestone C is full-rate production)**; an approved ICD (if Milestone C is program initiation); an approved Capability Production Document (CPD); a refined integrated architecture; acceptable interoperability; acceptable operational supportability; and **demonstration that the system is affordable** throughout the life cycle, fully funded, and properly phased for rapid acquisition. The CPD reflects the operational requirements, informed by EMD results, and details the performance expected of the production system. If Milestone C approves LRIP, a subsequent review and decision shall authorize full-rate production.

"The purpose of the Production and Deployment Phase is to achieve an operational capability that satisfies mission needs. Operational test and evaluation shall determine the effectiveness and suitability of the system. The MDA shall make the decision to commit the Department of Defense to production at Milestone C and shall document the decision in an ADM. Milestone C authorizes entry into LRIP (for MDAPs and major systems), into production or procurement (for non-major systems that do not require LRIP)."

- **DoDI 5000.02 dated 8 December 2008**

*"This effort is intended to result in **completion of manufacturing development** in order to ensure adequate and efficient manufacturing capability and to produce the minimum quantity necessary to provide production or production-representative articles for IOT&E, **establish an initial production base for the system**; and **permit an orderly increase in the production rate for the system, sufficient to lead to full-rate production upon successful completion of operational (and live-fire, where applicable) testing**. Evaluations shall be conducted in the mission context expected at time of fielding, as described in the user's capability document. The MDA shall consider any new validated threat environments that will alter operational effectiveness. **If the program has not demonstrated readiness** to proceed to full rate production, the MDA shall assess the cost and benefits of a break in production versus continuing buys before approving an increase in the LRIP quantity."*

DoDI 5000.02 dated 8 December 2008

"*An MDAP may not proceed beyond LRIP without MDA approval. **The knowledge required to support this approval shall include demonstrated control of the manufacturing process***

***and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes**."*

DoDI 5000.02 dated 8 December 2008

"Low-Rate Initial Production (LRIP) Phases, the industrial and manufacturing readiness should be assessed to identify remaining risks prior to a full-rate production go-ahead decision."

DAG dated 10 January 2010

6.1 Purpose of MRLs in LRIP

The use of MRLs, in LRIP, addresses the completion of the manufacturing processes to ***permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes*** from DODI 5000.02. The effort in this phase is mainly evaluating the results from your production line and comparing it with program requirements to achieve your cost, schedule, and performance objectives. The key drivers to focus on during this phase will be design stability, manufacturing process performance/capability (Prime and Suppliers), and capacity (Prime and Suppliers). The MRL process is designed to answer the question are you ready for Full Rate Production (FRP).

6.1.1 Using MRLs for Managing, Assessing and Demonstrating Manufacturing Capability in the LRIP phase

The use of MRLs in this phase is very similar to what is expected in EMD. Managing, assessing and demonstrating manufacturing capability using the MRL criteria is basically always a three step process. The first step is to contractually establish a program to require the contractor to mature the manufacturing processes, perform a manufacturing maturity assessment, and then to use the assessment data to establish effective manufacturing process maturation activities. The MRL process does this by defining key activities/criteria to reach a target level of manufacturing maturity during this phase (i.e. MRL 9). An essential step in the process is to decide up front which suppliers should implement this effort. As a general rule at this phase of program it will usually be the prime and most of the major subcontractors, but the major subcontractors may also need to flow this requirement down to some of their key suppliers. Specific criteria are available in the MRL Deskbook to determine where to apply this effort on your program. The second step in the MRL process is to use the MRL criteria to ensure all recommended activities have been completed. This is explained in the MRL Deskbook. The third and final step is to use the data created by the first two steps to determine if the manufacturing capability has been adequately demonstrated (i.e., the manufacturing processes meet the program's cost and schedule objectives) before proceeding into the FRP Phase. As part of this effort, you must perform a risk assessment where shortfalls are identified. The use of MRL criteria is considered an industry best practice for maturing the manufacturing process so your program managers fully understand the manufacturing risk before proceeding into the next FRP. If the program doesn't follow the steps outlined in the MRL process, it is likely that the program will not capture all the manufacturing risk and will only transfer it to the next phase of the program. It must be stressed that following this process does not necessarily eliminate all risk, but it does increase the likelihood that you will be able to identify the manufacturing risk before entering FRP.

6.1.2 Overview of MRLs for assessing the manufacturing process in the LRIP Phase

During LRIP, assessments of manufacturing readiness are conducted to demonstrate the completion of the manufacturing processes to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes***. These manufacturability assessments should be conducted in concert to support the FRP decision. The assessment should focus on design maturity (especially results coming from OT&E) and program-wide manufacturing risks such as fabrication, assembly, integration and test operations; supply chain performance; maturity of manufacturing planning; maturity of manufacturing management systems; adequacy of funding for manufacturing risk reduction efforts and other factors defined in MRL thread descriptions. Key considerations include:

- Industrial base viability

- Probability of meeting the delivery date (e.g., for qualification units)
- Design stability
- Process maturity
- Manufacturing costs
- Supply chain management
- Quality management
- Facilities
- Manufacturing skills availability

This assessment assures that adequate progress is being made toward FRP targets. The program-level PRR is a Systems Engineering technical review that is sometimes used in LRIP to determine if a program is ready for FRP. The PRR historically assesses more than just manufacturing maturity; it looks at the readiness of all the functional areas as they relate to the entire program's readiness to go into FRP. The manufacturing portion of the PRR will assesses whether the prime contractor and major subcontractors and suppliers have adequately demonstrated that their production capability will support program objectives and that there are no unacceptable risks for schedule, performance, cost, or other objectives. The use of MRLs to assess manufacturing maturity and risk should be a principal area of emphasis during the PRR. The assessment of manufacturing readiness should highlight any areas where manufacturing maturity falls short of requirements. The assessment should discuss the risks that these shortfalls pose to the program and the status of efforts to mitigate these risks. It should also include an estimate of schedule or funding changes required to correct significant shortfalls. If any program manufacturing area is found to fall short at the end of LRIP, there are two basic choices available to an acquisition program manager:

- Request a delay in the FRP decision point to implement efforts to reduce manufacturing risk before proceeding
- Carry higher manufacturing risk into FRP and try to mitigate the risk.

Neither of these options are optimum. This shows the importance of addressing manufacturing earlier in the process. There are some other options available, but due to the timing are less viable as you enter production. Some of these options are:

- Challenge Requirements – If performance requirements exceed manufacturing capability, first ask the design team and user to consider relaxing performance requirements to make the proposed solution more producible.
- Use multiple sources in the next phase to increase the probability of success.
- Use ManTech and/or other technical funds to explore solutions to solving your risk areas.
- Use Title III funds where applicable to address risk areas.

- Look at S&T options to provide a more producible performance option.
- Use SBIR funding where applicable to explore solutions to solving the risk areas.

6.2 Key Activities, and Documents in the LRIP Phase

The following activities and supporting documentation during the LRIP phase are essential steps in developing an affordable and executable manufacturing process and demonstrating that manufacturing capability can support FRP requirements. Here you need to focus on three efforts. The first effort is accomplishing the up-front planning and contractual activities necessary to ensure manufacturing maturity efforts required to be performed in the LRIP phase are in place and on contract. This step is essential to demonstrate the completion of the manufacturing processes to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes*** (per DODI 5000.02). The second effort is managing the necessary activities to achieve desired manufacturing maturity before exiting the LRIP phase and to mitigate the manufacturing risk identified while demonstrating manufacturing capability. The final effort is ensuring that the manufacturing risk of proceeding to FRP is clearly presented to decision makers and that it is reflected in cost (budgets), schedule, and performance projections in the production phase.

The following are the necessary activities and documents to accomplish the planning and execution of a manufacturing readiness assessment in LRIP.

6.2.1 Key Activities in the LRIP Phase

- **Lifecycle Cost Estimates** – This estimate should be performed on each final design coming out of OT&E. This is an area where manufacturing risks must be adequately addressed. We must ensure that projected costs reflect the appropriate manufacturing risk and risk reduction efforts. - Link to DAG
- **Industrial Base Assessment** – For the final design coming out of OT&E you need to perform an assessment to ensure that industrial capability can support your program. A focus on material availability and unique manufacturing products are keys in this analysis; however, you should look at any unique demand that may push existing capability and capacity beyond today's industrial base limits.– Link to DAG
- **Assessments of Manufacturing Readiness** –During this phase the assessment needs to focus on demonstrating the manufacturing capabilities to meet the cost, schedule, and performance requirements of the program at FRP. The MRL Deskbook spells out clearly how to perform an assessment and provides the criteria to be evaluated (i.e. MRL Matrix). The focus will be on assessing manufacturing maturity at the MRL 9 criteria level

to ensure you have developed an affordable and executable manufacturing process. The assessment must also demonstrate that manufacturing processes can support the system production rate requirements. The assessment effort is to support a FRP Decision process prior to entering LRIP. Fundamentally the manufacturing assessment at this time must be able to ***demonstrate that manufacturing processes are mature enough to permit an orderly increase in the production rate for the system and achieve that the system is affordable permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes*.** The manufacturing assessment in this phase probably will be linked to Production Readiness Review activities. In addition to having the data needed to answer these critical questions for the MDA, another key product coming out of these assessments is the risk mitigation plan to minimize shortfalls identified. It is important that results of this assessment be used to update the cost (budget), schedule and performance objectives/projections for FRP. – **Link to Deskbook and DAG**

- **Production Readiness Review (PRR) –** At his phase the PRR examines a program to determine if the program is ready for FRP. Specifically the design maturity and if the prime and major subcontractors have accomplished adequate production planning without incurring unacceptable risks that breach thresholds of schedule, performance, cost, or other established criteria. The review examines risk; it determines if production or production preparations identify unacceptable risks that might breach thresholds of schedule, performance, cost, or other established criteria. The review evaluates the full production-configured system to determine if it correctly and completely implements all system requirements. Since the PRR looks at all system requirements, it will look at more than manufacturing issues (e.g., software, sustainment, operational testing, etc.). The review determines whether traceability of final system requirements to the final production system is maintained. Typical PRR success criteria include affirmative answers to the following exit questions:
  1. Has the system product baseline been established and documented to enable hardware fabrication and software coding to proceed with proper configuration management?
  2. Are adequate processes and metrics in place for the program to succeed?
  3. Are the risks known and manageable?
  4. Is the program schedule executable (technical/cost risks)?
  5. Is the program properly staffed?
  6. Are all technologies mature enough for production?
  7. Is the detailed design producible within the production budget?
  8. Are the production facilities ready and required workers trained?
  9. Is detail design complete and stable enough to enter low rate production?
  10. Is the supply chain established and stable with materials available to meet planned low rate production?
  11. Have manufacturing processes been demonstrated and proven in a pilot line environment?

12. Have all producibility trade studies and risk assessments been completed?

13. Is the production cost model based upon the stable detailed design and been validated?

14. Are the ESOH residual risks known and manageable?

The manufacturing assessments are certainly a large portion of any PRR and should be performed in conjunction with any PRR to maximize efficiency.

- **Program Management Review (PMR) -** A PMR is conducted at defined intervals (monthly or quarterly) by the Program Manager for the purpose of determining the status of an assigned system. PMRs are designed as tools to report program status, identify issues and problems, discuss risks, and to develop appropriate follow-up actions as required. Typically, the SOW tasks the contractor to participate in the PMR and to capture minutes. During these reviews the progress and concerns about the manufacturing ability to achieve your program requirements should be addressed.
- **Integrated Business Review (IBR)** -An Integrated Baseline Review (IBR) is a joint assessment conducted by the government program manager and the contractor to establish the Performance Measurement Baseline (PMB). Completion of this review should result in the assessment of risk within the program measurement baseline and the degree to which the following have been established:
  1. Technical scope of work fully included and is consistent with authorizing documents,
  2. Key project schedule milestones identified and supporting schedules reflect a logical flow to accomplish the work,
  3. Resources (budgets, facilities, infrastructure, personnel, skills, etc.) available and are adequate for the assigned tasks,
  4. Tasks planned and can be measured objectively relative to the technical progress,
  5. Rationale underlying the PMB is reasonable, and
  6. Management processes support successful execution of the project.

A key consideration during the IBR is how manufacturing capability is addressed to determine whether the program will achieve its cost and schedule constraints at FRP. The maturity of the manufacturing process and associated risk of that maturity is an essential element in a program achieving performance requirements within budget and schedule objectives. Therefore, the IBR should spell out how program resources will support manufacturing readiness assessments and how these efforts relate to the System Engineering Plan (SEP) which spells out how manufacturing risk will be identified and mitigated in the EMD phase. –Link to DAG

Physical Configuration Audit (PCA) - The PCA is conducted around the time of the Full-Rate Production Decision. The PCA examines the actual configuration of an item being produced. It verifies that the related design documentation matches the item as specified in

the contract. In addition to the standard practice of assuring product verification, the PCA confirms that the manufacturing processes, quality control system, measurement and test equipment, and training are adequately planned, tracked, and controlled. Results of the manufacturing assessments will be critical in performing this Audit –Link to DAG

Operational Test and Evaluation (OT&E) – It will be a critical to ensure that units being used in the test are production-representative. Results of the manufacturing assessment will be used to make that determination.

- **Budget Process** – It is critical that the budgets provide adequate funding to address the **manufacturing risk** that has been identified, and that efforts to minimize those risks are in place to demonstrate adequate manufacturing maturity progress in the FRP phase.

6.2.2 Key Documents in the LRIP Phase

To accomplish the above activities certain documents should address how the program will ***develop an affordable and executable manufacturing process*** and ensure that they have matured to a level that ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes***. The following are the key documents that must be considered, along with a brief explanation on what should be addressed in each.

- **System Engineering Plan (SEP)** – The SEP is a detailed formulation of activities that encompass all technical aspects of an acquisition program. The SEP describes the program's overall technical approach, including systems engineering activities, resources, and key technical tasks, along with their metrics and success criteria. Integration or linkage to other program management control efforts, such as Integrated Master Plans, Integrated Master Schedules, Technical Performance Measures, risk management, and Earned Value Management, is fundamental to successful program execution. The manufacturing lead on the program should have the SEP explain how the program will develop affordable and executable manufacturing processes and demonstrate that the manufacturing capability can support production requirements prior to entering FRP. The SEP should therefore specify how they plan to integrate program manufacturing requirements with all the technical efforts in LRIP. – **Link to DAG**
- **Capability Production Document (CPD) -** The final step in the capabilities refinement process is the CPD development. This document describes the refined operational capabilities and system performance expected for the production articles. The CPD is used by the T&E working-level Integrated Product Team to update the Test and Evaluation Master Plan for the FRP decision. Operational testing focuses on evaluating the Low-Rate Initial Production system's operational effectiveness, suitability, survivability, and

mission capability. It is essential that manufacturing personnel use this document to translate manufacturing risks into information the Warfighter understands, so he can possibly change what the requirements will cost.– Link to DAG

- **Acquisition Strategy (AS) –** The Acquisition Strategy is a comprehensive, integrated plan that identifies the acquisition approach and describes the business, technical, and support strategies that management will follow to deal with program risks and meet program objectives. The Acquisition Strategy should define the relationship between the acquisition phases and work efforts, key program events such as decision points, reviews, contract awards, test activities, production lot/delivery quantities, and operational deployment objectives. An AS should be linked to the SEP and should address how the program will develop an affordable and executable manufacturing process. The PM will prepare, and the MDA will approve an Acquisition Strategy to guide activity during LRIP.

  (a) The Acquisition Strategy describes how the PM plans to employ contract incentives to achieve required cost, schedule, and performance outcomes.

  (b) The strategy includes a time-phased workload assessment identifying the manpower and functional competency requirements for successful program execution and the associated staffing plan, including the roles of government and non-government personnel.

  (c) If the program is dependent on the outcome of other acquisition programs or must provide capabilities to other programs, those relationships should be detailed in th***e*** acquisition strategy. Similarly, if a program is part of a system-of-systems or family-of-systems, the relationship and associated dependencies with other system elements should be described. Link to DAG

- **Acquisition Plan (AP)** – This document usually does not require outside program approval since it is a tool of the Program Manager (PM) to translate the AS into specific details needed to accomplish the strategy. This would be an excellent place to identify how the program will implement the tasks necessary to develop affordable and executable manufacturing processes and demonstrate that the manufacturing capability can support production requirements prior to entering FRP. – Link to DAG

- **Request For Proposal (RFP)** – This is the key document that must be adequately addressed by the manufacturing SME supporting the program. In LRIP it is essential to develop affordable and executable manufacturing processes and ensure that these processes have been effectively demonstrated to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical***

processes. It is also crucial that system production can be supported by demonstrated manufacturing processes. These requirements must be put to into contractual language within the RFP. The MRL Deskbook will provide suggestions on what might used in the RFP. - Link to DAG and Deskbook

- **Cost Analysis Requirements Description (CARD) -** the CARD is used to formally describe the acquisition program for purposes of preparing both the DoD Component Cost Estimate and the Cost Assessment independent cost estimate. DoD Instruction 5000.02 specifies that for major defense acquisition programs, the CARD will be provided in support of major milestone decision points (Milestone B, Milestone C, or the full-rate production decision review). The manufacturing assessments performed during this phase should be a source document to capture the cost associated with the manufacturing risk identified to support a FRP decision.

- **Integrated Master Plan (IMP)** – The IMP is a critical tool used to manage the program. The program manager should use event-driven schedules and require manufacturing SMEs to identify all tasks that need to be accomplished in a rational and logical order. Necessary entry and exit criteria for each major task should be identified, and no major task should be started or declared complete until all required criteria have been satisfied. When documented in a formal plan and used to manage the overall program, this event-driven approach can help ensure that all tasks are integrated properly and that the management process is based on the accomplishment of significant events in the acquisition life cycle and not on arbitrary calendar dates. This planning effort should take documents such as the SEP, AS, AP and MRL threads and translate them into defined activities that need to be performed during this phase in order to develop an affordable and executable manufacturing process. Following the IMP will ensure that all manufacturing processes have been effectively demonstrated to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes***. - Link to DAG

- **Integrated Master Schedule (IMS)** – The IMS takes the IMP requirements and defines the requirements in terms of calendar time and resources needed to accomplish the IMP. The IMS should address the resources needed to accomplish the requirements to develop an affordable and executable manufacturing process.

- **Program Objective Memorandum (POM)/Budget Estimate Submission (BES)** – It is critical that this document reflect the manufacturing risk and efforts to develop an affordable and executable manufacturing process and to ensure manufacturing processes have been effectively demonstrated to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical***

process control data, and the demonstrated control and capability of other critical processes. The BES should include adequate funding to cover the activities to mitigate those risks carried over into FRP.

- **Selected Acquisition Report (SAR)** - In accordance with 10 U.S.C. 2432 , the Secretary of Defense will submit a SAR to Congress for all MDAPs. The program manager will use the Defense Acquisition Management Information Retrieval (DAMIR) application to prepare the SAR. The program manager will submit quarterly exception SARs for the quarters ending March 31, June 30, and September 30 not later than 45 days after the quarter ends. Quarterly SARs are reported on an exception basis, as follows:
  - The current estimate exceeds the Program Acquisition Unit Cost (PAUC) objective or the Average Procurement Unit Cost (APUC) objective of the currently approved APB in base-year dollars by 15 percent or more;
  - The current estimate includes a 6-month or greater delay, for any schedule parameter, that occurred since the current estimate reported in the previous SAR;
  - Milestone C approval occurs within the reportable quarter.

  Results from the manufacturing assessment should be used in updating the SAR.

- **Defense Acquisition Executive Summary (DAES) Report -** The program manager will report the unit costs of the program to the CAE on a quarterly basis through the electronic Defense Acquisition Executive Summary (DAES) submission process. The program manager should submit updates in accordance with DAES submission procedures. Reporting should begin with submission of the initial SAR, and end with submission of the final SAR. Each report should include the current estimate of the Program Acquisition Unit Cost and the Average Procurement Unit Cost (in base-year dollars), cost and schedule variances for each of the major contracts since entering the contract, and all changes that the program manager knows will occur, or expects to occur, to program schedule or performance parameters as compared to the currently approved Acquisition Program Baseline. Results from the manufacturing assessments should be used to update this information.

- **Contractor Cost Data Reporting (CCDR) -** CCDR reports provide for each contract a display of incurred costs to date and estimated costs at completion by Work Breakdown Structure element, with nonrecurring and recurring costs identified separately. CCDR reports in some cases can display costs by functional category (**manufacturing labor**, engineering, etc.). Where appropriate, a functional category is broken out by direct labor hours, direct material, overhead, and other indirect. The impact of system manufacturing maturity needs to be reflected in this report.

6.3 Supporting the FRP Decision Review (DR)

An MDAP may not proceed beyond LRIP without MDA approval. The knowledge required to support this approval shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes. Continuation into full-rate production requires a successful Full-Rate Production (or Full Deployment) Decision Review by the MDA. The decision to proceed into Full-Rate Production will be documented in an ADM. This effort delivers the fully funded quantity of systems and supporting materiel and services for the program or increment to the users. During this effort, units will typically attain Initial Operational Capability (IOC). As technology, software, and threats change, FOT&E shall be considered to assess current mission performance and inform operational users during the development of new capability requirements.

- Program Support Reviews (PSRs) - The PSR, if performed on the program, will assess the technical progress being made. The PSR should address the program's progress in assessing the manufacturing risk and the mitigation efforts being planned in the program. This information should be used at the FRP DR. Defense Acquisition Program Support (DAPS) Methodology, Version 2.0, Change 3
  March 20, 2009
- Overarching Integrated Product Team (OIPT) - An OIPT reviews program planning, facilitates program communications and issue resolution, and supports the MDA for ACAT ID. It will be important that the OIPT is aware of the manufacturing risk issues and how these issues will be addressed so the MDA has the required information to make a sound decision on the program's direction.

6.4 Summary

The bottom line: The purpose for using MRLs in the LRIP phase is to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the demonstrated control and capability of other critical processes***.. The key document is the contract. In this document you must require the contractor to perform the activities necessary to mature manufacturing processes. The contract should identify a procedure that lets both government and contractor assess manufacturing maturity against program requirements. The contract is essential to develop affordable, executable manufacturing processes, and a key activity specified in the contract should be the performance of manufacturing assessments. The main purpose of those assessments is to ensure that manufacturing capability has been demonstrated to ***permit an orderly increase in the production rate for the system leading to full-rate production permit an orderly increase in the production rate for the system leading to full-rate production*** and ***the knowledge required to support this shall include demonstrated control of the manufacturing process and acceptable reliability, the collection of statistical process control data, and the***

demonstrated control and capability of other critical processes. and that all risks are identified, assessed and mitigated. It is also essential to use data obtained from these assessments to update the budgeting and funding documents to show the likelihood of achieving program cost, schedule, and performance objectives. Finally, the assessment process will be critical to present the manufacturing risk and mitigation efforts to decision makers before proceeding into FRP.

7.0 MRLs in the Full Rate Production (FFP) Phase – Reserved

8.0 MRLs in the Operation and Support (O&S) Phase – Reserved

9.0 Summary -Reserved

Appendices

Appendix a Detail History of MRL Development

In 2000 a group of senior industry leaders were empanelled to study the Army's Future Combat System Manufacturing. They were asked by DUAD (AS & C) to formulate a set of initial draft Manufacturing Readiness Levels (MRLs) using TRLs as the basis. Their recommendations were implemented by Dr Andrews, (SAALT). Study members were:

- Mr. Herman Reininga (Co-Chair) Rockwell-Collins
- Dr. Jacques S. Gansler (Co-Chair) University of Maryland
- Mr. Dale G. Adams Aerojet Corporation
- Mr. Robert L. Cattoi Consultant
- Mr. Jonathan L. Etherton Aerospace Industries Association
- Dr. Michael F. McGrath Sarnoff Corporation
- Mr. James Mattice Universal Technologies Corporation
- Mr. Jesse T. (Tom) McMahon Modern Technology Solutions Incorporated
- Mr. Fredrick J. Michel NGM Knowledge Systems
- Dr. John W. (Jack) Gillespie University of Delaware
- Mr. R. Noel Longuemare Consultant
- Dr. Samuel A. Musa Northwestern University
- Mr. Ralph L. Resnick Extrude Hone
- Mr. Robert L. Shelby Caterpillar, Incorporated
- Mr. James M. Sinnett Consultant

Over the next three years, DDR & E continued socializing the concept of MRLs throughout the AT & L community, including industry and academia. In 2004, DUSD (AS & C) requested the Joint Defense Manufacturing Technology Panel (JDMTP) accept the challenge of refining and institutionalizing a set of DoD MRLs, with the guidance that the MRLs should be:

- Consistent with Current DoD 5000 Acquisition Doctrine, Practice, and Milestone Decision Points,
- Reconciled With TRLs,
- Reconcilable With MDAs EMRLs,
- Constructed in the form of Guidance versus “Prescriptive”,
- Aligned with Evolving NASA TRL/MRL Evolution,

- Potentially Capable of Serving as the basis for a wider GATE-M “Standard”.

The JDMTP established a working group of subject matter experts from each of the services, DoD Agencies and OSS staff organizations, industry and academia. They concluded that:

- Most programs that “fail” lack a disciplined systems engineering process
- While a mature manufacturing body of knowledge exists, it is too diffused to be useful to program management teams,
- Is often conflicted,
- Use is sporadic, and not uniformly applied by all programs at all milestones
- Problems with manufacturing resulted in many of the adverse cost, schedule and technical impacts to programs, including reliability.
- Programs that paid attention to manufacturing early and often fared better than those who do not
- Industry is looking to DoD for leadership in manufacturing.

Furthermore, the group found Best Industry Practices:

- Looks at a broad spectrum of processes and performance before committing to expensive systems development and/or production
- Successful technology transition requires, at a minimum, an understanding of critical manufacturing processes
    - For some companies … a mature production capability
- Current TRL descriptions focus on evaluating prototype components within increasingly relevant environments to judge readiness for transition based upon performance demonstration
- Providing a manufacturing readiness level should move producibility concerns into earlier development phases
- Maturity of the manufacturing processes should to be evaluated continuously along the technology development path, else transition will be delayed or will not occur

The JDMTP MRL Working Group began with a literature search of manufacturing management, including DoD policy guidance (current and legacy - including previous military specifications and standards), industry standards and best practices, and academic texts and guiduance.

Prior to acquisition reform manufacturing management was governed by MIL-STD-1528A which called for manufacturing assessments in each phase being with concept exploration as shown in Figure 1 above.

Utilizing the initial set of draft MRLs, the working group further fleshed put the various levels, definitions, descriptions, and alignment with the AT& L critical processes (beginning with Science and Technology through development, production, and post production support. It should be noted that the working group examined many models to define the MRL levels. EMRLs use four levels, TRLs use nine, OSD/SSE proposed 15, but the working group defined ten. These being the natural phases of manufacturing from concept to breadboards to brassboard to advanced prototype to engineering development model to LRIP article to production article etc, MRL Considerations are found in Appendix C.

At the same time, the working group went the next step of further defining each of the MRLs in terms of nine critical areas of manufacturing risk. These nine risk categories (along with subcategories) are:

The working group believed a shortcoming of the TRLs was the lack of detailed definition to be of use to MRLs. The nine risk areas (including twenty sub areas) represent the manufacturing management community's major risk areas (see Appendix D). The JDMTP believes the MRL body of knowledge provides the AT&L community with an opportunity to:

- Solidify Technology Transition Programs in DoD Acquisition Stage Gate Process
- Bridge the Gap from S&T to Production
- Provide Program Managers with Knowledge of Technology ,Product and Process Risks.
- Empower IPPD Teams with Technical bodies of Knowledge based on Best Practices.
- Provide DoD Decision-makers with Knowledge-Based tools at Milestones.
- Transition Programs with “Known” Risks, and Coordinated Risk Mitigation Strategies/Plans.

In addition to interviews with practitioners and stakeholders (including a Defense Science Board Task Force), the working group hosted four workshops including over four hundred government and industry attended. The working group developed a library of artifacts including a guidebook, a Deskbook, web-based tools, and suggested language for contracts and policy guidance. Further, each year the working group hosts a workshop to refresh the manufacturing readiness body of knowledge.