TRLs and MRLs: Supporting NextFlex PC 2.0

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Outline

- Purpose and Scope of Webinar
- Readiness Levels: Measures, Assessments, Process and Purpose
- Why MRLs are specifically applied within Institutes
- Technology Readiness Levels
  - As a Measure
  - Assessment Process
- Manufacturing Readiness Levels
  - As a Measure
  - Assessment Process
- Best Practice and Lessons Learned
- Questions?

Purpose and Scope of Webinar

- Provide Background for why Institutes use MRLs
- Provide Adequate Background on the role of TRLs and MRLs, and differentiate from TRAs and MRAs.
- Explain the Progression of MRLs and Requirements for Substantiation
- Discuss how MRLs can be used within the NextFlex Proposals
- Discuss Lesson Learned from Past Experience
- Answer Questions

Readiness Levels:

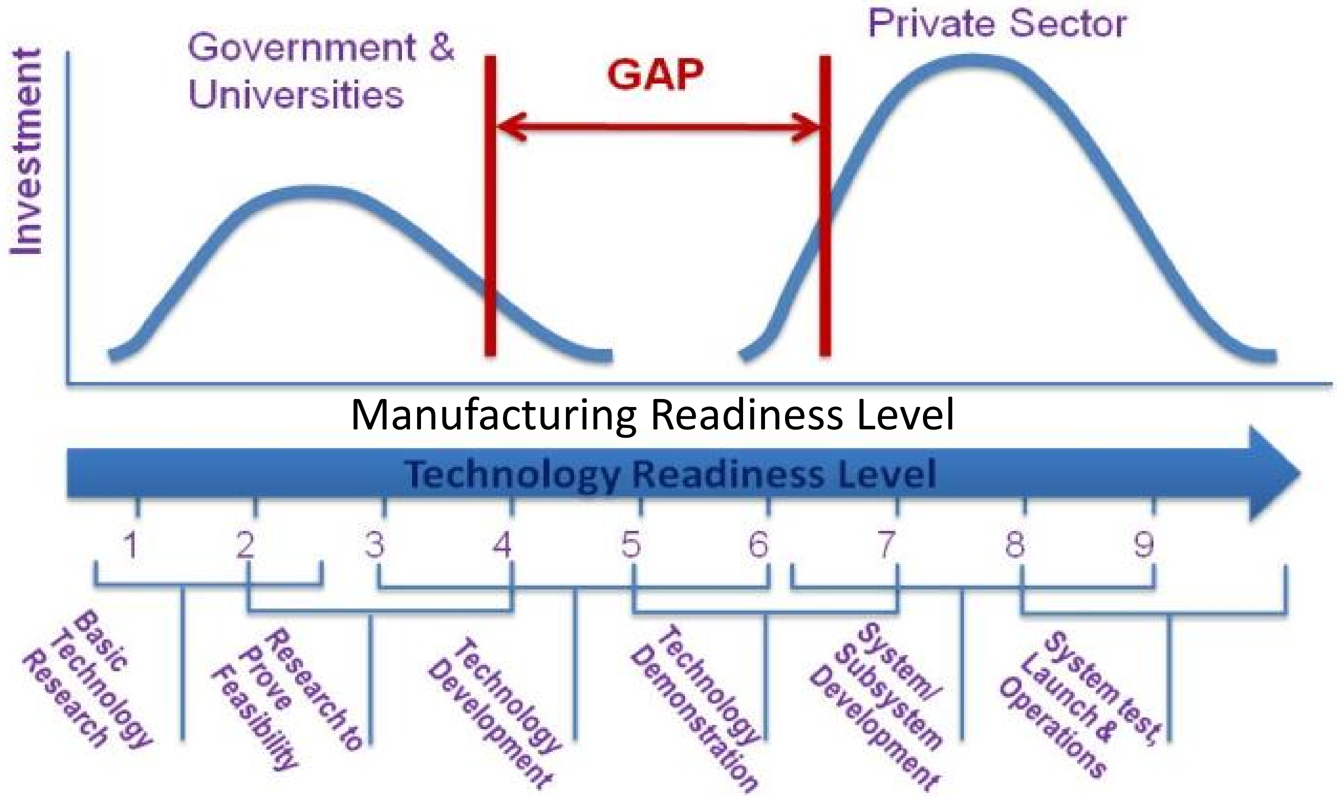
Measures, Assessments, Process and Purpose

- Technology Readiness Levels (and Manufacturing Readiness Levels) are a measurement scale, just like a ruler.
  - TRLs have definitions, documentation needs, and notes for use.
  - MRLs have definitions, 9 threads, 27 sub-threads, master matrix, documentation needs, examples situations, an interactive guide, and tools. (more comprehensive)
- Technology Readiness Assessment is a recommended process for how to determine critical technology elements, assess TRL level, and document results.
- Manufacturing Readiness Assessment is a recommended process for how to tailor MRL threads, apply criteria robustly, assess MRLs, document results, and recommend mitigation.
- The outcomes of utilizing TRLs and MRLs are to provide a common language and standard for *demonstrated* Tech and Mfg Maturity and for an estimate of risk in system acquisition (market success).

Mfg Institutes were created to fill the missing middle [MRL 4-7]

Common terms
The "valley of death"
The "missing Bell Labs"
The "industrial commons"

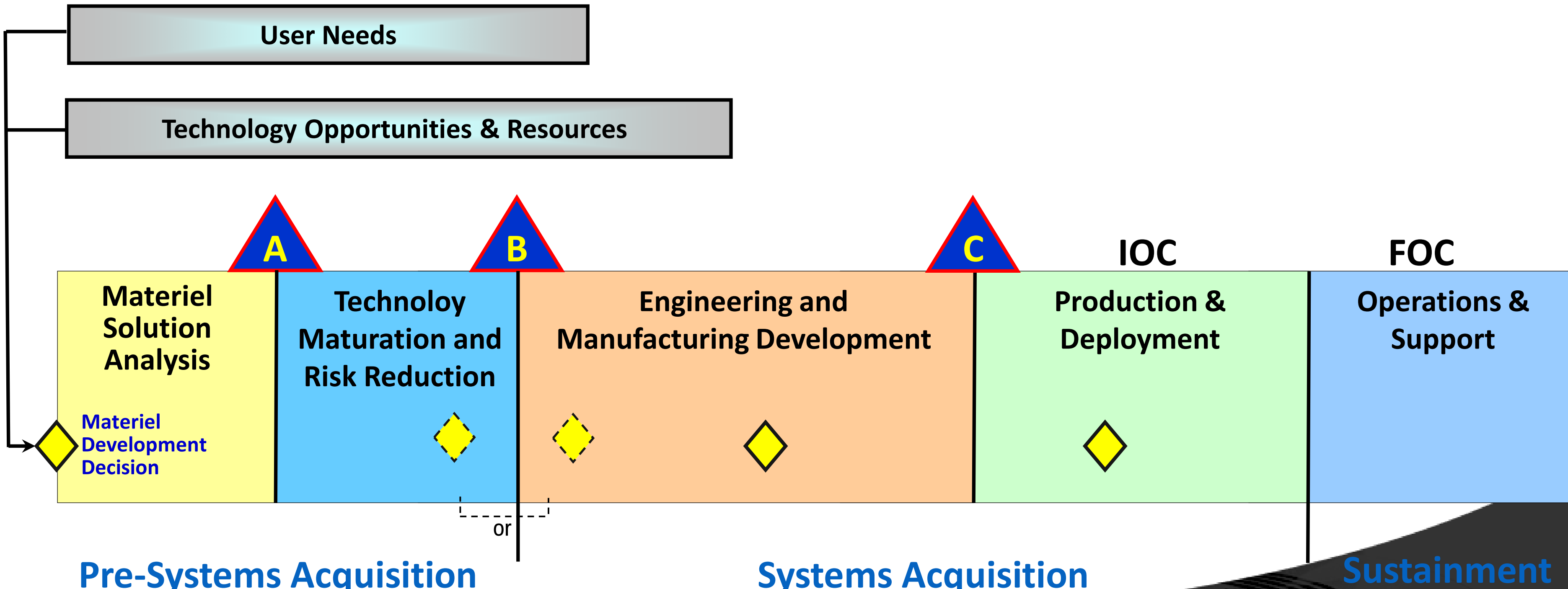
Gap in Manufacturing Innovation



NEXTFLEX

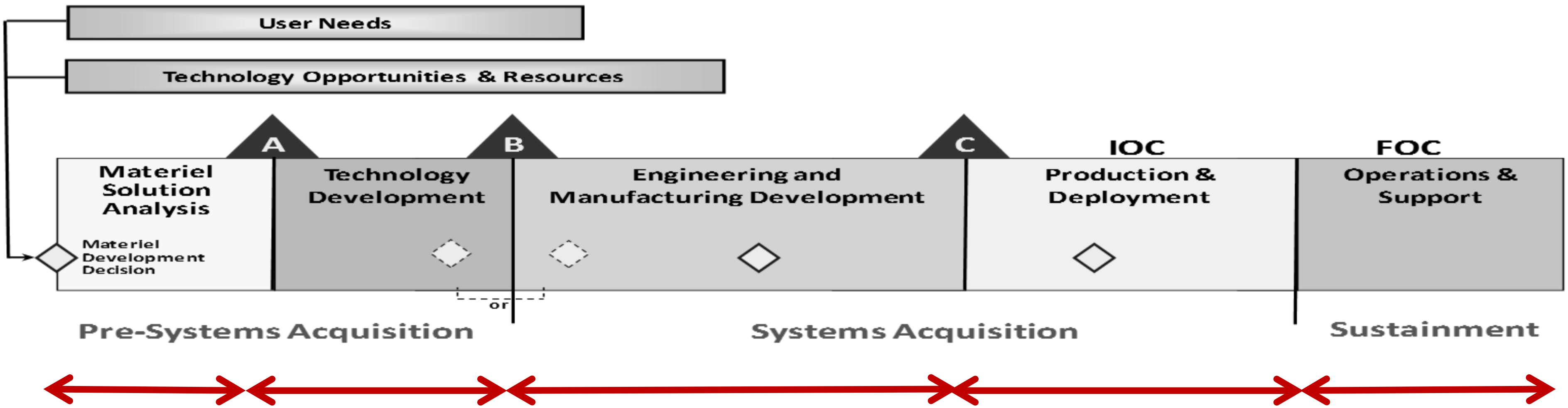
Common Starting Point

The Defense Acquisition Management Framework



Common Starting Point

Commercial Product Development



Research Opportunities Demand | **Prototyping & Testbeds** | **Design & Manufacturing** | **Production & Certification** | **Launch Support**

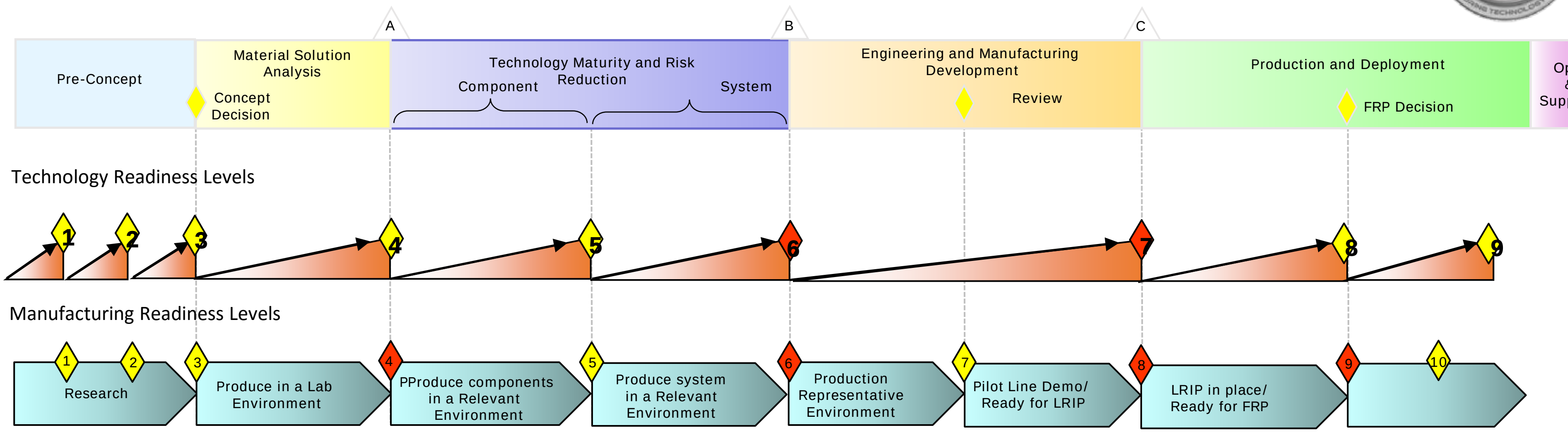
Ideation | Business Case | Product Development | Launch

Preliminary Design Review

Critical Design Review

Production Decision

The Environment for Applying Readiness Levels



	MRL 1–3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Considerations	*Manufacturing Concepts Identified* *Basic Research* *Advanced Research* *Advanced Technology Development*	Mfg. Processes Identified Key Processes Identified Producibility Assessments Initiated	Mfg. Processes Emerging Producibility Assessments On-going Mfg. Cost Drivers Identified	Mfg. Processes Demonstrated in Relevant Env. Cost Drivers Analyzed Long Lead Items Identified Equipment in a Relevant Env.	Mfg. Processes in Development Producibility Improvement Underway Trade Studies Supply Chain Mgmt in place	Process Maturity Demonstrated All Materials Ready for LRIP Mfg. Processes Proven Supply Chain stable for LRIP	Mfg. Processes Operating at Target Quality, Cost and Performance Supply Chain Established and Meeting Lead Times	Lean/Six Sigma Production in Place Meeting or Exceeding Cost, Schedule and Performance Goals
MRL Exit Criteria	✓ Assess at TRL 1 – 3 ✓ Identify IB Sources ✓ Characterize Basic Materials for Mfg. ✓ Identify Material Concerns ✓ Identify Funding ✓ Identify Advanced ManTech Initiatives ✓ Coordinate with Technology Plan	✓ Assess at TRL 4 ✓ Identify IB Gaps ✓ Assess DFX ✓ Baseline Materials and Issues ✓ Funding/Budgeting for Trade Studies ✓ Identify ManTech or Other Initiatives ✓ Technology Development Strategy should include elements of Mfg/QA	✓ Assess at TRL 5 ✓ IB Analysis Finished ✓ KPPs Allocated ✓ Key Characteristics Identified ✓ SEP includes MFG/QA approach ✓ Funding to Meet Next Level ✓ ManTech Initiatives Initiated ✓ Early Supply Chain assessment	✓ Assess at TRL 6 ✓ IB Capability Assessment ✓ Initial Trade Studies ✓ Materials Matured Similar Lines ✓ Funding to Meet Next Level ✓ ManTech Solutions Developed in Relevant Env ✓ Acquisition Strategy includes Mfg/QA ✓ Quality Thresholds Established	✓ Assess at TRL 7 ✓ IB Monitored ✓ PEP Completed ✓ Materials Being Proven ✓ Funding to Meet Next Level ✓ ManTech Solutions Demonstrated ✓ Supply Chain being assessed ✓ BOM Identified ✓ QA data collected	✓ Assess at TRL 8 ✓ Est. Multi-Sources ✓ Pilot Line Builds Validated ✓ Materials Proven ✓ Funding to Meet Next Level ✓ ManTech Solutions Validated ✓ Quality Characteristics Validated ✓ BOM Supports LRIP	✓ Assess at TRL 9 ✓ IB Supports Sched. ✓ Continuous Process Improvement is Ongoing ✓ Materials in Control ✓ Funding to Meet Next Level ✓ Quality Validated with LRIP Articles ✓ Make/Buy Supports FRP ✓ IB Capabilities Assessment	✓ Monitor and Manage all Key Characteristics at a Six Sigma Level ✓ Funding to Meet 6σ goals ✓ No Make/Buy Changes ✓ Key/Critical Suppliers all meet Six Sigma Goals

Technology Readiness Levels:

- Technology Readiness Levels were originally developed by NASA in the 1980s
- TRL are based on a scale from 1 to 9 with 9 being the most mature technology. A TRL of 6 is aligned with PDR.
- Technology Readiness Levels (TRL) are a method of estimating the technology maturity of program during the development process, and the readiness of the program to proceed to subsequent stages. (Assessment is limited to Critical Technology Elements (CTE) of Program)
- TRLs represent a logical procession of "DEMONSTRATED" capabilities, ranging from lab experiments to component prototypes to subsystems and systems. Demonstration also progress in terms of environment, from artificial to relevant to operational.
- TRLs are a measure of technology maturity through performance.

Technology Readiness Level Definitions

Technology Readiness Level	Description
1. Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3. Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard **validation** in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5. Component and/or breadboard **validation** in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components.
6. System/subsystem model or prototype **demonstration** in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment.
7. System prototype **demonstration** in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space).
8. Actual system completed and qualified through **test and demonstration.**	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system **proven** through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions.

Technology Readiness Assessments

- Well defined and rigorous process for assessing the technology maturity of a product or system using TRLs.
- DoD, NASA, and other organizations have processes.
- DoD TRA Deskbook (2011) is most widely used.
  - Establish a TRA Plan and Schedule
  - Form a SME Team
  - Identify Technologies To Be Assessed
  - Collect Evidence of Maturity
  - Assess Technology Maturity
    - SME team Assessment
    - Prepare, Coordinate, and Submit a TRA Report
    - Review and Evaluation
- In most cases, only Critical Technology Elements (CTEs) are assessed.
  - CTEs are those that directly related to system performance requirements or design critical.
  - CTEs should be identified in the context of the program's systems engineering process, based on a comprehensive review of the most current system performance and technical requirements and design

Why Aren't Technology Readiness Levels Enough?

- TRL Definitions deal primarily with demonstration of performance.
  - Within increasingly realistic environments.
- Initially, during a 2000 manufacturing study of the FCS critical technologies, TRLs were rejected as a sole method of assessing readiness.
- TRLs do not encompass any production or sustainment attributes, and <u>cannot answer questions</u> such as:
  - **Is the prototype level of performance reproducible in items 2- 1000?**
  - **What will these cost in production?**
  - **Can these be made in a production environment by someone without a PhD?**
  - **Is the acquisition schedule realistic**
  - **Are the key materials and components available?**
- So Manufacturing Readiness Levels were proposed, along with an initial scale and entrance criteria.
- MRLs measure the maturity (or readiness) of a technology for scale up and commercialization.

Manufacturing Readiness Levels:

- Manufacturing Readiness Levels were originally developed by DoD ManTech starting in 2001
- MRLs are based on a scale from 1 to 10 with 10 being the most mature manufacturing capability. An MRL of 6 is aligned with PDR, and an MRL of 8 is aligned with a Production Decision.
- The MRL scale generally correlates with TRLs, with an additional level consisting of continuous improvement and lean practices.
- MRLs indicate the level of program risk – compared to an ideal progression of demonstrated knowledge- for meeting production goals (including cost, schedule, performance) based upon successful completion of manufacturing-related activities during development.
- Program maturity and readiness are compared to the “target” MRL based upon the product development phase.
- Assessment of “Level” is not based upon ‘Quick look,’ but instead based upon **substantiation**, usually in the form of supporting documents, tasks, or benchmarks. MRLs have a great deal more depth than TRLs in descriptions and criteria.

Manufacturing Readiness Level Definitions

MRL	Definition
1	Manufacturing Feasibility Assessed
2	Manufacturing Concepts Defined
3	Manufacturing Concepts Developed
4	Capability to produce the technology in a laboratory environment.
5	Capability to produce prototype components in a production relevant environment.
6	Capability to produce a prototype system or subsystem in a production relevant environment.
7	Capability to produce systems, subsystems or components in a production representative environment.
8	Pilot line capability demonstrated. Ready to begin low rate production.
9	Low Rate Production demonstrated. Capability in place to begin Full Rate Production.
10	Full Rate Production demonstrated and lean production practices in place.

MRL- Further Definition of Terms

- **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

MRL Descriptions- DETAIL

MRL	Definition	Description	Phase
1	Manufacturing Feasibility Assessed	This is the lowest level of manufacturing readiness. The focus is on a top level assessment of feasibility and manufacturing shortfalls. Basic manufacturing principles are defined and observed. Begin basic re-search in the form of studies (i.e. 6.1 funds) to identify producibility and material solutions.	Pre Concept Refinement
2	Manufacturing Concepts Defined	This level is characterized by developing new manufacturing approaches or capabilities. Applied Research translates basic research into solutions for broadly defined military needs. Begin demonstrating the feasibility of producing a prototype product/component with very little data available. Typically this is applied research (i.e. 6.2) in the S&T environment and includes identification and study of material and process approaches, including modeling and simulation.	Pre Concept Refinement
3	Manufacturing Concepts Developed	This begins the first real demonstrations of the manufacturing concepts. This level of readiness is typical of technologies in the S&T funding categories of 6.2 and 6.3. Within these levels, identification of current manufacturing concepts or producibility has occurred and is based on laboratory studies. Materials have been characterized for manufacturability and avail-ability but further evaluation and demonstration is required. Models have been developed in a lab environment that may possess limited functionality.	Pre Concept Refinement
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 Performance Parameters (KPP) identified. Special needs identified for tooling, facilities, material handling and skills.	Concept Refinement (CR) leading to a Milestone A decision.
5	Capability to produce prototype components in a production relevant environment.		Technology Development (TD) Phase.
6	Capability to produce a prototype system or subsystem in a ...	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, ... tems ... cated. ... ents	Technology Development (TD) phase leading to a Milestone B decision.
		... ned ... Cost ... st ... n	System Development & Demo (SDD) leading to Design Readiness Review (DRR).
		... ost	System Development & Demo leading to a Milestone C decision.
		... o ... and ... als	Production & Deployment leading to a Full Rate Production (FRP) decision
10	... lean production practices in place.	... 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

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.

MRL in Depth: Nine "Threads"

- **Technology and the Industrial Base**: Requires an analysis of the capability of the national technology and industrial base to support the design, development, production, operation, and maintenance support of the system.
- **Design**: Requires an understanding of the maturity and stability of the evolving system design and any related impact on manufacturing readiness.
- **Cost and Funding**: Requires an analysis of the adequacy of funding to achieve target manufacturing maturity levels. Examines the risk associated with reaching manufacturing cost targets.
- **Materials:** Requires an analysis of the risks associated with materials (including basic/raw materials, components, semi-finished parts, and subassemblies).
- **Process Capability and Control:** Requires an analysis of the risks that the manufacturing processes are able to reflect the design intent (repeatability and affordability) of key characteristics.
- **Quality Management:** Requires an analysis of the risks and management efforts to control quality, and foster continuous improvement.
- **Manufacturing Workforce** (Engineering and Production): Requires an assessment of the required skills, availability, and required number of personnel to support the manufacturing effort.
- **Facilities:** Requires an analysis of the capabilities and capacity of key manufacturing facilities (prime, subcontractor, supplier, vendor, and maintenance/repair).
- **Manufacturing Management**: Requires an analysis of the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting Program goals for affordability and availability).

MRL in Detail- Criteria Matrix

DoD Manufacturing Readiness Levels (MRLs)									
S&T Phase		6.1 - 6.2 SBIR	6.3 SBIR	6.3 / 6.4 / 7…	…	…	7.8	7.8	7.8 Title III
Acq Phase		Pre CR	CR - MS A	…	…	…	MS C	LRIP - FRP	FRP
Thread	Sub-Thread	MRL 1-3	MRL 4	…	…	…	MRL 8	MRL 9	MRL 10
Technology & Industrial Base	Technology Maturity	TRLs 1-3	Should be assessed at TRL …	…	…	…	…ld be assessed at TRL 8.	Should be assessed at TRL 9.	
	Technology Transition to Production	Potential manufacturing sources identified for technology needs. (Commercial/Government, Domestic/Foreign)	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Indus… identify potential manu… sources.	… completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	… been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.	Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk.	Industrial capability is in place to support start of FRP.	Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements.
	Manufacturing Technology Development	Mfg Science considered	Mfg Science & Advanced Mfg Technology requirements identified	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology efforts continuing. Manufacturing technology process improvements efforts initiated for FRP.	Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing.
	…ducibility …m	Evaluate relevant materials/processes for manufacturability & producibility	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Manufacturing Processes assessed for capability to test and verify in production, and influence on O&S.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints.	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. DFMA) initiated.	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.	On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, DMSMS and other changes assessed for producibility.
	…ty	Evaluate product lifecycle requirements and product performance requirements.	Systems Engineering Plans and the Test and Evaluation Strategy recognize the need for the establishment/validation of manufacturing capability and management of manufacturing risk for the product lifecycle. Initial Key Performance Parameters (KPPs) identified.	Identification of enabling/critical technologies and components is complete and includes the product lifecycle. Evaluation of design Key Characteristics (KC) initiated.	Basic system design requirements defined. All enabling/critical technologies/components have been tested and validated. Product data required for prototype manufacturing released. A preliminary performance as well as focused logistics specification is in place. Key Characteristics and tolerances have been established.	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.	Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program.	Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KC's are controlled in production to three sigma or other appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled to six sigma or other appropriate quality levels.
Cost & F…	…t …st	Technology cost models developed for new process steps and materials based on engineering details at MRL 1-2. High-level process chart cost models with major production steps identified at MRL 3.	Detailed process chart cost models driven by key characteristics and process variables. Manufacturing, material and specialized reqt. cost drivers identified.	Detailed end-to-end value stream map cost model for major system components includes Materials, Labor, Equipment, Tooling/STE, setup, yield/scrap/rework, WIP, and capability/capacity constraints. Component simulations drive cost models.	Cost model inputs include design requirements, material specifications, tolerances, integrated master schedule, results of system/subsystem simulations and production relevant demonstrations.	Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, obsolescence solutions.	Engineering cost model driven by detailed design and validated with data from relevant environment.	Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact, potential for continuous improvement.	Cost model validated against actual FRP cost.
		Sensitivity, Pareto analysis to find cost drivers and production representative scenario analysis to focus S&T initiatives and address scale-up issues.	Material, manufacturing, and specialized reqt. costs identified for design concepts. Producibility cost risks assessed and manufacturing technology initiatives identified to reduce costs.	Current state analysis of cost of design choices, make/buy, capacity, process capability, sources, quality, key characteristics, yield/rate, and variability.	Cost analysis of mfg future states, design trades, supply chain/yield/rate/SDD/technology insertion plans. Allocate cost targets. Cost reduction and avoidance contract incentives identified.	Costs rolled up to system level and tracked against targets. Detailed trade studies and engineering change requests supported by cost estimates. Cost reduction efforts underway, incentives in place.	Cost analysis of proposed changes to requirements or configuration.	LRIP cost goals met, learning curve validated.	FRP cost goals met. Cost reduction initiatives ongoing.
	…ring …t Budget	Program/ projects have budget estimates for reaching MRL of 4.	Program has budget estimate for reaching MRL 5. All Risk Mitigation Plans required to raise deficient elements to MRL of 4 are fully funded.	Program has budget estimate for reaching MRL 6 by MS B. Estimate includes capital investment for Production-representative equipment. All Risk Mitigation Plans required to raise deficient elements to MRL of 5 are fully funded.	Program has budget estimate for reaching MRL 7 by CDR. All Risk Mitigation Plans required to raise deficient elements to MRL of 6 are fully funded.	Program has budget estimate for reaching MRL 8 by MS C. Estimate includes investment for Low Rate Initial Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 7 are fully funded.	Program has budget estimate for reaching MRL 9 by the FRP decision point. Estimate includes investment for Full Rate Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 8 are fully funded.	Program has budget estimate for lean implementation during FRP. All Risk Mitigation Plans required to improve deficient subsystems to MRL of 9 during FRP are fully funded.	Production budgets sufficient for production at required rates and schedule.

MRL in Detail- Criteria Matrix

DoD Manufacturing Readiness Levels (MRLs)

S&T Phase		6.1 - 6.2 SBIR	6.3 SBIR	6.3 / 6 4 / 7			7.8	7.8	7.8 Title III
Acq Phase		Pre CR	CR - MS A				MS C	LRIP - FRP	FRP
Thread	Sub-Thread	MRL 1-3	MRL 4				MRL 8	MRL 9	MRL 10
Technology & Industrial Base	Technology Maturity	TRLs 1-3	Should be assessed at TRL				...ld be assessed at TRL 8.	Should be assessed at TRL 9.	
	Technology Transition to Production	Potential manufacturing sources identified for technology needs. (Commercial/Government, Domestic/Foreign)	Industrial Base capabilities and gaps/risks identified for key technologies, components, and/or key processes.	Indus... identify potential ma... sources.	...completed. Industrial capability in place to support mfg of development articles. Plans to minimize sole/foreign sources complete. Need for sole/foreign sources justified. Potential alternative sources identified.	...been analyzed. Sole/foreign sources stability is assessed/monitored. Developing potential alternate sources as necessary.	Industrial Capability Assessment (ICA) for MS C has been completed. Industrial capability is in place to support LRIP. Sources are available, multi-sourcing where cost-effective or necessary to mitigate risk.	Industrial capability is in place to support start of FRP.	Industrial capability supports FRP. Industrial capability assessed to support mods, upgrades, surge and other potential manufacturing requirements.
	Manufacturing Technology Development	Mfg Science considered	Mfg Science & Advanced Mfg Technology requirements identified	Required manufacturing technology development efforts initiated.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production relevant environment.	Manufacturing technology efforts continuing. Required manufacturing technology development solutions demonstrated in a production representative environment.	Manufacturing technology efforts continuing. Required manufacturing technology solutions validated on a pilot line.	Manufacturing technology efforts continuing. Manufacturing technology process improvements efforts initiated for FRP.	Manufacturing technology efforts continuing. Manufacturing technology continuous process improvements ongoing.
	...ducibility ...m	Evaluate relevant materials/processes for manufacturability & producibility	Producibility & Manufacturability assessment of design concepts completed. Results guide selection of design concepts and key components/technologies for Technology Development Strategy. Manufacturing Processes assessed for capability to test and verify in production, and influence on O&S.	Producibility & Manufacturability assessments of key technologies and components initiated. Systems Engineering Plan (SEP) requires validation of design choices against manufacturing process and industrial base capability constraints.	Producibility assessments of key technologies/components and producibility trade studies (performance vs. producibility) completed. Results used to shape System Development Strategy and plans for SDD or technology insertion programs phase.	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g. DFMA) initiated.	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.	On-going producibility improvements analyzed for effectiveness. Producibility refinements continue. All mods, upgrades, DMSMS and other changes assessed for producibility.
					...gn ...ned. All ...ponents hav ...alidated. ...ired for ...cturing ...inary ...ell as focused ...ion is in place. ...s and ...een	Product requirements and features are well enough defined to support detailed systems design. All product data essential for manufacturing of component design demonstration released. Potential KC risk issues have been identified and mitigation plan is in place. Design change traffic may be significant.	Detailed design of product features and interfaces is complete. All product data essential for system manufacturing released. Major product design features are sufficiently stable such that key LRIP manufacturing processes will be representative of those used in FRP. Design change traffic does not significantly impact LRIP. Key characteristics are stable and have been demonstrated in SDD or technology insertion program.	Major product design features are stable and LRIP produced items are proven in product testing. Design change traffic is limited to minor configuration changes. All KC's are controlled in production to three sigma or other appropriate quality levels.	Product design is stable. Design changes are few and generally limited to those required for continuous improvement or in reaction to obsolescence. All KCs are controlled to six sigma or other appropriate quality levels.
Cost & F...					...includ design ...terial ...rance, ...schedule, ...subsystem ...roduction ...ations.	Cost models updated with detailed designs and features, collected quality data, plant layouts and designs, obsolescence solutions.	Engineering cost model driven by detailed design and validated with data from relevant environment.	Actual cost model developed for FRP environment. Variability experiments conducted to show FRP impact, potential for continuous improvement.	Cost model validated against actual FRP cost.
					...fg ...uture ...des supply ...D technology ...All ...cate cost ...ction and ...ncentives	Costs rolled up to system level and tracked against targets. Detailed trade studies and engineering change requests supported by cost estimates. Cost reduction efforts underway, incentives in place.	Cost analysis of proposed changes to requirements or configuration.	LRIP cost goals met, learning curve validated.	FRP cost goals met. Cost reduction initiatives ongoing.
			Mitigation Plans required to raise deficient elements to MRL of 4 are fully funded.	Estimate includes capital investment for Production-representative equipment. All Risk Mitigation Plans required to raise deficient elements to MRL of 5 are fully funded.	...t estimate for ... CDR. All Risk Mitigation Plans required to raise deficient elements to MRL of 6 are fully funded.	Program has budget estimate for reaching MRL 8 by MS C. Estimate includes investment for Low Rate Initial Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 7 are fully funded.	Program has budget estimate for reaching MRL 9 by the FRP decision point. Estimate includes investment for Full Rate Production. All Risk Mitigation Plans required to raise deficient sub systems to MRL of 8 are fully funded.	Program has budget estimate for lean implementation during FRP. All Risk Mitigation Plans required to improve deficient subsystems to MRL of 9 during FRP are fully funded.	Production budgets sufficient for production at required rates and schedule.

MRL 1 to 10 →

Producibility assessments of key technologies /components and producibility trade studies completed. Results used to shape System Development Strategy and plans for EMD technology insertion.

Manufacturing Readiness Assessments

- Well defined and rigorous process for assessing the status of a product or system against standard benchmarks using MRLs.
- Tailoring of the main matrix criteria is permitted based upon specific situations. MRLs are NOT limited to critical technology items.
- DoD has published an MRL Deskbook describing the MRA Process.
  - Determine Scope
  - Determine Assessment Taxonomy and Schedule
  - Form and Orient Assessment Team
  - Request Contractors Perform Self-Assessment
  - Set Agenda for Site Visits
  - Conduct the Assessment of Manufacturing Readiness
    - Start with MRL Benchmark, work backwards along Threads
    - Consider self assessment, use VSM, WBS, mfg flow and other techniques to understand and document process.
    - Discuss tooling and supply chain management, ask for evidence & Documentation
  - Prepare the Assessment Report and MMP

Lessons Learned- Best Practices 1/ 2

- MRL is **limited** by TRL- If Technology or design is not sufficiently defined and demonstrated, how can manufacturing capability be proven. MRL may exceed TRL by one level in most cases.
- MRL is **NOT** about the number- focus on the meaning of each level, the number indicates progression and is used for communication
- MRL **cannot** be a 4.5 or 5.725- Levels represent stages, consider activities or milestones that will demonstrate maturity.
- MRLs are **not** an auditing mechanism- the descriptions, threads and criteria are mean to be adapted to the specific nature of a product under development. Provide reasoning for tailoring.
- The time, effort, and investment to progress from MRL 4 to 5 is **not** similar to MRL 6 to 7.

Lessons Learned- Best Practices 2/2

- TRL or MRL is a contact sport- claims must be made based upon actual experience by team members, at team facilities, with known technology scope. One cannot claim a TRL or MRL of a 787 aircraft due to Boeing's experiences if one is not Boeing.
- In proposal planning, consider what steps would be necessary to progress through each MRL, and schedule milestones.
- Do NOT start with an MRL 4 and then magically have the project end at an MRL of 7. Describe progression of MRL 4 to 5, then 6, then 7. (if MRL 7 is indicated). Integrate with increasing TRL in program plan.
- Institute Project may involve limited demonstrations of Manufacturing Areas, or Technology Platform Demonstrations. If so, tailor the MRL matrix to focus on limited demonstration, but indicate what would be necessary to pursue commercialization.
- A formal MRA is not require for a pre-proposal or proposal.

TRL / MRL Resources

- TRL and TRA- Several references, an example is:

http://www.acq.osd.mil/chieftechnologist/publications/docs/TRA2011.pdf

- MRL and MRA- one key location

http://dodmrl.com

Deskbook / Definitions / Matrix / Interactive User Guide / POCs

Questions