Ready or Not? Using Readiness Levels to Reduce Risk on the Path to Production

August, 2011
Are You Ready …

• To adopt a new technology?
• To incorporate a new technology into a design?
• To integrate subsystems?
• To transition to production?

The Answers to these Questions Have Critical Implications to the Product Developer, Acquirer and User
Agenda

- Introduction to Readiness Levels
- DoD Policy & Guidance
- Readiness Methods Survey
  - Technology Readiness
  - Manufacturing Readiness
  - Integration Readiness
  - System Readiness
- Implementation Suggestions
Introduction

● A management method
● Informs risk management
● A measurement scale and vocabulary
  ➤ Technology Readiness
  ➤ Manufacturing Readiness
  ➤ Integration Readiness
  ➤ System Readiness
  ➤ And others…
● Used in various forms
  ➤ Multiple Federal departments/agencies
  ➤ Multiple industries
An Approximate History

**Past**
- NASA
- USAF
- TRL
- TRL/MRL

**Present**
- DoD & MoD
- TRL
- MoD SRL
- IRL $\rightarrow$ SRL

**Future**
- Readiness Indices?
- DoD MRL

**Forcing Functions**
- Commercial Practice, GAO studies, DoD Policy & Guidance

**GENERAL DYNAMICS**
Armament and Technical Products
DoD Policy – Technology Readiness Assessment, TRA

- Required by DoD 5000.01 (directive) and DoD 5000.02 (instruction)
- TRA are required for ALL MDAP at Milestone B (before EMD phase).
- TRA not required for non-MDAP or MAIS
- TRA should focus on "technology maturity as opposed to engineering and integration risk"… memo: Improving Technology Readiness Assessment Effectiveness; Ashton Carter, May 2011.
Technology Readiness

- Approximate measure of technical maturity
- Technology Readiness Assessment (TRA)
  Deskbook, July 2009
- Applicable to ‘critical’ hardware and software technology elements (CTE(s))
  - Identified during material solution analysis
  - Depend on element to meet op requirements
  - New, novel or poses ‘major technological risk’
  - Assessment criteria for hardware, software; aircraft, ground vehicles, missiles, ships...
## Technology Readiness, Continued

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL 1</td>
<td>Basic principles observed and reported</td>
</tr>
<tr>
<td>TRL 2</td>
<td>Technology concept and/or application formulated</td>
</tr>
<tr>
<td>TRL 3</td>
<td>Analytical and experimental critical function and/or characteristic proof of concept</td>
</tr>
<tr>
<td>TRL 4</td>
<td>Component and/or breadboard validation in a laboratory environment</td>
</tr>
<tr>
<td>TRL 5</td>
<td>Component and/or breadboard validation in a relevant environment</td>
</tr>
<tr>
<td>TRL 6</td>
<td>System/subsystem model or prototype demonstration in a relevant environment (required to start EMD)</td>
</tr>
<tr>
<td>TRL 7</td>
<td>System prototype demonstration in an operational environment (required to start LRIP)</td>
</tr>
<tr>
<td>TRL 8</td>
<td>Actual system completed and qualified through test and demonstration</td>
</tr>
<tr>
<td>TRL 9</td>
<td>Actual system proven through successful mission operations</td>
</tr>
</tbody>
</table>

Source: Technology Readiness Assessment (TRA) Deskbook, July 2009
DoD Policy, Manufacturing Readiness

- Manufacturing Readiness Requirements
  - Implied by DoD 5000.02
    - Requires assessment of manufacturing capabilities and risks
  - Not institutionalized to degree TRLs are
    - Lack of consensus on use across services
    - Not currently required by DoD acquisition policy
  - Use growing in DoD and defense industry
  - Analogs used routinely in other industries
Manufacturing Readiness

- Approximate measure of manufacturing maturity
- Resource: Manufacturing Readiness Level Deskbook, July 2010 (OSD Mfg Tech Program)
- Threads used to assess risk areas
  - Technology & Industrial Base
  - Design
  - Cost and Funding
  - Materials
  - Process Capability and Control
  - Quality Management
  - Manufacturing Personnel
  - Facilities
  - Manufacturing Management
## Manufacturing Readiness, Cont

<table>
<thead>
<tr>
<th>Level</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRL 1</td>
<td>Basic Manufacturing Implications Identified</td>
</tr>
<tr>
<td>MRL 2</td>
<td>Manufacturing Concepts Identified</td>
</tr>
<tr>
<td>MRL 3</td>
<td>Manufacturing Proof of Concept Developed</td>
</tr>
<tr>
<td>MRL 4</td>
<td>Capability to Produce the Technology in a Laboratory Environment</td>
</tr>
<tr>
<td>MRL 5</td>
<td>Capability to produce prototype components in a production relevant environment</td>
</tr>
<tr>
<td>MRL 6</td>
<td>Capability to produce a prototype system or subsystem in a production relevant environment</td>
</tr>
<tr>
<td>MRL 7</td>
<td>Capability to produce systems, subsystems or components in a production representative environment</td>
</tr>
<tr>
<td>MRL 8</td>
<td>Pilot line capability demonstrated; Ready to begin low rate initial production</td>
</tr>
<tr>
<td>MRL 9</td>
<td>Low rate production demonstrated; Capability in place to begin full rate production</td>
</tr>
<tr>
<td>MRL 10</td>
<td>Full rate production demonstrated and lean production practices in place</td>
</tr>
</tbody>
</table>

*Source: Manufacturing Readiness Level Deskbook, July 2010*
Role in DoD Acquisition

Increasing Maturity, Decreasing Risk

Source: Manufacturing Readiness Level Desk Book, July 2010
What About Interfaces?

- Interface A, C
- Interface A, B
- Interface B, C
Integration Readiness

● Approximate measure of integration maturity
  ➔ Between two or more items or subsystems

● Work on integration measures, assessments and indices culminated in Integration Readiness Levels (IRLs) proposed by Gove et al., at Stevens Institute of Technology, School of Systems & Enterprises

● Resources: No deskbook equivalent, multiple papers and briefings on subject
## Integration Readiness, Continued

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</thead>
<tbody>
<tr>
<td>IRL 1</td>
<td>An interface between technologies has been identified with sufficient detail to allow characterization of the relationship</td>
</tr>
<tr>
<td>IRL 2</td>
<td>There is some level of specificity to characterize the interaction between technologies through their interface</td>
</tr>
<tr>
<td>IRL 3</td>
<td>There is compatibility between technologies to orderly and efficiently integrate and interact</td>
</tr>
<tr>
<td>IRL 4</td>
<td>There is sufficient detail in the quality and assurance of the integration between technologies</td>
</tr>
<tr>
<td>IRL 5</td>
<td>There is sufficient control between technologies necessary to establish, manage, and terminate the integration</td>
</tr>
<tr>
<td>IRL 6</td>
<td>The integrating technologies can accept, translate, and structure information for its intended application</td>
</tr>
<tr>
<td>IRL 7</td>
<td>The integration of technologies has been verified and validated with sufficient detail to be actionable</td>
</tr>
<tr>
<td>IRL 8</td>
<td>Actual integration completed and Mission Qualified through test and demonstration, in the system environment</td>
</tr>
<tr>
<td>IRL 9</td>
<td>Integration is Mission Proven through successful mission operations</td>
</tr>
</tbody>
</table>

Example: F35JSF and Gun System

*IRL values are arbitrary and for illustrative purposes only.*
System Readiness

- Approximate measure of system maturity
- Aggregated measure of technology and integration readiness across elements and interfaces of a product/system
- Based on the outcome of TRL and IRL assessments
  \[ SRL = f(\text{technology readiness, integration readiness}) \]
- Matrix of pair wise comparisons of IRLs & TRLs
  \[ [SRL]_{nx1} = [IRL]_{nxn} \times [TRL]_{nx1}; \text{ IRL & TRL normalized} \]
  \[ SRL \text{ composite} = f(SRL_n) \]
- Resources: No deskbook equivalent, many papers

Sample SRL Analysis

Changing the Gun System Control Unit - Ammunition Handling System (GSCU - AHS) IRL from 5 to 8 impacts the SRL of both Line Replaceable Units (LRUs) and the overall SRL.
Implementation Model

One Perspective

Technology Development
- Definition
- Design
- Implementation & Integration
- Verification & Validation
- Transition to Production

Engineering and Manufacturing Development
- SRR
- SFR
- PDR
- CDR
- PRR
- IRR
- SVR
- PRR

Production and Deployment

TRL 5
- Components Validated in Relevant Env

TRL 6
- Proto/Model Demonstrated in Relevant Env

TRL 7
- System Demonstrated in Operational Env

TRL 8
- Pilot Line Demonstrated, Ready for LRIP

TRL 9
- Ready to Produce Prototype System

MRL 5
- Ready to Produce Prototype Components

MRL 6
- Ready to Produce System in Production Environment

MRL 7
- System in Production Environment

MRL 8
- Ready to Produce System

MRL 9
- Prototype System

→ Burn Down Technical and Manufacturing Risk →

# Risks

General Dynamics
Armament and Technical Products
Implementation Methods

- Concurrent product & mfg process development
- Engineering & manufacturing professionals working together closely and early
- Risk management
- Standard but tailorable work products
- Work product check lists
- Gate exit criteria
- Lessons learned
- Product & process prototyping
- Assessment & risk management tools
Conclusion

- Readiness assessments can reduce risk and improve program outcomes
- Technology & manufacturing readiness assessment methods are most mature
- Integration and system readiness assessment methods hold potential for use in future
- Meaningful assessments and relevant actions depend on experience and judgment
- Best used with concurrent development of product and manufacturing process
Select Resources

- **Motivation for Readiness Assessments**
  - GAO-10-439 DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed, April 2010

- **Assessment Methods & Guidance**
  - DoD Technology Readiness Assessment Deskbook
  - DoD Manufacturing Readiness Level Deskbook, July 2010

- **Papers on Advanced Assessment Methods**

- Other references identified in the papers above
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