Determining System Interoperability using an Integration Readiness Level

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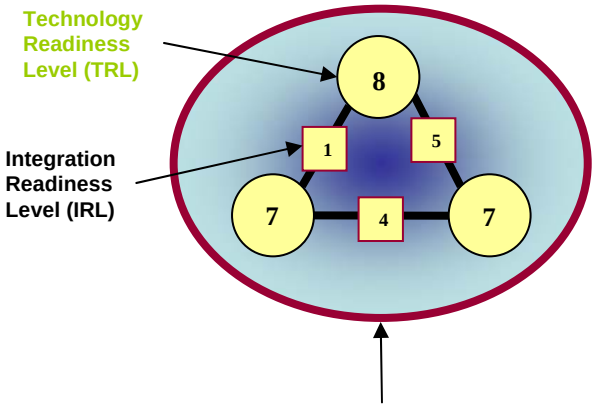
Introduction

Our research team at Stevens Institute of Technology has found that System Interoperability can be measured using the purposed **S**ystem **R**eadiness **L**evel (SRL). SRL is a function of both technology and integration readiness. We contend that by using the already established **T**echnology **R**eadiness **L**evel (TRL) scale, originally developed by NASA, and the additional **I**ntegration **R**eadiness **L**evel (IRL) scale purposed here System Interoperability and readiness can be accurately and effectively assessed.

We will start by examining what the literature tells us about TRL's application to complex systems, then introduce the purposed SRL model. We will then apply the SRL model to a brief case study. Finally, our current effort to gather **S**ubject **M**atter **E**xpert (SME) perspectives though an interactive survey which will be described along with the future work that needs to be done.

What is Technology Readiness Level (TRL)?



SRL = *f* (TRL, IRL)

A systematic metric/measurement system that supports assessment of the maturity of a particular technology and the consistent comparison of maturity between different types of technologies.

TRL	Definition
9	Actual System Proven Through Successful Mission Operations
8	Actual System Completed and Qualified Through Test and Demonstration
7	System Prototype Demonstration in Relevant Environment
6	System/Subsystem Model or Prototype Demonstration in Relevant Environment
5	Component and/or Breadboard 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 Formulated
1	Basic Principals Observed and Reported

- **GAO showed that failure to properly mature new technologies in the science and technology, or laboratory environment almost invariably leads to cost and schedule over-runs in acquisition weapons systems programs.**
- **Technology maturity can be an indicator of program risk.**
- **As a measure of risk, it can be helpful in management of programs and projects.**
- **Legislative and regulatory mandates require DoD to measure technology maturity.**

What is TRL?

Mankins described TRLs as "…systematic metric/measurement system that supports assessments of the maturity of a particular technology and the consistent comparison of maturity between different types of technology…"

This is the official definition of TRL, it describes technology maturity and says nothing about:

- Integration
- Risk
- System-Level Readiness

TRL was simply not created to handle these issues.

What does TRL provide?

The literature has shown

- Accurately and effectively provides component technology readiness assessment [1, 2, 3, 8]
- Stakeholders coming together to evaluate component TRLs initiates the considerations of other important factors [4]
- Assessment using TRL is a fast, iterative process that can be easily repeated during development [1, 4]

What's Missing in TRL?

- Does not assess maturity at the system-level [2, 4, 5, 6]
- Distorts many aspects of technology readiness into one metric, the most problematic being integration [2]
- Cannot assess uncertainty involved in maturing and integrating a technology into a system [2, 5]
- More factors other than readiness to consider during technology integration into a system environment [2, 4, 5]
- Does not consider obsolescence and the ability of a less mature technology to meet system requirements [2, 5]
- Need for a common platform for system development and technology insertion evaluation [1, 6]
- Hierarchal view of technology insertion/system development assessment [6]

"In order to succeed over the longer term, additional methodologies are needed, including those which allow the identification of anticipated uncertainty in planned R&T programs…" (Mankins, 2002)

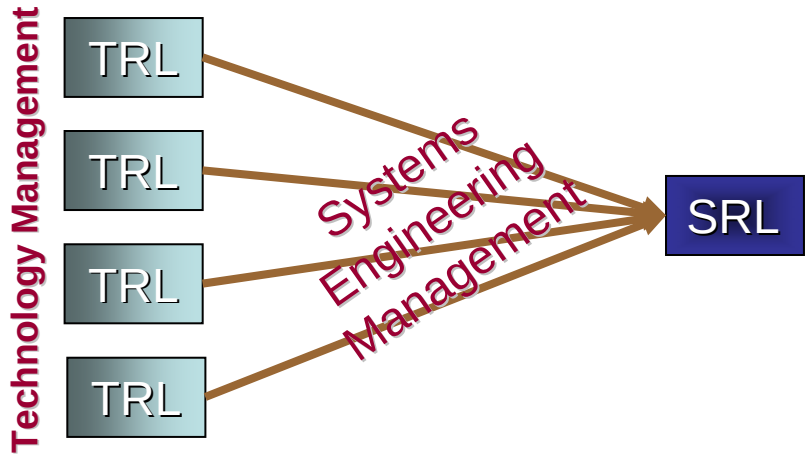
What is Systems Readiness Level?

SRL will be defined by the current state of development of a system in relation to the United States Department of Defense's (DoD) Phases of Development for the Life Cycle Management Framework [1].

SRL	Name	Definition
5	**Operations & Support**	Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manor over its total life cycle.
4	**Production & Development**	Achieve operational capability that satisfies mission needs.
3	**System Development & Demonstration**	Develop a system or increment of capability; reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for producibility; ensure affordability and protection of critical program information; and demonstrate system integration, interoperability, safety, and utility.
2	**Technology Development**	Reduce technology risks and determine appropriate set of technologies to integrate into a full system.
1	**Concept Refinement**	Refine initial concept. Develop system/technology development strategy

Why do we need a Systems Readiness Level (SRL)?

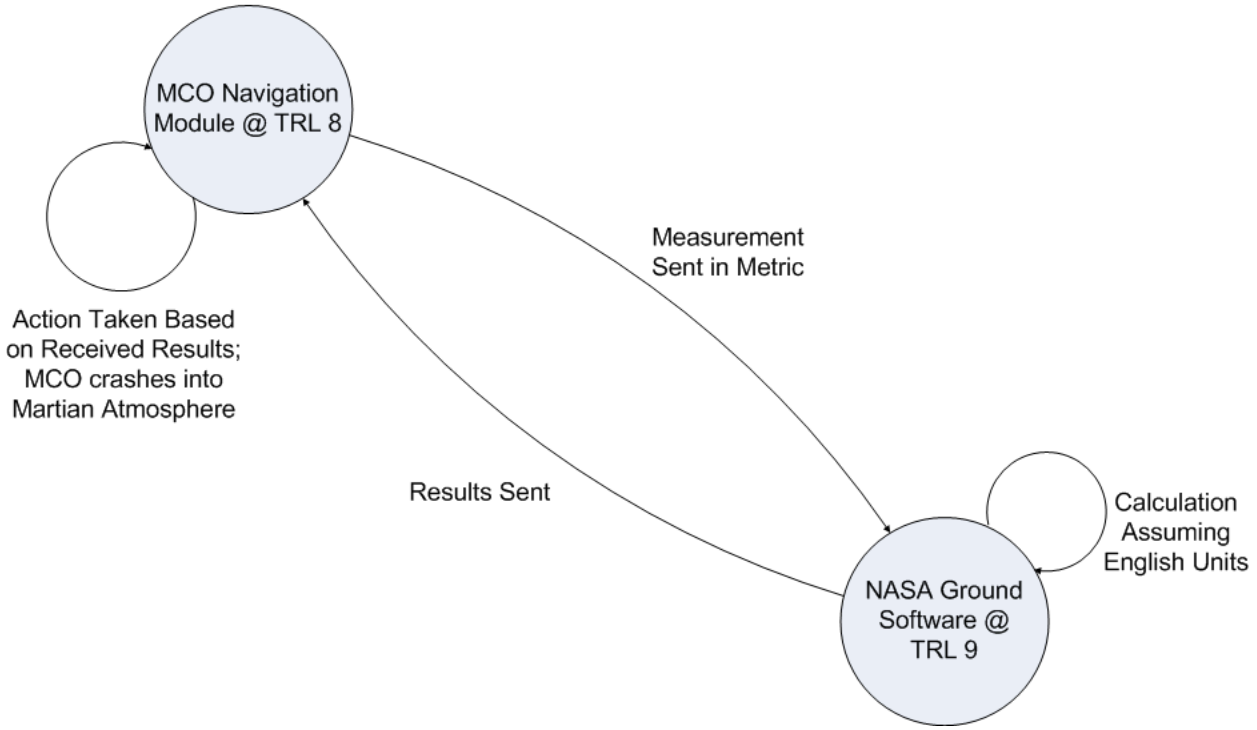
- Another metric(s) apart from TRL is needed for system-level assessment.
- Even with SRL the picture is incomplete, how does TRL relate to SRL? How can many TRLs accurately provide one SRL ranking? What about Integration?



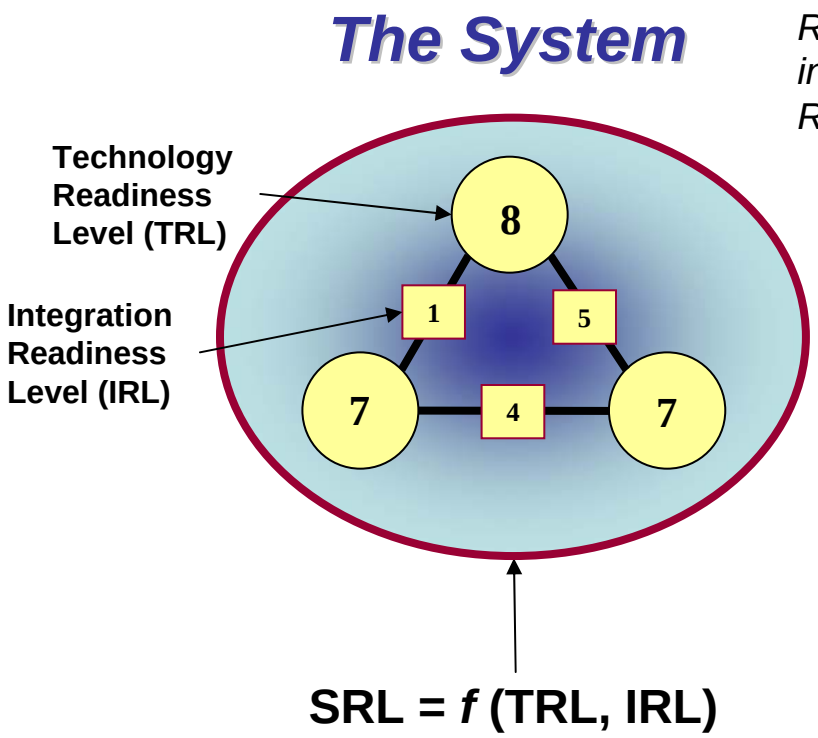
A 1999 GAO Report stated that programs started with a technology at TRL 5 or below experienced "significant cost and schedule increases." GAO also recommended that technologies should mature until the equivalent of TRL 7 before they are included in weapon system programs.

Case Example:
What TRL's may not tell us…

Mars Climate Orbiter

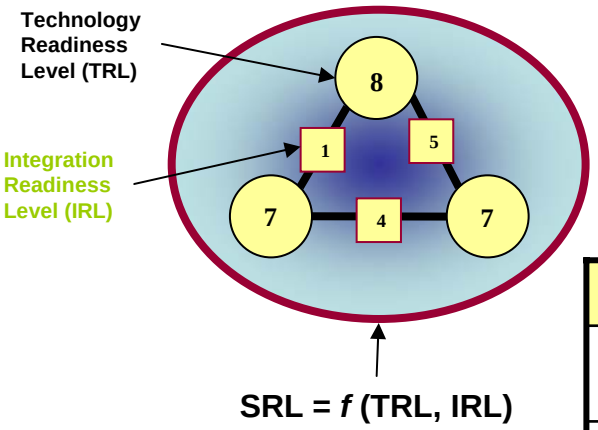


System Readiness Level Model



The SRL Model is a function of the individual Technology Readiness Levels (TRL) in a system and their subsequent integration points with other technologies, the Integration Readiness Level (IRL).

What is Integration Readiness Level?



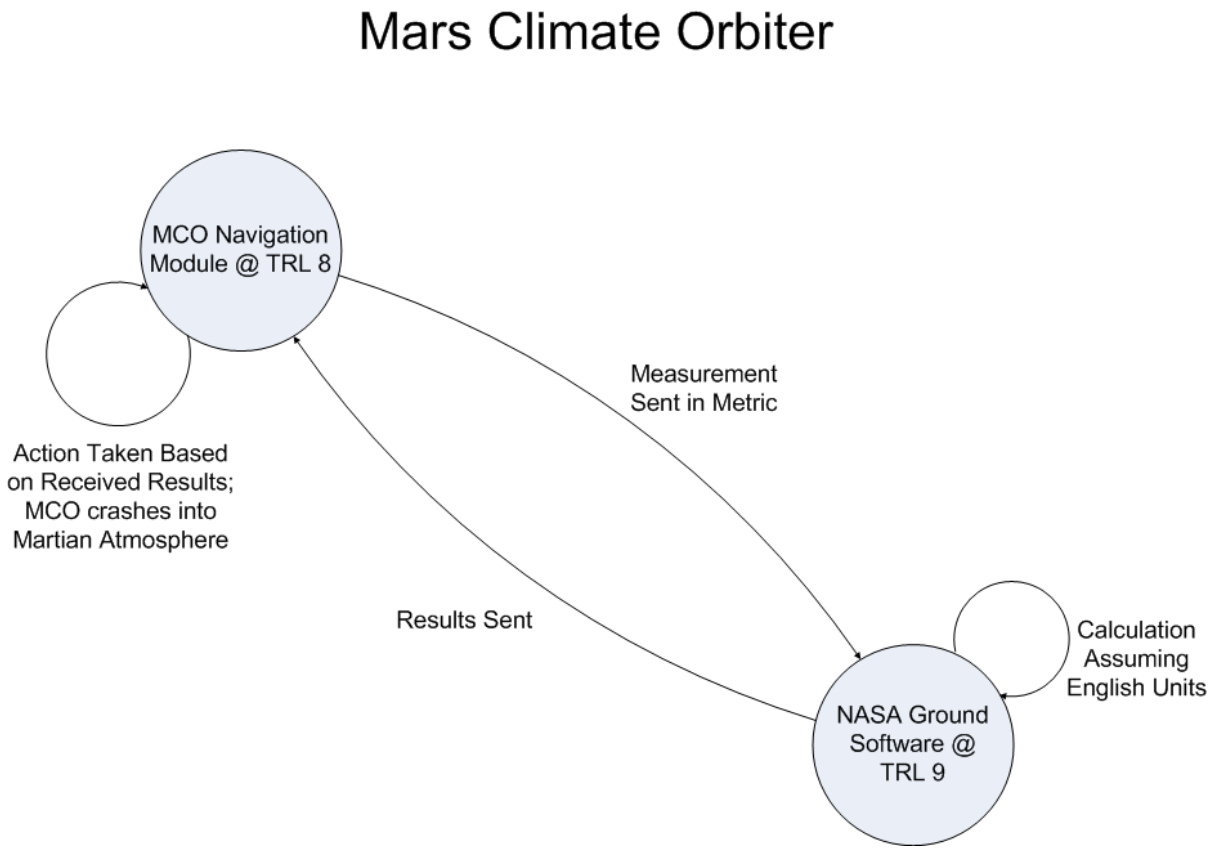
A systematic measurement of the interfacing of compatible interactions for various technologies and the consistent comparison of the maturity between integration points.

Integration – the combining and coordinating of separate components into a seamless unit – interfacing the compatible interactions of various technologies together

IRL	Definition [9]
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*** (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterization of the relationship.

"Technologies are not only getting more complex, they are getting more integrated."
- Murray Cantor, Distinguished Engineer, IBM Rational Group

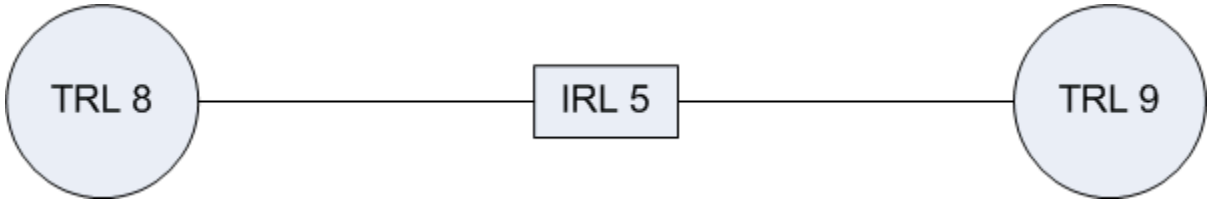
Case Example: What IRL can tell us…



What is the IRL?
Without the details of the algorithm used to transfer data between the Ground-Software and MCO we can assume the IRL was at least a 3 (compatibility), but not a 6 (translation and structuring of data).

For reasons of simplicity we will assume there was an ability to provide quality and control of data being transmitted (IRL 4 & 5), so we will assume IRL 5.

Case Example: The MCO Navigation System



The MCO Navigation System can now be assed as a SRL and relevant SE and PM practices can be applied. To do this, a function of TRL and IRL must be developed whose output is a SRL. Even without the ability to determine a SRL, this picture already demonstrates a potential integration problem between the two technologies, and the attempt to increase the IRL might have resulted in the discovery of the ground software 'bug'.

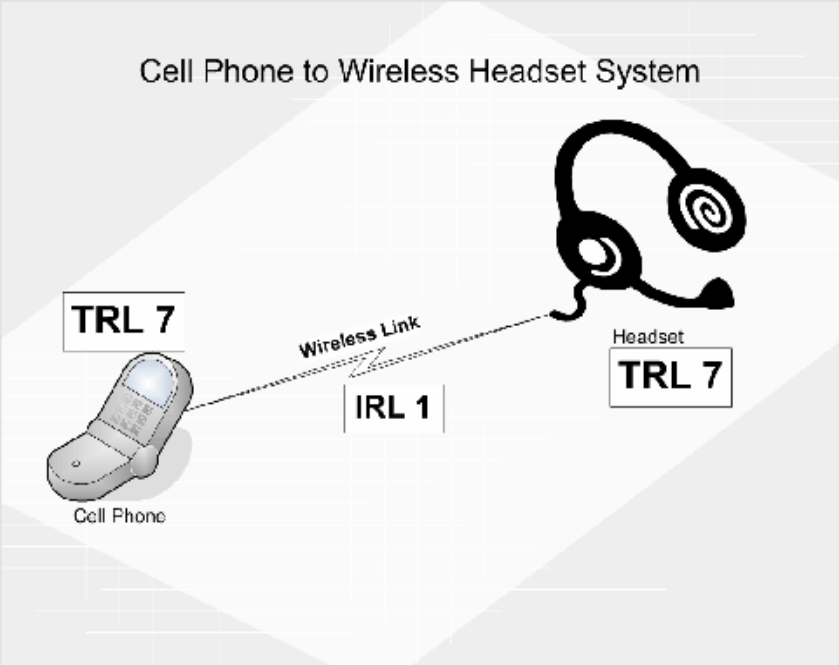
Developing the SRL Model

- Limit our focus to the integration of two technologies
- TRL-IRL-TRL system has 567 possible variations that must map to 5 SRLs, obviously a non-linear function.
- Eliminate any system that is the same forward and backward, and any system with a TRL of <= 3, with an IRL > 1, this is an obvious observation from the definitions of both TRL and IRL
- Finally reduced to 171 systems.
- Must develop a Survey to allow SMEs to evaluate the TRL-IRL-TRL systems

Creating the SRL Survey

- 171 possible TRL-IRL-TRL systems to evaluate and map to SRLs
- Since we are really concerned with the TRL-IRL effect on SRL, we further limit our sample space to all the systems where the TRLs are equal.
- We chose 26 systems evenly distributed throughout the sample space, and designed an online survey to capture SME evaluation and comments on these systems
- Survey presented to 30 SMEs from NASA, DoD, and private industry

SRL Survey



SRL Rank

Comments

1 - Concept Refinement
2 - Technology Development
3 - System Development and Demonstration
4 - Production and Development
5 - Operations and Support

Submit

TRL - IRL - SRL

Survey Results

- 33% Response Rate
- Assumptions:
  - 1-1-1 = SRL 1 w/ 100% certainty
  - 9-7-9 = SRL 5 w/ 100% certainty
- From SRL 3 and Higher, IRL is a 7

Not to Scale

Case Example: Where does MCO fit?

$$SRL = f(\min[TRL_1, TRL_2], IRL_{12})$$

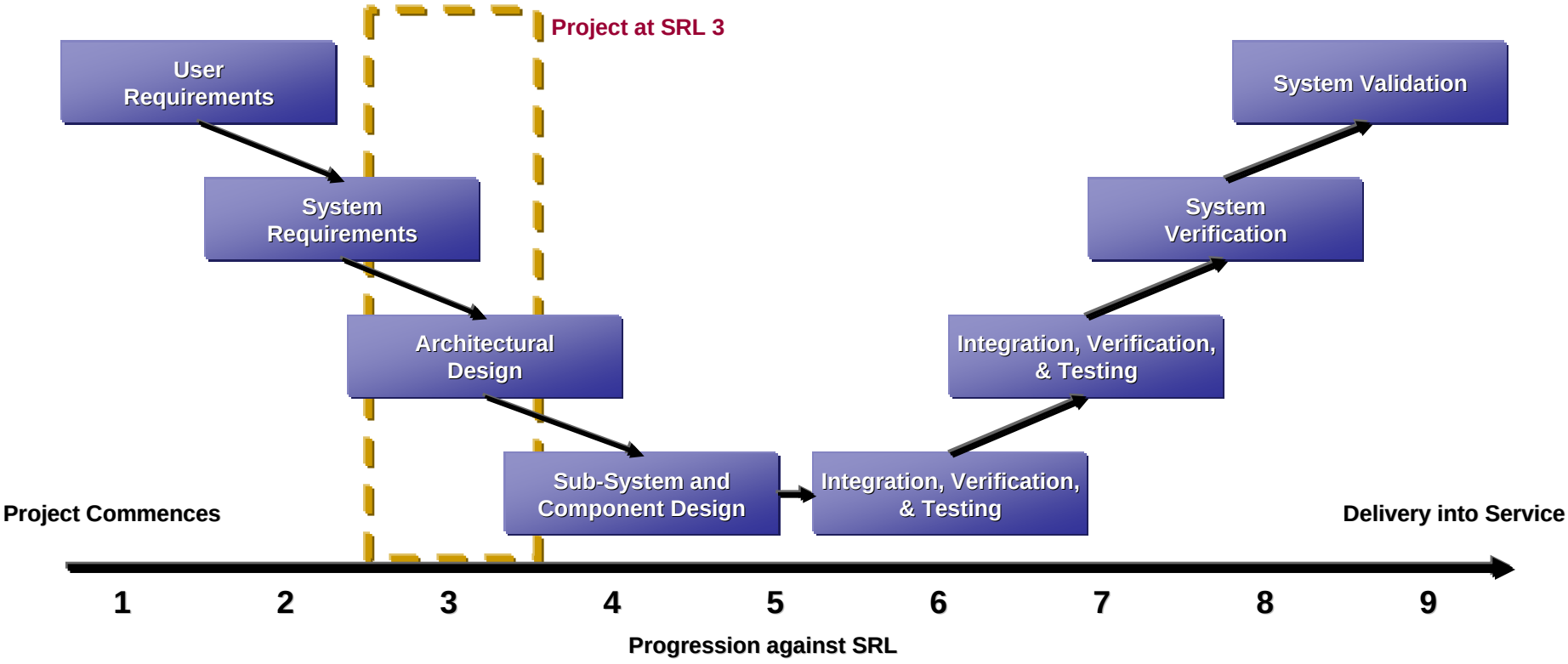
SRL = 3

Certainly MCO was more mature than a SRL 2, but also obviously not a SRL 5. So it must fit somewhere in-between, our current data shows that MCO should have been in the System Development and Demonstration phase based upon ground software integration. Certainly this is not the whole picture of the MCO system, but it is interesting how two obviously mature pieces of technology, could form an immature system simply due to immature interoperability.

Future Research Objectives…
Future Work

- Interpolate SRL data from survey to fill the gaps.
- Continue to administer survey to use the data to refine the SRL Model.
- Verify and Validate the SRL Model.
- A practical and applicable tool for calculating SRL.
- Model of best Systems Engineering and Project Management practices correlated to SRL.

Ministry of Defense SRL [6]



References

1. DoD, *Technology Readiness Assessment (TRA) Deskbook*, DUSD(S&T), Editor. 2005, Department of Defense.
2. Smith, J., *An Alternative to Technology Readiness Levels for Non-Developmental Item (NDI) Software*. 2004, Carnegie Mellon: Pittsburgh, PA.
3. Mankins, J.C., *Approaches to Strategic Research and Technology (R&T) Analysis and Road Mapping.* Acta Astronautica, 2002. **51**(1-9): p. 3-21.
4. Graettinger, C.P., et al., *Using the "Technology Readiness Levels" Scale to Support Technology Management in the DoDs ATD/STO Enviornments*, SEI, Editor. 2002, Carnegie Mellon.
5. Valerdi, R. and R.J. Kohl. *An Approach to Technology Risk Managment*. in *Engineering Systems Division Symposium*. 2004. Cambridge, MA: MIT.
6. Dowling, T. and T. Pardoe, *TIMPA - Technology Insertion Metrics*, M.o. Defense, Editor. 2005, QINETIQ. p. 60.
7. Mankins, J.C., *Technology Readiness Levels*. 1995, NASA.
8. GAO, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO, Editor. 1999.
9. Beasley, J.S., *Networking*. 2004, Upper Saddle River, NJ: Pearson Education, Inc. 579.
10. NASA, *Mars Climate Orbiter, Mishap Investigation Board: Phase I Report*. 1999.