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Evaluating Complex System Development Maturity

The Creation and Implementation of a System Readiness Level for Defense Acquisition Programs

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Overview

- Defining the Need
- SRL Methodology
- Refinement, Verification and Validation
- Implementation / Application
- Next Steps

The Complex System Development Problem

- A 2006 Government Accountability Office study of DOD technology development practices concluded:
  - A lack of insight into the technical maturity of complex systems during development has contributed to an environment of:
    - Significant cost overruns
    - Schedule slips leading to program delays
    - Canceled acquisition efforts
    - Reduced system performance at fielding

- These symptoms will only grow worse as demands for rapid development and quick delivery increase
- DOD needs to strengthen its technology development monitoring and gate review processes

"Over the next 5 years, many of the programs in our assessment plan to hold design reviews or make a production decisions without demonstrating the level of technology maturity that should have been there before the start of development."

U.S. Government Accountability Office on the Department of Defense, 1999

GAO 06-883 "Best Practices: Stronger Practices Needed to Improve DOD Transition Process"

Defining Program Office Needs

- PEO LMW / PMS 420 is responsible for the development and integration of a series of Mission Modules to be used on the Littoral Combat Ship
- Modules leverage considerable amounts of technology from existing programs of record while also conducting new development
- Keys aspects of the project include not only monitoring the status of technology development, but also the maturity of the numerous integrations between those technologies
- This has resulted in a very complex and diverse system of systems engineering activity with a need to obtain quick and accurate snapshots of program status, risks, and issues

Methodology

TRL Shortcomings

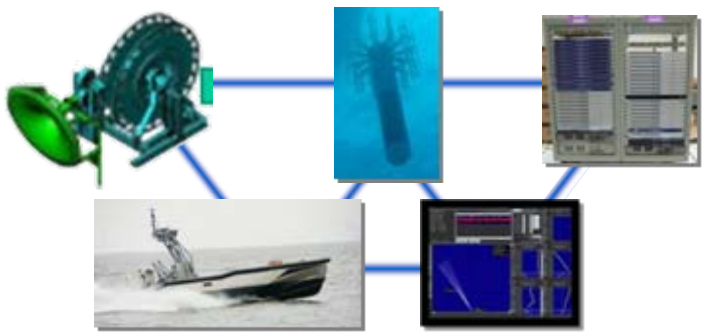
- Application of TRL to systems of technologies is not sufficient to give a holistic picture of complex system of systems readiness
  - TRL is only a measure of an individual technology
- Assessments of several technologies rapidly becomes very complex without a systematic method of comparison
- Multiple 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

Individual Technology

Can TRL be applied?

Yes

System of Technologies



Can TRL be applied?

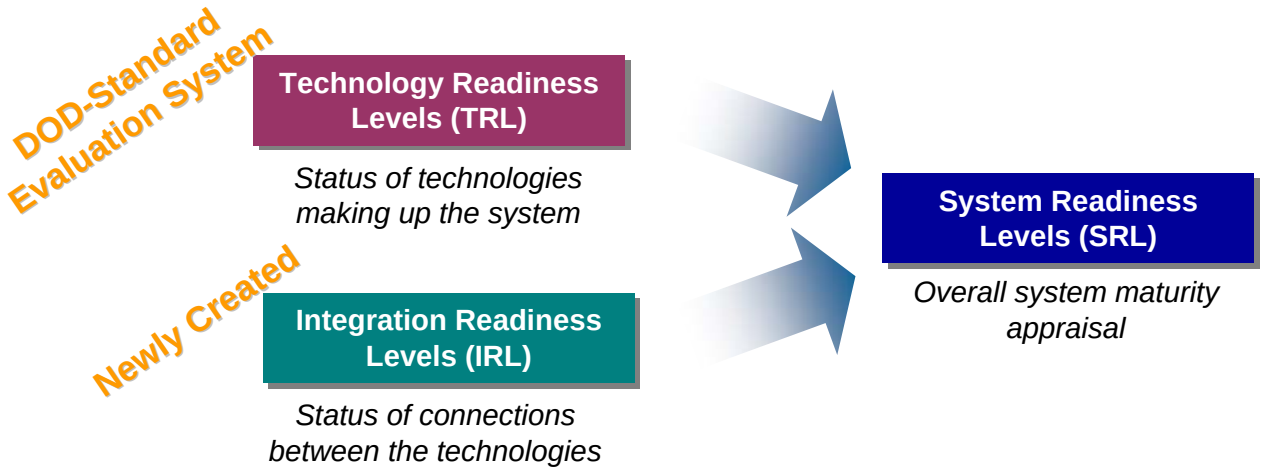
NO

Methodology Development Overview

GOAL: Institute a robust, repeatable, and agile method to monitor / report system development and integration status

APPROACH

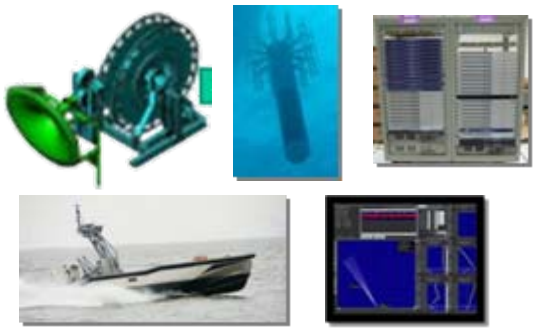
Create a System Readiness Level (SRL) that utilizes SME / developer input on technology and integration maturity to provide an objective indication of complex system development maturity



- 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 system engineering development efforts
- Can be applied as a **predictive** tool for technology insertion trade studies and analysis

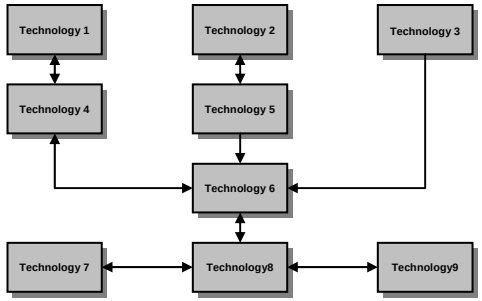
SRL Methodology and Analysis Flow

Step 1: Identify hardware and software components



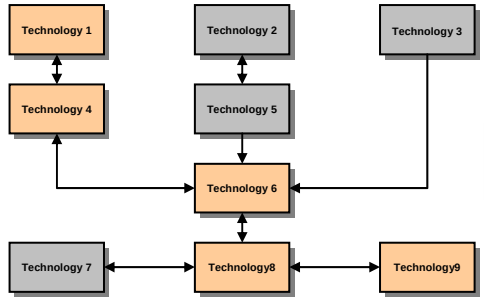
Include all technologies that make-up the overall system

Step 2: Define network diagram for systems



Emphasis is on the proper depiction of hardware and software integration between the components

Step 3: Define system operational strings *(If applicable)*



String analysis allows for the option of weighting the most important components and evaluation of alternate operational states

Initial Architecture Definition and Setup

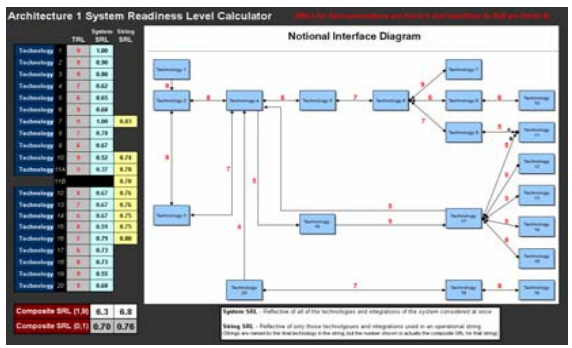
Step 4: Apply detailed TRL and IRL evaluation criteria to components and integrations

%	Integration Maturity Level 1
100	Components to be integrated are selected
100	Component interface points are identified
100	Documented phase/build plan for component availability
100	Data types identified

%	Technology Readiness Level 1
100	Physical laws and assumptions used in new technologies defined
50	Have some concept in mind that may be realizable in software
25	Know what software needs to do in general terms
30	Paper studies confirm basic principles and system concepts
N/A	Mathematical formulations of concepts that might be realizable in software
100	Have an idea that captures the basic principles of a possible algorithm
0	Basic scientific principles observed
100	Research hypothesis formulated
75	Identify who will perform research and where it will be done
60	**Readiness Level Percent Complete** (non-weighted)

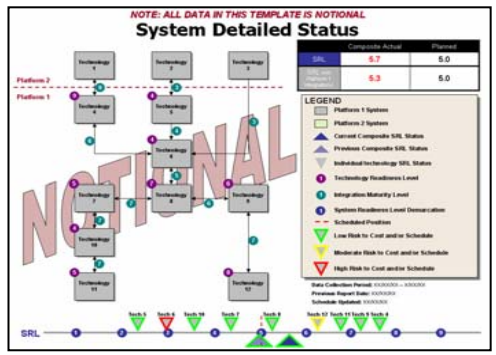
Checklist style evaluation allows for the ability to "take-credit" for steps that have taken place beyond the current readiness level

Step 5: Calculate individual and composite SRLs



Input TRL and IRL evaluations into algorithm to compute an assessment of overall system status via SRLs

Step 6: Document status via roll-up charts



Populate reporting chart templates with evaluation and calculation outcomes to highlight both current status and performance over time

Iterative SME Evaluation Throughout Development Cycle

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

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

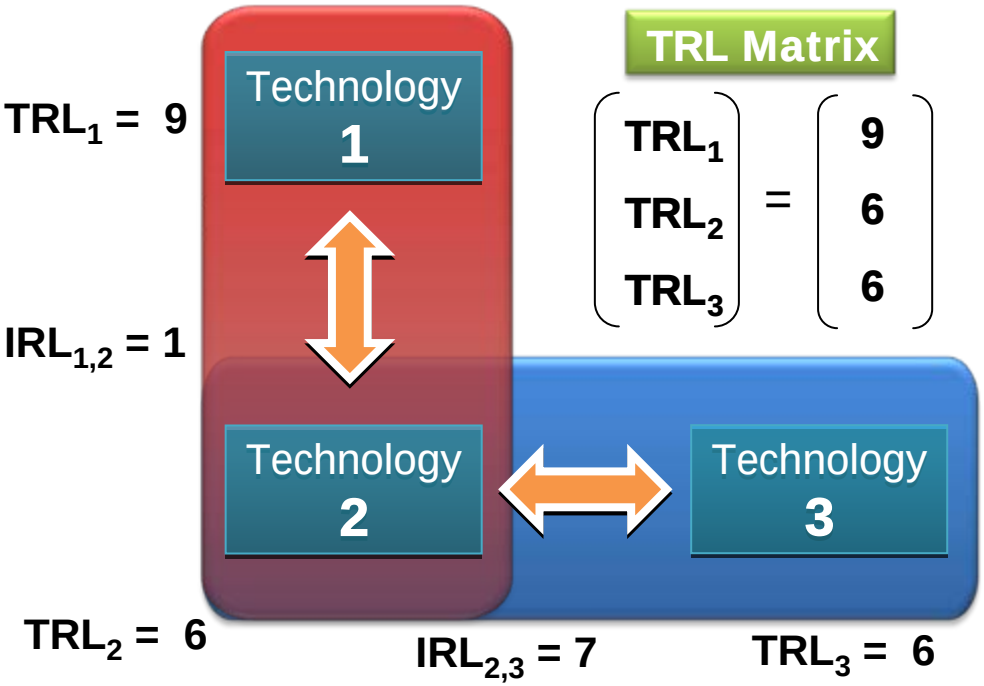
$$\begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} IRL_{11} & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_{22} & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_{33} \end{pmatrix} \times \begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix}$$

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

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

- 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

SRL Calculation Example



TRL Matrix

$$\begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix} = \begin{pmatrix} 9 \\ 6 \\ 6 \end{pmatrix}$$

IRL Matrix

$$\begin{pmatrix} IRL_1 & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_2 & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_3 \end{pmatrix} = \begin{pmatrix} 9 & 1 & 0 \\ 1 & 9 & 7 \\ 0 & 7 & 9 \end{pmatrix}$$

SRL = IRL x TRL
(Normalized)

$$\text{Component SRL} = \begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} 0.54 & 0.43 & 0.59 \end{pmatrix}$$

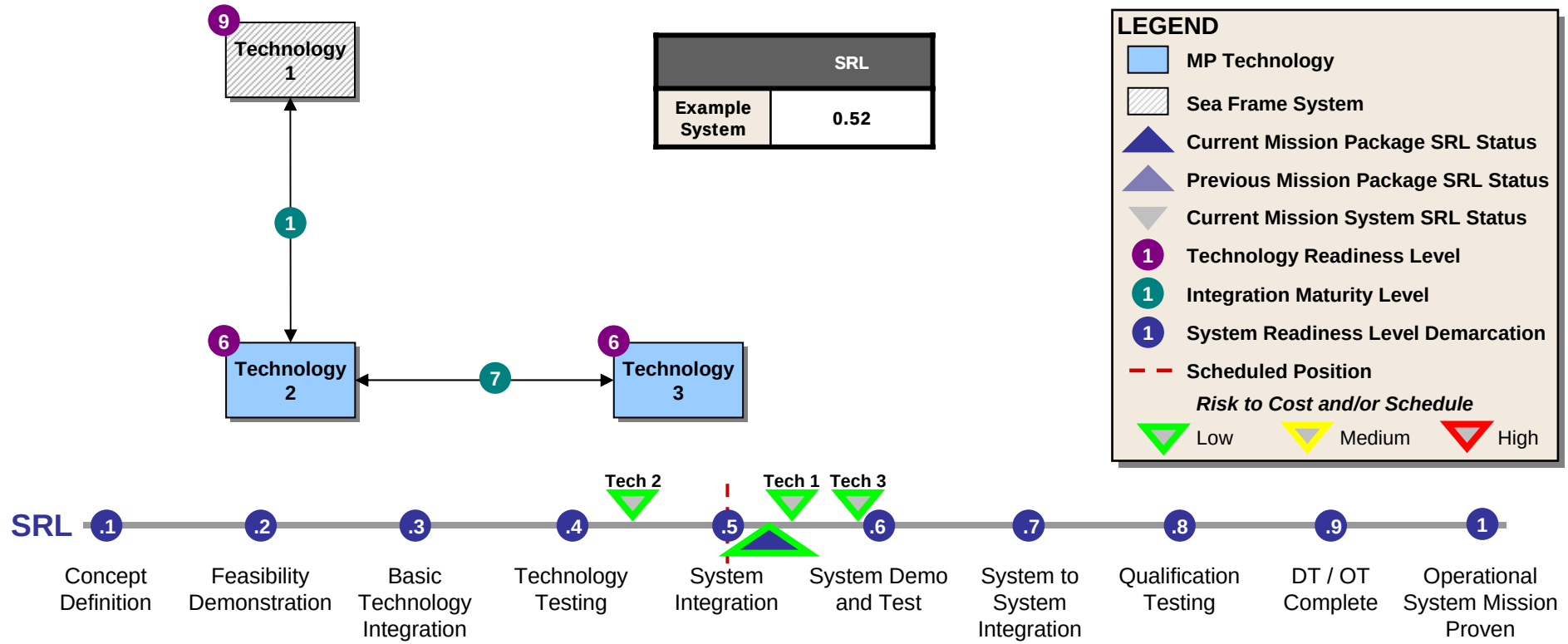
Component SRL_x represents Technology "X" and its IRLs considered

$$\text{Composite SRL} = 1/3\ (\ 0.54 + 0.43 + 0.59\ ) = 0.52$$

The Composite SRL provides an overall assessment of the system readiness

Sauser, B., J. Ramirez-Marquez, D. Henry and D. DiMarzio. (2007). "A System Maturity Index for the Systems Engineering Life Cycle." *International Journal of Industrial and Systems Engineering*. 3(6). (forthcoming)

SRL Reporting Method



- For complex systems, the amount of information obtained from the SRL evaluation can be overwhelming
- To maximize applicability SRL outputs are tied to key, program- specific development milestones
- Progress against these milestones provide key insight to the user regarding current program status, risk and progress

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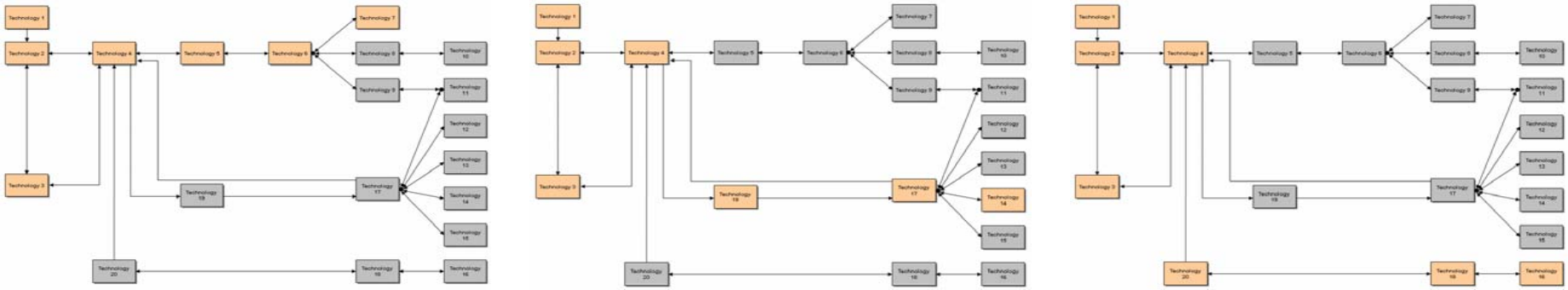
Refinement, Verification and Validation

“String” Analysis Incorporated

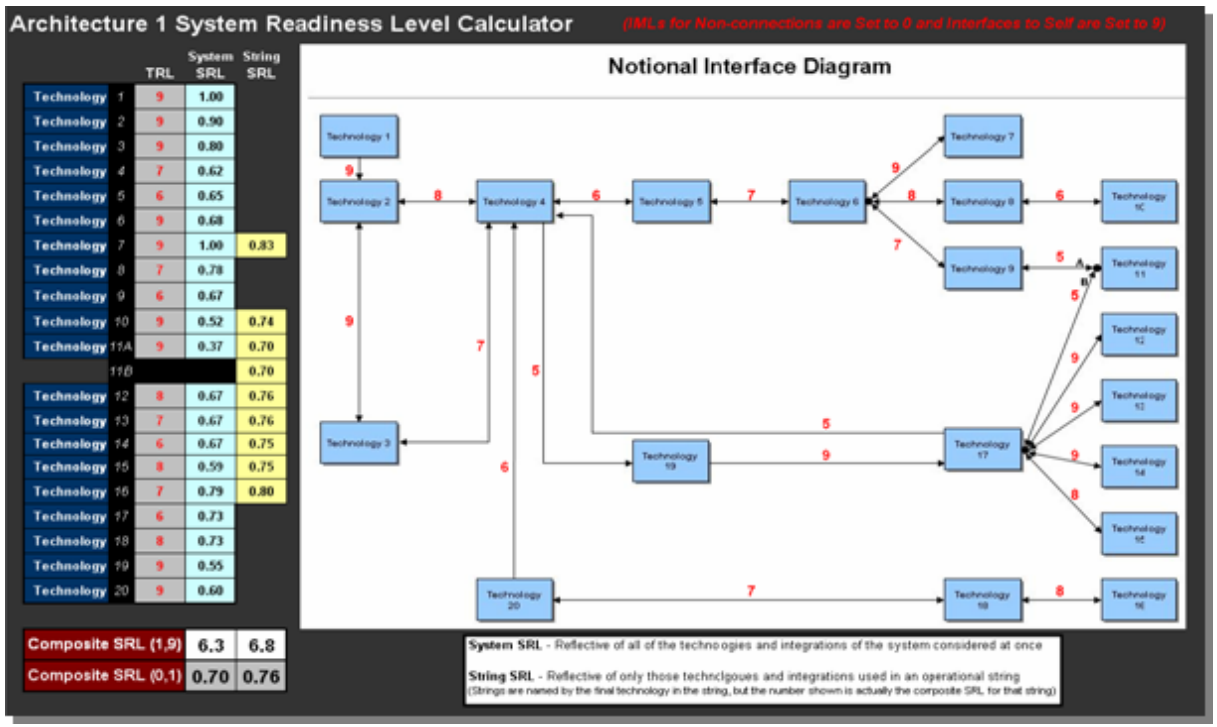
Complex systems often offer numerous options for conducting operations



- Operational strings were created that identified the components required to utilize a single function of the system
- Assessment of the SRL for each of these options allows for a better understanding of the maturity of each operating configuration
- Understanding the true status of the system on an operational string level allows for the opportunity to field initial capability earlier and then add to it as other strings mature

SRL Calculators Developed

- Calculators are developed and defined for the system being evaluated
- Allows for real-time updates to TRL and IRL inputs and the resulting SRL evaluation providing decision-makers with instant feedback on “what if” scenarios
- Intuitive interface removes the need for the user to manipulate and deal with the mathematics of the SRL calculation



	TRL	System SRL	String SRL
Technology 1	9	1.00	
Technology 2	9	0.90	
Technology 3	9	0.80	
Technology 4	7	0.62	
Technology 5	6	0.65	
Technology 6	9	0.68	
Technology 7	9	1.00	0.83
Technology 8	7	0.78	
Technology 9	6	0.67	
Technology 10	9	0.52	0.74
Technology 11A	9	0.37	0.70
11B			0.70
Technology 12	8	0.67	0.76
Technology 13	7	0.67	0.76
Technology 14	6	0.67	0.75
Technology 15	8	0.59	0.75
Technology 16	7	0.79	0.80
Technology 17	6	0.73	
Technology 18	8	0.73	
Technology 19	9	0.55	
Technology 20	9	0.60	
Composite SRL (1,9)		6.3	6.8
Composite SRL (0,1)		0.70	0.76

Verification and Validation Activities

IRL Criteria

- Created expanded list of IRL criteria for each readiness level
- Goal was to capture the key elements of the integration maturation process
- Presented to 30 integration SMEs from across government, academia, and industry
- Asked to assess importance of each criterion
- Results show solid buy-in among SMEs that identified criteria are key factors in successful integration

SRL Evaluation Process

- Conducted a “blind trial” of SRL methodology and evaluation process
- User’s Guide and evaluation criteria were sent to key system SMEs
- From just these resources SMEs were asked to conduct the evaluation and report on the results
- Compiled results and iterated on lessons learned to improve the process

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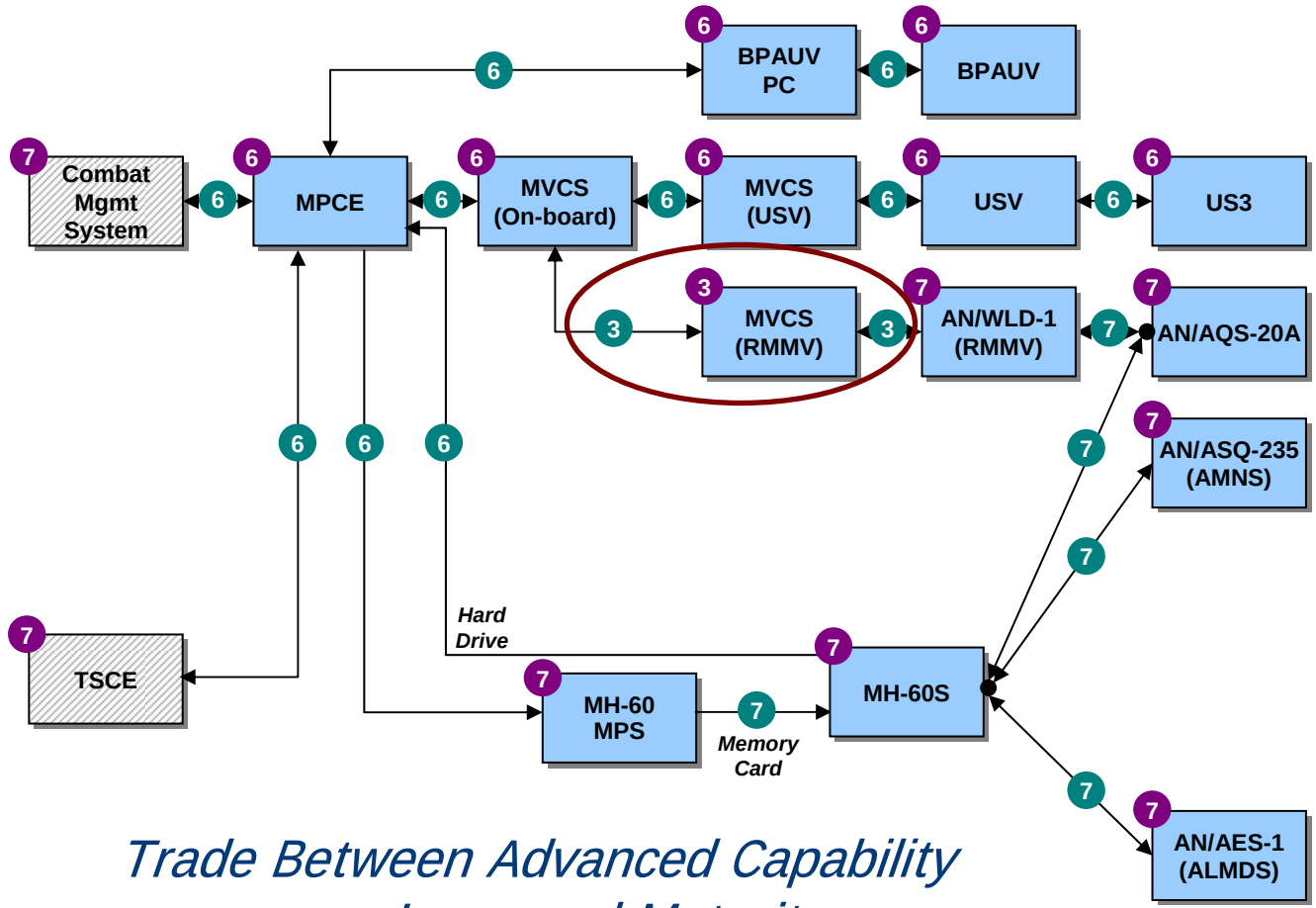
Implementation / Application

Trading Off Technology Options



	MP SRL	MP SRL w/o Sea Frame
MP 1	0.60	0.57

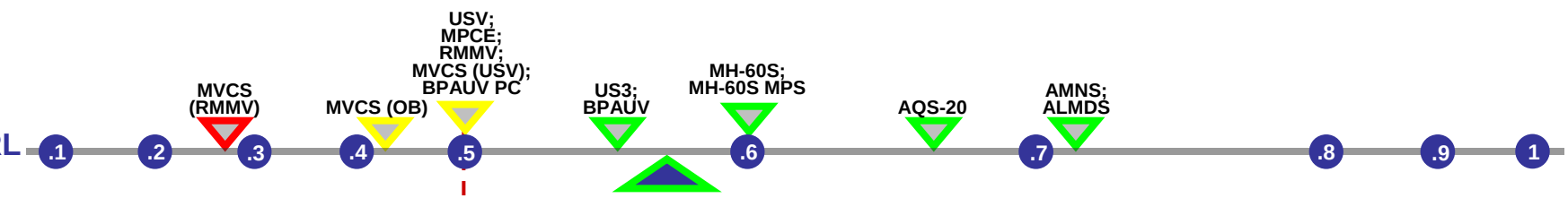
LEGEND

- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- Technology Readiness Level
- Integration Maturity Level
- System Readiness Level Demarcation
- Scheduled Position

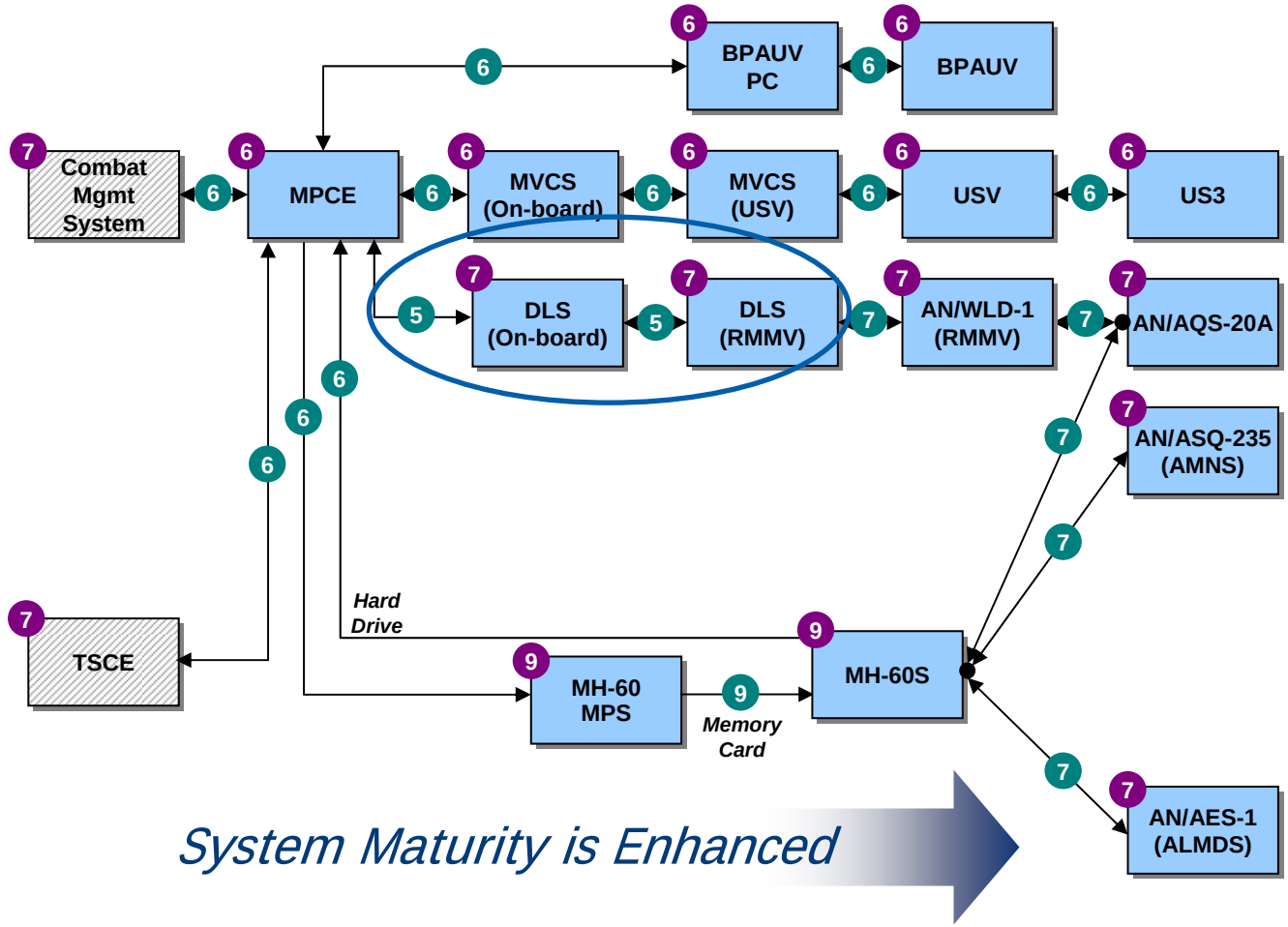
Risk to Cost and/or Schedule

Low Medium High

Trade Between Advanced Capability or Increased Maturity



Taking Action to Mitigate Risk



	MP SRL	MP SRL w/o Sea Frame
MP 1	0.64	0.67

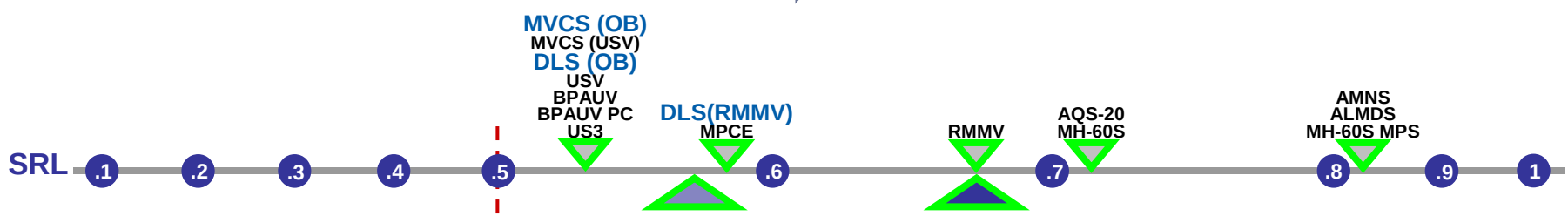
LEGEND

- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- Technology Readiness Level
- Integration Maturity Level
- System Readiness Level Demarcation
- Scheduled Position

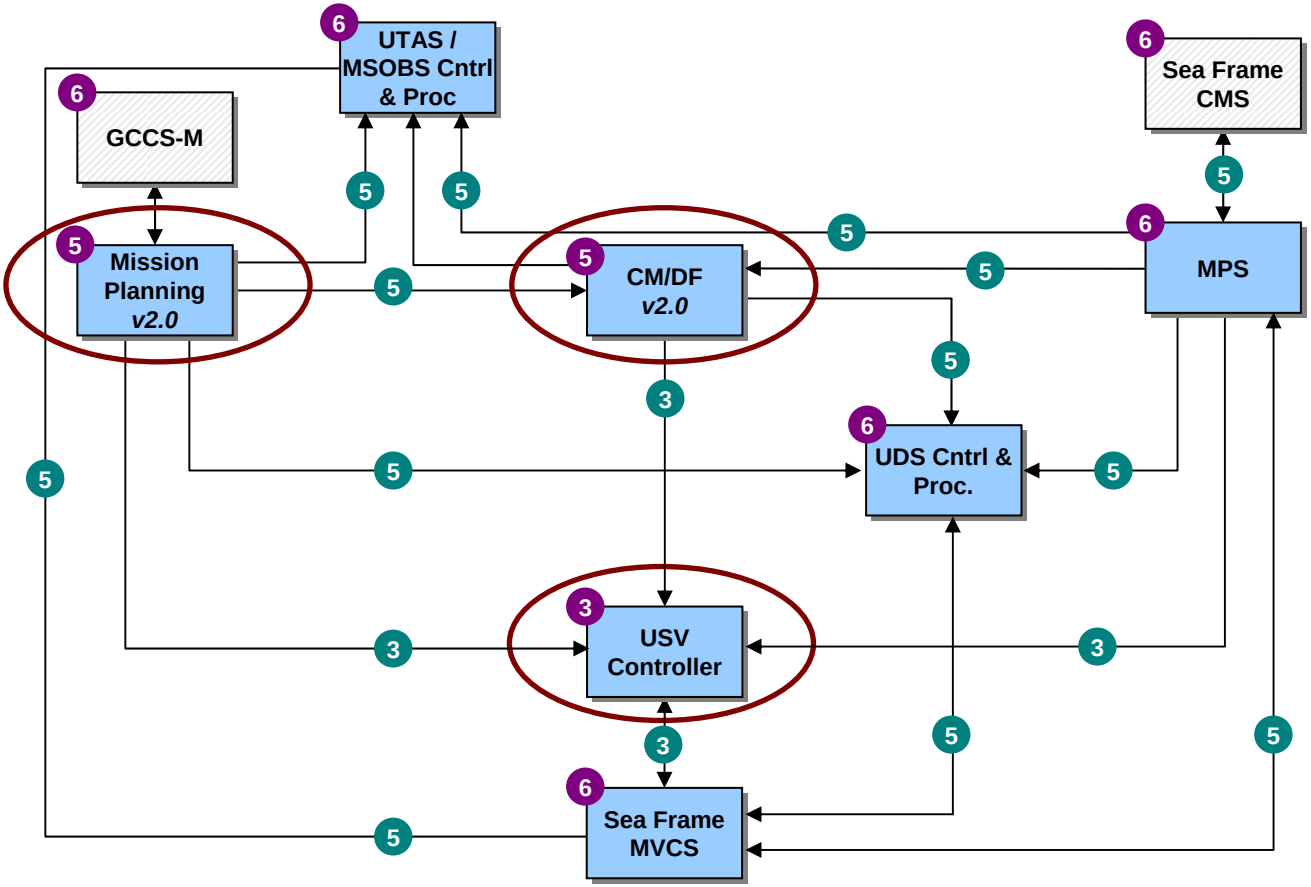
Risk to Cost and/or Schedule

Low Medium High

System Maturity is Enhanced



Planning for the Unexpected



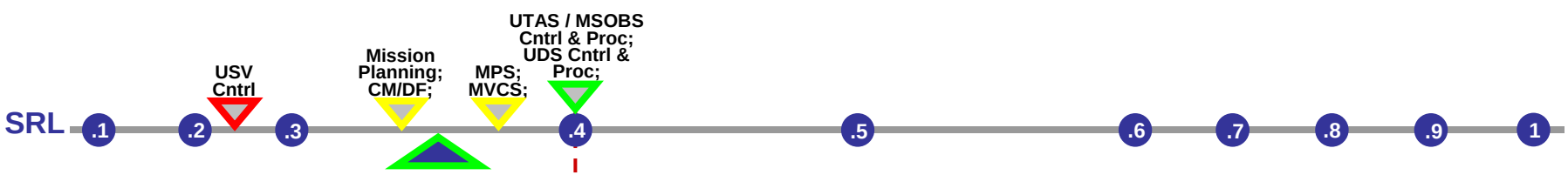
	MP SRL	MP SRL w/o Sea Frame
MP SW	0.39	0.35

LEGEND

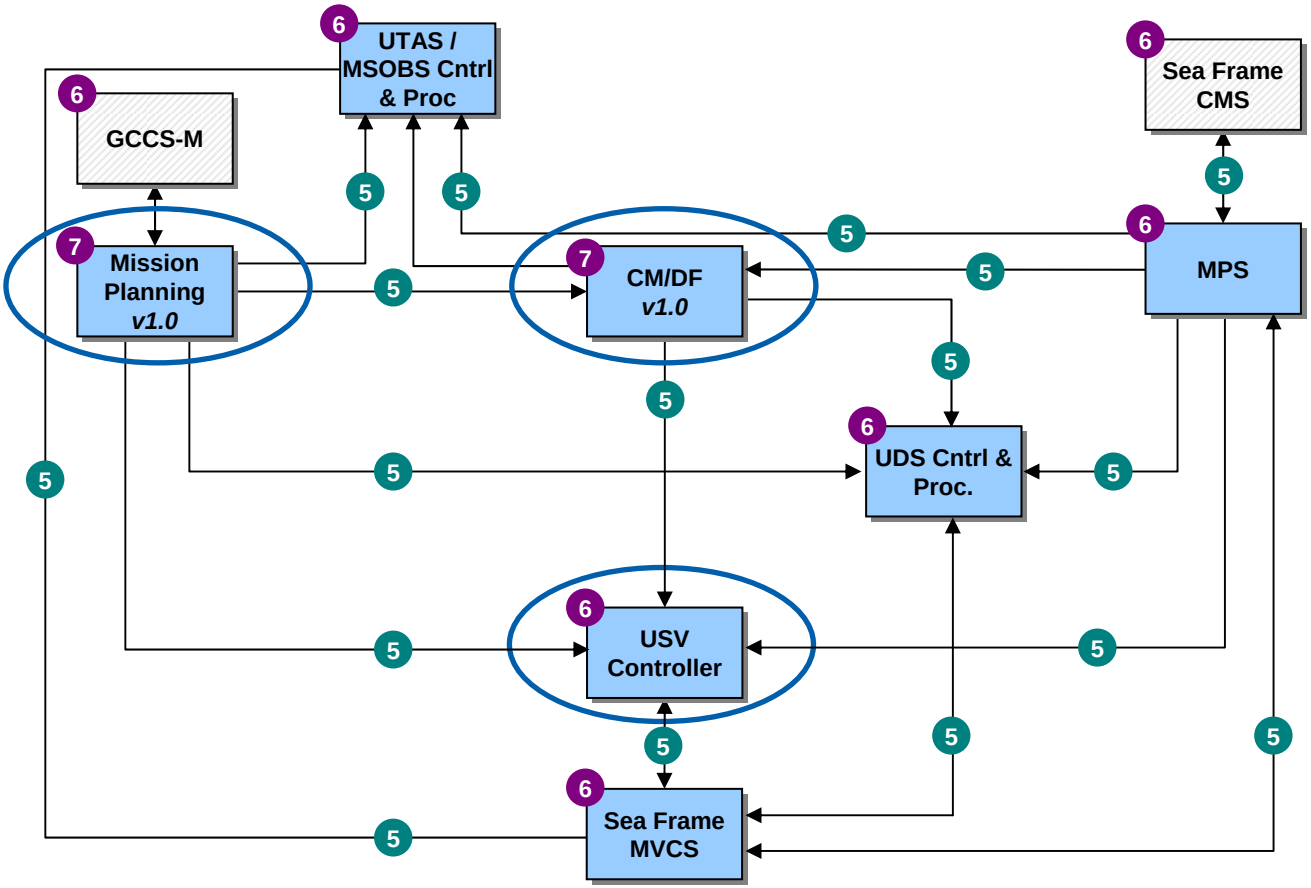
- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- 1 Technology Readiness Level
- 1 Integration Maturity Level
- 1 System Readiness Level Demarcation
- Scheduled Position

Risk to Cost and/or Schedule

Low Medium High



Effectively Channeling Resources



	MP SRL	MP SRL w/o Sea Frame
MP SW	0.46	0.45

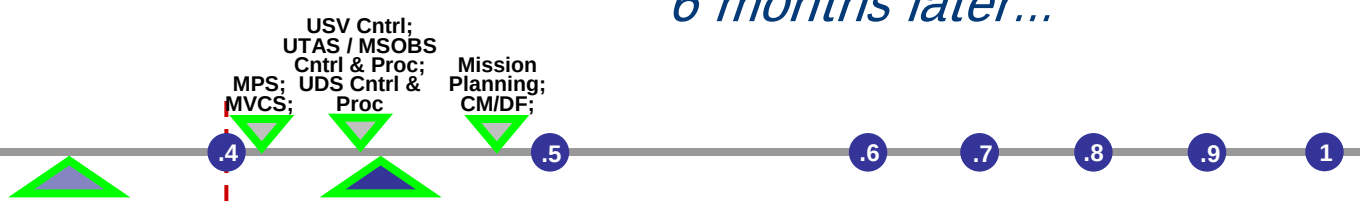
LEGEND

- MP Technology
- Sea Frame System
- Current Mission Package SRL Status
- Previous Mission Package SRL Status
- Current Mission System SRL Status
- 1 Technology Readiness Level
- 1 Integration Maturity Level
- 1 System Readiness Level Demarcation
- Scheduled Position

Risk to Cost and/or Schedule

Low Medium High

6 months later...



Lessons Learned

- Methodology is highly adaptable and can be quickly applied to a wide variety of development efforts
- Programs tend to minimize the importance of system and subsystem integration and thus overestimate the maturity of their development
- Widespread familiarity with TRL makes acceptance and utilization of TRL and IRL easier
- Formulating the system architecture early in development is a key step and leads to an enhancement of the overall systems engineering effort
- System architecture formulation also provides the opportunity to bring together SMEs from both the physical and logical realms and necessitates insightful discussions across the team
- The decision maker is afforded the ability to asses program status from a system of systems perspective

The SRL methodology delivers a holistic evaluation of complex system readiness that is robust, repeatable, and agile

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Next Steps

Future Work and Applications

SRL methodology can be used not only to assess current program performance against plan, but also to roadmap and assess future development options

Future work will focus on the creation of an interactive technology insertion options tradeoff and decision environment

Key Aspects:

- Development of a tool to assess technology options and architectures
- Incorporation of a semi-automated tradeoff capability that considers SRL, cost, risk, schedule, and performance impact
- Gathering of data from potential suppliers detailing how they fit into the defined architecture and the maturity of their product

Applications:

- Future technology, obsolescence, and upgrade planning

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QUESTIONS?

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Back-up

Abstract

A 2006 Government Accountability Office study of Department of Defense (DoD) technology transition processes concluded that a lack of insight into the technical maturity of complex systems during development has lead to an environment of program cost overruns, schedule slips, and reduced performance. A key aspect of current development practices is the reliance on the Technology Readiness Level (TRL) as a core provider of maturity assessments. While the TRL has been well proven for its effectiveness in gauging individual technology maturity in research and development applications, its extrapolation to the complex systems of systems integration dictated by emerging DoD requirements brings about a host of issues. Principally, by looking only at the status of individual component technical maturity, TRL fails to account for the complexities involved in the integration of these components into a functional system and creates the opportunity for performance gaps to remain hidden until late in the development cycle.

To address this lack of a true system-level maturity analysis process, the Northrop Grumman Corporation, the Stevens Institute of Technology, and NAVSEA have collaborated to create and implement a methodology known as the System Readiness Level (SRL). The SRL is a composite rating system relying on input from the traditional TRL scale as well as a new readiness gauge known as the Integration Maturity Level (IRL). These two scales are combined analytically to provide a systems readiness indicator that yields a holistic assessment of both the maturity of individual technologies within a system as well as the status of their corresponding integrations and interdependencies. This presentation will detail the application and value of this methodology to complex DoD integration efforts as well as the theory behind the SRL concept and the steps taken to minimize ambiguity and subjectivity in the evaluation process. Through this it will be shown that the SRL is an effective tool for system maturity and risk monitoring and contributes greatly to enhancing development program performance for complex systems.

Detailed SRL Calculation Example

Matrix Setup

- The computation of the SRL is a function of two matrices:
  - The TRL Matrix provides a blueprint of the state of the system with respect to the readiness of its technologies. That is, TRL is defined as a vector with *n* entries for which the *i*th entry defines the TRL of the *i*th technology.
  - The IRL Matrix illustrates how the different technologies are integrated with each other from a system perspective. IRL is defined as an $n \times n$ matrix for which the element IRL*ij* represents the maturity of integration between the *i* th and *j* th technologies.
- Populate these matrices with the appropriate values from the previously documented TRL and IRL component evaluations and then normalize to a (0,1) scale by dividing through by 9
- For an integration of a technology to itself (e.g. IRL_{nn}) a value of "9" should be placed in the matrix
- For an instance of no integration between technologies a value of "0" should be placed in the matrix

$$[TRL]_{n\times 1} = \begin{bmatrix} TRL_1 \\ TRL_2 \\ \dots \\ TRL_n \end{bmatrix} \qquad [IML]_{n\times n} = \begin{bmatrix} IML_{11} & IML_{12} & \dots & IML_{1n} \\ IML_{21} & IML_{22} & \dots & IML_{2n} \\ \dots & \dots & \dots & \dots \\ IML_{n1} & IML_{n2} & \dots & IML_{nn} \end{bmatrix}$$

Decision Support Metrics for Developmental Life Cycles, Users Guide: Version 2.0, Northrop Grumman Corp. and Stevens Institute of Technology, 5 September 2007

Detailed SRL Calculation Example

Calculation

- Obtain an SRL matrix by finding the product of the TRL and IRL matrices

$$[SRL]_{n\times 1} = [IML]_{n\times n} \times [TRL]_{n\times 1}$$

- The SRL matrix consists of one element for each of the constituent technologies and, from an integration perspective, quantifies the readiness level of a specific technology with respect to every other technology in the system while also accounting for the development state of each technology through TRL. Mathematically, for a system with *n* technologies, [SRL] is:

$$[SRL] = \begin{bmatrix} SRL_1 \\ SRL_2 \\ \dots \\ SRL_n \end{bmatrix} = \begin{bmatrix} IML_{11}TRL_1 + IML_{12}TRL_2 + \dots + IML_{1n}TRL_n \\ IML_{21}TRL_1 + IML_{22}TRL_2 + \dots + IML_{2n}TRL_n \\ \dots \\ IML_{n1}TRL_1 + IML_{n2}TRL_2 + \dots + IML_{nn}TRL_n \end{bmatrix}$$

Decision Support Metrics for Developmental Life Cycles, Users Guide: Version 2.0, Northrop Grumman Corp. and Stevens Institute of Technology, 5 September 2007

Detailed SRL Calculation Example

Analysis

- Each of the SRL values obtained from the previous calculation would fall within the interval (0, # of Integrations for that Row). For consistency, these values of SRL should be divided by the number of integrations for that row of the matrix to obtain the normalized value between (0,1). (e.g. if there are four non-zero numbers in the IRL matrix for that row, divide by four)
- This number should then be multiplied by 9 to return to the familiar (1,9) scale
- For Example:

$$\begin{pmatrix} IRL_1 & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_2 & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_3 \end{pmatrix} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 7 \\ 0 & 7 & 0 \end{pmatrix}$$

1 Integration (Divide SRL for that Row by 1 and multiply by 9)

2 Integrations (Divide SRL for that Row by 2 and multiply by 9)

1 Integration (Divide SRL for that Row by 1 and multiply by 9)

Decision Support Metrics for Developmental Life Cycles, Users Guide: Version 2.0, Northrop Grumman Corp. and Stevens Institute of Technology, 5 September 2007

Detailed SRL Calculation Example

Analysis

$$SRL = \left(SRL_1 \quad SRL_2 \quad SRL_3 \right)$$

- These individual 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
- The composite SRL for the complete system is the average of all normalized SRL values. (Note that weights can be incorporated here if desired.)

$$SRL_{Composite} = \frac{\left(\frac{SRL_1}{n} + \frac{SRL_2}{n} + \ldots + \frac{SRL_n}{n} \right)}{n}$$

- A standard deviation can also be calculated to indicate the variation in the system maturity

Decision Support Metrics for Developmental Life Cycles, Users Guide: Version 2.0, Northrop Grumman Corp. and Stevens Institute of Technology, 5 September 2007

SRL Calculation Example

Normalizing the TRLs and IRLs

$$\begin{pmatrix} IRL_1 & IRL_{12} & IRL_{13} \\ IRL_{12} & IRL_2 & IRL_{23} \\ IRL_{13} & IRL_{23} & IRL_3 \end{pmatrix} \begin{pmatrix} TRL_1 \\ TRL_2 \\ TRL_3 \end{pmatrix}$$

Populate with Evaluation Results

Non-Normalized [(1,9) scale]

$$\begin{pmatrix} 9 & 1 & 0 \\ 1 & 9 & 7 \\ 0 & 7 & 9 \end{pmatrix} \begin{pmatrix} 9 \\ 6 \\ 6 \end{pmatrix}$$

Divide by 9

Normalized [(0,1) scale]

$$\begin{pmatrix} 1.0 & 0.11 & 0 \\ 0.11 & 1.0 & .78 \\ 0 & .78 & 1.0 \end{pmatrix} \begin{pmatrix} 1.0 \\ 0.67 \\ 0.67 \end{pmatrix}$$

Remember… a technology integrated with itself receives an IRL value of 9 (e.g. IRL_{11}), while technologies for which there is no connection between them receive a value of 0 (e.g. IRL_{13}).

Sauser, B., J. Ramirez-Marquez, D. Henry and D. DiMarzio. (2007). "A System Maturity Index for the Systems Engineering Life Cycle." *International Journal of Industrial and Systems Engineering*. 3(6). (forthcoming)

SRL for System Alpha

Calculating the SRL and Composite Matrix

$$SRL = IRL \times TRL$$

Component SRL

$$\begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} 1.07 & 1.30 & 1.19 \end{pmatrix}$$

(0,n) scale

Where "n" is equal to the number of integrations for that technology

$$\begin{pmatrix} SRL_1 & SRL_2 & SRL_3 \end{pmatrix} = \begin{pmatrix} 0.54 & 0.43 & 0.59 \end{pmatrix}$$

(0,1) scale

Component SRL_x represents Technology "X" and its IRLs considered

Composite SRL

$$\text{Composite SRL} = 1/3\ (0.54 + 0.43 + 0.59)$$

$$= \boxed{0.52}$$

The Composite SRL provides an overall assessment of the system readiness

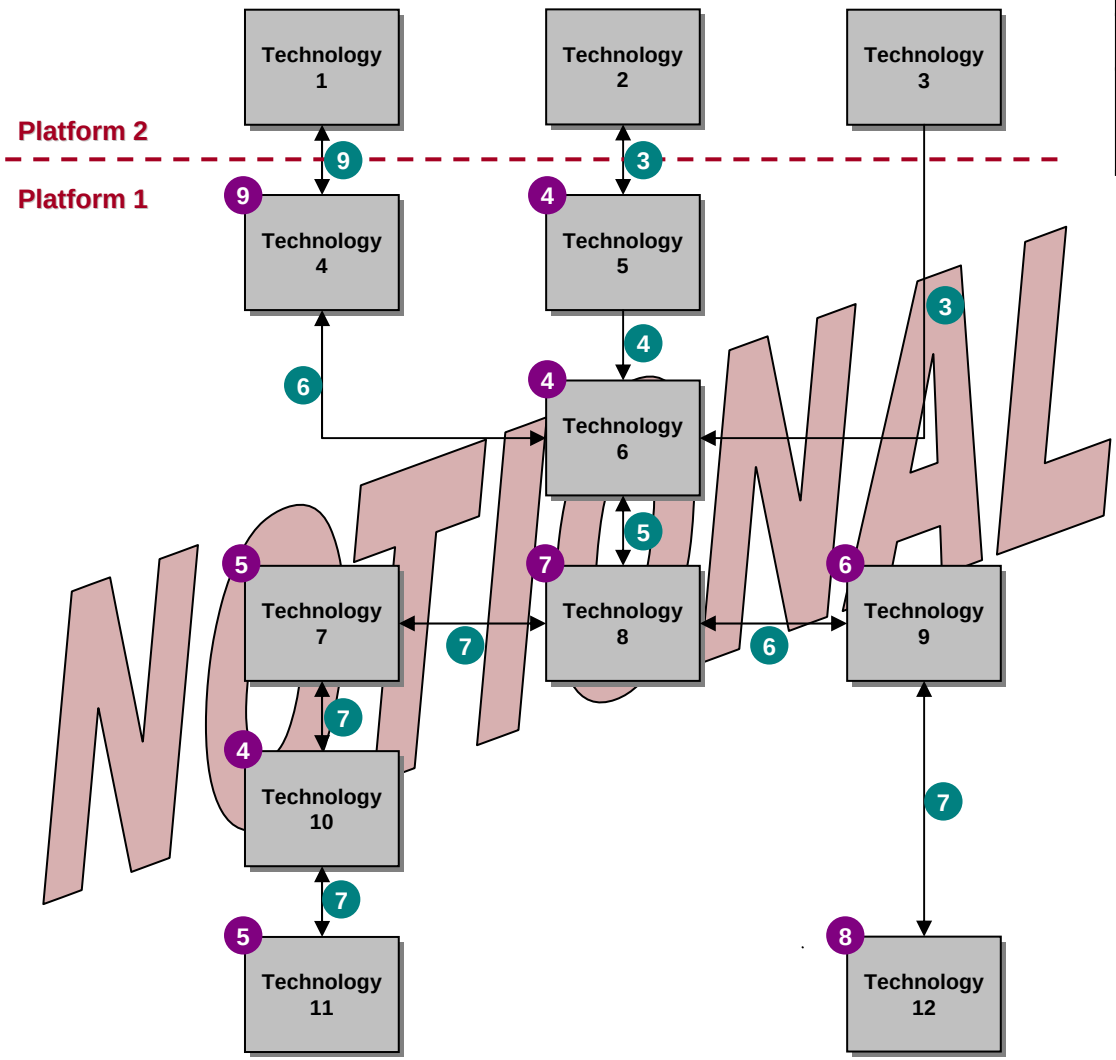
Both individual and composite scores provide key insights into the actual maturity of the system as well as where risk may lie and attention directed for greatest benefit

Sauser, B., J. Ramirez-Marquez, D. Henry and D. DiMarzio. (2007). "A System Maturity Index for the Systems Engineering Life Cycle." *International Journal of Industrial and Systems Engineering*. 3(6). (forthcoming)

NOTE: ALL DATA IN THIS TEMPLATE IS NOTIONAL

System Detailed Status

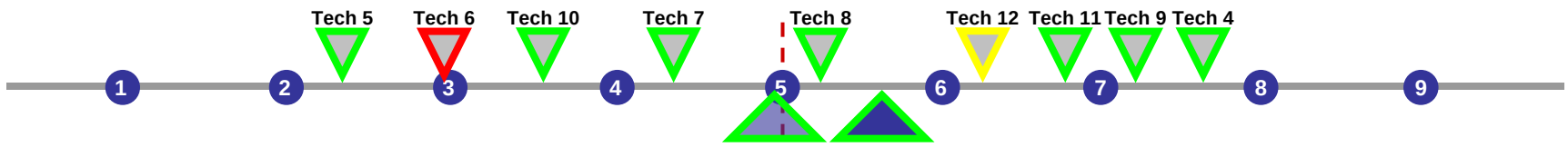
	Composite Actual	Planned
SRL	5.7	5.0
SRL w/o Platform 1 Integrations	5.3	5.0



LEGEND

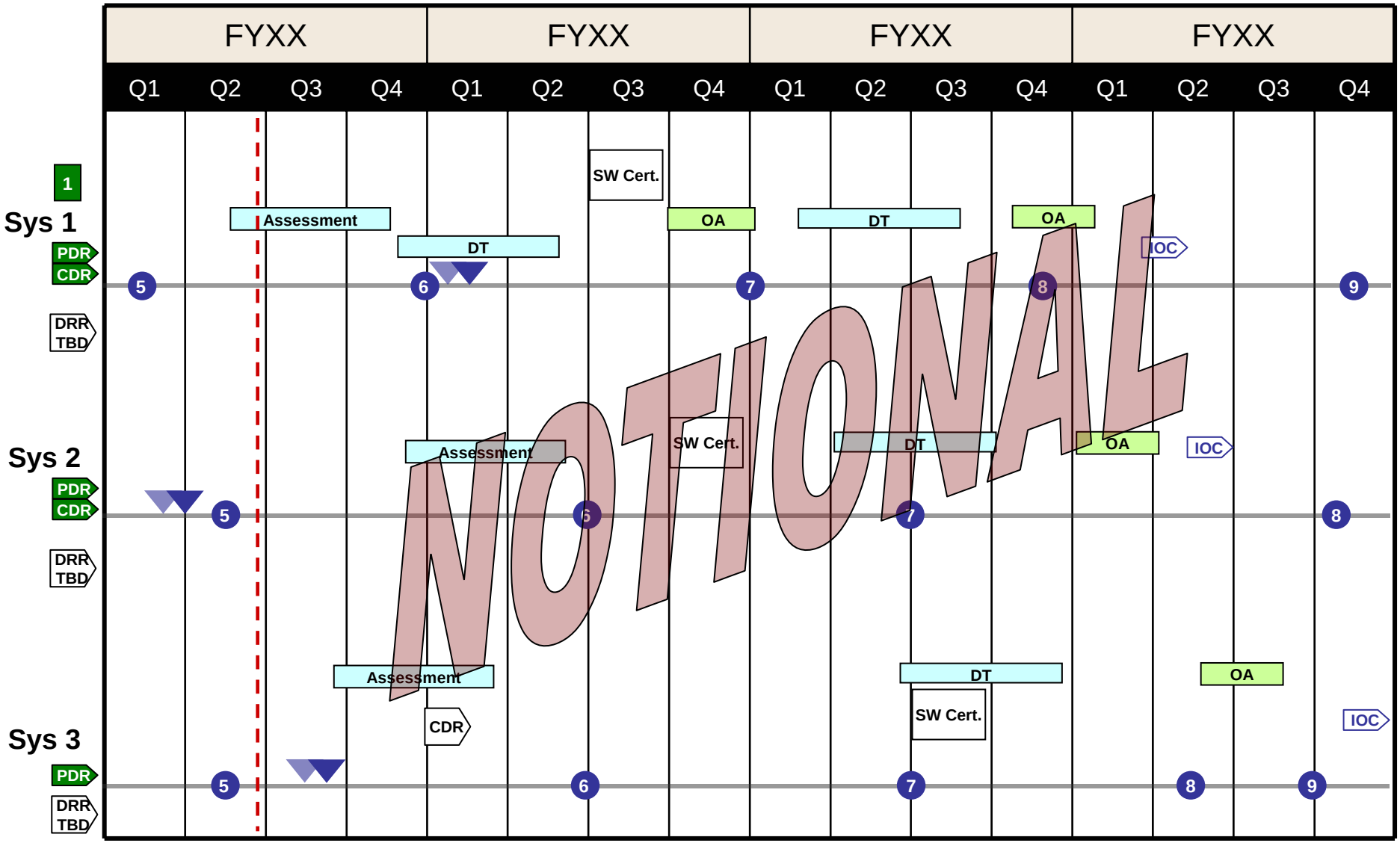
- Platform 1 System
- Platform 2 System
- Current Composite SRL Status
- Previous Composite SRL Status
- Individual technology SRL Status
- Technology Readiness Level
- Integration Maturity Level
- System Readiness Level Demarcation
- Scheduled Position
- Low Risk to Cost and/or Schedule
- Moderate Risk to Cost and/or Schedule
- High Risk to Cost and/or Schedule

Data Collection Period: XX/XX/XX – X/XX/XX
Previous Report Date: XX/XX/XX
Schedule Updated: XX/XX/XX



NOTE: ALL DATA IN THIS TEMPLATE IS NOTIONAL

Program Status Roll-up



LEGEND

- Current Reporting Period Status
- Previous Reporting Period Status
- Scheduled Position
- 7 System Readiness Level

Data Collection Period: XX/XX/XX – X/XX/XX

Previous Report Date: XX/XX/XX

Schedule Updated: XX/XX/XX

What is an IRL?

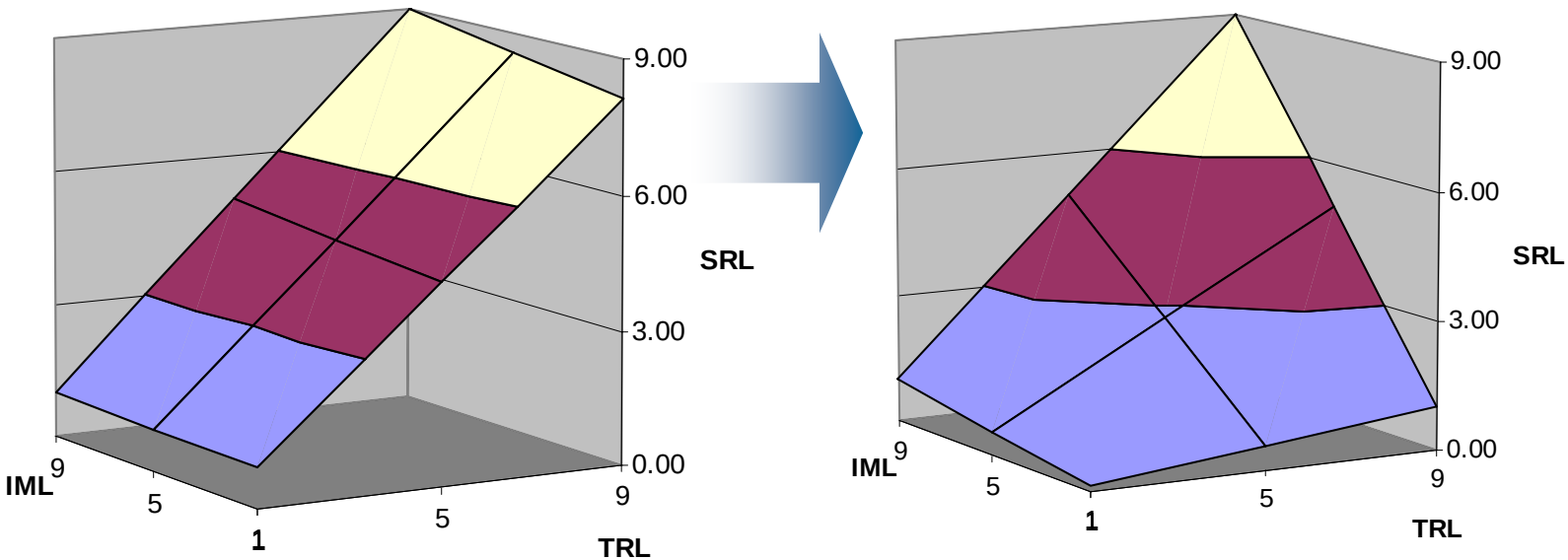
A systematic measurement reflecting the status of an integration connecting two particular technologies

	IRL	Definition
Pragmatic	9	Integration is Mission Proven through successful mission operations.
	8	Actual integration completed and Mission Qualified through test and demonstration, in the system environment.
Syntactic	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.
Semantic	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

SRL Algorithm Sensitivity Evaluated

- Observed that the SRL algorithm did not take into account the varying levels of “importance” between technologies
- Examined the sensitivity of the algorithms to changes in the TRL and IRL ratings of systems with varying levels of importance
- Modified the methodology to automatically include weightings for those technologies that are most important by looking at operational “strings” or mission threads



SRL Response Analysis

* Indicates unreasonable combination

IML = 1

Components to be integrated are selected and interfaces identified

TRL	Composite SRL
1	0.06
3	0.17
5	0.28
7	0.39
9	0.51*

IML = 4

Integration and data requirements are defined; low fidelity experimentation

TRL	Composite SRL
1	0.08
3	0.23
5	0.38
7	0.54
9	0.69*

IML = 7

End-to-end system integration accomplished; prototype demonstrated

TRL	Composite SRL
1	0.10*
3	0.29*
5	0.49
7	0.68
9	0.88

IML = 9

System installed and deployed with mission proven operation

TRL	Composite SRL
1	0.11*
3	0.33*
5	0.56*
7	0.78
9	1.00

Algorithms Evaluated for Sensitivity

TRL Variation Analysis

All TRLs in the system are set to 9 with the exception of the one corresponding to the system in each row, which was set to 1.

	Standard Methodology		Non-connected, Self IRLs = 0	
	Sys	String	Sys	String
MPCE 6 Connections Used by all Threads	8.6	7.9	7.9	7.2
Radar 1 Connections Used by all Threads	8.6	7.9	8.8	8.5
MH-60S 7 Connections Used by 5 Threads	8.6	8.4	7.7	8.1
COBRA 1 Connections Used by 1 Thread	8.6	8.9	8.8	8.9

NOTE: There are 9 total threads

IRL Variation Analysis

All IRLs in the system are set to 9 with the exception of the one corresponding to the link in each row, which was set to 1

	Standard Methodology		Non-connected, Self IRLs = 0	
	Sys	String	Sys	String
MPCE - CMS Used by all Threads	9.0	8.7	8.6	8.0
Radar - CMS Used by all Threads	9.0	8.7	8.6	8.0
MH-60S - MPCE Used by 5 Threads	9.0	8.8	8.6	8.4
COBRA - VTUAV Used by 1 Thread	9.0	9.0	8.6	8.9

NOTE: There are 9 total threads

Comparative Sensitivity – A look at how the algorithms penalized the SRL rating relative to one another (1 is most severe)

	Standard Methodology		Non-connected, Self IRLs = 0	
	Sys	String	Sys	String
1.) MPCE	1,4	1,2	2	1
2.) MH-60S	1,4	3	1	2
3.) Radar	1,4	1,2	3,4	3
4.) COBRA	1,4	4	3,4	4

	Standard Methodology		Non-connected, Self IRLs = 0	
	Sys	String	Sys	String
1.) MPCE - CMS	1,4	1,2	1,4	1,2
2.) MH-60S - MPCE	1,4	3	1,4	3
3.) Radar - CMS	1,4	1,2	1,4	1,2
4.) COBRA - VTUAV	1,4	4	1,4	4