



A comprehensive overview of techniques for measuring system readiness

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Technology Assessment vs. System Assessment



•Advanced, complex Missions cannot meet their goals and objectives without having to rely on advancements in technology.

•Even "heritage" systems can require technology development when they are incorporated into a new architecture with different operational environments or goals.

•Consequently, all "system" assessments must have a technology assessment as a component.





Technology Assessment vs. System Assessment

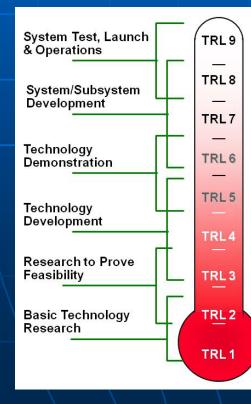
What does Technology Impact?

All aspects of the Systems Engineering Process!

- Stakeholder Expectation:
- Requirements Definition:
- Design Solution:
- Risk Management:
- Technical Assessment:
- Trade Studies:
- Verification/Validation:
- Lessons Learned:

Technology Readiness Level (TRL)

- A Technology Readiness Level (TRL), describes the maturity of a given technology relative to its development cycle.
- At its most basic, it is defined at a given point in time by what has been done and under what conditions.



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Technology Readiness Levels (TRLs)

- 9. Actual system proven through successful mission operations (sw mission-proven operational capabilities)
- 8. Actual system completed and qualified (sw mission qualified) through test and demonstration (sw in an operational environment)
- 7. System prototype demonstration in an operational (sw high-fidelity) environment
- 6. System/subsystem model or prototype demonstration in a relevant environment (sw module and/or subsystem validation in a relevant end-to-end environment)
- 5. Component and/or breadboard (sw module and/or subsystem) validation in relevant environment
- 4. Component and/or breadboard validation in laboratory environment
- 3. Analytical and experimental critical function and/or characteristic proof-of-concept
- 2. Technology concept and/or application formulate
- 1. Basic principles observed and reported





Technology Assessment vs. System Assessment

 But – Technology Assessment alone is not sufficient to determine the maturity of a system under development.

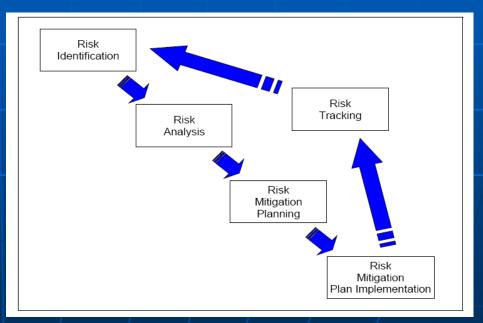


Risk Identification, Integration & Illities (RI3)

RI3 is a methodology for identifying technical risks due to the introduction of "new" technology, based on case studies, "lessons learned," and "best practice" from an Air Force-wide development team.

RI3 used to support, not replace, existing Risk Identification process

Questions in nine 'ilities areas Design Maturity and Stability Scalability & Complexity Integrability Testability Software Reliability Maintainability Human factors People, organization, & skills

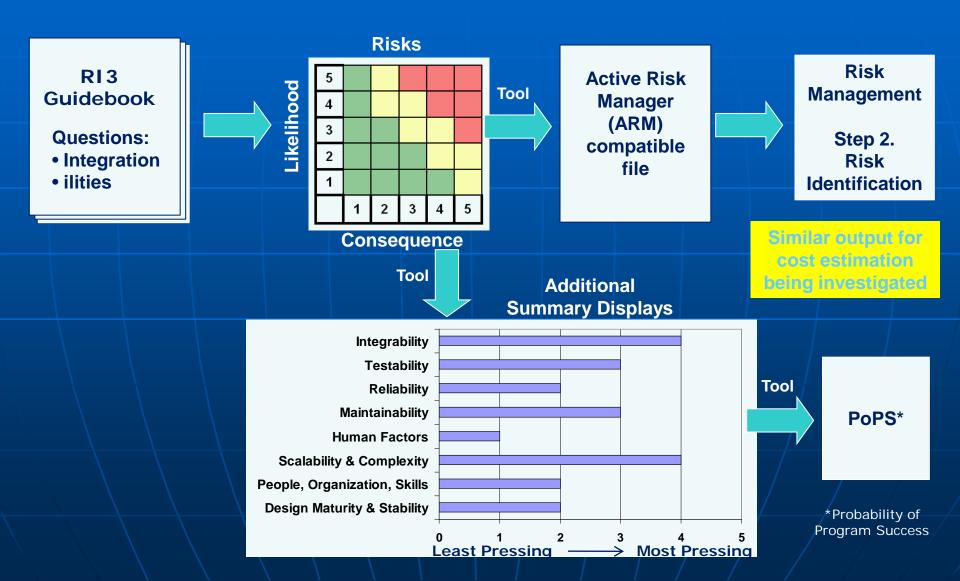


Questions based on commonly occurring problems are contained in a <u>compact</u> guidebook and an Excel tool - a web based tool is under development.



Risk Identification, Integration & Illities (RI3)





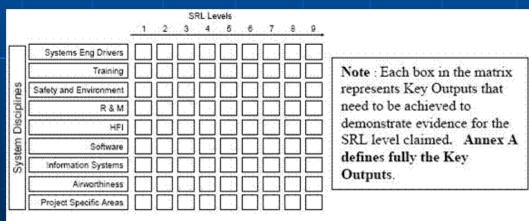
Unternational System Readiness Level (SRL) UK Ministry of Defense

SRLs are an analysis of key outputs of an acquisition project structured in such a way as to provide an understanding of work required to mature the project.

The SRL analysis is achieved using a matrix to capture the results of a comprehensive set of questions centered around System Engineering Drivers (SEDs) and selected systems disciplines (i.e., Training, Safety and Environment, etc.) and understand how they

should mature over time.

The SRL analysis employs TRL analyses to provide a means of progressively measuring project maturity at technology, component, sub system and whole system levels. TRL_{system} \leq TRL_{component}



Outline SRL Matrix.

N.B. – Integration Readiness Levels (IRLs) & Design Readiness Levels (DRLs) were initially used but later rejected.

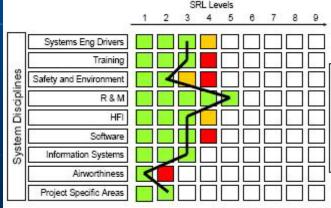
Binternational System Readiness Level (SRL) — UK Ministry of Defense

SRLs are intended to be 'descriptive' and not 'absolute' as work on each systems discipline may progress at different rates.

An SRL assessment therefore produces a 'signature' rather than an absolute single point SRL figure.

The signature records the variation of maturity that has been achieved across the systems disciplines, acknowledging that not all projects mature against the systems disciplines at a consistent rate.

The color of the boxes in the Systems Maturity Matrix is determined by analysis of the SRL signature obtained against the expectations for SRL maturity at the time of review



Note:

Each box on the matrix represents a Key Output for that system discipline. The colours represent: Green: full achievement of the required outputs

Amber: some shortfalls in the required outputs Red: significant shortfall in the required outputs.

Example of an SRL 'Signature'

SRL Self Assessment Tool Results





Advancement Degree of Difficulty (AD²)

Advancement Degree of Difficulty (AD2) is a method of systematically dealing with aspects beyond TRL.

It is a "predictive" description of what is required to move a system, subsystem or component from one TRL to another.

It provides information in the form of:

- Likelihood of occurrence of an adverse event. ightarrow Risk
- Cost to ensure that such an event does not occur.
- The time required to implement the necessary action.

Impact

- AD² consists of a set of questions in 5 specific areas:
- Design and Analysis
- Manufacturing
- Software Development
- Test
- Operations



AD2 Tool Outoption Sat

Advancement Degree of Difficulty (AD²)



The levels of risk associated with AD² are described in terms of the experience base of the developers.

i.e., have they done this before?

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A	dva	ncemer	nt Degi	ree of Diffi	culty - Questions		8/22/2008		Return To			-up of Subsyster	Drivere	Re-Calculat	
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						Questions			11 1.6.0	1.6.1	Turbine Housing Manifolds				
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		0 to 6me	-	\$10M to \$20M	Level 1: 0% Risk		000000000000000000000000000000000000000					D&A - Necessary data bases D&A - Appropriate skills	zero time zero time	zero cost \$50M to \$100M	Level 7: 60% Risk Level 7: 60% Risk
			_			Do the necessary design tools exist and if not, what level of development is required to produce them?	000000000000000000000000000000000000000					D&A - Mfg - Necessary metrology	zero time zero time	zero cost \$20M to \$50M	Level 8: 80% Risk Level 7: 60% Risk
		0 to 6mo		\$10M to \$20M	▼ Level 5: 40% Risk ▼	Do the necessary analytical methods exist and if not, what						Mfg - Appropriate skills Mfg -	0 to 6mo 6mo to 1yr	> \$100M \$1M to \$10M	Level 7: 60% Risk Level 7: 60% Risk
		1				level of development is required to produce them?	dddddddd ddddddd dddddd					SW Dev - T&V - Test facilities	1yr to 2yr 6mo to 1yr	\$20M to \$50M \$1M to \$10M	Level 7: 60% Risk Level 7: 60% Risk
		2yr to 3yr	¥	\$20M to \$50M	Need more data	Do the necessary analysis tools exist and if not, what level			1	a1.2.3.5.22	2nd Bleed valve				
						of development is required to produce them? Do the appropriate models with sufficient accuracy exist	eeeeeee eeeeeeeeeeeeeeeeeeeeeeeeeeeeee					D&A - Necessary design methods D&A - Necessary analysis tools	zero time 2yr to 3yr	\$1M to \$10M \$20M to \$50M	Level 7: 60% Risk Need more data
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						produce them? Do the available personnel have the appropriate skills and	((()))))))))))))))))))))))))))))))))))	_				D&A - D&A -	zero time 2yr to 3yr	zero cost \$50M to \$100M	Level 7: 60% Risk Level 9: 100% Risk
		zero time	-	\$50M to \$100M	▼ Level 3: 20% Risk ▼	if not, what level of development is required to acquire them?						Mfg - Necessary materials Mfg - Necessary mfg. tooling	1yr to 2yr 6mo to 1yr	\$10M to \$20M \$20M to \$50M	Need more data Not Applicable
			_				99999999999999					Mfg - Necessary metrology Mfg - Necessary mfg, software	zero time 0 to 6mo	\$20M to \$50M 0 to \$1M	Level 7: 60% Risk Level 7: 60% Risk
		zero time	•	zero cost	Not Applicable	Has the design been optimized for manufacturability and it not, what level of development is required to optimize it?	bbbbbbbbbbb					Mfg - Brassboards Mfg - Qualification models	zero time 0 to 6mo	zero cost \$50M to \$100M	Not Applicable Not Applicable
		0 to 6mo	-	\$50M to \$100M	▼ Level 5: 40% Risk ▼							Mg - Quaincation moders Mg - Mg -	2yr to 3yr 6mo to 1yr	0 to \$1M \$1M to \$10M	Need more data Level 9: 100% Risk
			_			Has the design been optimized for <u>testability</u> and if not, what level of development is required to optimize it?						SW Dev -	0 to 6mo	\$20M to \$50M	Level 8: 80% Risk
		2yr to 3yr	•	> \$100M	▼ Level 5: 40% Risk ▼	Has the design been optimized for integration at the component, subsystem and system level and if not, what is						SW Dev - SW Dev -	zero time zero time	\$20M to \$50M \$50M to \$100M	Level 9: 100% Risk Not Applicable
		Table of All		I. must 1		required to optimize it?						SW Dev -	1yr to 2yr	\$20M to \$50M	Need more data

AD2 Tool Outout



System Readiness Level (SRL) – the Stevens Institute

The SRL in this case is defined through the combination of the TRL of a given technology with the Integration Readiness Level (IRL) of each of the elements with which it will be integrated.

 $SRL_i = f(TRL_j, IRL_{ij})$

The overall SRL will be a function of the individual subsystem SRL_i

 $SRL = f(SRL_1, SRL_2, ..., SRL_n)$

Integration Readiness Levels

IRL	Definition	Description
9	Integration is Mission Proven through successful mission operations.	IRL 9 represents the integrated technologies being used in the system environment successfully. In order for a technology to move to TRL 9 it must first be integrated into the system, and then proven in the relevant environment, so attempting to move to IRL 9 also implies maturing the component technology to TRL 9.
8	Actual integration completed and Mission Qualified through test and demonstration, in the system environment.	IRL 8 represents not only the integration meeting requirements, but also a system-level demonstration in the relevant environment. This will reveal any unknown bugs/defect that could not be discovered until the interaction of the two integrating technologies was observed in the system environment.
7	The integration of technologies has been Verified and Validated with sufficient detail to be actionable.	IRL 7 represents a significant step beyond IRL 6; the integration has to work from a technical perspective, but also from a requirements perspective. IRL 7 represents the integration meeting requirements such as performance, throughput, and reliability.
6	The integrating technologies can Accept, Translate, and Structure Information for its intended application.	IRL 6 is the highest technical level to be achieved, it includes the ability to not only control integration, but specify what information to exchange, label units to specify what the information is, and the ability to translate from a foreign data structure to a local one.
5	There is sufficient Control between technologies necessary to establish, manage, and terminate the integration.	IRL 5 simply denotes the ability of one or more of the integrating technologies to control the integration itself; this includes establishing, maintaining, and terminating.
4	There is sufficient detail in the Quality and Assurance of the integration between technologies.	Many technology integration failures never progress past IRL 3, due to the assumption that if two technologies can exchange information successfully, then they are fully integrated. IRL 4 goes beyond simple data exchange and requires that the data sent is the data received and there exists a mechanism for checking it.
3	There is Compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact.	IRL 3 represents the minimum required level to provide successful integration. This means that the two technologies are able to not only influence each other, but also communicate interpretable data. IRL 3 represents the first tangible step in the maturity process.
2	There is some level of specificity to characterize the Interaction (i.e. ability to influence) between technologies through their interface.	Once a medium has been defined, a "signaling" method must be selected such that two integrating technologies are able to influence each other over that medium. Since IRL 2 represents the ability of two technologies to influence each other over a given medium, this represents integration proof-of-concept.
1	An Interface between technologies has been identified with sufficient detail to allow characterization of the relationship.	This is the lowest level of integration readiness and describes the selection of a medium for integration.



System Readiness Level (SRL) – the Stevens Institute

The computation of SRL is considered as a normalized matrix of pairwise comparisons of normalized TRL and IRL.

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

 $SRL = \frac{(SRL_1/n_1 + SRL_2/n_2 + \dots + SRL_n/n_n)}{n}$

System Maturity Optimization is underway at Stevens



Additional Areas that have been addressed with varying degrees of success



Design Readiness Level (DRL) Manufacturing Readiness Level (MRL) Integration Readiness Level (IRL) Software Readiness Level (SRL) Operational Readiness Level (ORL) Human Readiness Levels (HRL) Capability Readiness Level (CRL) Organizational Readiness Level (ORL) Programmatic Readiness Level (PRL





<u>Summary</u>

- Technology Assessment is a vital part of any overall system maturity assessment.
- There are many approaches to overall system assessment.
- Any successful approach for system maturity assessment must balance the need for data against the resources required to obtain that data.







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- Mankins, John C. "Technology Readiness Levels" a White Paper, April 6, 1995.
- Nolte, William, "Technology Readiness Level Calculator, "Technology Readiness and Development Seminar, Space System Engineering and Acquisition Excellence Forum, The Aerospace Corporation, April 28, 2005.
- Mankins, John C., "Research & Development Degree of Difficulty (RD3)" A White Paper, March 10, 1998.



Bibliography



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- Bilbro, James W. "Systematic Assessment of the Program/Project Impacts of Technological Advancement and Insertion Revision A," <u>http://www.jbconsultinginternational.com</u>







TOOLS

- RI3 Tool and Guidebook are available at: <u>http://www.afit.edu/cse/page.cfm?page=164&sub=95</u>
- AD2 Tool along with integrated TRL tool available at:
- <u>http://www.jbconsultinginternational.com</u>
- TRL Calculator is available at Website at: <u>https://acc.dau.mil/communitybrowser.aspx?id=25811</u>
- UK MOD Tool is available at: <u>http://www.aof.mod.uk/aofcontent/tactical/techman/index.htm</u>
- Stevens SRL Tool is under development at: <u>http://www.systemreadinesslevel.com/</u>
- Manufacturing Readiness Level Tool is available at: https://acc.dau.mil/CommunityBrowser.aspx?id=18231