Manufacturing Readiness Levels (MRLs)
Manufacturing Readiness Assessments (MRAs)

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Integrity - Service - Excellence
**Manufacturing Readiness Levels (MRLs) Manufacturing Readiness Assessments (MRAs)**

See also ADM002182. Presented at the AFRL Technology Maturity Conference held in Virginia Beach, VA on 11-13 September 2007.
Why MRLs?

"Advanced weapon systems cost too much, take too long to field, and are too expensive to sustain" -- Congress, OSD, CSAF, GAO

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

• Need way to mitigate impact of 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 manufacturing risk
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 the technology producible? Reproducible?
- What will these cost in production?
- Can these be made in a production environment?
- Are key materials and components available?
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 the technology into a weapon system application

Designed to complement TRLs

Designed to help set the agenda for manufacturing risk mitigation

Usage
  - Army, for Future Combat Systems development efforts
  - Missile Defense Agency using EMRLs on all development programs
  - Several defense primes using on weapon system programs
  - *Mandated by AFRL for phase-in on all hardware ATDs*
**MRL Relationships**

**Relationship to System Acquisition Milestones**

<table>
<thead>
<tr>
<th>Pre-Concept Refinement</th>
<th>Concept Refinement</th>
<th>Technology Development</th>
<th>System Development &amp; Demonstration</th>
<th>Production &amp; Deployment</th>
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</thead>
<tbody>
<tr>
<td>MRL 1-3 Mfg Concepts Identified</td>
<td>MRL 4 Mfg Processes In Lab Environmt</td>
<td>MRL 5 Mfg Processes In Relevant Environmt</td>
<td>MRL 6 Mfg Processes Maturing for LRIP</td>
<td>MRL 7 Mfg Processes In Place for LRIP</td>
</tr>
<tr>
<td>MRL 8 Mfg Processes In Prod Rep Environmt</td>
<td>MRL 9 Mfg Processes In Place for FRP</td>
<td>MRL 10 Lean Mfg Processes</td>
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**Relationship to Technology Readiness Levels**

| TRL 1 Basic Principles Observed | TRL 2 Concept Formulation | TRL 3 Proof of Concept | TRL 4 Breadboard in Lab | TRL 5 Breadboard in Rep Environmt | TRL 6 Prototype in Rep Environmt | TRL 7 Prototype in Ops Environmt | TRL 8 System Qual | TRL 9 Mission Proven |
MRL Evaluation Criteria (Threads)

- Technology and Industrial Base
- Design
- Materials
- Cost and Funding
- Process Capability and Control
- Quality Management
- Manufacturing Personnel
- Facilities
- Manufacturing Management
## MRL Evaluation Criteria (Threads)

<table>
<thead>
<tr>
<th>Acq Phase</th>
<th>Pre CR</th>
<th>CR - MS A</th>
<th>TD</th>
<th>MS B</th>
<th>MRL 1-3</th>
<th>MRL 4</th>
<th>MRL 5</th>
<th>MRL 6</th>
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</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Metric</td>
<td>MRL 1-3</td>
<td>MRL 4</td>
<td>MRL 5</td>
<td>MRL 6</td>
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<tr>
<td>Technical</td>
<td>Technical</td>
<td>TRLs 1-3</td>
<td>Must be assessed at minimum of TRL 4</td>
<td>Must be assessed at minimum of TRL 5</td>
<td>Must be assessed at minimum of TRL 6</td>
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<tr>
<td>Technology &amp; Industrial Base</td>
<td>TECHNOLOGY TRANSITION TO PRODUCTION</td>
<td>Identify technology leadership as potential sources (foreign/domestic); (commercial/government)</td>
<td>IB capabilities and gaps/risks identified for key technologies.</td>
<td>Industrial Base analysis accomplished to identify potential sources.</td>
<td>IB capability in place to support mfg of development articles. IB exists for similar components or plan developed for developing facilities.</td>
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<tr>
<td>Design</td>
<td>Productivity Program</td>
<td>Initial productivity assessment of design completed.</td>
<td>Initial productivity of technology completed (components).</td>
<td>Initial productivity of technology completed (systems level). Initial trade studies conducted - performance vs. productivity.</td>
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<tr>
<td>Form, Fit, &amp; Function</td>
<td>Unique Components</td>
<td>Unique components identified.</td>
<td>Unique component issues identified.</td>
<td>Plans completed to address unique component issues.</td>
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<tr>
<td>Key Characteristics</td>
<td>Key Performance Parameters (KPPs) identified.</td>
<td>KPPs allocated at the component level.</td>
<td>Tolerances established for KC.</td>
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<tr>
<td>Maturity</td>
<td>Characterize basic materials for manufacturability</td>
<td>Completed survey to determine if materials have been used before in a mfg environment. Preliminary plans in place to address gaps.</td>
<td>Related material development efforts known. Maturity has been assessed on similar materials.</td>
<td>Maturity has been assessed on similar materials in production. Specific programs identified. Preliminary material specifications in place.</td>
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<tr>
<td>Availability</td>
<td>New material scale-up challenges assessed</td>
<td>All exotic/critical/hazardous materials, and associated lead times have been identified. Significant material risks have been identified: high cost, availability, safety, health, hazards, etc.</td>
<td>Identify availability issues.</td>
<td>Complete a plan to address availability issues. Identify long lead items.</td>
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<tr>
<td>Special Handling</td>
<td>Identify potential special handling concerns (i.e. shelf life, HMMP, SECURITY, HAZMAT, storage environment, etc.) Prepare MSDS as necessary.</td>
<td>Identify special handling reqts (i.e. shelf life, HMMP, SECURITY, HAZMAT, storage environment, etc.) Review and update MSDS.</td>
<td>Special handling gaps identified.</td>
<td>Complete a plan to address special handling gaps.</td>
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MRL definitions/threads

• Rewritten by MRL working group in July 07
  – Based on MRA experience to date
• Sponsored MRL workshop on 6-7 Sept 07
  – Government and Industry representatives
  – Scrub definitions/threads
  – AF Goal – easily used by S&T and Acquisition communities
• New definitions/threads to be published soon
MRL Implementation Approach

In partnership with Joint Defense Manufacturing Technology Panel (JDMTP)
  – Develop and MRL definitions & policy language

• Conduct pilots on various programs
  – Advanced Technology Demonstrators
  – Weapon System Acquisition programs
  – Demonstrate benefits of using MRL

• Conduct training for key program personnel
  – What are MRLs, how to conduct an MRA
    • Air Force ManTech personnel
    • ATD and ACAT pilot program personnel
    • Various training materials that can be tailored
  – Transition to DAU once MRLs are in policy

• Put MRLs into policy
  – AFRL, AFMC, AF, OSD
Manufacturing Readiness Level Implementation Approach (ATDs)

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

OBJECTIVE STATEMENT DEFINED
- Define objective of program
- Define what is to be assessed and why

ASSESS
- Determine current MRL
- Develop plan, actions, and estimate costs to get to target MRL
- Schedule for implementation

INCORPORATE
- Incorporate MRL into program baseline

MANAGE
- Manage overall process
- Manage risk identification and reduction process
- Manage manufacturing maturity to target MRL
- Reassess as appropriate

OBJECTIVES
- Hardware-intensive
- Critical mass of time to complete
- Newly developed products
MRA Deliverables

- Identification of *current MRL*
- Identification of key factors where manufacturing readiness falls short of *target MRL*
  - Define driving issues
  - Define high risk areas
- Identify programs and plans to reach target MRL
  - Generate the manufacturing maturity plan (MMP)
- Assess type and significance of risk to cost, schedule and/or performance
Emerging MRA Successes

High Durability Hot Exhaust Structures

- Provided identification of high risk processes and single point failures driving scale-up from MRL 3
- Maturation plan provides awareness of issues relating to move to new production facility
- Follow-on MRA at new facility will help ensure transition success

F135

- Enabling opportunity to accelerate transition for F135 thrust improvement by ~4 years
- Advanced feature high cost driver: must overcome producibility issues
- Developed plan to mature from MRL 3 to 5 leveraging commercial and military IR&D, F135 program, and ManTech funding
ACAT MRA Pilot

- Translate the successful MRL ATD process to acquisition programs
- Common themes
  - Utilize approximately the same process
  - Utilize current MRL definitions to assess against
  - 3-5 people per MRA
- What is different
  - ATDs focusing on MRL 3 – MRL 6
    - Assessing technical maturity with a goal of transition/implementation
  - ACATs focusing on MRL 4 – MRL 9
    - Schedule, cost, manning considerations
    - Milestone decisions
    - Production planning process
    - Will require a more rigorous approach
- Develop and document a structured ACAT assessment approach
  - MRA Deskbook
    - First draft completed Mar 07 based on ATD and limited ACAT experience
    - Drafted with SAF/AQRE, MRL Working Group, and ASC/EN
    - Test drive on Reaper
      - Update based on lessons learned
Manufacturing Readiness Implementation Approach (ACATs)

INTRODUCE

TRAIN

OBJECTIVE STATEMENT DEFINED

ASSESS

INCORPORATE

MANAGE

Meet with Wing/Program Management Team And Other Stakeholders

Define Objectives
- Yield Improvement
- New Variant (eg Spiral)
- Increased Capacity (Surge)

Decompose the Problem Space
- By Technology (ie Component)
- By Supplier
- Handle Assembly & Test

Wing/PM Team owns the plan

OBJECTIVE STATEMENT DEFINED

Meet with Wing/Program Management Team And Other Stakeholders

Define Objectives
- Yield Improvement
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Decompose the Problem Space
- By Technology (ie Component)
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- Handle Assembly & Test

Wing/PM Team owns the plan
AMRAAM

• Manufacturing Readiness Assessment and process improvements of AIM-120 C-7
  • **What:** Performed a system-level MRA on the AMRAAM C-7 variant
   – Looked at all test and assembly steps, including FACO
   – Fourteen key suppliers; over thirty-five technology areas examined
  • **Impact:** Based on independent assessment, AMRAAM Group received go-ahead to proceed to next production lot for C-7 variant; reduced testing cycle time in particular cell by 90%
MRL/MRA Training

• Air Force ManTech Personnel
  – Industrial Preparedness
  – MRL/MRA methodology
  – Continuing education
  – Subject Matter Experts
    • Six sigma
    • Lean

• ATD IPTs
  – MRL definitions and MRAs
  – Training can be tailored for various audiences

• Air Force Product Centers
  – Based on ATD training with lessons learned from ACAT experience
  – DAU
    • Currently in PQM 201, SYS 302, and PQM 301
Policy Formulation Status

• DoD
  – Policy language written by MRL working group
  – OSD motivated to get policy in place by end of Sept 07
  – Initial policy likely to come out as a letter signed by Mr. Young
    • Actual policy, not guidance
  – Following policy letter
    • DAG
    • 5000.2
  – We are available to support as required

• AF
  – SAF/AQR team leading the charge
    • Goal to issue guidance by 1 Jan 08
    • Policy memo signed my Ms. Payton
    • Put into systems engineering, AFI 63-1201
    • Working with AQR to implement
MRA Deskbook

• The “how-to” of MRAs
• First draft completed in March 07
• Modeled after TRA Deskbook
  – Similarities
    • Achieving levels of readiness for risk reduction
    • Selection process for CTEs
  – Differences
    • Readiness in S&T and Acquisition world
    • Rigorous assessment process
• Next draft based on lessons learned from Reaper MRA
  – Dec 07, Public releasable
Lessons Learned

• 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*
Future Steady State

• Programs utilizing MRLs
  – Funding MRL maturation
  – Understanding of manufacturing concepts

• Use of MRLs in policy
  – Program offices staffed/trained
  – Manufacturing a key component to MS reviews

• Training
  – DAU acts as the primary government training agent
  – Air Force supports training updates
Additional Information

• MRL definitions can be found at DAU web site:
    • Look for MR definitions
    • Look for MR matrix
    • Look for MRL tutorial

• Google – manufacturing readiness assessments
In Closing

• Using a three-pronged approach to implementation
  – Piloting and incorporating into various programs
  – Training
  – Policy insertion

• Overall implementation progressing
  – Air Force
  – DoD

• We are still learning and applying lessons learned

Air Force is Leading DoD-wide Implementation
BACKUP
# MRL/MRA Implementation across DoD

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<thead>
<tr>
<th></th>
<th>ATDs</th>
<th>ManTech</th>
<th>SBIR</th>
<th>Acquisition</th>
<th>Policy</th>
<th>Other</th>
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<td><strong>Army</strong></td>
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<td>Assist Tool</td>
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- **MRLs**
- **EMRLs**