Manufacturing Readiness Levels Overviews

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18
Session Outline

- **What are Manufacturing Readiness Levels (MRLs)**
- Implementing MRLs into a Program
- What is a Manufacturing Readiness Assessment (MRA)?
- How to perform a MRA
- Sample Outputs and Deliverables
- Findings and Conclusions
- Additional Information
What are MRLs?

• Common language and standard for
  – Assessing the **manufacturing maturity** of a technology or product and plans for its future maturation
  – Understanding the level of **manufacturing risk** in trying to produce a weapon system or transition technology into a weapon system application

• Designed to complement TRLs
• Designed to help set the agenda for manufacturing risk mitigation
• Establish an expectation of achieving manufacturing maturity at critical decision points

**NOTE:** FY04 - Joint Defense Manufacturing Technology Panel (JDMTP) formed MRL Working Group to develop basic MRL definitions and criteria
What are TRLs?

• Provide a common language and widely-understood standard for:
  • Assessing the performance maturity of a technology and plans for its future maturation
  • Understanding the level of performance risk in trying to transition the technology into a weapon system application
Why MRLs?

• Acquisition Performance perceived as broken

• Numerous Studies conducted in last 25 Years to improve Acquisition Process
  • Packard Commission, Goldwater – Nichols Act, SecDef Perry Memo, etc

• GAO continues to identify cost and schedule overruns on Major DoD Acquisition Programs
  • Need better knowledge early in acquisition to guide decisions

• Congress trying to help improve Acquisition Process
  • TRL Legislation
  • Weapons Systems Acquisition Reform Act of 2009

• New DoDI 5000.02 adding new requirements to perform manufacturing assessments

• **BOTTOM LINE** Current Performance in Acquisition must be improved – MRLs just one key tool to help
New Emphasis on Manufacturing

Per 5000.02, all programs shall:

assess the manufacturing feasibility and risk of alternatives being evaluated in the Analysis of Alternatives,

assess the manufacturing feasibility and risk of the proposed materiel solution for use in the Milestone A decision,

conduct assessments to identify manufacturing risks and ensure manufacturing processes have been demonstrated in a relevant environment in conjunction with the Preliminary Design Review (PDR) for use in the Milestone B decision,

conduct assessments to ensure the maturity of critical manufacturing processes has been demonstrated in a representative environment in conjunction with the Critical Design Review (CDR), and

conduct assessments to ensure that manufacturing processes have been effectively demonstrated in a pilot line environment and that there are no significant manufacturing risks for use in the Milestone C or FRP decisions.
How does MRLs Help

• Great Management Tool

• Defines Disciplined Process – Industry Best Practice
  • Analogous to Stage Gates for new product development

• Improves Communications and alignment of purpose between key stakeholders:
  • Government and Contractor
  • Prime and Suppliers
  • Industry’s functional organizations (i.e. engineering, manufacturing, supply chain, quality, and program office)

• Opportunity to generate fact-based technical discussions
MRLs A Great Management Tool

• Structured Approach
  • Develops Knowledge
    - Manufacturing processes, characteristics, constraints, requirements
    Supports analysis of cost, schedule, producibility, scale-up, trades
  • Identifies & Manages Risk
    - Key manufacturing risks identified as early as milestone A
    - Comprehensive assessment of total manufacturing requirements
• Great Program Review Tool
  - Assess manufacturing progress at reviews

• Products/Processes now aligned prior to entering production

• Can be used both tactically to solve a problem and strategically to identify Global and Enterprise issues that need to be addressed
MRLs A Best Practice

• Good Commercial Companies address manufacturing maturity early in development

• Provides discipline in addressing key manufacturing areas
  • Prime and Suppliers on same work sheet
  • Requires both Government and Industry to address manufacturing risk

• Developed with SMEs from over 60 major DoD suppliers and Multiple Government Agencies
MRLs A Great Communication Tool

- Standardize methodology across multiple suppliers
  - Requirements to achieve a defined level of manufacturing maturity is consistent
  - Provides consistency across the industrial base

- Provides a consistent set of expectations throughout the life cycle

- Identifies systemic problems across programs, suppliers, and services
Key Variables for Successful MRL Implementation

- Program leadership commitment

- Doing MRL Assessments early in Acquisition Process can lead to greater impact

- Using qualified SMEs to effectively implement and assess

- Follow through on planning and execution of necessary maturity/risk reduction efforts
MRL Benefits

- MRLs provide a lot of value at very little cost
  - Benefits significantly out weigh cost
  - Cost to implement and manage MRLs should not be considered “added cost” but rather early focus of risk mitigation efforts that tend to occur later, after the fact, and in worst case scenarios….not at all

- MRLs provide the required early visibility into manufacturing maturity to effectively manage risk

- MRLs set measurable and performance-based goals and provide oversight of contractor’s performance at both Prime and Suppliers

- MRLs provide clear expectations on what’s expected -more effective planning from everyone

- MRLs provide needed visibility and encourages proactive risk management

- Implementing MRL process can answer the new DoDI 5000.02 requirements for performing manufacturing assessments
Today’s Air Force Reality

- Diminishing manufacturing infrastructure
  - People, policy, programs gutted
  - Lost recipe on how to manage manufacturing risk
  - Won’t get infrastructure back, but still need to manage and mitigate manufacturing risk
MRL & TRL Relationships
In Acquisition Process

**Relationship to System Acquisition Milestones**

<table>
<thead>
<tr>
<th>MRL 1</th>
<th>MRL 2</th>
<th>MRL 3</th>
<th>MRL 4</th>
<th>MRL 5</th>
<th>MRL 6</th>
<th>MRL 7</th>
<th>MRL 8</th>
<th>MRL 9</th>
<th>MRL 10</th>
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</thead>
<tbody>
<tr>
<td>Basic Mfg Implications Identified</td>
<td>Mfg Concepts Identified</td>
<td>Mfg Proof of Concept Developed</td>
<td>Manufacturing Processes In Lab Environment</td>
<td>Components In Production Relevant Environment</td>
<td>System or Subsystem In Production Relevant Environment</td>
<td>System or Subsystem In Production Representative Environment</td>
<td>Pilot Line Demonstrated Ready for LRIP</td>
<td>LRIP Demonstrated Ready for FRP</td>
<td>Demonstrated Lean Production Practices in place</td>
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**Relationship to Technology Readiness Levels**

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<tr>
<th>TRL 1</th>
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# MRL Definitions

<table>
<thead>
<tr>
<th>MRL</th>
<th>Definition</th>
<th>Description</th>
<th>Phase</th>
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<tbody>
<tr>
<td>1</td>
<td>Basic Manufacturing Implications Identified.</td>
<td>Basic research activities expand technology principles that may have manufacturing implications. The focus is on a high level assessment of manufacturing opportunities. The research is unstructured.</td>
<td>Pre-Concept Refinement</td>
</tr>
<tr>
<td>2</td>
<td>Manufacturing Concepts Identified.</td>
<td>Innovation begins. Manufacturing science and/or concepts is described in an application context. Identification of material and process approaches are limited to paper studies and analysis. Initial manufacturing feasibility and issues are emerging.</td>
<td>Pre-Concept Refinement</td>
</tr>
<tr>
<td>3</td>
<td>Manufacturing Proof of Concept Developed.</td>
<td>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.</td>
<td>Pre-Concept Refinement</td>
</tr>
<tr>
<td>4</td>
<td>Capability to produce the technology in a laboratory environment.</td>
<td>Manufacturing technology development is complete and critical processes are validated. Manufacturing cost drivers identified. Production assessments of design concepts have been completed. Key Performance Parameters (KPP) identified. Special needs identified for tooling, facilities, material handling and skills.</td>
<td>Concept Refinement (CR) leading to a Milestone B decision.</td>
</tr>
<tr>
<td>5</td>
<td>Capability to produce prototype components in a production relevant environment.</td>
<td>Mfg strategy refined and integrated with Risk high Pt. Identification of elements critical technologies and components are 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. Productivity assessments of key technologies and components ongoing. Cost model based upon detailed end-to-end value stream map.</td>
<td>Technology Development (TD) Phase.</td>
</tr>
<tr>
<td>6</td>
<td>Capability to produce a prototype system or subsystem in a production relevant environment.</td>
<td>Initial mfg approach developed. Majority of mfg processes have been defined and characterized, but there are still significant engineering/design changes. Preliminary design of critical components complete. Productivity assessments of key technologies complete. Prototype materials, tooling and test equipment, as well as personnel skills have been demonstrated on subsystems in production relevant environment. Detauled cost analysis includes design trades. Cost targets allocated. Productivity considerations shape system development plans. Long lead and key supply chain elements defined. Industrial Capabilities Assessment (IC) for MS 8 completed.</td>
<td>Technology Development (TD) Phase leading to a Milestone C decision.</td>
</tr>
<tr>
<td>7</td>
<td>Capability to produce systems, subsystems or components in a production relevant environment.</td>
<td>Detailed design is underway. Material specifications are approved. Materials availability is ensured. Detailed manufacturing processes and procedures are demonstrated in a production representative environment. Detailed productivity trade studies and risk assessments underway. Cost model updated with detailed design. All major system elements and traded 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 &amp; development initiated.</td>
<td>System Development &amp; Demo (SD&amp;D) leading to Design Readiness Review (DRR).</td>
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<tr>
<td>8</td>
<td>Pilot line capability demonstrated Ready to begin low rate production.</td>
<td>Detailed 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 productivity risks pose no significant risk for low rate production. Engineering cost model driven by detailed design and validated. Supply chain established and stable. CA for MS 9 completed.</td>
<td>System Development &amp; Demo leading to a Milestone D decision.</td>
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<td>9</td>
<td>Low Rate Production demonstrated Capability in place to begin Full Rate Production.</td>
<td>Major system design features are stable and proven in detail &amp; evaluation. Materials are available to meet planned 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 is monitoring ongoing. LRP cost goals met, learning curve validated. Actual cost model developed for FRP environment, with impact of Continuous improvement.</td>
<td>Production &amp; Deployment leading to a Full Rate Production (FRP) decision.</td>
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<td>10</td>
<td>Full Rate Production demonstrated and lean production practices in place.</td>
<td>This is the highest level of production readiness. Engineering design changes are few and general, limited to cost and improvements. System, components, or parts are in 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 three-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.</td>
<td>Full Rate Production/Sustainment</td>
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### MRL Definitions con’t

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<td>Low rate production demonstrated. Capability in place to begin full rate production</td>
<td>Full rate production demonstrated and lean production practices in place</td>
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- **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. Furthermore, there must be an indication of how the contractor(s) intend to achieve the requirements in a production representative and pilot environments.

- **Production representative environment** – 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.

- **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.
9 MRL Evaluation Criteria
(“Threads”)

1. **Technology and Industrial Base**
   - Technology maturity, technology transition to production, ManTech development

2. **Design**
   - Producibility program, design maturity

3. **Cost and Funding**
   - Production cost knowledge (cost modeling), cost analysis, mfg investment budget

4. **Materials (raw matls, components, subassys, subsystems)**
   - Maturity, availability, supply chain management, special handling

5. **Process Capability and Control**
   - Modeling & Simulation (product & process), mfg process maturity, process yields/rates

6. **Quality Management, to include supplier quality**

7. **Manufacturing Personnel, to include specialization, training, & certification**

8. **Facilities, to include capacity and plant layout & design**

9. **Manufacturing Management**
   - Manufacturing planning and scheduling
   - Materials planning
   - Tooling and special test equipment
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<tr>
<th>Acq Phase</th>
<th>Pre CR</th>
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<th>CR - MS A</th>
<th>TD</th>
<th>MS B</th>
<th>SDD</th>
<th>MS C</th>
<th>LRIP - FRP</th>
<th>FRP</th>
<th>MRL</th>
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<tr>
<td>Technology Maturing</td>
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<td>Shown at TRL 2</td>
<td>Shown at TRL 5</td>
<td>Should be at TRL 4</td>
<td>Should be at TRL 5</td>
<td>Should be at TRL 6</td>
<td>Should be at TRL 7</td>
<td>Should be at TRL 8</td>
<td>Should be at TRL 9</td>
<td>Should be at TRL 10</td>
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<tr>
<td>Technology Transition to Production</td>
<td>Industrial basic capability is identified in key technologies, components, and key processes.</td>
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Session Outline

- What are Manufacturing Readiness Levels (MRLs)
- Implementing MRLs into a Program
- What is a Manufacturing Readiness Assessment (MRA)?
- Why Manufacturing Readiness?
- Sample Outputs and Deliverables
- Findings and Conclusions
- Additional Information
MRLs in Program

• Address MRLs in Key Documents
  • SEP, TDS, Acq Plans, RFP
• Use manufacturing maturity/risk in Source Selection
• Manufacturing Risk needs to be integrated into Program’s Risk Management activity
• Implementing MRLs into a Program Management Activity
  • Incorporate in IMP and IMS
  • EVS data
  • Address Manufacturing Maturity into Program Management Reviews
• Assess manufacturing maturity in Technical Reviews
  • PDRs, CDRs, etc
  • Perform manufacturing readiness assessments
• Status manufacturing maturity at milestone reviews
  • Address DoDI 5000.02 requirements
• **BOTTOM LINE – Manufacturing is important and needs to be addressed in your programs**
Session Outline

• What are Manufacturing Readiness Levels (MRLs)
• Implementing MRLs into a Program
• **What is a Manufacturing Readiness Assessment (MRA)?**
• How to perform a MRA
• Sample Outputs and Deliverables
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What is an MRA?

• An evaluation of a program’s ability to produce on schedule while meeting cost and performance requirements

• A tool to develop and implement:
  – Manufacturing risk mitigation plans
  – Business strategies

• Results in an assignment of MRLs to key system components

• Results in the development of a manufacturing maturation plan as required
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MRA Process

• Assessment Lead works with PM and contractor on Manufacturing Assessments Process
  – MRA Deskbook spells out process

• Assessment lead responsibilities
  • Determine appropriate level to perform Manufacturing Readiness Assessment(s) (MRAs) -- System may contain several critical technologies/components/manufacturing cells
  • Schedule on-site MRA with contractor(s)
  • Send Orientation Package to contractor(s)
  • Define Assessment Team Membership
  • Define Deliverables of Assessment Results
  • Conduct on-site assessment with contractor(s)
  • Deliver final report/briefing
Manufacturing Readiness Implementation Approach (ACATs)

**INTRODUCE**
- Meet with Wing/Program Management Team And Other Stakeholders

**TRAIN**
- Define Objectives
  - Yield Improvement
  - New Variant (e.g. Spiral)
  - Increased Capacity (Surge)

**OBJECTIVE STATEMENT DEFINED**

**ASSESS**
- Decompose the Problem Space
  - By Technology (i.e. Component)
  - By Supplier
  - Handle Assembly & Test

**INCORPORATE**

**MANAGE**
- Wing/PM Team owns the plan
Preparations

• Determine where to perform MRAs
  – Address **contract issues**
• Notify companies and send orientation package
  – Purpose, approach, questions, strawman agenda
  – MRL definitions/threads
  – Self-Assessment
• Select Assessment team(s)
  – Typically 2-6 members per team
  – Appropriate members (include Gov’t customer)
    • Specialists for key technologies (if needed)
• Schedule On-site assessments
  – Months prior to key milestone decisions
    • Allow time to develop/implement risk mitigation plans
• Team Orientation–Meet prior to on-site assessment
Where to perform MRA

• **Key questions to ask!**

• **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?

• **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?

• **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?

• **If yes, consider performing an MRA at this facility.**
On-Site Activities

• Introduce team and highlight specific roles
  • Purpose of assessment and how results will be used
  • Assessment process
  • Expectations

• Contractor should:
  • Introduce contractor participants – highlight responsibilities
  • Provide detailed responses to questions provided in orientation package
  • Indicate who is available to work with team counterparts in later meetings for detailed discussions
  • Lead shop floor tour

• Perform initial assessment

• Private meeting of Government assessment team to:
  • Prepare feedback and identify any action items
  • Key strengths/risks/issues
  • Key missing data (if any)
  • Proposed action items

• Out-briefing by Government team to contractor
Example Process Flow
Generic Aircraft

• Large programs can require multiple MRAs

Colors represent supplier/facility location
Supplier MRA Plan

• Identify and prioritize critical suppliers to perform MRA
• Determine Contract requirements (e.g. SOW)
  – Scope of MRA detailed
  – Method of MRA detailed
  – Output defined
• Developed detailed MRA execution plan with each supplier (schedule, format, personnel)
• Execute MRA
• Define/Plan/Execute MRL mitigations
• Measure mitigation effectiveness, update assessment
• NOTE: Similar to prime MRA – Prime should lead
Follow-on Activities

• Gather any key missing data
• Convene team meeting -- Typically within 2 weeks of on-site assessment
  • Discuss and finalize assessment
  • Examine current program and manufacturing risk reduction plans
  • Agree on likely MRL at completion of milestone if current plan is followed
• Share results with contractor
• Identify the specific risk reduction activities necessary to reach the next milestone
• Identify the funding, time-phasing and approach to carrying out each activity
• Prepare and submit final report
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• How to perform a MRA
• **Sample Outputs and Deliverables**
• Findings and Conclusions
• Additional Information
MRA Deliverables

• Provide briefing and/or written report
  • Identify target MRL
  • Identify current MRL
  • Identify key factors where manufacturing readiness falls short of target MRL
    • Define driving issues
  • Identify programs and plans to reach target MRL
  • Assess type and significance of risk to cost, schedule or performance

• Next step: Implement and execute the Manufacturing Maturation Plan
## SAMPLE SUMMARY ROLL-UP OF COMPONENTS

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Top Level MRL</th>
<th>Observations</th>
<th>Most Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidance</td>
<td>3</td>
<td>- Lacking detailed process information</td>
<td>Detector from supplier A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Key suppliers identified; Need key performance parameters</td>
<td>- Design &amp; production issues</td>
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<tr>
<td></td>
<td></td>
<td>- Need detailed process plans</td>
<td>- No alternate source</td>
</tr>
<tr>
<td>Data Processor</td>
<td>3</td>
<td>- New processor architecture</td>
<td>Board Supplier can't test at their site</td>
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<tr>
<td></td>
<td></td>
<td>- Immature design tools</td>
<td>Low yields on initial run</td>
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<td></td>
<td></td>
<td>- New attachment processes needed</td>
<td></td>
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<tr>
<td>Propulsion</td>
<td>6</td>
<td>- Same as other systems in use</td>
<td>Re-validate manufacturing process</td>
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<td></td>
<td></td>
<td>- New component scheme</td>
<td>Supplier handle increased rate</td>
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<tr>
<td>Air Vehicle</td>
<td>7</td>
<td>- Same supplier as system X</td>
<td>No critical items</td>
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<tr>
<td></td>
<td></td>
<td>- Need to test new mating and assembly processes at the prime</td>
<td></td>
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<tr>
<td>Test Plan</td>
<td>6</td>
<td>Several instances of re-design work and new test processes</td>
<td>- New test strategy and plan</td>
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<td></td>
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<td></td>
<td>- What will new design incorporate?</td>
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<td></td>
<td></td>
<td></td>
<td>- Manufacturing experience vital</td>
</tr>
<tr>
<td>Guidance Subsystems</td>
<td>Top Level MRL</td>
<td>Observations</td>
<td>Most Critical</td>
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</table>
| Front End Sensor    | 3            | - Lacking details on builds  
- Process procedures need more work  
- Test and assembly procedures have not been verified in manufacturing environment | Detector from supplier A  
- Design & production issues  
- No alternate source | |
| Data Processing PWB | 3            | - New processor architecture  
- Awaiting Design for Manufacturing and Assembly (DFMA) results | Low yields on initial build  
Working process controls  
Looking at re-design for easier fabrication | |
| Cables For: Power Data | 3 | - Using same suppliers other weapon systems  
- Have not received prototypes, awaiting supplier delivery | Re-validate manufacturing process as seen on past programs  
Need new process plan | |
| Housing             | 4            | - New supplier: limited experience  
- Need new assembly processes at the prime | Need supplier management process; need new process plans | |
| Cooling             | 3            | - Form, fit factors for new cooling design not in place  
Initial process plan for build in place | Final cooling plan will be defined after front end is stable | |
| Integration Process that includes assembly and test | 3 | - Several new test processes need development for new components | New test strategy and plan  
New special test equipment must be ordered | |
MRA Risk Management

• Assessing Risk is independent of the MRL value assigned
  – Higher MRL value may be highest risk
    • Eg. Requires new equipment, high cost process

• Risk Assessment should consider
  – Time needed to reach target MRL
  – Require new personnel, training, capital, or more POM samples to flush out the process
  – Leverage other programs
  – Captive or Merchant Supplier Dependency??
  – Part of a company’s core business
    • Leads into an industrial base assessment

• Effective of use of Design for Manufacturing Tools and other simulation techniques.
Session Outline

• What are Manufacturing Readiness Levels (MRLs)
• Implementing MRLs into a Program
• What is a Manufacturing Readiness Assessment (MRA)?
• How to perform a MRA
• Sample Outputs and Deliverables
• Findings and Conclusions
• Additional Information
Some MRL Thoughts

• MRLs are not a report card
  – MRL 7 might not be good
  – MRL 3 might not be bad

• MRLs are a tool to manage and mitigate manufacturing risk
  – A common language used to assess manufacturing maturity
  – Provide insight not oversight
MRA Thoughts

- MRA process highlights areas needing attention to lower production risk
- Sets expectation and measures Prime contractor and Suppliers Manufacturing’s progress as program matures
- Detailed analysis rank ordered; Can be an investment strategy and feeds into risk management
- Effective tool to convince Senior Leaders you are ready for production

Manufacturing maturity through the MRA process enables efficient, cost effective manufacturing
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- **Additional Information**
Additional Information

- DoD Manufacturing Readiness Reference
  http://www.dodmrl.com/
  - MRL Definitions
  - MRL Criteria Matrix
  - MRL Deskbook
  - Defense Acquisition University MRL Website
  - AF ManTech’s MRA Tool and Users Manual