Manufacturing Readiness Levels (MRLs)

for
Multi-Dimensional Assessment of Technology Maturity

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## Manufacturing Readiness Levels (MRLs)

### Abstract

See also ADM002184. Presented at the Air Force Research Laboratory Seminar/Workshop on Multi-Dimensional Assessment of Technology Maturity in Fairborn, OH on 9-11 May 2006.
Outline

• Why MRLs?
• What are MRLs?
• MRL implementation plan
• Status
• ACAT pilots
Why MRLs?
Manufacturing & Industrial Base Challenge

• Consensus among Congress, OSD, CSAF, GAO:
  “Advanced weapon systems cost too much, take too long to field, and are too expensive to sustain”

• Recent GAO study of 54 weapons programs:
  – Core set of 26 programs: RDT&E costs up by 42% and schedule slipped by 20%
    • $42.7B total cost growth
    • 2.5 years slip on average
  – Characteristics of successful programs (GAO):
    • Mature technologies, stable designs, production processes in control
    • S&T organization responsible for maturing technologies, rather than program or product development manager

• Defense Science Board evaluated ManTech roles/impacts for AT&L
  – ManTech can significantly impact across all acquisition phases
  – Facilitates manufacturing/industrial base readiness for S&T transition and acquisition
Technology Readiness Levels (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

TRLs leave major transition questions unanswered:

- Is this 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?
- Are key materials and components available?
What are MRLs?

- Framework to evaluate “manufacturing maturity”
- Complements existing Technology Readiness Levels
- Used to assess maturity and risk of a technology’s underlying manufacturing processes
  - Enable rapid, affordable transition to weapon system programs
- Designed to address manufacturing risk mitigation
DoD MRL Implementation

• DoD (AS&C) vision is to develop and institutionalize MRLs
  – Assess the manufacturing maturity of a technology or product and plans for its future maturation; common language to convey status
  – Understand the level of manufacturing risk in trying to produce a weapon system or transition the technology into a weapon system application

• DoD Joint Defense Manufacturing Technology Panel (JDMTP) chartered an MRL Working Group to refine definitions and develop plans to institutionalize MRLs within the AT&L community
  – Government and industry representatives participating
  – Developed definitions that interface with TRLs and milestone decision points
  – Develop implementation strategy consistent with DoD 5000 acquisition doctrine, practice, and milestone decision points

• SAF/AQ
  – Conduct ACAT pilots and then develop policy

• AFRL/CD
  – Implement into all AFRL ATDs
MRL Relationships

Relationship To System Milestones

<table>
<thead>
<tr>
<th>Concept Refinement</th>
<th>Technology Development</th>
<th>System Development &amp; Demonstration</th>
<th>Production &amp; Deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRL 3</td>
<td>MRL 4</td>
<td>MRL 5</td>
<td>MRL 6</td>
</tr>
<tr>
<td>MRL 10</td>
<td>MRL 1</td>
<td>MRL 2</td>
<td>MRL 3</td>
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</tbody>
</table>

Relationship To Technology Readiness Levels

<table>
<thead>
<tr>
<th>TRL 1</th>
<th>TRL 2</th>
<th>TRL 3</th>
<th>TRL 4</th>
<th>TRL 5</th>
<th>TRL 6</th>
<th>TRL 7</th>
<th>TRL 8</th>
<th>TRL 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Principles Observed</td>
<td>Concept Formulat</td>
<td>Proof of Concept</td>
<td>Breadbrd in Lab</td>
<td>Breadbrd in Rep Environmt</td>
<td>Prototype in Rep Environmt</td>
<td>Prototype in Ops Environmt</td>
<td>System Qual</td>
<td>Mission Proven</td>
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</tr>
</tbody>
</table>

TRL 1  Basic Principles Observed
TRL 2  Concept Formulat
TRL 3  Proof of Concept
TRL 4  Breadbrd in Lab
TRL 5  Breadbrd in Rep Environmt
TRL 6  Prototype in Rep Environmt
TRL 7  Prototype in Ops Environmt
TRL 8  System Qual
TRL 9  Mission Proven
MRL Definitions & Tools

<table>
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<tr>
<th>MRL 3</th>
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<th>MRL 5</th>
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<th>MRL 7</th>
<th>MRL 8</th>
<th>MRL 9</th>
<th>MRL 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg Concepts Identified</td>
<td>Mfg Processes Identified</td>
<td>Mfg Processes Identified</td>
<td>Critical Mfg Processes Demo’d</td>
<td>Prototype Mfg System</td>
<td>Process Maturity Demo</td>
<td>Mfg Processes Proven</td>
<td>Lean System Production</td>
</tr>
<tr>
<td>Key Processes Identified</td>
<td>Key Processes Identified</td>
<td>Mfg equipment in relative environment</td>
<td>Mfg processes in validation</td>
<td>Mfg processes proven for LRIP</td>
<td>Overall Mfg Processes Operates At target Quality, Cost and Lead times</td>
<td>Overall Mfg Process Operates At 6-Sigma Quality, and Meets Cost and Lead times</td>
<td></td>
</tr>
<tr>
<td>Prodibility assessment initiated</td>
<td>Prodibility assessment ongoing</td>
<td>Prodibility assessment ongoing</td>
<td>Prodibility improvement underway</td>
<td>Supply chain established</td>
<td>All key Processes Meet process Control Targets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost drivers identified</td>
<td>Cost drivers analyzed</td>
<td>Long lead plans in place</td>
<td></td>
<td></td>
<td>Meets Engineering Performance &amp; Reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Long lead items identified</td>
<td></td>
<td></td>
<td>Overall Mfg</td>
</tr>
</tbody>
</table>
| | | | | | | | Lean System 
| | | | | | | | Production |

Key Char.; Variables Mapping
Process Flow Charts

FMEA
Process Capability; DOE

Value Stream Maps

Process & Sources at Deeper Levels & Custom / Tailored Tools
<table>
<thead>
<tr>
<th>MRL</th>
<th>Tools</th>
<th>Use to Evaluate…</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Process Flow Charts</td>
<td>Basic manufacturing concepts</td>
</tr>
<tr>
<td>4</td>
<td>Detailed Process Flow</td>
<td>Key manufacturing processes charts</td>
</tr>
<tr>
<td>5</td>
<td>Value Stream Mapping and identifying waste</td>
<td>Mapping the current state</td>
</tr>
<tr>
<td>6-10</td>
<td>Value Stream Mapping and eliminating waste</td>
<td>Mapping the future state</td>
</tr>
</tbody>
</table>
## Process Control Tools for MRL

<table>
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<th>Tools</th>
<th>Use to Evaluate…</th>
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</thead>
<tbody>
<tr>
<td>4-6</td>
<td>Key Characteristics</td>
<td>Requirements and tolerances</td>
</tr>
<tr>
<td>4</td>
<td>Process Variables Map</td>
<td>Which variables to control</td>
</tr>
<tr>
<td>5-9</td>
<td>Process Capability Performance</td>
<td>Predictability of process</td>
</tr>
<tr>
<td>5-9</td>
<td>Design of Experiments</td>
<td>Multiple factors and levels of</td>
</tr>
<tr>
<td></td>
<td>independent variables</td>
<td></td>
</tr>
<tr>
<td>6-9</td>
<td>Failure Modes and Analysis</td>
<td>Risks associated with failure effects</td>
</tr>
</tbody>
</table>
MRL Evaluation Criteria

- Technology and Industrial Base
- Design
- Materials
- Cost and Funding
- Process Capability and Control
- Quality Management
- Manufacturing Personnel
- Facilities
- Manufacturing Management
What is an ATD?

- Any Air Force science and technology program (6.3)
  - Objective of demonstrating an integrated set of technologies
    - Superior warfighting capability
    - Ready to transition before the end of the FYDP
- Sufficiently mature the technology(ies) for transition into an advanced system development or a fielded system upgrade
- Categories
  - CAT 1
    - MAJCOM/Agency supports and has programmed required funding for transition within the FYDP
  - CAT 2A
    - MAJCOM/Agency supports and is committed to identify transition funding in next programming cycle
  - CAT 2B
    - MAJCOM/Agency supports but is not currently able to POM for transition
MRL Incorporation into AFRL ATDs

• Conducted ATD pilot assessments on five ATDs
• Tasked to implement MRLs into hardware intensive ATDs
• Developed basic approach/process for implementation
• Developed training for ATD IPTs and ManTech personnel
• Identified core ManTech funding for MRAs and selected follow-on MRL maturation
• Conducted assessments of four additional ATDs
• Currently working with ten total ATDs
ATD MRA Approach

**INTRODUCE**
- Meet with PM to get buy-in and gather program info
- Customize MRL approach for program

**TRAIN**
- Train program IPT on manufacturing tools to support manufacturing maturity efforts (orientation)

**ASSESS**
- Current MRL
- Final MRL if current plan is followed
- Plan, actions, and costs to get them to target MRL

**INCORPORATE**
- Incorporate MRL into program plan

**MANAGE**
- Manage overall process
- Manage risk identification and reduction process
- Manage manufacturing maturity to target MRL
Current ATD Portfolio

- F135 (PR)
- F136 (PR)
- Common Weapons Data Link (MN)
- X-band Thin Radar Array (SN)
- Shredder (MN)
- High Temperature Polymeric Matrix Composites (ML)
- High Durability Hot Exhaust Structures (ML)
- Affordable Responsive Space Lift (VA)
- Battlefield Air Operations Kit (MN)
- Advanced Multi-junction Solar Cells (VS)
Manufacturing Readiness
Current Planning Process

• ATD selection has been by TD
  – Primary Customer Base, CAT I ATDs
    • PR, SN, MN, VA, VS, and ML
    • Implement MRLs into five ATDs per quarter
      –Introduced MRLs to wide AFRL community
• Training ManTech personnel to conduct effective assessments
• Train IPT, conduct assessment, execute plan to reach target MRL
• Developing process with AFRL/XP for timely new ATD identification
  – ManTech to become an integral part of ATD selection process
ATDs Planned for FY06

• Choose ATDs based on similar technologies areas
• ATD candidate technology areas
  – Electronics
  – Propulsion & Power
  – Space
  – Structures
• Identify cross-cutting technologies
  – Develop ManTech program to satisfy several ATDs
  – Leverage on-going programs
• Planning a summer blitz to implement into several ATDs
• Per SAF/AQ tasking, select pilots with SAF/AQR
  – Need to manage with on-going ATD workload
• Convene experienced assessment team
  – Experience with assessment process
  – Subject matter expertise
  – Acquisition wing personnel and contractors
• Conduct MRAs on pilots – key technologies or components
  – E.g. F-22A, AMRAAM
• Develop/refine assessment process for acquisition programs
  – Will vary from ATD process and may be program specific
  – Dependent on current or target milestone
  – Significant program office involvement
MRA Deliverables

• Current MRL
  – Key risk areas
  – Driving issues

• Plan to obtain target MRL
  – Risk mitigation plans
  – Schedule
  – Funding
  – Contract modification language
Additional Information

• MRL definitions can be found at DAU web site:
      • Click on Production Quality & Manufacturing
      • Click on Manufacturing Readiness Assessments
In Closing

• MRL working definitions established
  – JDMTP on board
  – Exercising on ATDs and ACATs
  – But no formal policy yet
• MRL process established in AFRL ATDs
• Managing current manpower issues
• Initializing ACAT pilot efforts

*Moving forward but still developing...*