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Using A System Maturity Scale to Monitor and Evaluate the Development of Systems

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SYSTEMS
Development &
Maturity Laboratory

Using a System Maturity Scale to Monitor and Evaluate the Development of Systems

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TRL Shortcomings

- Application of TRL to systems of technologies is not sufficient to give a holistic picture of complex system of systems readiness
  - TRL is only a measure of an individual technology
- Assessments of several technologies rapidly becomes very complex without a systematic method of comparison
- Multiple TRLs do not provide insight into integrations between technologies nor the maturity of the resulting system
  - Yet most complex systems fail at the integration points

But, what's missing…

- "Readiness" values tend to be *soft metrics*[1] that are:
  - Relatively easy to derive, but require a complementing rational that explains the assessment,
  - Human-intensive,
  - Subjective,
  - Contain inherent variations or ambiguity that is averaged away.

[1]Dowling, T. & Pardoe, T. (2005) 'TIMPA - Technology Insertion Metrics Volume 1', Ministry of Defence, United Kingdom, QinetiQ.

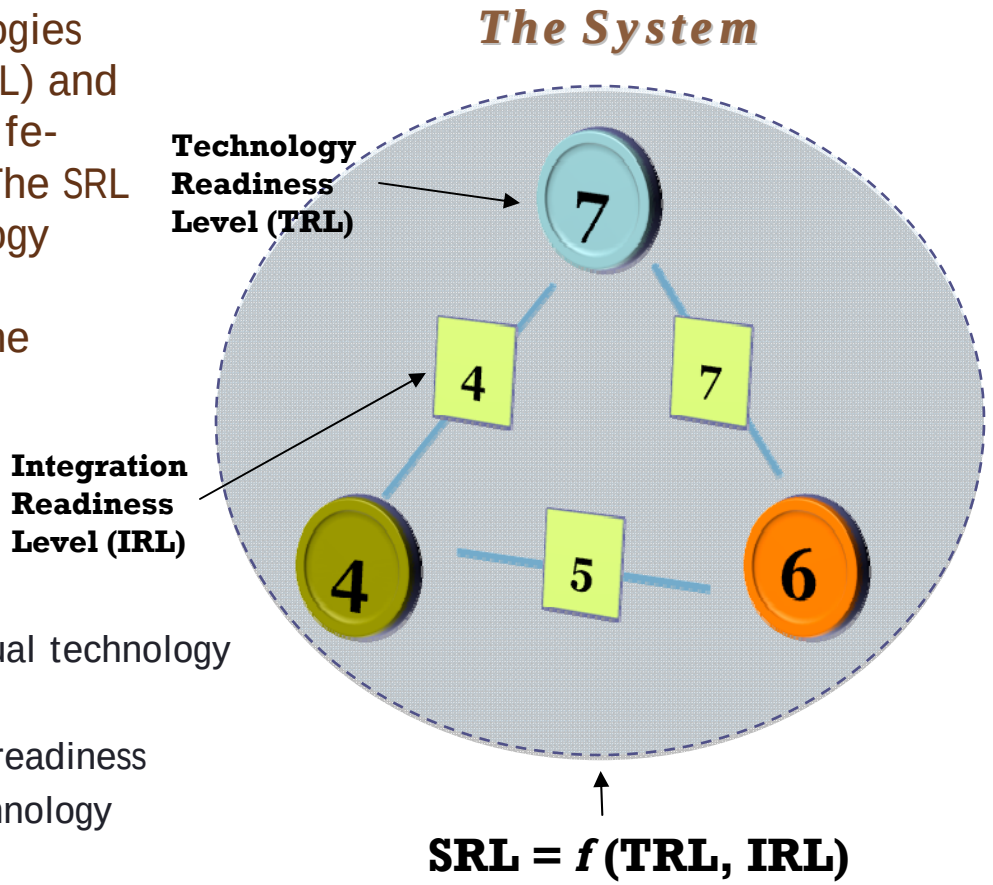
Integration Readiness Level

IRL	Definition
9	Integration is **Mission Proven** through successful mission operations.
8	Actual integration completed and **Mission Qualified** through test and demonstration, in the system environment.
7	The integration of technologies has been **Verified and Validated** with sufficient detail to be actionable.
6	The integrating technologies can **Accept, Translate, and Structure Information** for its intended application.
5	There is sufficient **Control** between technologies necessary to establish, manage, and terminate the integration.
4	There is sufficient detail in the **Quality and Assurance** of the integration between technologies.
3	There is **Compatibility** (i.e. common language) between technologies to orderly and efficiently integrate and interact.
2	There is some level of specificity to characterize the **Interaction** (i.e. ability to influence) between technologies through their interface.
1	An **Interface** between technologies has been identified with sufficient detail to allow characterization of the relationship.

Gove, R. (2007) *Development of an Integration Ontology for Systems Operational Effectiveness*. M.S. Thesis. Stevens Institute of Technology. Hoboken, NJ

What we are doing?

Development of metrics, tool, and methodologies for determining a systems readiness level (SRL) and potential for making efficient and effective life-cycle 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:**
  - Currently TRL is only a measure of an individual technology
  - There is no method for integrating TRLs
  - There is no systematic measure of a systems readiness
  - Cost and schedule reduction in strategic technology development planning
- **Deliverable:** Integration of methodologies for strategic roadmap planning that illustrate the timely implementation of capability increments.

SRL Calculation

- The SRL is not user defined, but is instead based on the outcomes of the documented TRL and IRL evaluations
- Through mathematically combining these two separate readiness levels, a better picture of overall complex system readiness is obtained by examining all technologies in concert with all of their required integrations

$$\mathbf{SRL = IRL \times TRL}$$

$$\begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} IRL_{11} & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_{22} & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_{33} \end{pmatrix} \times \begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix}$$

$$\text{Composite SRL} = 1/n \left(SRL_1/n + SRL_2/n + SRL_3/n \right)$$

$$= 1/n^2 \left(SRL_1 + SRL_2 + SRL_3 \right)$$

- These values serve as a decision-making tool as they provide a prioritization guide of the system's technologies and integrations and point out deficiencies in the maturation process

Sauser, B., J. Ramirez-Marquez, R. Magnaye, and W. Tan. (2008). "A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition." *International Journal of Defense Acquisition Management.*

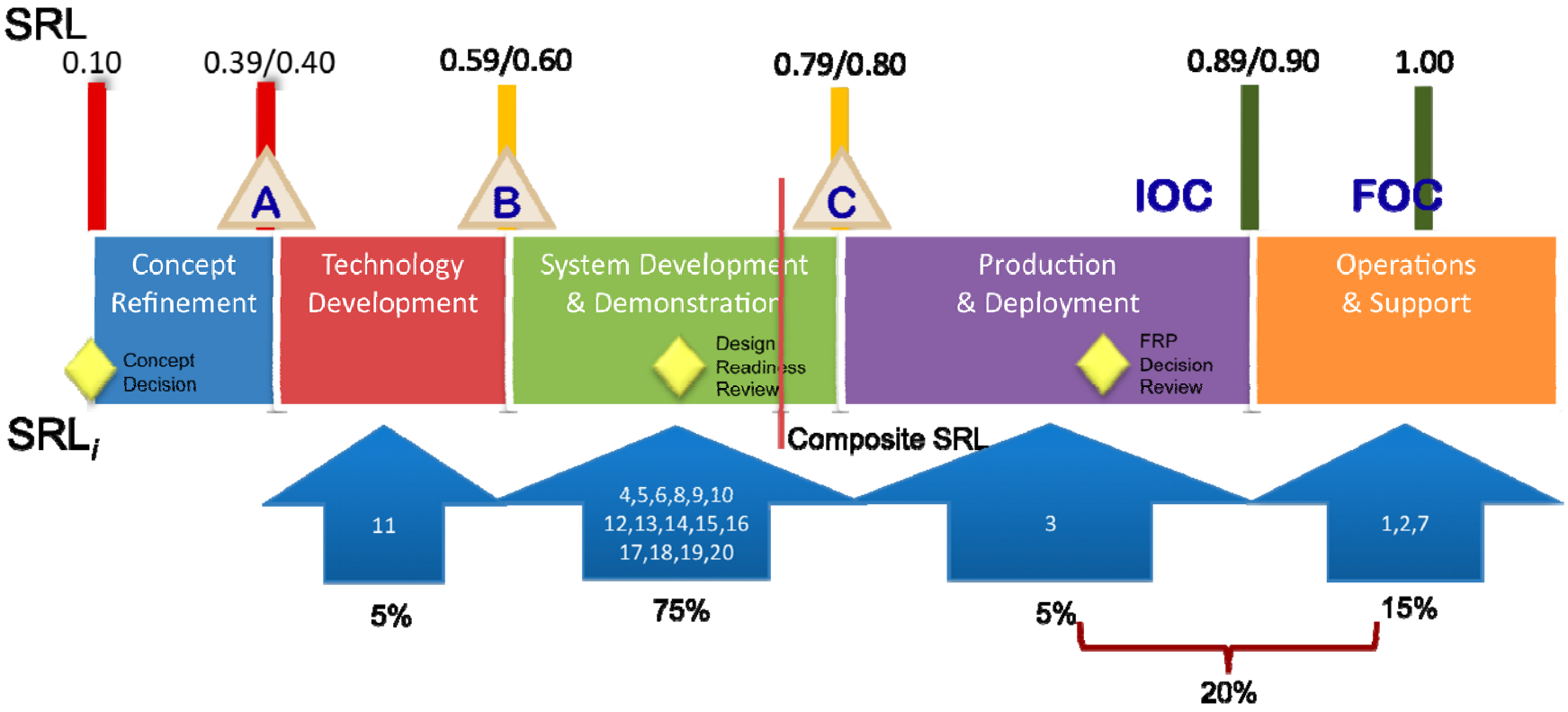
Key Assumptions and Limitations

- Ordinal data is given numeric value in order to assess overall progression or performance.
  - Grade Point Average (GPA), Failure Modes and Effects Analysis (FMEA)
- One system cannot be compared to the SRL of another system unless they are the same system.
  - You cannot compare a student with a 3.2 GPA in physics with a student that has a 3.8 GPA in biology. These students belong to different systems of education, but they are evaluated with the same system of metrics.
- Analysis is limited by the experience of previous assessments and experience of the assessors

Key Assumptions and Limitations

- 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.
- If used as a top-down tool, SRL may only identify major maturity deficiencies in a system.
  - When used as a "bottom-up" tool SRL can augment or complement other (systems) engineering management activities and identify many more maturity deficiencies resulting in top-level symptoms.

What it can tell us?



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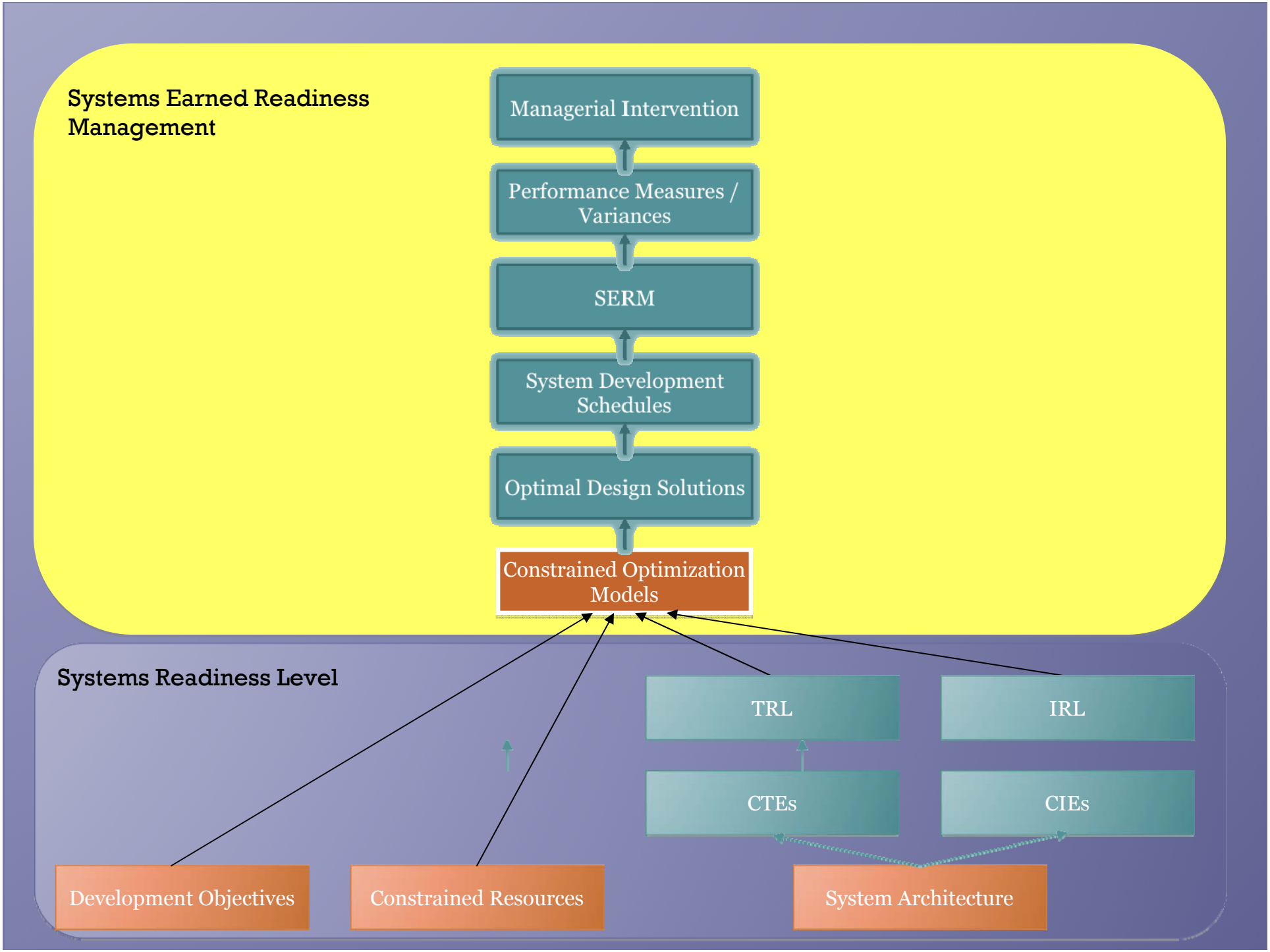

Systems Earned Readiness Management
Managerial Intervention
Performance Measures / Variances
SERM
System Development Schedules
Optimal Design Solutions
Constrained Optimization Models
Systems Readiness Level
TRL
IRL
CTEs
CIEs
Development Objectives
Constrained Resources
System Architecture

Resource Optimization Models and System Earned Readiness Management (SERM)

Generic Development Strategies:

- Optimize development cost – SCODmin Model
  - Magnaye, R., B. Sauser, J. Ramirez-Marquez, and W. Tan. (2008). "System Development Planning Using Readiness Levels in a Cost of Development Minimization Model." *Systems Engineering*.
- Optimize SRL (first-to-deploy) – SRLmax Model
  - Sauser, B.J. and J.E. Ramirez-Marquez. (2009). "System Development Planning via System Maturity Optimization." *IEEE Transactions on Engineering Management*. (in press; available at http://ieeexplore.ieee.org)
- Optimize system performance parameters

Other Development Strategies:

- Optimize system value
- Multi-objective optimization

SRL Resource Optimization

Model SRL_{max} = an optimization model with the objective to maximize the SRL (a function of TRL and IRL) under constraints associated with resources.

Year	Target SRL	TRL						IRL						
		1	2	3	4	5	6	1,2	1,3	2,3	2,4	3,5	4,5	5,6
6	1.000	9	9	9	9	9	9	9	9	9	9	9	9	9
5	0.896	9	9	9	8	9	9	9	9	9	8	8	5	7
4	0.792	8	9	9	6	9	9	9	9	9	5	8	4	6
3	0.688	8	8	9	6	9	9	8	8	7	5	7	2	4
2	0.584	8	8	8	6	7	6	7	7	7	5	6	2	4
1	0.480	8	8	7	6	6	6	5	6	6	5	6	2	2

SRL Resource Optimization

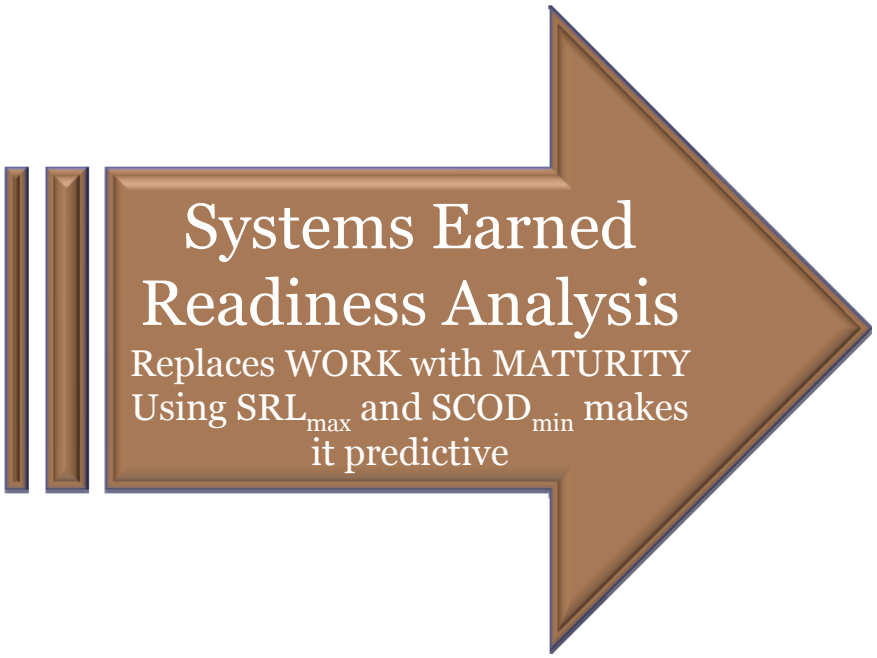
Model $SCOD_{min}$ = an optimization model whose objective is to minimize development cost (a function of TRL and IRL development) under constraints associated with schedule and the required SRL value.

Model	SRL	TRL						IRL						
		1	2	3	4	5	6	1,2	1,3	2,3	2,4	3,5	4,5	5,6
$SCOD_{min}$	0.69	8	***8***	9	6	9	9	8	8	***7***	5	7	2	***4***
SRL_{max}	0.73	8	***9***	9	6	9	9	8	8	***8***	5	7	2	***5***

Systems Earned Readiness Management

Earned value analysis

- Is a performance monitoring tool
- Provides a measure of performance that is:
  - Realistic?
  - Based on actual data?
- Provides answers to these questions:
  - What WORK is scheduled to have been completed?
  - What was the cost estimate for the WORK scheduled?
  - What WORK has been accomplished?
  - What was the cost estimated of the completed WORK?
  - What have our actual costs been?
  - What are the variances?



Model Based Systems Engineering

- Utilizing Model Based Systems Engineering (MBSE):
  - Setup an environment to model the current SRL approach;
  - Review other 'metrics' needed to be included and determine their relationships to TRL, IRL, and the System Architecture;
  - Provide a process for determining SRL within MBSE.
  - Determine a set of 'views' or diagrams on the model creation which enables a way to communicate (e.g. a System Maturity Diagram)
  - MBSE allows for the functional decomposition of models which would allow for a recursive SRL assessment whereby an SRL at one level transforms to a TRL at another.

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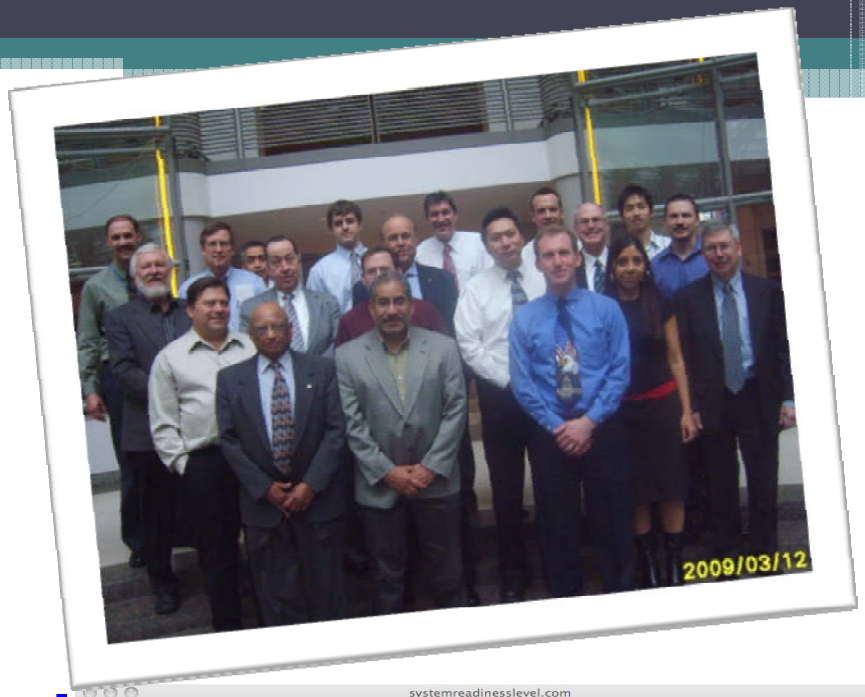

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WELCOME PUBLICATIONS RESEARCH CALCULATOR LEARN MORE SMA ROUNDTABLE

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MOVING BEYOND TRL...

SYSTEMS Development & Maturity Laboratory

WHAT WILL YOU FIND HERE...

The Technology Readiness Level (TRL) scale is a measure of maturity of an individual technology, with a view towards operational use in a system context. A comprehensive set of concerns becomes relevant when this metric is abstracted from an individual technology to a system context, which may involve interplay among multiple technologies that are integrated through the acquisition life cycle. This research has been pursuing the development of a system-focused approach for managing system development and making effective and efficient decisions during the acquisition life cycle. For this to be accomplished our research has been evolving in a series phases:

Phase 1 (10/06 – 09/07): Development of system maturity indices such as a System Readiness Level (SRL) and Integration Readiness Level (IRL) which work with TRL in order to assess developmental maturity during the acquisition life cycle;

Phase 2 (08/07 – 12/07): Validation and calibration of the systems maturity indices to the acquisition life cycle;

Phase 3 (12/07 – present): Building on the foundation of the SRL and providing techniques for determining current and future readiness of a system to determine its position in the acquisition life cycle.

We are now expanding Phase 3 into a program of research to explore the optimization of the SRL index based on constrained resources to provide a decision support approach to enhance managerial capabilities and create a systems life cycle maturity management approach, which we define as **System Earned Readiness Management (SERM)**. Alternatively to Earned Value Management (EVM), SERM addresses the earned readiness or maturity of systems development as it equates to the acquisition life cycle.

There is a need for "...research in developing more formal metrics and models for determining systems engineering effectiveness for enabling continuous improvement."

- Kelly Miller, Chief Systems Engineer, NSA at the 2005 Conference on Systems Engineering Research

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LEADING INDICATORS IN SYSTEM MATURITY

Beyond Technology Readiness Level...

March 12, 2009 **Washington, DC**

TOPICS RELATED TO SYSTEM MATURITY ASSESSMENT

LIFECYCLE FORECAST &PLANNING
The ability to consider additional maturity metrics and obsolescence through comparative analysis of multiple technologies in trade studies, spiral development, or evolutionary acquisition.

SYSTEMS ARCHITECTURE
The ability to collectively evaluate component integration and system readiness to reduce developmental risks as it relates to a systems architecture.

POLICY AND DIRECTIVES
Dynamic systems assessment platforms with a set of rules, guidelines, and ontology for consistency, repeatability and traceability during

FOCUS

The Technology Readiness Level (TRL) scale is a measure of maturity of an individual technology, with a view towards operational use in a system context. A comprehensive set of concerns becomes relevant when this metric is abstracted from an individual technology to a system context, which may involve interplay among multiple technologies that are integrated through a developmental life cycle. This research symposium is **focused on innovations in system maturity indices for the development of a system-focused approach for managing system development and making effective and efficient decisions.**

PURPOSE

The purpose of this roundtable is to provide system designers and developers, program and project managers, and researchers a platform to discuss and disseminate emerging knowledge in systems maturity indices (beyond TRL). The objective is **to create a community of practitioners and researchers focused on new knowledge in system maturity indices and assessment.**

FORMAT

For the first half of day one, Presentation Sessions will run in succession and comprise presentations from Stakeholders on the emerging challenges and potential solutions in systems maturity indices and assessment. The sessions will be run in a panel/discussion format to assure all attendees are engaged in the **knowledge exploration.** For the second half of day one, breakout groups will be asked to address these three questions with respects to the future of systems maturity assessment:

1. **What are the real questions?**
2. **What do we know?**
3. **What do we need to know?**

SMA Roundtable – Preliminary Results

- What are the real questions?
  - What is SRL useful for? To ensure stakeholders and users that the program is progressing satisfactorily.
  - Are existing metrics adequate to define SRL?
  - What has changed that makes SRL necessary? Hardware and software complexity have increased by several orders of magnitude, more complex interfaces, & systems are no longer stovepiped.
  - How broadly can the SRL be applied. Is it flexible and scalable to SoS, software, integration?

SMA Roundtable – Preliminary Results

- What do we know?
  - We have TRL
  - Systems are complex
  - Some alternatives exist
  - Interfaces are difficult
  - Technologies are changing rapidly (Moore's law)
  - Assessment taxonomies vary
  - Management likes single numbers
  - Requirements creep impacts schedule performance

SMA Roundtable – Preliminary Results

- What do we need to know?
  - We need better data for acquisition decisions
  - We need better fidelity tools to aid in making decisions (integrated tool set to handle metrics, portfolios, enterprises)
  - We need to know how to validate the SRL assessment criteria against actual performance. Are there any success / failure stories (case studies)?

SMA Roundtable – Preliminary Results

- What could we do to learn that?
  - Look for case studies for successes/failures and identify the data that warns of program failure.
  - Perform a tool gap analysis
  - Survey stakeholders/users to determine what criteria they feel indicates maturity
  - Conduct a pilot program to validate SRL
  - New issues are emerging and need to be addressed
    - System assurance
    - Trusted sources
    - Information assurance
    - Industrial base adequacy

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