USING SYSTEM READINESS LEVELS TO IMPROVE RELIABILITY PREDICTIONS AND T&E INVESTMENT DECISIONS

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This presentation was developed in partial fulfillment of the requirements for the Doctor of Philosophy degree from the Department of Engineering Management and Systems Engineering at the George Washington University.
USING SRL TO IMPROVE RELIABILITY AND T&E INVESTMENT

1) Purpose of Presentation

2) DoD Reliability and System Readiness Levels

3) SRL Applied to Reliability Growth

4) SRL Applied to T&E Investment

5) Results and Conclusions
Problem Statement

Since 1998 nearly one-half of DOD systems failed reliability requirements using legacy reliability growth models that do not use system maturity metrics.

Purpose of Presentation

Demonstrate a correlation model of System Readiness Levels (SRL) and Reliability Growth Models.

General Approach

- Develop Monte-Carlo Optimization model
- Correlate SRL model output to Reliability parameters.
The 2012 Director of Operational Test & Evaluation report suggests nearly 50% of DoD programs from 1998-2012 did not meet reliability requirements.

Fraction of DOD programs meeting reliability requirements at IOT&E from FY97-FY12 [Gilmore 2012].
Numerous methods of system maturity assessment have been developed.\(^{(1)}\)

- Manufacturing Readiness Level
- Integration Readiness Level
- Technology Readiness Level
- TTRL
- MDA Checklist
- AD2
- RD3
- System Readiness Level (UK)
- System Readiness Level (Sauser)
- TRRA
- ITAM

*We will focus on the Sauser SRL.*

\(^{(1)}\) Azizian (2009)
SRL Combines Technology and Integration Readiness Levels

- SRL developed in mid-2000s\(^1\).
- SRL assesses system readiness for subsequent phases.
- Early SRL used matrix math to combine Technology and Integration Readiness Levels.
- Several SRL calculation methods in literature.

\(^1\) Sauser et al, 2008.
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**TRL** assess the maturity of Critical Technology Element technologies

- **1980’s**
  NASA uses to assess space technology.
  - **2001**
    Selected for use in DOD TRA assessments.
  - **2000s**
    Used with IRL to Develop SRL metric.

1. (1) Basic Principles
2. (2) Technology Concept
3. (3) Analytical/Experimental Proof-of-Concept
4. (4) Component/Breadboard ~ Lab Env.
5. (5) Component/Breadboard ~ Relevant Env.
6. (6) System Demo ~ Relevant Lab Env.
7. (7) System Demo ~ Dynamic Operational Env.
8. (8) System Validated Via DT
9. (9) System Validated Via OT

**TRL Hardware definitions**

- **TRL 9**
- **TRL 8**
- **TRL 7**
- **TRL 6**
- **TRL 5**
- **TRL 4**
- **TRL 3**
- **TRL 2**
- **TRL 1**

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(1) DOD TRA Deskbook, 2009.
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**IRL** developed as a new measurement tool to complement TRL\(^{(1, 2)}\)

<table>
<thead>
<tr>
<th>IRL Scale</th>
<th>IRL Scale Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Mission Proven through successful mission operations.</td>
</tr>
<tr>
<td>8</td>
<td>Mission Qualified through test and evaluation</td>
</tr>
<tr>
<td>7</td>
<td>Verified and Validated with sufficient detail.</td>
</tr>
<tr>
<td>6</td>
<td>Integration can Accept, Translate and Structure information</td>
</tr>
<tr>
<td>5</td>
<td>Sufficient Control to establish, manage, and terminate the integration.</td>
</tr>
<tr>
<td>4</td>
<td>Sufficient detail in Quality and Assurance of the integration.</td>
</tr>
<tr>
<td>3</td>
<td>Compatibility between technologies is established.</td>
</tr>
<tr>
<td>2</td>
<td>Interaction of technologies is characterized.</td>
</tr>
<tr>
<td>1</td>
<td>Interface between technologies is established.</td>
</tr>
</tbody>
</table>

\(^{(1, 2)}\) Sauser et al., 2008 & 2010.
Applying SRL to Reliability Growth model parameters

**Step #1: Optimization Model**
- Monte-Carlo model evaluates SRL parameters over time
- Eventually develop a full Constrained Optimization model

**Step #2: Correlation of SRL and RGM parameters**
- SRL and RGM parameter relationships are NOT causally related!
- Correlation analysis supports SRL integration with RGM evaluations
Step #1: Optimization Model

- Prior research \(^{(1, 2)}\) applies SRL to program cost/schedule.
- We expand SRL applications to Reliability Growth.

Sample SRL system and Reliability Growth Model parameters.

<table>
<thead>
<tr>
<th>SRL Model Parameters</th>
<th>Reliability Growth Model Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Component TRL system</td>
<td>Exponential data</td>
</tr>
<tr>
<td>Monte-Carlo model for TRL &amp; IRL</td>
<td>Component reliability increases with increased system complexity</td>
</tr>
<tr>
<td>TRL &amp; IRL transition probabilities P[TRL+], P[IRL+]</td>
<td>Series-Reliability System model assumed</td>
</tr>
</tbody>
</table>

\(^{(1, 2)}\) Ramirez-Marquez et al., 2008 & 2009.
Model run: 100 time steps.

TRL & IRL = 5 @ t = 0.

P(TRL+) = P(IRL+) = 0.10.

SRL changes over time.

\[ SRL(t) \approx -0.0001 \cdot t^2 + 0.0116 \cdot t + 0.2064 \]
Step #2: Correlation of SRL and RGM parameters

- Optimization model provides SRL parameters for Correlation analysis.
- MIL-HDBK-189C\(^{(1)}\) provides selected RGM parameters.

<table>
<thead>
<tr>
<th>SRL Parameters</th>
<th>Selected RGM Parameters (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRL vs. time - SRL(_t)</td>
<td>MTBF Growth Rate - MTBF(_{dt})(t)</td>
</tr>
<tr>
<td>SRL Growth - SRL(_{dt})(t)</td>
<td>MTBF Growth Ratio - (M_o/M_i(t))</td>
</tr>
<tr>
<td>SRL Growth Potential - SRL(_{GP})(t) = (1 - SRL(t))</td>
<td>MTBF Growth Potential - MTBF(<em>{GP})(t) = (1 - \text{MTBF}</em>{\text{OBJ}})</td>
</tr>
</tbody>
</table>

\(^{(1)}\) MIL-HDBK-189C (2011).
Correlation Analysis of SRL & RGM parameters. Consider the same system but from a Reliability perspective.

**SRL system definition**

...using a Series Reliability system assumption...

**Equivalent Reliability system definition**
Notional System Mean-Time-Between-Failure Data

- MTBF increases as IRL & TRL increase \(^{(1,2)}\)
- Assumes Exponential failure rates \(^{(3)}\)
- Equally weights components

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\(^{(1)}\) Ramirez-Marquez (2008).
\(^{(2)}\) Ramirez-Marquez (2009).
\(^{(3)}\) Kececioglu (1993).
Applying SRL to T&E Investment

- Literature considers problems of resource allocation for development costs\(^{(1, 2)}\).
- Resource priorities directed to less mature systems and components.

<table>
<thead>
<tr>
<th>Test Hrs.</th>
<th>5to6</th>
<th>6to7</th>
<th>7to8</th>
<th>8to9</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL-1</td>
<td>934</td>
<td>1007</td>
<td>978</td>
<td>1087</td>
<td>4006</td>
</tr>
<tr>
<td>TRL-2</td>
<td>559</td>
<td>945</td>
<td>570</td>
<td>865</td>
<td>2939</td>
</tr>
<tr>
<td>TRL-3</td>
<td>943</td>
<td>739</td>
<td>586</td>
<td>649</td>
<td>2917</td>
</tr>
<tr>
<td>IRL-1,2</td>
<td>1126</td>
<td>859</td>
<td>638</td>
<td>1074</td>
<td>3697   (PRIMARY IRL OPTION)</td>
</tr>
<tr>
<td>IRL-1,2</td>
<td>------</td>
<td>------</td>
<td>545</td>
<td>431</td>
<td>976   (SECONDARY IRL OPTION)</td>
</tr>
<tr>
<td>IRL-2,3</td>
<td>989</td>
<td>642</td>
<td>211</td>
<td>458</td>
<td>2300</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SRL</th>
<th>[0.56--------0.67------0.78--------0.99]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totals</td>
<td>4551</td>
</tr>
<tr>
<td>Totals</td>
<td>3425</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Anderson-Cook et al. (2009).
\(^{(2)}\) Bjorkman et al. (2012).
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Results
- Provided a Monte-Carlo SRL correlation model for Reliability Growth
- Demonstrated strong correlation of SRL and Reliability parameters
  - Positive correlation of $MTBF_{SYS}(t)$ vs. $SRL(t) = +0.9297$
  - Positive correlation of $MTBF_{GP}(t)$ vs. $SRL_{GP}(t) = +0.9257$
  - Negative correlation of $MTBF_{GP}(t)$ vs. $SRL(t) = -0.9297$
  - Negative correlation of $MTBF_{SYS}(t)$ vs. $SRL_{GP}(t) = -0.9297$
- Suggested application of SRL to T&E resource allocation problems.

Conclusions
- Extend SRL models to Reliability and T&E resource allocation
- Expand SRL mathematics beyond current approaches
- Real SRL and Reliability data needed for full analysis
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