The trouble with the System Readiness Level (SRL) index for managing the acquisition of defense systems

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Acknowledgments & Disclaimers

• I thank the conference technical committee for the opportunity to make this presentation. I commend them for their courage and good technical judgment.

• Work supported in part by the Acquisition Research Program at the Naval Postgraduate School.

• Heartfelt thanks to three of my NPS colleagues, Tom Huynh, Gary Langford and Greg Miller, for their moral support.

• Being an educator and practicing systems engineer, it is my duty and responsibility to speak out against serious errors in my field of expertise.

• The presenter’s opinions, findings, and recommendations are not necessarily shared by the NPS, the NDIA, and/or the DoD; but they should be!
My communications with B. Sauser

From: Brian Sauser  
To: Kujawski, Edouard (CIV)  
Subject: Re: NDIA presentation on SRL  
Date: Thursday, September 02, 2010 10:08:23 AM

“Ed:
First, thank you for sharing your presentation and thoughts with us prior to NDIA. We respect that decision greatly.
Second, we are encouraged that you have chosen to look into what we have published and find ways to make it better or do further research. This is a true academic spirit that can advance a knowledge base in an area.
Third, while you argue that what we have done is flawed, we can equally present counter arguments as why it is not. So while you may not find it “pleasant” to do what you did, we are enthusiastic that you did. ..................................................
Stephen Hawking said, if no one criticized my research, it could not be right..................................................
We would feel remorse at your presentation and ideas if it was not for the fact that the application of the SRL as a managerial tool has been working well with all of our customers and stakeholders, who have graciously offered to discuss with you how it has worked for them. Let me know, we can provide their contact information. Some will also be at NDIA. ..................................................”

Two of my thoughts reading the above email
1. The Law of Excluded Middle. A proposition is either true or false; it cannot be anything in between.
2. Einstein’s reply when he heard of the book “100 Authors Against Einstein”
   “If I were wrong, one would be enough.”

B. Sauser DID NOT provide the contact information that I requested!
Imagine SE in these titles

- Failure of risk management ➔ failure of SE
Or these titles!

Let’s work together to avoid further notoriety!
The B. Sauser & Co. false premise!

B.J. Sauser & J. Ramirez-Marquez, Systems Engineering Collaborators Information Exchange (SECIE) Community Event, Slide #5

Development of metrics, tool, and methodologies for determining a systems readiness level (SRL) and potential for making efficient and effective lifecycle acquisition and operational decisions. The SRL Model is a function of the individual Technology Readiness Levels (TRL) and their subsequent integration points with other technologies, the Integration Readiness Level (IRL).

- Value Proposition:
  - Provides a system-level view of development maturity with opportunities to drill down to element-level contributions
  - Allows managers to evaluate system development in real-time and take proactive measures
  - Highly adaptive to use on a wide array of systems engineering development efforts
  - Can be applied as a predictive tool for technology insertion, trade studies, and analysis

The B. Sauser & Co. SRL is predicated on the false premise, $SRL = f(TRL, IRL)$.

♫ The rest of my presentation is commentary!
The B. Sauser & Co. SRL can do harm!

Test Case 1*
Results obtained with the Systems Development & Maturity Laboratory (B. Sauser & Co.) SRL calculator

Test Case 2*
Irrational results!

* Proceeding with “Production & Deployment” ➔ Program Failure
The B. Sauser & Co. SRL is misleading and therefore worse than useless!
Types of measures

- **Natural measures**: In general use and have a common interpretation to everyone.
  - Speed: Miles/hr; Cost: $; Weight: tons; Volume: m³...

- **Constructed measures**: Integrates multiple numerical and/or verbal descriptions into a single description of the state of a fundamental objective.
  - Subjective scale
  - Context dependent
  - Utility

**HAZARD**

**Constructed measures can be hazardous to your program’s health.**
Levels of measurement

- **Numbers MUST be assigned to observations/attributes according to the following rules:**

<table>
<thead>
<tr>
<th>Level of Measurement</th>
<th>Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal</strong></td>
<td>Put data in <em>categories</em>.</td>
</tr>
<tr>
<td><strong>Ordinal</strong></td>
<td>Put data in <em>rank order</em>.</td>
</tr>
<tr>
<td><strong>Interval</strong></td>
<td>Put data in rank order with <em>equal intervals between each unit</em>.</td>
</tr>
<tr>
<td><strong>Ratio</strong></td>
<td>Put data in rank order with equal intervals between each unit, and anchor with a <em>true zero point</em>.</td>
</tr>
</tbody>
</table>
TRL & IRL are ordinal scales

J.C. Mankins, Technology readiness levels, NASA, Houston, TX, 1995.


The Sauser & Co. SRL scale

<table>
<thead>
<tr>
<th>SRL</th>
<th>Acquisition Phase</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.90 to 1.00</td>
<td>Operations &amp; Support</td>
<td>Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its total life cycle.</td>
</tr>
<tr>
<td>0.70 to 0.89</td>
<td>Production</td>
<td>Achieve operational capability that satisfies mission needs.</td>
</tr>
<tr>
<td>0.60 to 0.79</td>
<td>System Development &amp; Demonstration</td>
<td>Develop system capability or (increments thereof): reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for production; ensure affordability and protection of critical program information; and demonstrate system integration, interoperability, safety and utility.</td>
</tr>
<tr>
<td>0.40 to 0.59</td>
<td>Technology Development</td>
<td>Reduce technology risks and determine appropriate set of technologies to integrate into a full system.</td>
</tr>
<tr>
<td>0.10 to 0.39</td>
<td>Concept Refinement</td>
<td>Refine initial concept; Develop system/technology strategy.</td>
</tr>
</tbody>
</table>

The Sauser & Co. SRL = f(TRL, IRL) is a deeply flawed entrance index for the various acquisition phases!
Don’t be dazzled by the mathematics; it’s Computationally Accurate But Irrelevant (CABI)!
The B. Sauser & Co. SRL violates basic engineering principles

- As shown on slide 7, the B. Sauser & Co. SRL provides irrational results
- Component SRL\(_x\)/ITRL\(_x\) do not credibly represent “technology X” and ITRLs
  - They depend on the other TRLs
  - Note the change from SRL\(_x\) to ITRL\(_x\)!
- Adding integration can increase SRL\(_x\)/ITRL\(_x\) beyond TRL\(_x\).

No integration between TRL1 & TRL3: IRL(1, 3) = 0
ITRL3 = 0.59, SRL = 0.52

Integration between TRL1 & TRL3: IRL(1, 3) = 9
ITRL3 = 0.73, SRL = 0.58
1. Flawed FMECA RPN Rationale

The approach to estimating SRL is similar to the one used in Failure Mode Effects and Criticality Analysis or FMECA [Becker and Flick, 1996; Deb et al., 1998], where an ordinal datum, Severity, is transformed into a numerical value and combined with the probabilities of Occurrence (O) and Detection (D) to generate a Risk Priority Number (RPN).

2. Flawed AHP Rationale

Transforming ordinal data into numbers is also done in Analytical Hierarchy Process [Saaty, 1988], which allows the use of subjective human judgment to determine the relative importance of variables used in pair-wise comparisons to find an optimal solution to a problem. Sample applications can be found in Bahurmoz [2003] and Tavana [2003].

1. FMECA RPN Truth & Negative Example

1A. The RPN is NOT an integral element of the FMECA (NOT in Mil-Std-1629A)


– “RPN is an inconsistent risk-prioritization technique.”

– “It is valid to rank failure along a single ordinal dimension (e.g., “Severity”) but multiplying ordinal scale is not an “admissible transformation.”

2. AHP Truth & Negative/Non-Example

2A. Sauser & Co. don’t use pairwise comparison!


– “Rank reversal in the AHP has been a hotly contested subject for the last 30 years [Dyer, 1990a, 1990b; Harker and Vargas, 1990; Saaty, 1990, 2000; Triantaphyllou, 2000...]”
3. **GPA Truth & Negative/Non-Example**

- The GPA model is a **COMPENSATORY MODEL** and it does not have universal acceptance.
- Based on the educational system in some counties, I would argue that a project with a low SRL\textsubscript{X} for a critical technology X should not automatically proceed to the next phase even if the other SRLs and IRLs yield a sufficient high B. Sauser & Co. SRL.
- B. Sauser & Co. multiply TRLs by IRLs. The GPA does not multiply grades.
- Technologies are not equivalent to academic subjects. The effort to advance a sensor with a TRL of 5 to 7 has no relation to the effort to advance a power system from a TRL of 5 to 7.

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**B. Sauser & Co. SRL rationale fails content validity!**

- They use negative examples as positive examples and non-examples.
- They consider a SELECTIVE set of AHP and FMECA/RPN papers; i.e. those that are applications and discard those that investigate fallacies.
There are many simple ways to construct “Rational” system readiness measures

1. Simple tabular summary of technology & integration scores, TRLs/IRLs

<table>
<thead>
<tr>
<th>Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRL_X</td>
<td>#1</td>
<td>#2</td>
<td>#3</td>
<td>#4</td>
<td>#5</td>
<td>#6</td>
<td>#7</td>
<td>#8</td>
<td>#9</td>
</tr>
<tr>
<td>IRL_XY</td>
<td>#1</td>
<td>#2</td>
<td>#3</td>
<td>#4</td>
<td>#5</td>
<td>#6</td>
<td>#7</td>
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</table>

- \( \#_i \) is the number of technologies with TRL or IRL = level

2. Min-Min Principle

\[
SRL_{MM} = (\text{Min } \text{TRL}_i, \text{Min } \text{IRL}_{jk})
\]

- \( i, j, k \) denote subsystem technologies and integration elements

3. Other constructs …..

😊 The tabular summary and the Min-Min principle are rational measures that provide more useful information of system readiness/maturity than the B. Sauser & Co. SRL.

😢 BUT, they still DO NOT provide quantitative estimates of the schedule and cost for entering the next stage of the life cycle development including Performance, Cost, & Schedule Risks.
Please consider the Slide 12 example

1. Simple tabular summary of technology & integration scores, TRLs/IRLs

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<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRLX</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>IRLXY</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

2. Min-Min Principle

\[ SRL_{MM} = (6, 1) \rightarrow \text{Could be a serious problem!} \]

The tabular summary and the Min-Min principle provide visibility as well as valid and useful information of system status and require NO mathematics!
B. Sauser & Co. know that their SRL is flawed!

NEVERTHELESS, B. Sauser & Co. are aggressively promoting their SRL model and it is gaining acceptance as a program management tool.

• Analysis may result in rank reversals, where a less mature SRL receives a higher rating than a more mature SRL.
  ▫ The reason for this is that the rankings are ordinal scale numbers, and multiplication is not a valid operation on them. The ordinal rankings only say that one ranking is better or worse than another, but not by how much.

Educational, Professional, and Organizational Failings

Academic Research

Technical Journals

Professional Societies

Defense Industry SysComs

DoD Acquisition

Program Failures
Many unwitting accomplices

A stakeholder’s thoughts

Kujawski, 

requested some thoughts on your presentation of SRL material and view of SRL follow. 

sically, I concur with your view that there are 1s inherent in the use of SRL and that it does not provide an authoritatively accurate answer for the theorist. I believe Dr. Sauser would concur with the statement as well. However, I do believe that SRL remains a valid and useful tool for the SE and practitioner ....................

my view, SRL as a single number does provide a PM, similar to how Risk Rankings PNs), PRL's, TRL's, or IRL's value as a standalone value. Again concurring that all are subjective inputs that can be easily manipulated as y are not values directly linked to physical

ures but are interpretations of data that can be wed multiple ways. They are through the tools that the real world of Program Management uses to make critical and strategically choices. It is the province of the PM and his staff to interpret the available data and make the best choice possible in an imperfect world where accurate data and the ability to predict the occurrence of precisely seldom st................................

3. SAUSER & CO. SRL TRUMPING RATIONALITY AND VALIDITY!
Flawed ratings: Déjà vu

The Doomsday Machine

That average number. And herein lay a huge opportunity. A pool of borrowers all of whom had a score of 615 was far less likely to suffer huge losses than a pool of loans composed of borrowers half of whom had FICO scores of 680….

In Vegas it became clear to me that this entire industry was trusting in the ratings,” Eisman said. “Everyone believed in the ratings, so they didn’t have to think about it.”…

The pool of data gave you the general characteristics – the average FICO scores, the number of no-doc loan, and so forth – but no

In early 2007 Grant wrote a series of pieces suggesting that the rating agencies had abandoned their posts… For his troubles, Grant, along with his trusted assistant, was called into S&P for a dressing down. “We were actually summoned to the rating agency and told, “You guys just don’t get it,” says Gertner. “Jim used the term “alchemy” and they didn’t like that term…”
System readiness (capability, maturity) is too complex a concept to be described by a single number on the interval \((0, 1]\).

It is necessary to be wary of performing matrix algebra on ordinal information. The B. Sauser & Co. SRL is at best CABI!

The B. Sauser & Co. SRL is an attractively deceitful model
- It aggregates technology readiness/maturity scores and therefore it hides important information.
- It provides invalid and therefore worse than useless information.
- It removes a degree of decision-making from the acquisition process.

Cease use of the B. Sauser & Co. SRL
- Do it before it becomes too widespread and does serious harm.

Implement quantitative risk analysis
- Ensure successful acquisition based on performance, cost, & schedule risks for entering the acquisition life-cycle phase.
Managers need to build organizations that support good analysis

- “The softer scoring methods and half-baked, hybrid deterministic methods are of no value – stop using them.”
  

Good analysis requires SE operational rationality

- “It is our observation that much of system engineering practice suffers from a lack of rationality, while a significant body of system engineering literature suffers from an attempt to be excessively rational, at the expense of external correspondence (Occasionally practice also suffers from an attempt to be too rational).”
  

To those who funded, published, and/or used the B. Sauser & Co. SRL: Be honest with yourselves! Admit that you have been duped!
Questions/Comments?