

MRL	Definition	Description	Phase
1	Basic Manufacturing Implications Identified.	Basic research activities expand scientific principles that may have manufacturing implications. The focus is on a high level assessment of manufacturing opportunities. The research is unfettered.	Pre Materiel Solution Analysis
2	Manufacturing Concepts Identified.	Invention begins. Manufacturing science and/or concept is described in application context. Identification of material and process approaches are limited to paper studies and analysis. Initial manufacturing feasibility and issues are emerging.	Pre Materiel Solution Analysis
3	Manufacturing Proof of Concept Developed.	Analytical or laboratory experiments are conducted to validate paper studies. Experimental hardware or processes have been created, but are not yet integrated or representative. Materials and/or processes have been characterized for manufacturability and availability but further evaluation and demonstration is required.	Pre Materiel Solution Analysis
4	Capability to produce the technology in a laboratory environment.	Required investments, such as manufacturing technology development identified. Processes to ensure manufacturability, producibility and quality are in place and are sufficient to produce technology demonstrators. Manufacturing risks identified for prototype build. Manufacturing cost drivers identified. Producibility assessments of design concepts have been completed. Key design performance parameters identified. Special needs identified for tooling, facilities, material handling and skills.	Materiel Solution Analysis (MSA) leading to a Milestone A decision.
5	Capability to produce prototype components in a production relevant environment.	Mfg strategy refined and integrated with Risk Mgt Plan. Identification of enabling/critical technologies and components is complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on components in a production relevant environment, but many manufacturing processes and procedures are still in development. Manufacturing technology development efforts initiated or ongoing. Producibility assessments of key technologies and components ongoing. Cost model based upon detailed end-to-end value stream map.	Technology Development (TD) Phase.
6	Capability to produce a prototype system or subsystem in a production relevant environment.	Initial mfg approach developed. Majority of manufacturing processes have been defined and characterized, but there are still significant engineering/design changes. Preliminary design of critical components completed. Producibility assessments of key technologies complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on subsystems/ systems in a production relevant environment. Detailed cost analyze includes design trades. Cost targets allocated. Producibility considerations shape system development plans. Long lead and key supply chain elements identified. Industrial Capabilities Assessment (ICA) for MS B completed.	Technology Development (TD) phase leading to a Milestone B decision.
7	Capability to produce systems, subsystems or components in a production representative environment.	Detailed design is underway. Material specifications are approved. Materials available to meet planned pilot line build schedule. Manufacturing processes and procedures demonstrated in a production representative environment. Detailed producibility trade studies and risk assessments underway. Cost models updated with detailed designs, rolled up to system level and tracked against targets. Unit cost reduction efforts underway. Supply chain and supplier QA assessed. Long lead procurement plans in place. Production tooling and test equipment design & development initiated.	Engineering & Manufacturing Development (EMD) leading to Post-CDR Assessment.
8	Pilot line capability demonstrated. Ready to begin low rate production.	Detailed system design essentially complete and sufficiently stable to enter low rate production. All materials are available to meet planned low rate production schedule. Manufacturing and quality processes and procedures proven in a pilot line environment, under control and ready for low rate production. Known producibility risks pose no significant risk for low rate production. Engineering cost model driven by detailed design and validated. Supply chain established and stable. ICA for MS C completed.	Engineering & Manufacturing Development (EMD) leading to a Milestone C decision.
9	Low Rate Production demonstrated. Capability in place to begin Full Rate Production.	Major system design features are stable and proven in test and evaluation. Materials are available to meet planned rate production schedules. Manufacturing processes and procedures are established and controlled to three-sigma or some other appropriate quality level to meet design key characteristic tolerances in a low rate production environment. Production risk monitoring ongoing. LRIP cost goals met, learning curve validated. Actual cost model developed for FRP environment, with impact of Continuous improvement.	Production & Deployment leading to a Full Rate Production (FRP) decision
10	Full Rate Production demonstrated and lean production practices in place.	This is the highest level of production readiness. Engineering/design changes are few and generally limited to quality and cost improvements. System, components or items are in rate production and meet all engineering, performance, quality and reliability requirements. All materials, manufacturing processes and procedures, inspection and test equipment are in production and controlled to six-sigma or some other appropriate quality level. FRP unit cost meets goal, funding sufficient for production at required rates. Lean practices well established and continuous process improvements ongoing.	Full Rate Production/ Sustainment

Definitions of Terms Found in Manufacturing Readiness Level Definitions

Production relevant environment – An environment normally found during MRL 5 and 6 that contains key elements of production realism not normally found in the laboratory environment (e.g. uses production personnel, materials or equipment or tooling, or process steps, or work instructions, stated cycle time, etc.). May occur in a laboratory or model shop if key elements or production realism are added.

Production representative environment – An environment normally found during MRL 7 (probably on the manufacturing floor) that contains most of the key elements (tooling, equipment, temperature, cleanliness, lighting, personnel skill levels, materials, work instructions, etc) that will be present in the shop floor production areas where low rate production will eventually take place.

Pilot line environment – An environment normally found during MRL 8 in a manufacturing floor production area that incorporates all of the key elements (equipment, personnel skill levels, materials, components, work instructions, tooling, etc.) required to produce production configuration items, subsystems or systems that meet design requirements in low rate production. To the maximum extent practical, the pilot line should utilize rate production processes.

Manufacturability – The characteristics considered in the design cycle that focus on process capabilities, machine or facility flexibility, and the overall ability to consistently produce at the required level of cost and quality. Activities can include some or all of the following activities:

- Design for commonality and standardization- fewer parts
- Perform comprehensive Technology Assessment, including commercial industrial applications and the supplier base
- Design for Multi-Use and Dual-Use applications
- Design for modularity and plug compatible interface/integration
- Design for flexibility, adaptability, and “robust design”
- Utilize reliable processes and materials

Producibility – Is the capability of an item to be produced, including some or all of the following activities:

- Design to specific Cp-CpK process control parameters- six sigma
- Perform material characterization analysis
- Perform variability reduction analysis- Taguchi, DOE
- Develop critical materials and processes before selecting product design
- Utilize pervasive modeling & simulation for product and process design tradeoffs
- Design and deployment of closed-loop process-control on critical items