Agenda

• Definitions
• DoD Acquisition Framework and Funding
• MRL Implementation
• MRL’s and TRL’s
• Threads and Sub-Threads
• Outline of the ARDEC MANTECH MRA Process
• Example
• Summary
What is a Manufacturing Process?

• The total set of activities and interfaces necessary to convert the product definition into an affordable product.

-MIL-HDBK-500
• Manufacturing Readiness is the ability to harness the manufacturing, production, quality assurance, and industrial functions to achieve an operational capability that satisfies mission needs - in the quantity and quality needed by the warfighter.
Relevant “-ilities”

- **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.

- **Producibility** - The relative ease of producing an item that meets engineering, quality and affordability requirements.

-DoD MRL Deskbook 2-7
• Formal Risk Assessment with defined Focus Areas and DoD standard Criteria applicable throughout the DoD Acquisition Life Cycle.

• Begins before and during the Development Phase of Systems, continues through the Production Phase and continues after a System has been fielded into the Sustainment Phase.

• Assesses the ability to transition manufacturing technology smoothly and efficiently from the Materiel Developers (RDEC’s) onto the factory floor and into the field.
Overview of Requirements for MRAs & MRLs

• **Public Law 111–383; 124 Stat. 4264; 10 U.S.C. 2430:**
  – “Require the use of manufacturing readiness levels or other manufacturing readiness standards as a basis for measuring, assessing, reporting, and communicating manufacturing readiness and risk on major defense acquisition programs throughout the DoD”

• **DoD Instruction 5000.02 (7 Jan 2015):**
  – “Program Manager will ensure manufacturing and producibility risks are identified and managed throughout the program’s life cycle”

• **DAG**
  – States that the MRL Assessment process described in the DoD MRL Deskbook is the “Best Practice” that should be used to accomplish identification and management of manufacturing risks

• **MRLs are used for all Army MANTECH projects**
• Supports reduction in production risks and manufacturing costs throughout the weapons system life cycle.

• The Program process is structured to fund projects that are deemed high priority for the Army.

• The Program supports process prototyping and pilot demonstration to develop or modify manufacturing technologies for the Army’s use. It does not acquire off-the-shelf capital equipment unless it is a minor portion of the investment and is required to establish the first-case application integral to the ManTech project.

• Program Manager (PM) or organization responsible for transition and implementation must demonstrate a robust Acquisition Strategy that includes a realistic plan to transition and implement the technology in the industrial base.
• **6.1 (Basic Research)** Basic research is systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind (e.g., SBIR, ILIR).

• **6.2 (Applied Research)** Applied research is systematic study to understand the means to meet a recognized and specific need. It is a systematic expansion and application of knowledge to develop useful materials, devices, and systems or methods.

• **6.3 (Advanced Technology Development)** Development of subsystems and components and efforts to integrate subsystems and components into system prototypes for field experiments and/or tests in a simulated environment. ATD includes concept and technology demonstrations of components and subsystems or system models. The results of this type of effort are proof of technological feasibility and assessment of subsystem and component operability and producibility rather than the development of hardware for service use.

• **6.7 (Operational System Development)** Development efforts to upgrade systems that have been fielded or have received approval for full rate production and anticipate production funding in the current or subsequent fiscal year (e.g., MANTECH).
DoD Acquisition Life Cycle Model

Source: DoD Instruction 5000.02 – Operation of the Defense Acquisition System (7 Jan 2015)
“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.”

-Draft DoD MRL Implementation Guide
• Use MRLs (1-4) to assess the manufacturing feasibility of the Basic Research results and provide leadership with knowledge of potential manufacturing shortfalls that should be addressed in the future development.

• Assess the application of the manufacturing capabilities, capacities, or materials needed to meet specific needs.
• Begin addressing manufacturing maturity of Prototypes being transitioned to acquisition.

• Determine the manufacturing risks before transitioning from ATD into EMD.

• Ensure that cost goals reflect manufacturing cost considerations and capabilities.

• Provide the PM with an understanding of the manufacturing maturity so they have a full understanding of the risk they assume by proceeding to the next phase.
MRLs vs. TRLs

• What is the difference between MRLs and TRLs?
  – **TRLs** are a metric used to assess the maturity of, and the risk associated with, evolving technologies.
  – **MRLs** are a metric used to assess manufacturing readiness and producibility. MRLs provide decision makers (at all levels) with a common understanding of the relative maturity, identification and mitigation of manufacturing risks associated with manufacturing technologies, products, and processes.

• **TRLs & MRLs are complementary, but their “scores” may not be directly linked**
  – A Critical Technology Element (CTE) might be very mature yet the manufacturing processes required to produce it may be immature. (or vice versa)

• **TRLs by themselves leave major transition questions unanswered:**
  – Is the technology producible? What will these cost in production?
  – Can these be made in a production environment?
  – Are key materials and components available?
Section 2366b of Title 10, United States Code, requires certification that: the **technology** in a MDAP has been demonstrated in a **relevant** environment to enter Milestone B. (TRL 6)
MRL Definitions

- **MRL 1**: Basic Manufacturing Implications Identified
- **MRL 2**: Manufacturing Concepts Identified
- **MRL 3**: Manufacturing Proof of Concept Developed
- **MRL 4**: Capability to produce the technology in a laboratory environment
- **MRL 5**: Capability to produce prototype components in a production relevant environment
- **MRL 6**: Capability to produce a prototype system or subsystem in a production relevant environment
- **MRL 7**: Capability to produce systems, subsystems, or components in a production representative environment
- **MRL 8**: Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
- **MRL 9**: Low rate production demonstrated; Capability in place to begin Full Rate Production
- **MRL 10**: Full Rate Production demonstrated and lean production practices in place

*DoD MRL Deskbook 2-2*
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 manufacturer(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. Furthermore, there must be an **indication of how the manufacturer(s) intend to achieve the requirements in a production representative and pilot environments.**

-DoD MRL Deskbook 2-6
An environment that has **as much production realism as possible**, considering the maturity of the design. **Production personnel, equipment, processes, and materials** that will be present on the pilot line should be used whenever possible. The work instructions and tooling should be of high quality, and the only changes anticipated on these items are associated with design changes downstream that address performance or production rate issues. **There should be no reliance on a laboratory environment or personnel.**

-DoD MRL Deskbook 2-6
An environment that incorporates all of the key production realism elements (equipment, personnel skill levels, facilities, materials, components, work instructions, processes, tooling, 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 normally represents the production line on which LRIP quantities will be manufactured.

-DoD MRL Deskbook 2-6
MRA’s and MRLs

• **Manufacturing Readiness Assessment (MRA):**
  – The generic name for an event or process to identify and manage manufacturing risk.

• **Manufacturing Readiness Level:**
  – A MRA tool used to identify, quantify, and manage the manufacturing maturity and risk of a product or process.
  – Has objective **criteria** for all 10 levels across 9 major categories (Threads) and 22 minor categories (Sub-threads)
    • 418 Total Questions across 22 Sub-Threads
  – **MRL criteria adds "objectivity" to an otherwise subjective MRA**
    • Provides a universal basis of understanding for what each score means
Nine MRL Evaluation Criteria (“9 Threads”)

A. Technology and Industrial Base
B. Design
C. Cost and Funding
D. Materials
E. Process Capability and Control
F. Quality Management
G. Manufacturing Personnel
H. Facilities
I. Manufacturing Management

-DoD MRL Deskbook 2-8
A. Technology and Industrial Base

– Analyzes the capability of the National Technology and Industrial Base to support the design, development, production, operation, uninterrupted maintenance support of the system and eventual disposal (environmental impacts)

– A.1: Industrial Base (19 Questions through MRL10)

– A.2: Manufacturing Technology Development (12 Questions)
B. Design

– Analyzes the maturity and stability of the evolving system design and any related impact on manufacturing readiness

– B.1: Producibility (21 Questions)

– B.2: Design Maturity (35 Questions)
C. Cost and Funding

- Analyzes the adequacy of funding to achieve target manufacturing maturity levels. Examines the risk associated with reaching manufacturing cost targets

- **C.1: Production Cost Knowledge/Cost Modeling** (14 Questions)

- **C.2: Cost Analysis** (25 Questions)

- **C.3: Manufacturing Investment Budget** (20 Questions)
D. Materials

- Analyzes the risks associated with materials (including basic/raw materials, components, semi-finished parts, and subassemblies)

- D.1: Maturity (16 Questions)
- D.2: Availability (21 Questions)
- D.3: Supply Chain Management (18 Questions)
- D.4: Special Handling (22 Questions)
E. Process Capability and Control

– Analyzes the risks that the manufacturing processes are able to reflect the design intent (repeatability and affordability) of key characteristics

– E.1: Modeling & Simulation (16 Questions)

– E.2: Manufacturing Process Maturity (17 Questions)

– E.3: Process Yields & Rates (18 Questions)
F. Quality Management

- Analyzes the risks and management efforts to control quality and foster continuous improvement at prime and suppliers

- F.1: Quality Management including Supplier Quality (16 Questions)

- F.2: Product Quality (17 Questions)

- F.3: Supplier Quality Management (17 Questions)
G. Manufacturing Personnel

–Assesses the required skills, availability, and required number of personnel to support the manufacturing effort

–G.1: Manufacturing Personnel (22 Questions)
H. Facilities

– Analyzes the capabilities and capacity of key manufacturing facilities (prime, subcontractor, supplier, vendor, and maintenance/repair)

– H.1: Tooling/Special Test and Inspection Equipment (STE/SIE) (15 Questions)

– H.2: Facilities (16 Questions)
I. Manufacturing Management

– Analyzes the orchestration of all elements needed to translate the design into an integrated and fielded system (meeting program goals for affordability and availability)

– I.1: Manufacturing Planning & Scheduling (20 Questions)

– I.2: Materials Planning (15 Questions)
• Apply DoD MRL Deskbook and provide a common language to assess:

  – *the performance maturity of a MANTECH project and plans for its future maturation*
  
  – the level of performance risk in trying to transition the ManTech project into an armament system application

• Identify Contract Data Requirements for future ARDEC ManTech projects (e.g., SAE AS 6500 - Manufacturing Management Program)
• The MRL criteria is the foundation for ARDEC MANTECH MRA’s
  – MDAP “requirements” can be scaled to fit Technology Development projects.

• Some of the 9 Threads may not apply to ARDEC MANTECH projects, but all 9 Threads should be reviewed to ensure no manufacturing risks are missed
  – If a thread does not apply to a project, then it is excluded from the assessment
  – If a thread is excluded from an assessment, “objective evidence” should be provided to justify the lack of a manufacturing risk

• Aggregate/average/composite scores are not recommended
1. Identify IPT Members to Perform MRA

2. Determine Products/Processes to be Assessed

3. Determine Target MRL & MRA Schedule

4. Determine Applicable MRL Criteria

5. Perform MRL Self-Assessment

6. IRT Conduct Initial MRA

7. Prepare & Execute Manufacturing Maturation Plan (MMP)

8. IRT Conduct Final MRA
Step 1: Identify IPT Members to Perform MRA

• Search Lessons Learned repository to review and learn from previous MRA experiences
• Identify IPT members responsible for conducting the MRA (can be adjusted throughout the MRA process)
• Notify IPT members of roles and responsibilities for conducting the MRA
Step 2: Determine Products & Processes to be Assessed

- Identify Products or Processes to be evaluated for manufacturing readiness considering:
  - Critical Technology Elements (CTEs)
  - Work Breakdown Structure/Bill of Materials
  - Uniqueness of the application

- Identify site visits, if required

- Adjust IPT membership to reflect MRA Scope
Step 3: Determine Target MRL and MRA Schedule

• Based on Stakeholder Input, identify or infer the Target MRL for each product or process to be assessed
  – Determine the “Should Be” state
  – Document in Technology Transition Agreement (TTA) with Customer

• Update project schedule identifying major tasks and milestones leading to Final MRA
Step 4: Determine Applicable MRL Criteria

- Use the 9 Filtering Questions for each product and process to focus down from the 22 MRL Criteria Sub-Threads to a specific sub-set which address the unique challenges/risks of each product or process.

- Create a MRL Questionnaire in the MRL Users Guide by filtering for the applicable MRL criteria for each identified product or process to be examined as a part the MRA.

Filtering Questions (1-3)

• **Materials**: Are there materials which have not been demonstrated in similar products or manufacturing processes?

• **Cost**: Is this item a driver that significantly impacts life-cycle cost (development, unit, or operations and support costs)? Is the technology new with high cost uncertainty?

• **Design**: Is the item design novel or does it contain nonstandard dimensions or tolerances or arrangements?

-DoD MRL Deskbook 4-4
Filtering Questions (4-6)

• **Manufacturing Process:** Will the item require the use of manufacturing technology, processes, inspection, or capabilities that are unproven in the current environment?

• **Quality:** Does the item have historical/anticipated yield or quality issues?

• **Schedule:** Does this item have lead time issues or does it significantly impact schedule?

-DoD MRL Deskbook 4-4
Filtering Questions (7-9)

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

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

- **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?

-DoD MRL Deskbook 4-4
Step 5: Perform MRL Self-Assessment

- Complete the MRL Questionnaire for each identified product or process in the MRA
- Determine(collect the documentation/objective evidence/tangible evidence required to conduct and support the Self-Assessment
  - Determine the “As Is” state
- Prepare the MRA Self-Assessment using the identified documentation/test data and correlating this information with the applicable MRL requirements and scores
- Develop the Manufacturing Maturation Plan (MMP), budget, & schedule to achieve the next higher MRL
MMP Contents

- Problem Statement
- Solution Options
- Maturation Plan identifying Budget and Schedule
- Key activities for the preferred approach
- Preparations for using an alternative approach
- Latest time that an alternative approach can be chosen
- Status of funding to execute the manufacturing plan
- Specific actions to be taken and by whom
- Prototypes or test articles to be built
- Tests to be conducted
- Threshold performance to be met
- MRL to be achieved and when it will be achieved
Step 6: Conduct Initial MRA Review

• Form Independent Review Team (IRT) of Management-level SME’s

• Each IRT member reviews MRA Self-Assessment, objective evidence and MMP and provides independent assessments to IRT Chairperson

• Chairperson integrates individual IRT assessments

• Conduct the Review and publish IRT independent assessment
  – The IRT must reach consensus on all issues

• Assign and close-out any Action Items

• Update MMP
Step 7: Execute MMP

• Execute maturation activities IAW the Manufacturing Maturation Plan
  – Conduct site visits
  – Collect objective evidence
  – Update/create MMPs as necessary
  – Adjust Scope as necessary

• Update MRL Self-Assessment

• Prepare for and conduct Interim MRA Reviews (if required)

• Prepare for Final MRA Review
Step 8: Conduct Final Independent MRA Review

• Convene IRT members for Review

• Assemble, organize, and distribute supporting artifacts and information to the IRT to review in advance of the Independent MRA Review
  – IRT reviews team assessment, recommendation and objective evidence

• Conduct the review and determine actual MRLs

• Prepare for transition to Customer or continue executing the MMP
MRA Review Approach

• Concentrate on the targeted MRL
  – If target MRL criteria is unsatisfied, review lower level questions to determine actual MRL and effort required to meet target MRL

• Confirm that all pertinent MRL criteria was addressed

• Verify (hands-on/eyes-on) that all objective evidence meets the MRL criteria
  – Seek tangible proof that the agreed upon interpretation of a particular MRL sub-thread definition has been satisfied; proof that manufacturing risk has been mitigated and/or maturity has increased

• Update Manufacturing Maturation Plans (MMPs) if target MRL has not been achieved
It’s Not About The Score

• Do not focus on the MRL number like a Report Card.

• Use MRL’s and the MRA process to identify and mitigate manufacturing RISK.

• Use the MMP to address residual manufacturing RISK.
## Example: F2. Product Quality

<table>
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<tr>
<th>Sub-Thread</th>
<th>MRL</th>
<th>Question</th>
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<td>Has a product inspection and acceptance testing strategy been identified as part of the Acquisition Strategy?</td>
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<td>Has a product inspection and acceptance testing strategy been included in the Systems Engineering Plan (SEP)?</td>
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<td>Have roles and responsibilities been identified for acceptance test procedures, in-process and final inspections?</td>
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<td>Have statistical process controls been identified for prototype units?</td>
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<td>Has a Key Characteristic management approach been defined?</td>
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<td>Have initial requirements been identified for acceptance test procedures and in-process and final inspection requirements for EMD units?</td>
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<td>Have appropriate inspection and acceptance test procedures been identified for prototype units?</td>
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<td>Has a product inspection and acceptance testing strategy been identified as part of the Technology Development Strategy?</td>
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<td>Has a product inspection and acceptance testing strategy been included in the Systems Engineering Plan (SEP)?</td>
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## Sample Graphic of MRA Scores

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### MRL 1 - Basic Manufacturing Implications Identified

- Manufacturing Concepts Identified
- Manufacturing Proof of Concept Developed

### MRL 2 - Manufacturing Processes In Lab Environment

- System or Subsystem In Production Relevant Environment
- Pilot Line Demonstrated Ready for LRIP

### MRL 3 - Components In Production Relevant Environment

- System or Subsystem Demonstrated Lean Production Practices in Place

### MRL 4 - Manufacturing Processes In Production Relevant Environment

- Manufacturing Processes In Lab Environment
- Demonstrated Ready for FRP
Summary

• ARDEC is implementing a New MRA Procedure for conducting MRL Assessments of Army MANTECH Projects:
  – Aligned with the DoD Acquisition Framework and Conforms with DoD Instruction 5000.02.
  – Based on Best Practices Described in the DoD Manufacturing Readiness Level (MRL) Deskbook.

• MRL Metrics Help Acquisition Program Managers Manage Manufacturing Capability and Readiness Risks
  – Goes Hand-In-Hand With Use of TRLs to Manage Technology Risks
Backup

(The following MRL Deskbook Criteria charts are hyperlinked in the Tutorial)
# MRL Threads & Criteria

## Acquisition Phase

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<td><strong>MRL 5</strong></td>
<td><strong>MRL 4</strong></td>
<td><strong>MRL 3</strong></td>
<td><strong>MRL 2</strong></td>
<td><strong>MRL 1</strong></td>
</tr>
</tbody>
</table>

## Material Solution Analysis (Pre MSA)

- **A.1: Industrial Base**
  - Potential sourced identified for add-on or health and safety needs. Understands the risk.
  - Industrial base capabilities assessed against industrial base potential market.
  - Manufacturing processes, capabilities identified and planning has been designed.
  - Industrial base capabilities assessed against industrial base potential market.
  - Manufacturing processes, capabilities identified and planning has been designed.

- **A.2: Technology Readiness**
  - New manufacturing concepts and potential sources identified.
  - Manufacturing technologies, concepts and experimental prototypes.
  - New manufacturing concepts and potential sources identified.
  - Manufacturing technologies, concepts and experimental prototypes.

- **A.3: Maturity**
  - Material properties identified for research.
  - Material properties and characteristics identified.
  - Material properties and characteristics identified.
  - Material properties and characteristics identified.

## Technology Readiness

- **A.1: Technology Readiness**
  - Information system identifies add-on or health and safety needs. Understands the risk.
  - Industrial base capabilities assessed against industrial base potential market.
  - Manufacturing processes, capabilities identified and planning has been designed.
  - Industrial base capabilities assessed against industrial base potential market.
  - Manufacturing processes, capabilities identified and planning has been designed.

- **A.2: Technology Readiness**
  - New manufacturing concepts and potential sources identified.
  - Manufacturing technologies, concepts and experimental prototypes.
  - New manufacturing concepts and potential sources identified.
  - Manufacturing technologies, concepts and experimental prototypes.

- **A.3: Maturity**
  - Material properties identified for research.
  - Material properties and characteristics identified.
  - Material properties and characteristics identified.
  - Material properties and characteristics identified.

## Cost-Analysis

- **C.1: Cost-Analysis**
  - Material costs and risks identified.
  - High level process charts identify costs.
  - Material costs and risks identified.
  - High level process charts identify costs.

- **C.2: Cost-Analysis**
  - Identify and analyze manufacturing cost implications.
  - Statistics and analysis charts identify costs.
  - Identify and analyze manufacturing cost implications.
  - Statistics and analysis charts identify costs.

- **C.3: Maturity**
  - Manufacturing costs identified.
  - Manufacturing cost implications identified.
  - Manufacturing costs identified.
  - Manufacturing cost implications identified.

## MRL 5: Final Cost-Analysis

- **MRL 5**
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.

## Final Cost-Analysis

- **MRL 5**
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.

## Final Maturity

- **MRL 5**
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
  - Manufacturing costs and implications identified.
# MRL Threads & Criteria

## DoD Manufacturing Readiness Levels (MRLs)

<table>
<thead>
<tr>
<th>Acquisition Phase</th>
<th>Pre Material Solution Analysis (Pre MSA)</th>
<th>Material Solution Analysis (MSA)</th>
<th>Technology Maturation &amp; Risk Reduction (TMRR)</th>
<th>Engineering &amp; Mfg Development (EMD)</th>
<th>Low-Rate Initial Production (LRIP)</th>
<th>Full-Rate Production (FRP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Reviews</td>
<td></td>
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<tr>
<td>Thread</td>
<td>Sub-Thread</td>
<td>MRL 1</td>
<td>MRL 2</td>
<td>MRL 3</td>
<td>MRL 4, MRL 5, MRL 6</td>
<td>MRL 7, MRL 8</td>
</tr>
<tr>
<td></td>
<td>Technology Maturity</td>
<td>Should be assessed at TRL 1, 2, 3</td>
<td>Should be assessed at TRL 2, 3</td>
<td>Should be assessed at TRL 3</td>
<td>Should be assessed at TRL 7</td>
<td>Should be assessed at TRL 8</td>
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<td>Innovation &amp; Process (I&amp;P)</td>
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<td></td>
<td>Concept Evolution</td>
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<td></td>
<td>Process Development &amp; Manufacturing</td>
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<td>Manufacturing &amp; Process Maturity</td>
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<td>Process Quality</td>
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<td>Quality Management</td>
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<td>System Engineering (SE)</td>
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<td>Manufacturing</td>
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<td>Quality Assurance</td>
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<td></td>
<td>Quality Management Program</td>
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</tbody>
</table>

### 1. System Engineering (SE)
- New manufacturing skills identification.
  - MRL 1: System and production requirements and production needs.
  - MRL 2: Identifying and developing processes for prototyping.
  - MRL 3: Identifying and developing processes for production.
- MRL 4, MRL 5, MRL 6: Developing new manufacturing and production skills.
- MRL 7, MRL 8: Developing new manufacturing and production skills.

### 2. Manufacturing (MFG)
- Manufacturing functions and development of manufacturing processes.
  - MRL 1: Concept evolution.
  - MRL 2: Process development and manufacturing.
  - MRL 3: Manufacturing processes.
- MRL 4, MRL 5, MRL 6: Manufacturing processes.
- MRL 7, MRL 8: Manufacturing processes.

### 3. Quality Assurance (QA)
- Quality assurance and control.
  - MRL 1: Quality assurance and control.
  - MRL 2: Quality assurance and control.
  - MRL 3: Quality assurance and control.
- MRL 4, MRL 5, MRL 6: Quality assurance and control.
- MRL 7, MRL 8: Quality assurance and control.

### 4. Quality Management (QM)
- Quality management.
  - MRL 1: Quality management.
  - MRL 2: Quality management.
  - MRL 3: Quality management.
- MRL 4, MRL 5, MRL 6: Quality management.
- MRL 7, MRL 8: Quality management.

### 5. Technology Maturation & Risk Reduction (TMRR)
- Technology maturation and risk reduction.
  - MRL 1: Technology maturation and risk reduction.
  - MRL 2: Technology maturation and risk reduction.
  - MRL 3: Technology maturation and risk reduction.
- MRL 4, MRL 5, MRL 6: Technology maturation and risk reduction.
- MRL 7, MRL 8: Technology maturation and risk reduction.

### 6. Engineering & Mfg Development (EMD)
- Engineering and Mfg development.
  - MRL 1: Engineering and Mfg development.
  - MRL 2: Engineering and Mfg development.
  - MRL 3: Engineering and Mfg development.
- MRL 4, MRL 5, MRL 6: Engineering and Mfg development.
- MRL 7, MRL 8: Engineering and Mfg development.

### 7. Low-Rate Initial Production (LRIP)
- Low-rate initial production.
  - MRL 1: Low-rate initial production.
  - MRL 2: Low-rate initial production.
  - MRL 3: Low-rate initial production.
- MRL 4, MRL 5, MRL 6: Low-rate initial production.
- MRL 7, MRL 8: Low-rate initial production.

### 8. Full-Rate Production (FRP)
- Full-rate production.
  - MRL 1: Full-rate production.
  - MRL 2: Full-rate production.
  - MRL 3: Full-rate production.
- MRL 4, MRL 5, MRL 6: Full-rate production.
- MRL 7, MRL 8: Full-rate production.

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**Note:** This table outlines the critical areas of focus for each phase of the MRL process, with specific MRL levels indicated for each technical review. The table highlights the progression from pre-concept development to full-rate production, emphasizing the maturation and risk reduction of technology and processes at each stage.