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

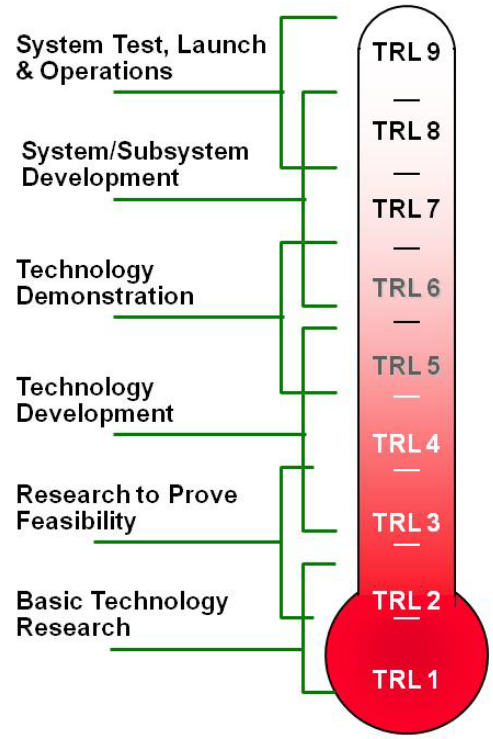
What does Technology Impact?

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.



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

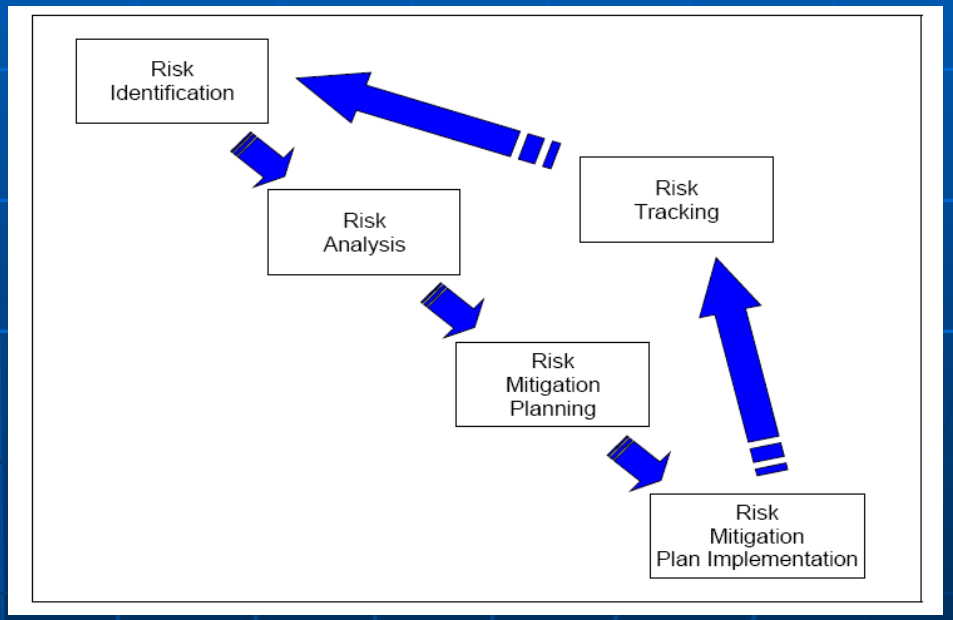
- But – Technology Assessment alone is not sufficient to determine the maturity of a system under development.

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



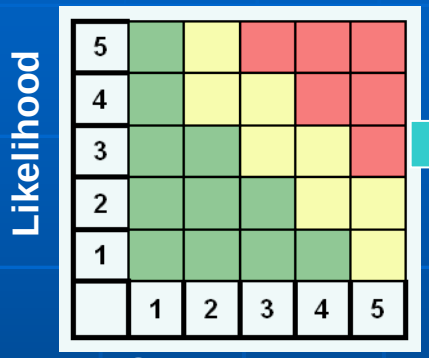
Questions based on commonly occurring problems are contained in a compact guidebook and an Excel tool - a web based tool is under development.

Risk Identification, Integration & Illities (RI3)

RI3 Guidebook

Questions:
- **Integration**
- **ilities**

Risks



Tool

Active Risk Manager (ARM) compatible file

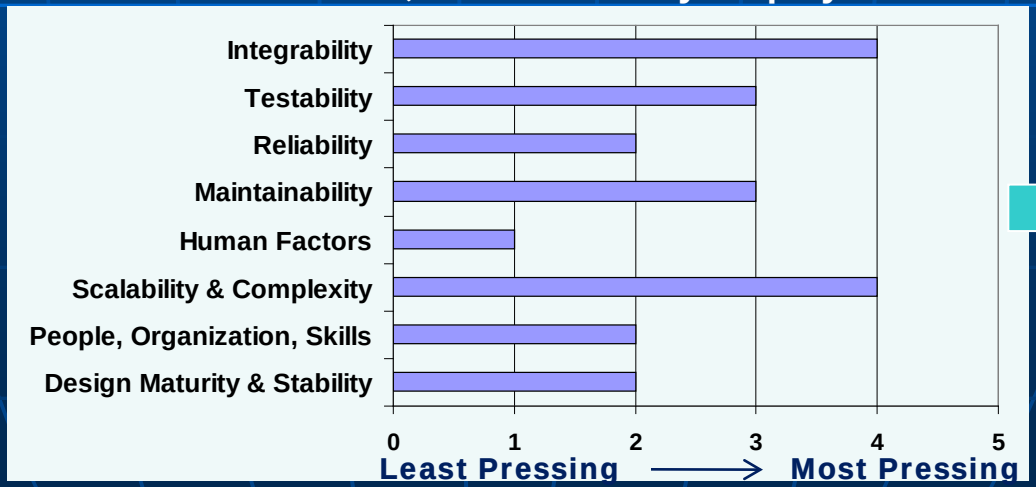
Risk Management

Step 2. Risk Identification

Similar output for cost estimation being investigated

Tool

Additional Summary Displays



Tool

PoPS*

*Probability of Program Success

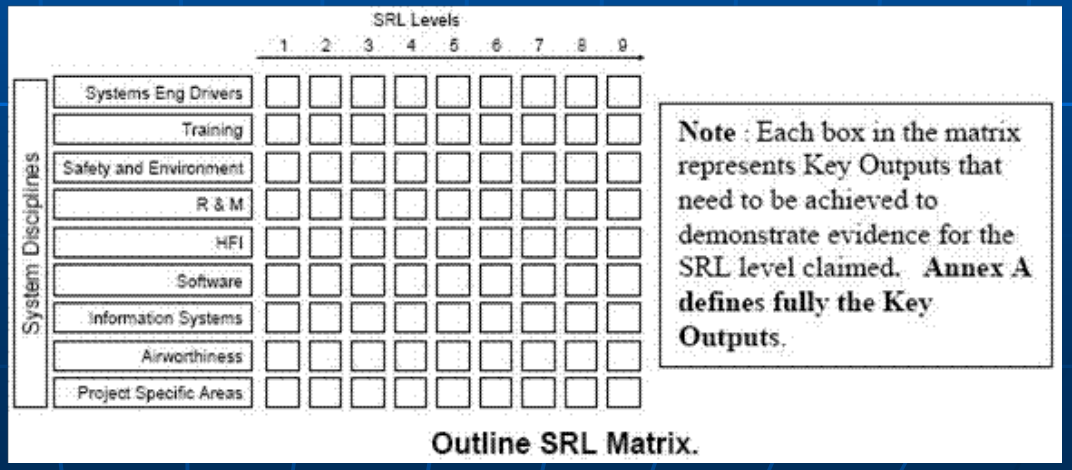
System Readiness Level (SRL) – UK Ministry of Defense

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.

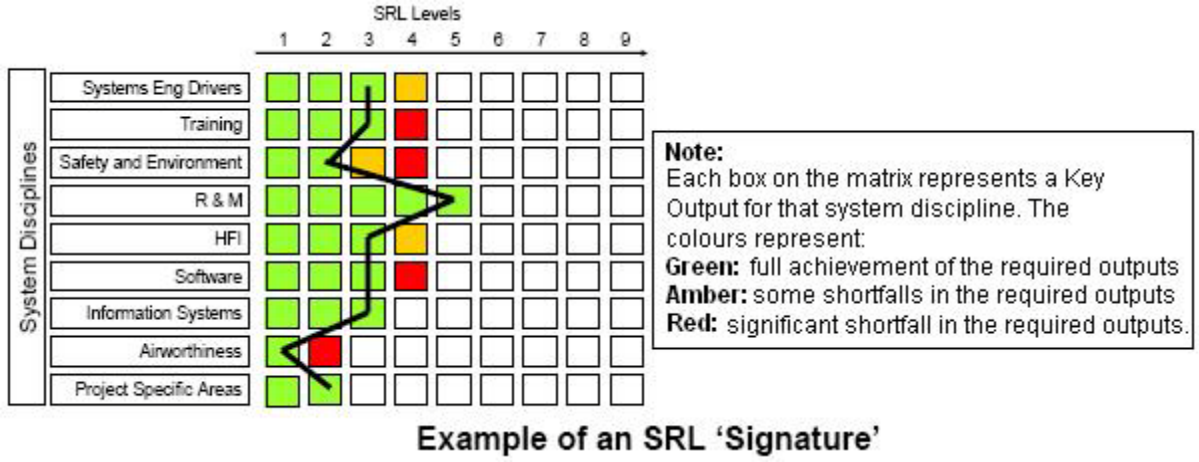
System Readiness Level (SRL) – UK Ministry of Defense

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



Example of an SRL ‘Signature’

SRL Self Assessment Tool Results

Advancement Degree of Difficulty (AD^2)

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. } **Risk**
- Cost to ensure that such an event does not occur. } **Impact**
- The time required to implement the necessary action. } **Impact**

AD^2 consists of a set of questions in 5 specific areas:

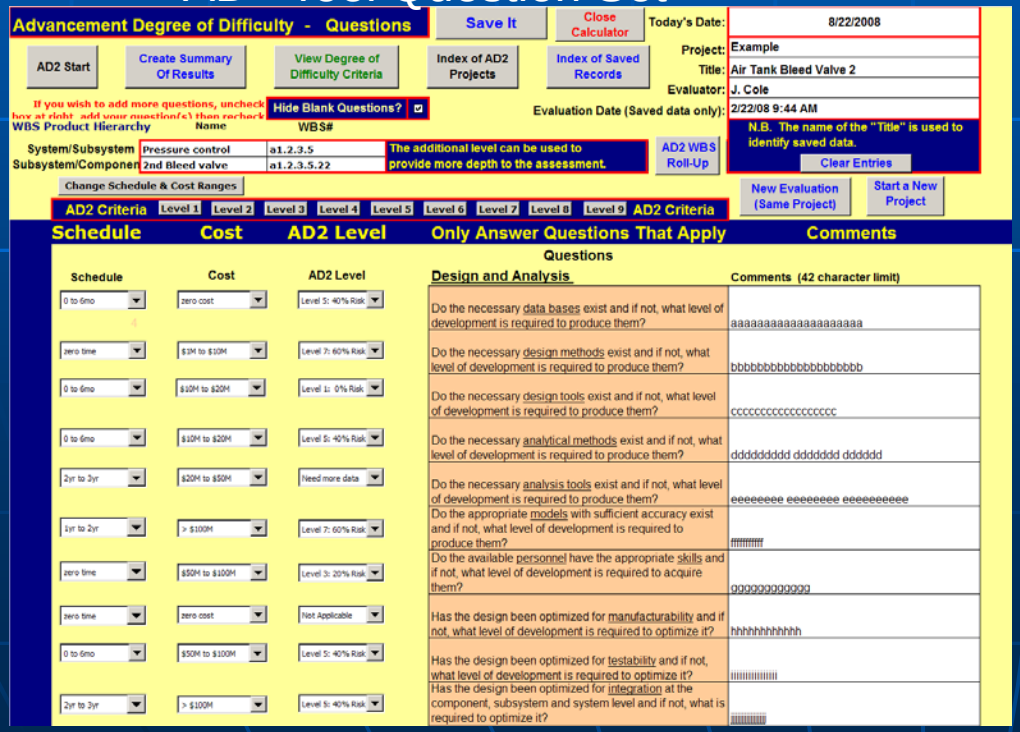
- Design and Analysis
- Manufacturing
- Software Development
- Test
- Operations

Advancement Degree of Difficulty (AD^2)

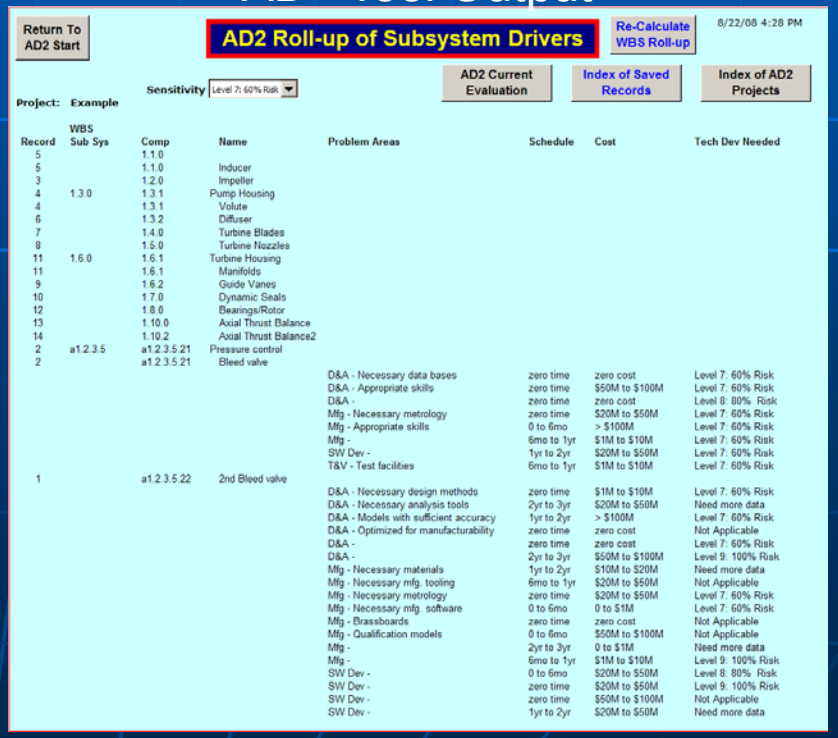
The levels of risk associated with AD^2 are described in terms of the experience base of the developers.

i.e., have they done this before?

AD^2 Tool Question Set



AD^2 Tool Output



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

$$SRL = f(SRL_1, SRL_2, \ldots SRL_n)$$

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.

$$[\mathrm{SRL}] = \begin{bmatrix} \mathrm{SRL}_1 \\ \mathrm{SRL}_2 \\ \cdots \\ \mathrm{SRL}_n \end{bmatrix} = \begin{bmatrix} \mathrm{IRL}_{11}\mathrm{TRL}_1 + \mathrm{IRL}_{12}\mathrm{TRL}_2 + \cdots + \mathrm{IRL}_{1n}\mathrm{TRL}_n \\ \mathrm{IRL}_{21}\mathrm{TRL}_1 + \mathrm{IRL}_{22}\mathrm{TRL}_2 + \cdots + \mathrm{IRL}_{2n}\mathrm{TRL}_n \\ \cdots \\ \mathrm{IRL}_{n1}\mathrm{TRL}_1 + \mathrm{IRL}_{n2}\mathrm{TRL}_2 + \cdots + \mathrm{IRL}_{nn}\mathrm{TRL}_n \end{bmatrix}$$

$$\mathrm{SRL} = \frac{(\mathrm{SRL}_1/n_1 + \mathrm{SRL}_2/n_2 + \cdots + \mathrm{SRL}_n/n_n)}{n}.$$

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

JB International

Summary

- 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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TOOLS

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