A Review and Analysis of Maturity Assessment Approaches for Improved Defense Acquisition Decision Support

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Presentation Overview

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2. GAO Major DoD Program Assessments
3. Knowledge Gaps
   A. Basis
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   C. How to Close
4. Congressional Policy
5. Technology Maturity
   A. Technology Readiness Assessment (TRA)
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   C. TRL Limitations
6. Introduction to Other Tech Maturity Assessment Methods
7. SWOT (Strength, Weakness, Threat, Opportunity) Analysis
8. Conclusions & Recommendations
Introduction

The Department of Defense (DoD) acquisition programs have a long history of experiencing various forms of risk

DoD is experiencing consequences of risk in the form of:
- Cost overruns
- Late deliveries
- Failure to meet performance requirements
- Program delays
- Program cancellations
- Failure to deliver promised capabilities

Underlying causes of risk:
- Unrealistic performance expectations
- Unrealistic baseline estimates for cost or schedule
- Immature technologies
- Evolving requirements
- Changes in procurement quantities;
- Funding instability;

Multiple assessments (2000-2008) of the DoD acquisition portfolio concluded a strong correlation between delayed knowledge points and poor performance.

GAO Assessments and Findings

GAO assessments of Acquisition Programs concluded that risk in poorly performing DoD programs result from not possessing the knowledge required to achieve a successful design at key points during development.

Knowledge gaps result in DoD programs moving forward without sufficiently:

- *Maturing the new technologies,*
- *stabilizing the design,* or
- *maturing the manufacturing processes*
DoD requires maturity assessment certification as entrance criteria for milestones B & C

Milestone B = TRL 6
Milestone C = TRL 7
2008 GAO Assessment of 72 Weapons Programs

- **12%** began system development with fully mature critical technologies
- **4%** had demonstrated design stability before entering system demonstration phase
- **No** program had fully matured their production processes before entering production

### Analysis of DOD Major Defense Acquisition Program

**Fiscal year 2008**

<table>
<thead>
<tr>
<th>Number of Programs</th>
<th>Fiscal Year</th>
<th>2000 Portfolio</th>
<th>2005 Portfolio</th>
<th>2007 Portfolio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Planned Commitments</td>
<td></td>
<td>$790 Billion</td>
<td>$1.5 Trillion</td>
<td>$1.6 Trillion</td>
</tr>
<tr>
<td>Commitments Outstanding</td>
<td></td>
<td>$380 Billion</td>
<td>$887 Billion</td>
<td>$858 Billion</td>
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</table>

### Change in total RDT&E costs from first estimate
- 27%
- 33%
- 40%

### Change in total acquisition cost from first estimate
- 6%
- 18%
- 26%

### Estimated total acquisition cost growth
- $42 Billion
- $202 Billion
- $295 Billion

### Share of programs with 25 percent or more increase in program acquisition unit cost
- 37%
- 44%
- 44%

### Average schedule delay in delivering initial capabilities
- 16 Months
- 17 Months
- 21 Months

Percentage of Programs Achieving Technology Maturity at Key Junctures
Why do DoD programs enter various phases of acquisition and product development with knowledge gaps?

- Organizational drive for better, faster, cheaper warfare technologies
- Program risk management strategies allow for inherent risk
- Program financial methods punish delays in program start date

Why do DoD knowledge gaps result in design, technology, and production risks?

- Risk is typically underestimated by organizational leaders
- Programs take risk to maintain production start date to avoid political risks of delay (loss of funding)

System development challenges:

- Increasingly complex Systems
- Increased data demand requirements
- Operating in a net-centric environment
- System-of-System centric
- Rapid development cycle
- Rapid technology obsolescence
- Evolving/untradeable requirements
1999 - GAO stated in report that

“Program managers’ ability to reject immature technologies is hampered by (1) untradeable requirements that force acceptance of technologies despite their immaturity and (2) reliance on tools that fail to alert the managers of the high risks that would prompt such a rejection.” GAO/NSIAD-99-162

2003 - DoDI 5000.02 (2003), para 3.7.2.2 required the inspection of technology maturity by stating

“Objective assessment of technology maturity and risk shall be a routine aspect of DoD acquisition.”

2006 – Congressional legislation (Title 10, section)

- Technology maturity must be assessed and certified to be adequate prior to MS B&C
Technology Readiness Assessment (TRA)

A TRA is a systematic, metrics-based process and accompanying report.

The TRA assesses the Maturity of Critical Technology Elements.

Critical Technology Elements (CTEs) are...

- The system depends on this element to meet operational requirements.
- The element or its application is either new or novel.
- Element poses major technological risk during detailed design or demonstration.

DoD standard tool for performing TRAs is Technology Readiness Level (TRL) metric.
Technology Readiness Level (TRL)

What is TRL?
- Technology Readiness Level (TRL) is a 9 tier metric that systematically assess the maturity of a technology with respect to a particular use.

Purpose of TRL
- Provides a common language for understanding the developmental status of a technology to date.
- Indicates the development maturity of a technology at a particular point in time.

TRL is not for suitability
- Does not indicate that the technology is right for the job or that application of the technology will result in successful development of the system.

Milestone B = TRL 6
Milestone C = TRL 7
TRL Limitations

- Subjective Assessment - there exist no formal guideline of implementing TRLs; the TRL value is assigned to technology by a technology developer who may be biased; the definitions of each TRL level is prone to broad interpretation.

- Not focused on system-to-system integration - TRLs focus on a component of a technology and when infusing the particular component with other in a larger scale, imperative integration concerns come forth.

- Lacking in definition of terminology - the definitions of each TRL level can be ambiguous and reliant on an individual’s interpretation.

- Combines many dimensions of technology readiness into one metric.

- Lacks accuracy and precision.

- Conveys the status of technology readiness on a single scale at a particular point in time – does not foretell the possibility and difficulty of further maturing technology to higher TRL levels.
Rational for Other Methods

TRLs are insufficient because they do not take into account many of DoD’s system development needs

- *large quantity manufacturing*
- *Integration and rapid obsolescence*
- *Increased system-of-system centricity*

To offset some of these issues, other models, tools, and methods have been developed

- **GOAL** - *introduce objectivity* and address the overlooked facets of technology maturity that have been omitted by the TRL
# Qualitative Techniques

<table>
<thead>
<tr>
<th>Tool</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Manufacturing Readiness Level (MRL)</td>
<td>The MRL is a 10 level scale used to define current level of manufacturing maturity, identify maturity shortfalls and associated risks, and provide the basis of manufacturing maturation and risk management (Cundiff 2003).</td>
</tr>
<tr>
<td>Integration Readiness Level (IRL)</td>
<td>The IRL is a 9 level scale intended to systematically measure the maturity, compatibility, and readiness of interfaces between various technologies and consistently compare interface maturity between multiple integration points. Further, it provides a means to reduce the uncertainty involved in maturing and integrating a technology into a system (Gove 2007).</td>
</tr>
<tr>
<td>TRL for non-system technologies</td>
<td>Expansion of the TRL definitions to account for non-system technologies such as processes, methods, algorithms, and architectures (Graettinger et al 2002).</td>
</tr>
<tr>
<td>TRL for Software</td>
<td>Expansion of the TRL metric to incorporate other attributes specific to software development (DoD TRA Deskbook 2005).</td>
</tr>
<tr>
<td>Technology Readiness Transfer Level (TRRL)</td>
<td>The TRRL is a 9 level scale describing the progress of technology transfer to a new application. It expands and modifies the TRL definitions to address the transfer to space technology into non-space system (Holt 2007).</td>
</tr>
<tr>
<td>Missile Defense Agency Checklist</td>
<td>A tailored version of the TRL metric specifically in support of hardware maturity through the development life-cycle of the product (Mahafza 2005).</td>
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<tr>
<td>Moorhous Risk Versus TRL Metric</td>
<td>A 9 level metric mapping risk progression analogous to technology maturity progression. The TRL descriptions are tailored specifically toward UAV (Moorehouse 2002).</td>
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<tr>
<td>Advanced Degree of Difficulty (AD2)</td>
<td>Leveraging the concept of RD3, the AD2 augments TRLs by assessing the difficulty of advancing a technology from its current level to a desired level on a 9 tier scale (Bilbro 2007).</td>
</tr>
<tr>
<td>Research and Development Degree of Difficulty (RD3)</td>
<td>The RD3 is a 5 level scale intended to supplement the TRL by conveying the degree of difficulty involved in proceeding from the current TRL state to desired level, with 5 being very difficult and 1 being least difficult to mature the technology (Mankins 1998).</td>
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<td>System Readiness Level (SRL)</td>
<td>The SRL is a normalized matrix of pair-wise comparisons of TRLs and IRL of a system. It is a quantitative method providing insight into system maturity as a product of IRL x TRL (Sauser et al. 2006, 2007, 2008).</td>
</tr>
<tr>
<td>SRL Max</td>
<td>The SRL Max is a quantitative mathematical model aiming to maximize the SRL under constraint resources. The objective of the SRLmax is the achievement of the highest possible SRL based on the availability of resources such as cost and schedule (Ramirez-Marquez et al. 2009).</td>
</tr>
<tr>
<td>Technology Readiness and Risk Assessment (TRRA)</td>
<td>TRRA is a quantitative risk model that incorporates TRLs, the degree of difficulty (RD3) of moving a technology from one TRL to another, and Technology Need Value (TNV). The TRRA expands the concept of the risk matrix by integrating “probability of failure” on the y-axis and “consequence of failure” on the x-axis (Mankins 2007).</td>
</tr>
<tr>
<td>Integrated Technology Analysis Methodology (ITAM)</td>
<td>ITAM is a quantitative mathematical model that integrates various system metrics to calculate the cumulative maturity of a system based on the readiness of its constituent technologies. The system metrics include TRLs, delta TRL, R&amp;D Degree of Difficulty (R&amp;D3), and Technology Need Value (TND) (Mankins 2002).</td>
</tr>
<tr>
<td>TRL for Non-Developmental Item (NDI) Software</td>
<td>A mathematical method to assess the maturity of Non-Developmental Item (NDI) software using orthogonal metrics in combination with a pair-wise comparison matrix to examine two equivalent technologies that are candidate for insertion into a system. Incorporate other attributes such as requirement satisfaction, environment fidelity, criticality, product availability, and product maturity (Smith).</td>
</tr>
<tr>
<td>Technology Insertion (TI) Metric</td>
<td>TI involves the integration of various metrics that deal with insertion of technology and subsystems into a current system in order to develop an “enhanced system.” The TI Metric is a high level metric computed from sub-metrics or dimensions intended to evaluate the risk and feasibility of technology insertion from a subsystem and a system level (Dowling and Pardo 2005).</td>
</tr>
<tr>
<td>TRL Schedule Risk Curve</td>
<td>This is a quantitative model that does not communicate the maturity of technology at a certain point in time but instead leverages the TRLs metric to identify the appropriate schedule margins associated with each TRL level in order to mitigate schedule slipp (Dubos et al. 2007).</td>
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### Automated Techniques

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<tbody>
<tr>
<td>Technology Readiness Level (TRL) Calculator</td>
<td>Microsoft excel based tool that enables the application of the TRL definitions to technology development. The calculator computes a TRL level based on the answers to a series of questions by the user and displays the output graphically (Nolte 2004).</td>
</tr>
<tr>
<td>Manufacturing Readiness Level (MRL) Calculator</td>
<td>Microsoft excel based tool that enables the application of the MRL definitions to technology development. Computes the MRL level based on answers to a series of questions in various threads related to manufacturing readiness.</td>
</tr>
<tr>
<td>Technology Program Management Model (TPMM)</td>
<td>TPMM is a technology-development activity model, partitioned into phases that are gate qualified using the TRLs. The model defines each TRL as a stage and establishes exit criteria (gate) for each stage of TRL. Each TRL stage has an associated checklist of activities that must be achieved before succeeding to the next stage. The TPMM is comprised of seven technology development phases (SMDTC 2006).</td>
</tr>
<tr>
<td>UK MoD System Readiness Level</td>
<td>Captures key outputs from the nine levels of product development depicted by the Systems Engineering V-model in an excel-based tool. These outputs are confined and tracked in a matrix. Each output is evaluated on a 9 level SRL scale (<a href="http://www.ams.mod.uk/aofcontent/tactical/techman/content/srl_whatarethey.htm">http://www.ams.mod.uk/aofcontent/tactical/techman/content/srl_whatarethey.htm</a>)</td>
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**SWOT**
*(Strength, Weakness, Opportunity, Threat)*

**Qualitative Tools**

**Strengths**
- Relatively Objective
- Relatively precise compared to qualitative techniques
- Integrates multiple system metrics
- Assessment of maturity of a particular technology at a point in time
- Tangible metric to support decision making
- Not subject to personal interpretation

**Weaknesses**
- Can be too complex and difficult to apply by the average technologist and acquisitionist
- More time consuming than performing qualitative analysis
- Can be system specific and be tailored to different projects
- Difficult to perform iteratively

**Opportunities**
- Make general enough to meet majority of DoD maturity assessment needs
- New acquisitions
- Achieve higher accuracy and precision by integrating relevant metrics in the model
- Automate mathematical model using tools such as Microsoft Excel

**Threats**
- Create language barriers for those who have working knowledge of the metrics and those that do not
- Discourage assessment of more complex models
- Prone to mathematical error, can lead to wrong maturity assessment, cost overrun, and schedule delays

**Quantitative Tools**

**Strengths**
- Assessment of maturity of a particular technology at a point in time
- Comparison of different technologies based on its standard set of questions
- Can be performed fast and iteratively
- Not subject to miscalculation

**Weaknesses**
- Discrepancy in result if questions are answered incorrectly or omitted
- Does not tell the risk involved in improving to a higher maturity
- Does not incorporate quantitative and tangible system metrics
- Definitions subject to misinterpretation
- Subjective

**Opportunities**
- Incorporate hard metrics
- Achieve accuracy and precision via more concrete and succinct exit criteria
- Make user-friendly

**Threats**
- Resulting output in the form of definitions is subject to personal interpretation
- Discrepancy in outcome as a result of ambiguous questions can result in wrong maturity assessment that can have adverse impact
- Commercial tools can cost big money

**Auto Tools**

**Strengths**
- 1) Assessment of maturity of a particular technology at a point in time
- 2) Brings together stakeholders to evaluate maturity of component technologies and can bring forth discussion about other important factors
- 3) Can be performed fast and iteratively
- 4) Does not require working knowledge of complex assessment tools

**Weaknesses**
- 1) Subjective
- 2) Over simplifies many factors of maturity into one value
- 3) Does not assess maturity of a complex system that comprised of multiple technologies
- 4) Blurs many factors of technology readiness into one value
- 5) Does not incorporate quantitative and tangible system metrics
- 6) Does not take into account the development cost
- 7) Does not consider the complex dependencies between the various technologies
- 8) Relies on expert judgment and subjective assessment

**Opportunities**
- Flexible and agile to allow tailoring for various systems
- Adaptable to new acquisitions
- Achieve accuracy and precision via more concrete and succinct exit criteria
- Expansion and integration with other system metrics

**Threats**
- Prone to mathematical error, can lead to wrong maturity assessment, cost overrun, and schedule delays
- Create language barriers for those who have working knowledge of the metrics and those that do not
- Discourage assessment of more complex models
- New acquisitions
Conclusion & Recommendations

Evaluation of technology maturity is critical because it provides insight into technical and programmatic risk by:

- Establishes milestones to track development progress
- Establishes entry and exit criteria for various milestones
- Provides direction for risk management and mitigation

Objective and robust methods that can assess technology maturity accurately improve acquisition outcome.

The success of programs depend on consistent and holistic evaluation of system maturity via a robust, repeatable and agile method.
“Every dollar spent on inefficiencies in acquiring one weapon system is less money available for other opportunities.” (GAO 2006)