Lessons Learned in the Application of System Readiness Level to the development of Systems of Systems for the Mission Modules Program Office

13th Annual NDIA Systems Engineering Conference
28 October 2010

Cecil Whitfield
PMS 420 Technical Director
cecil.whitfield@navy.mil

Richard Volkert
PMS 420 Deputy Technical Director
SPAWAR Systems Center Pacific
richard.volkert@navy.mil

Carly Jackson
PMS 420 Systems Engineer
SPAWAR Systems Center Pacific
carly.jackson@navy.mil

Paper Reference Number: 11446
Session: Early Systems Engineering

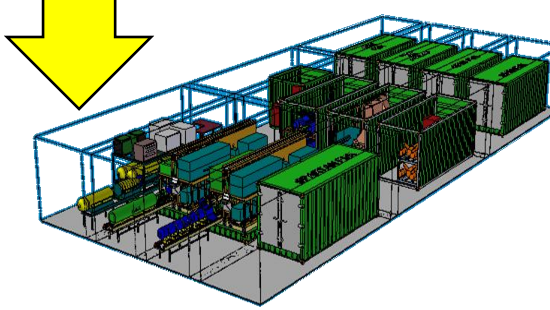
Overview

- LCS & Mission Module Definition, History, & Status
- Complexity of SoS Development
- Metrics –Good, Bad, & Ugly
- SRL –what is it & why use it?
- Lessons Learned
- Summary

Littoral Combat Ship (LCS)

- **Optimized for warfighting in the littorals**
  - Unique designs for unique environment
  - Fast, maneuverable, shallow draft
- **Targeted at critical capability gaps**
  - Reconfigurable single-mission focus
  - Mines; small fast surface craft; diesel submarines
- **Modular Open Systems Architecture approach**
  - Flexible system for dynamic battlespace
  - Advanced unmanned air, surface, and underwater vehicles
  - Onboard sensors, weapons, command and control
- **Naval and Joint Force multiplier**
  - Operational flexibility for sea superiority and assured access
  - Integral member of future surface combatant family of ships
  - Fully netted with the battle force

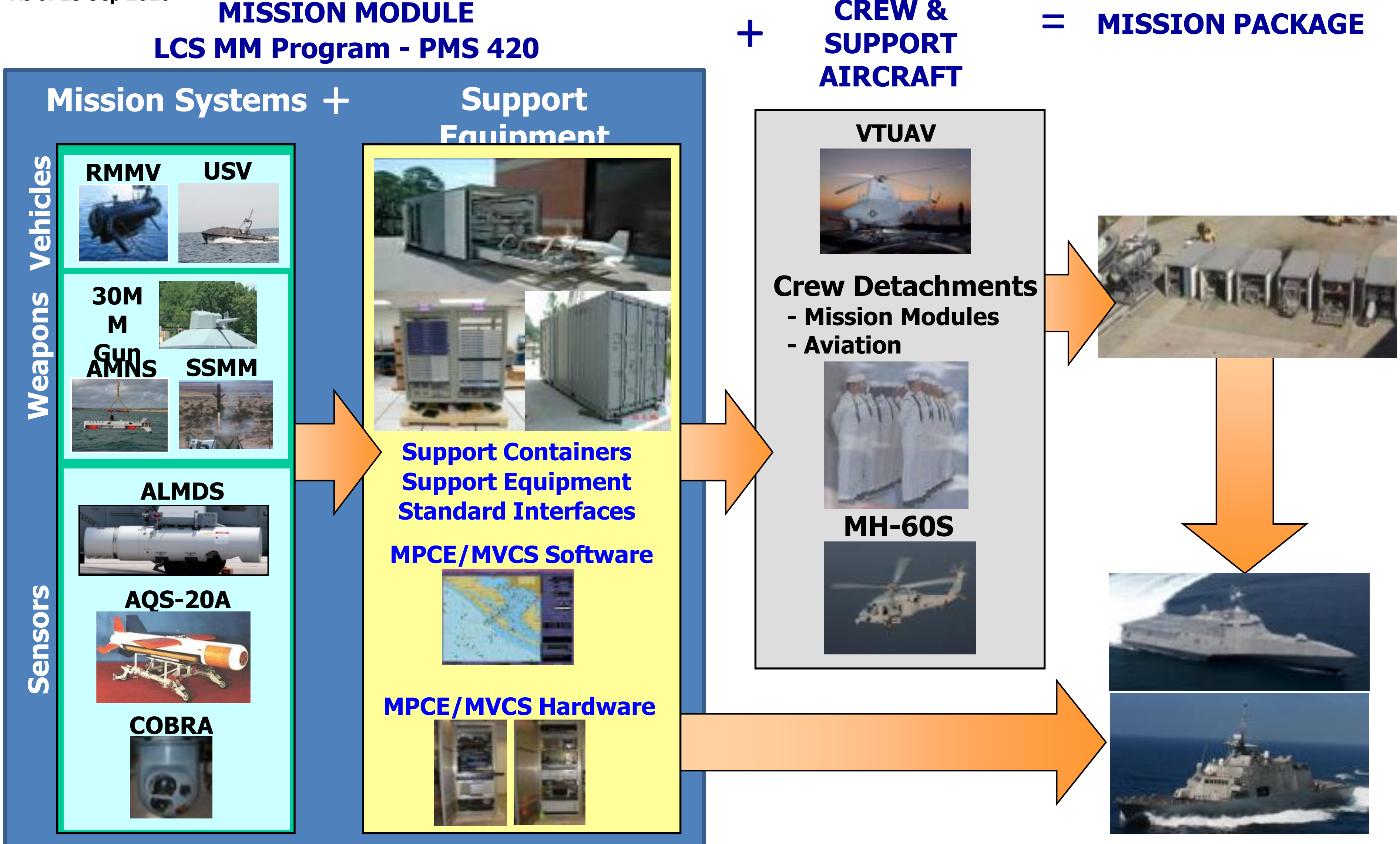
Littoral Combat Ship Interface Control Document



Navy Need: small, fast delivery vehicle with integrated focused mission package

Mission Packages Defined

As of 23 Sep 2010



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From a System to an Acknowledged System of Systems

Table 2-1. Comparing Systems and Acknowledged Systems of Systems

Aspect of Environment	System	Acknowledged System of Systems
Management & Oversight		
Stakeholder Involvement	Clearer set of stakeholders	Stakeholders at both system level and SoS levels (including the system owners), with competing interests and priorities; in some cases, the system stakeholder has no vested interest in the SoS; all stakeholders may not be recognized
Governance	Aligned PM and funding	Added levels of complexity due to management and funding for both the SoS and individual systems; SoS does not have authority over all the systems
Operational Environment		
Operational Focus	Designed and developed to meet operational objectives	Called upon to meet a set of operational objectives using systems whose objectives may or may not align with the SoS objectives
Implementation		
Acquisition	Aligned to ACAT Milestones, documented requirements, SE with a Systems Engineering Plan (SEP)	Added complexity due to multiple system lifecycles across acquisition programs, involving legacy systems, systems under development, new developments, and technology insertion; Typically have stated capability objectives upfront which may need to be translated into formal requirements
Test & Evaluation	Test and evaluation of the system is generally possible	Testing is more challenging due to the difficulty of synchronizing across multiple systems' life cycles; given the complexity of all the moving parts and potential for unintended consequences
Engineering & Design Considerations		
Boundaries and Interfaces	Focuses on boundaries and interfaces for the single system	Focus on identifying the systems that contribute to the SoS objectives and enabling the flow of data, control and functionality across the SoS while balancing needs of the systems
Performance & Behavior	Performance of the system to meet specified objectives	Performance across the SoS that satisfies SoS user capability needs while balancing needs of the systems

- Complex in Governance & Acquisition
- Composed of systems doing activities in ways that they may not of originally been intended
- Design requires balance and interfaces become a key management issue

Ref: DoD System Engineering Guide for Systems of Systems, V1.0, Aug 2008

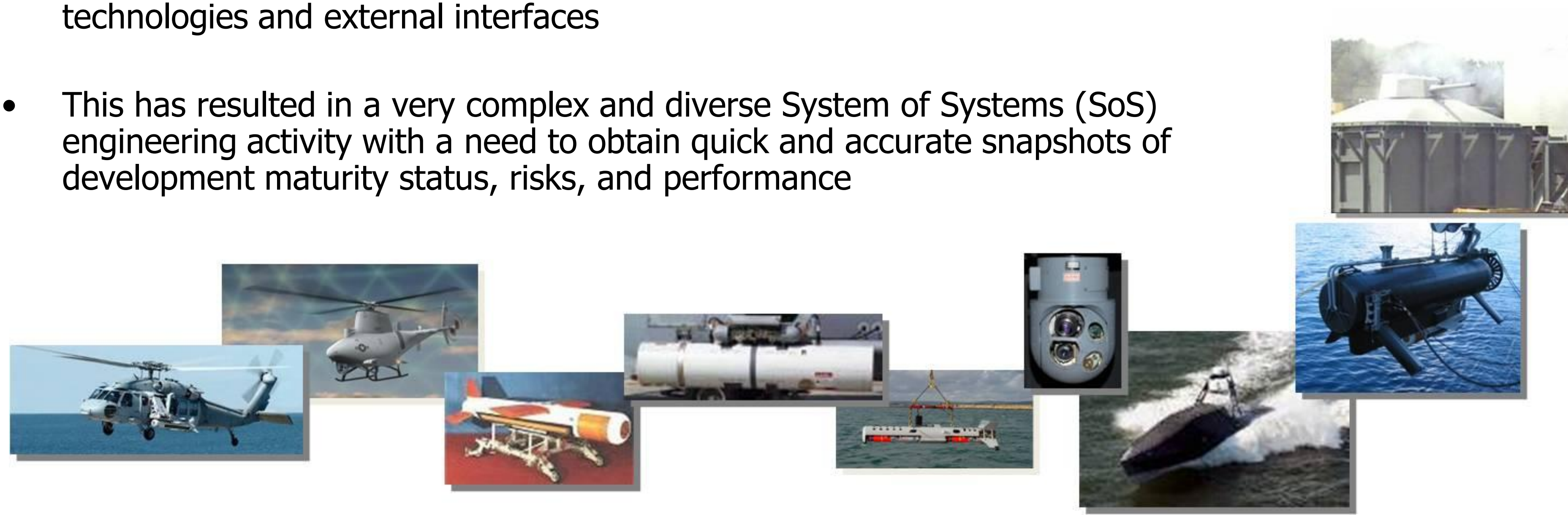
Unique SoS Acquisition Management Needs

- SoS acquisition management represents a significant increase in complexity over traditional system acquisition
- Development requires that significant numbers of new and existing technologies be integrated to one another in a variety of ways
- Poses challenges to traditional development monitoring tools and cost models due to the need to capture integration complexity and the level of effort required to connect individual components
- A high degree of inter-linkage between components can also cause unintended consequences to overall system performance as components are modified and replaced throughout the system life cycle

The result of this acquisition management paradigm shift has been significant schedule and cost overruns in SoS programs

Program Office Role and Needs

- PEO LMW / PMS 420 is responsible for the development, acquisition, and sustainment of modular, swappable Mission Modules to be used on the Littoral Combat Ship (LCS)
- Mission Modules leverage considerable amounts of technology from existing programs of record, while also requiring development of new integration software and components
- 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 and external interfaces
- This has resulted in a very complex and diverse System of Systems (SoS) engineering activity with a need to obtain quick and accurate snapshots of development maturity status, risks, and performance



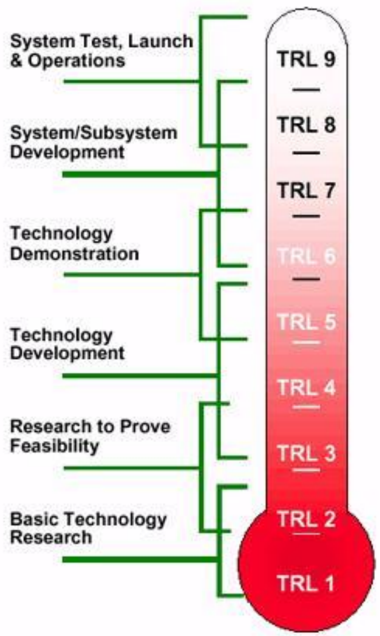
Use of Metrics

Used by Program Managers Today

- Technology Readiness Level
- Integration Readiness Level
- Manufacturing Readiness Level

MRL	Definition
1	Manufacturing Feasibility Assessed
2	Manufacturing Concepts Defined
3	Manufacturing Concepts Developed
4	Capability to produce the technology in a laboratory environment.
5	Capability to produce prototype components in a production relevant environment.
6	Capability to produce a prototype system or subsystem in a production relevant environment.
7	Capability to produce systems, subsystems or components in a production representative environment.
8	Pilot line capability demonstrated. Ready to begin low rate production.
9	Low Rate Production demonstrated. Capability in place to begin Full Rate Production.
10	Full Rate Production demonstrated and lean production practices in place.

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.



PM Need: Insight!

What is a Metric from the PM Viewpoint

Definition of *METRIC*

1 *plural* **:** a part of prosody that deals with metrical structure

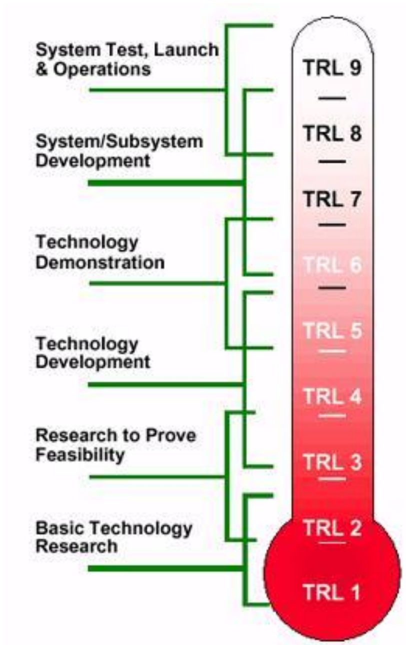
2**:** a standard of measurement <no *metric* exists that can be applied directly to happiness — *Scientific Monthly*>

3**:** a mathematical function that associates a real nonnegative number analogous to distance with each pair of elements in a set such that the number is zero only if the two elements are identical, the number is the same regardless of the order in which the two elements are taken, and the number associated with one pair of elements plus that associated with one member of the pair and a third element is equal to or greater than the number associated with the other member of the pair and the third element

Synonyms: bar, barometer, benchmark, criterion, gold standard, grade, mark, measure, standard, par, touchstone, yardstick

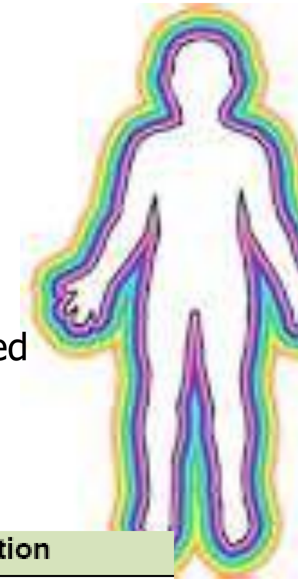
http://www.merriam-webster.com/dictionary/metric

Any metric is Fallible



TRL 6. System/subsystem model or prototype demonstration in a relevant environment

But a fuller definition is: **Representative model** or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a **relevant environment**. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment**.**

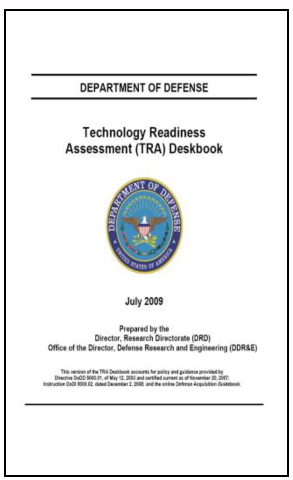


A *relevant environment* is a set of stressing conditions, representative of the full spectrum of intended operational employments, which are applied to a CTE as part of a component (TRL 5) or system/subsystem (TRL 6) to identify whether any design changes to support the required (threshold) functionality are needed.

A functional form of a system, generally reduced in scale, near or at operational specification. Models will be sufficiently hardened to allow demonstration of the technical and operational capabilities required of the final system.

Supporting Information

Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?


DEPARTMENT OF DEFENSE

Technology Readiness Assessment (TRA) Deskbook

July 2009

Prepared by the
Director, Research Directorate (DRD)
Office of the Director, Defense Research and Engineering (DDR&E)

Except at formal external reviews most values reported seldom have the detailed analysis supporting the value assigned by the owner

So Why do we use Metrics?

The road of life twists and turns and no two directions are ever the same. Yet our lessons come from the journey, not the destination." – Don Williams, Jr. (American Novelist and Poet, b.1968)

- metrics aid in providing insight, especially when time critical decisions must be made with imperfect or incomplete data –trends, notional rankings, etc.
- Need the ability to understand the impact of incremental development & acquisition choices within the systems comprising the SoS

Details of brake performance matter but the metric of interest is will your cars stop if you hit the brakes

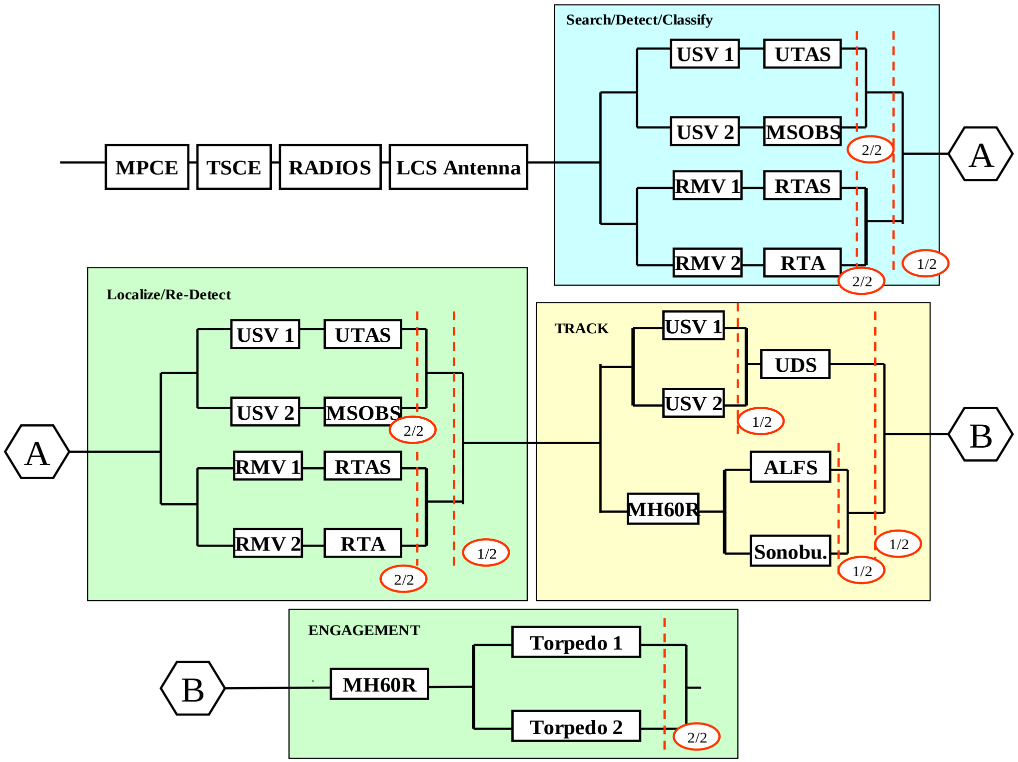
Metric Challenges in a SoS

- TPM – how do you track developmental performance measures for systems you don't own?
  - Sharing of data across POR's
  - What does compilation of the data mean for the SoS?
  - Issue of using a system different then original design concept – validity of metric
- TRL –what is the one number?
  - multiple systems, multiple options for doing the missions
  - different interfaces & end uses
  - multiple technology developmental states within the SoS

So Why Develop & Use another Metric?

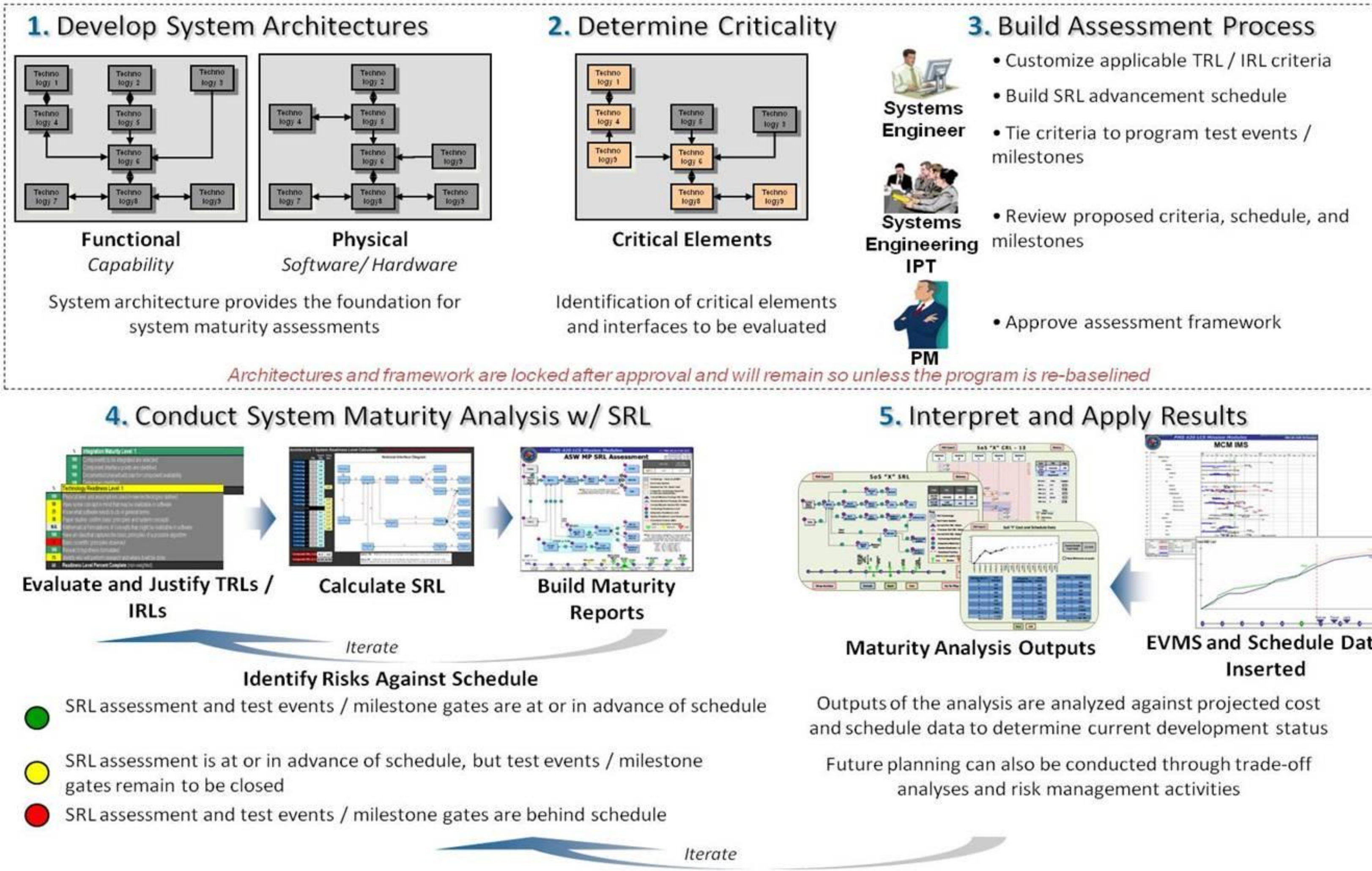
Needed Insight that other metrics presently don't address

- Performance/Risk related to the Inherent Integration Complexity of a SoS
- Needed ability to compare options/impacts in a SoS where task accomplishment could be done in multiple ways



Note: Spiral Alpha ASW capabilities on hold – used for example purposes only

System Maturity Model (SMM) Methodology



Ordinal Math – on no!

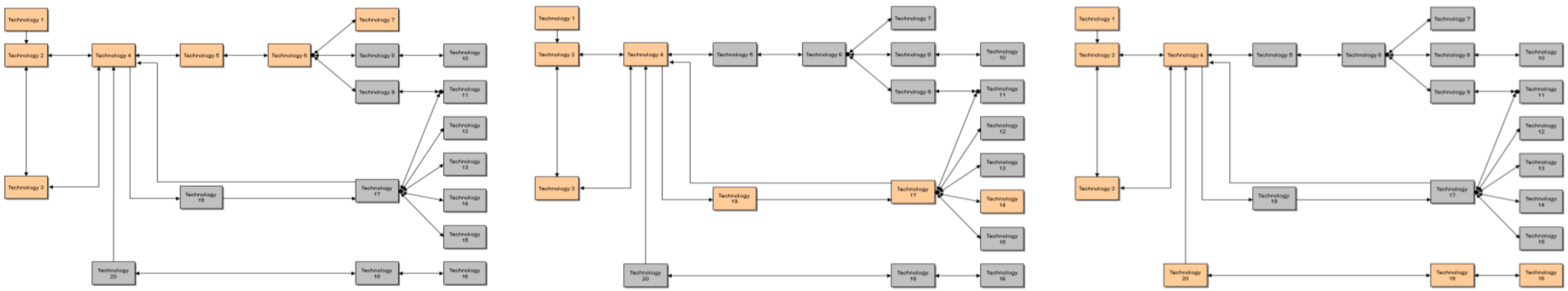
- Ordinal numbers are rank order numbers & can not be subject to mathematical operations
  - intuitively or deductively you're doing it; we combine technologies & capabilities of varying maturities and often provide a single ranking of the inherent risk in terms of a metric

The numerical value of the SRL is a point indicator, the usefulness comes from a having a methodology that allows rapid comparisons of options & allows trends to be monitored so the detailed questions can then be asked

What's is the TRL, MRL, SRL, Pick your RL of a new car, ship, missile?

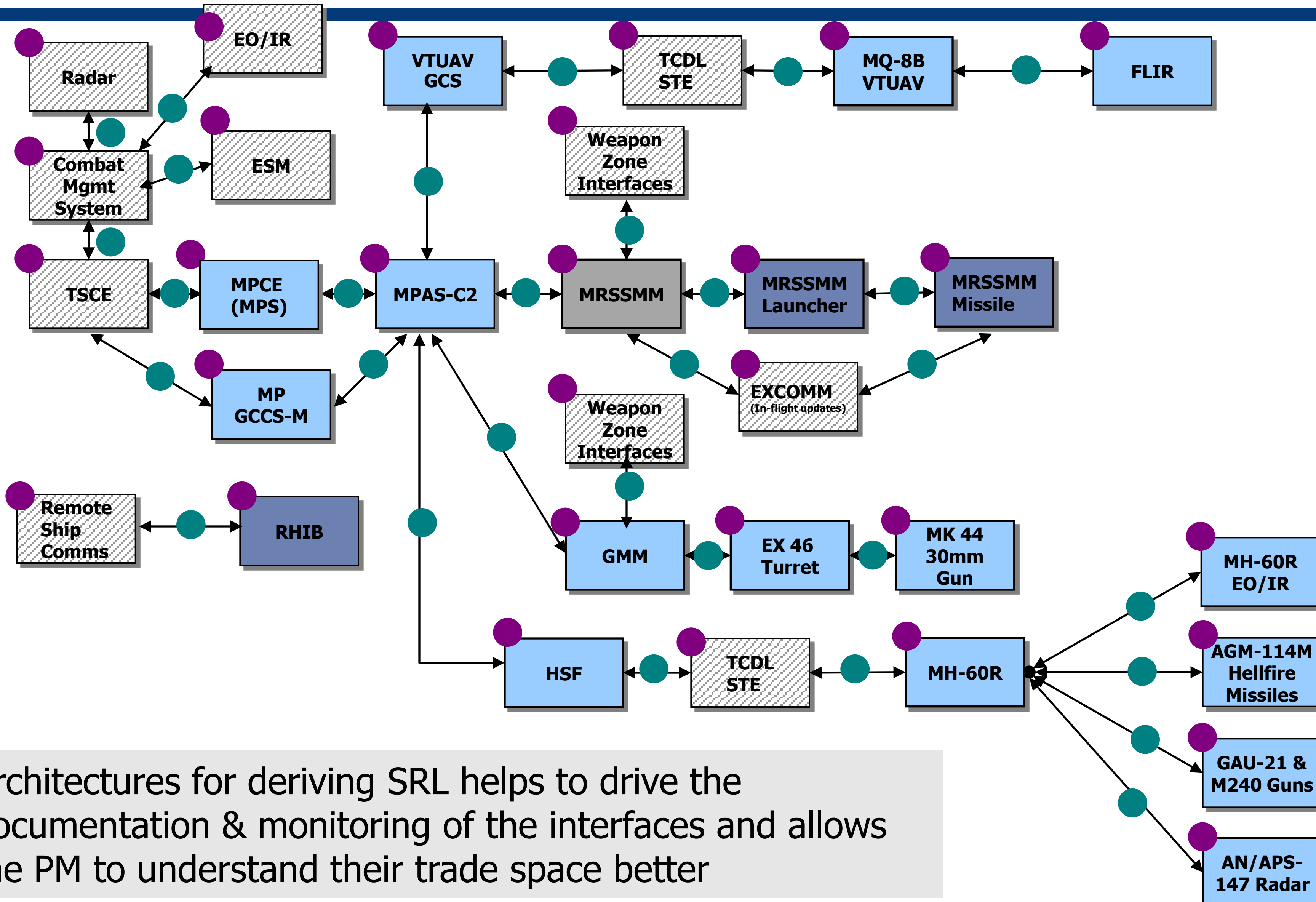
"String" Analysis Incorporated

Complex systems often offer numerous options for conducting operations



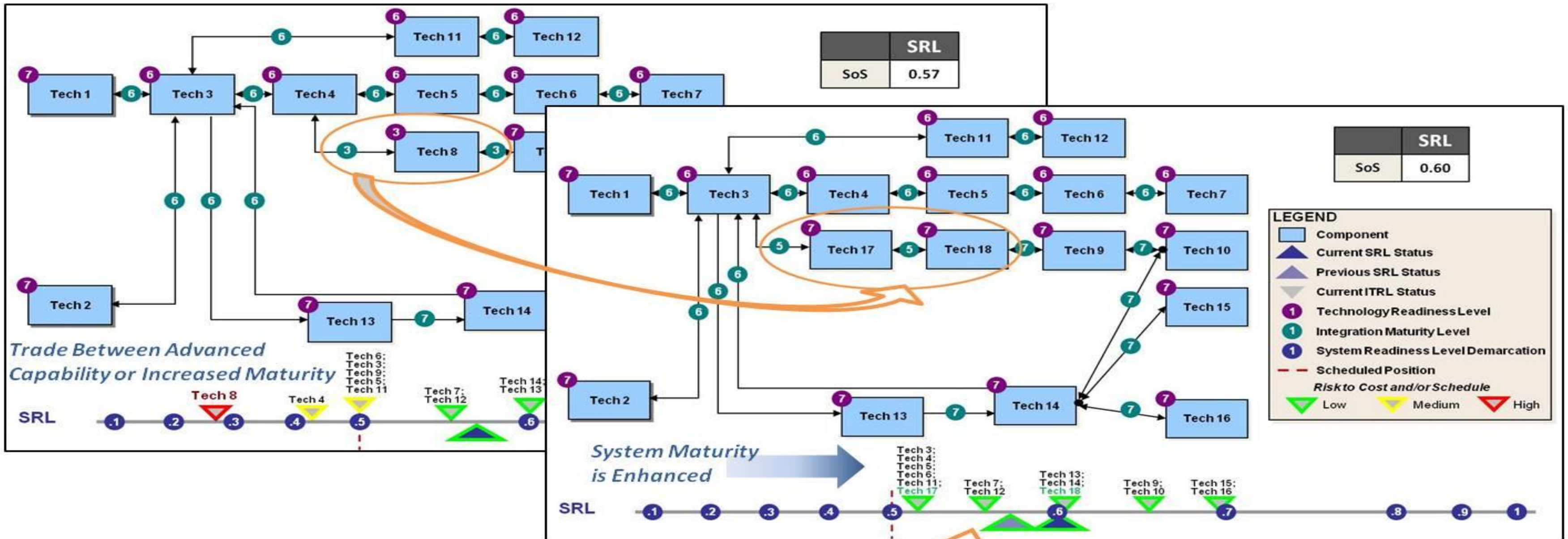
- Operational strings were created that identified the components required to utilize a single function of the system
- Assessment of the SRL for each of these options allows for a better understanding of the maturity of each operating configuration
- Understanding the true status of the system on an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

Lesson Learned-SRL Drives Discipline & Understanding

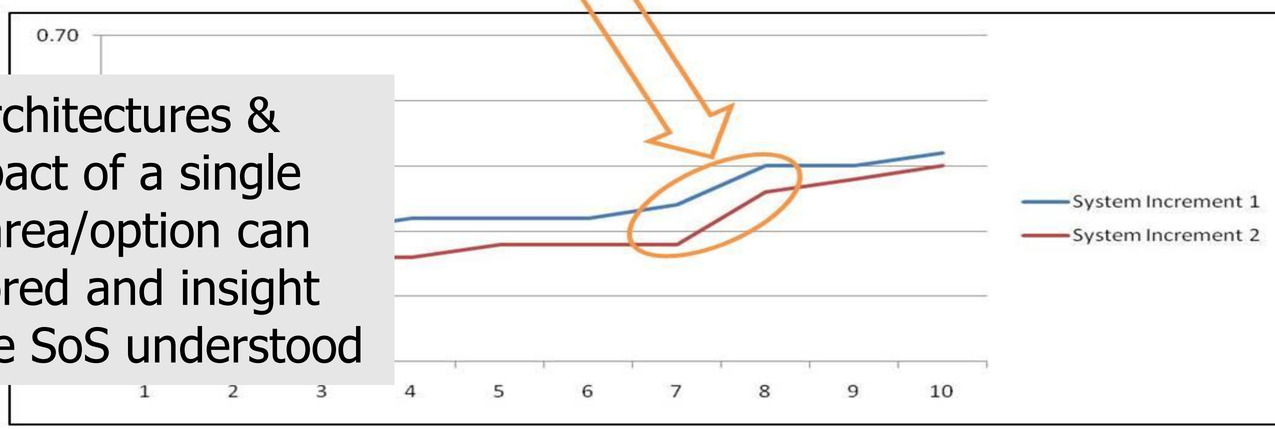


Architectures for deriving SRL helps to drive the documentation & monitoring of the interfaces and allows the PM to understand their trade space better

Supports Gathering of Insight wrt Options



By having defined architectures & integrations, the impact of a single technology change area/option can more easily be explored and insight into its impact on the SoS understood



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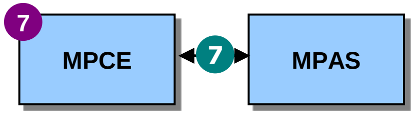
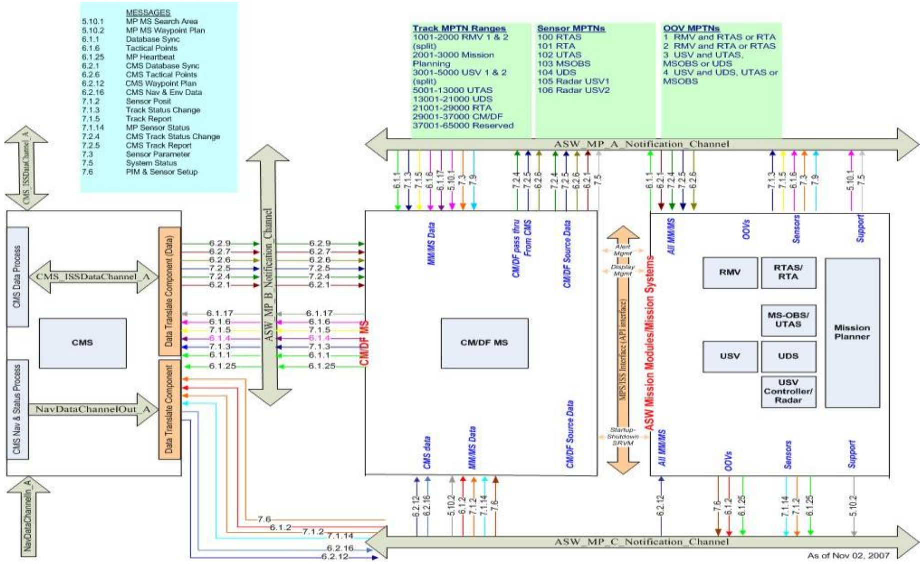
Where we need to improve

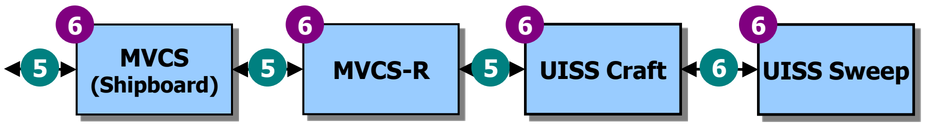
Software Integration – a multiple of potential issues within one box





ASW MP Spiral Alpha Messaging Structure

Note: Spiral Alpha ASW capabilities on hold – used for example purposes only



Incorporating all Integrations- focus on primary integration can miss key issues not viewed as high risk

Concluding Thoughts

- System of Systems (SoS) implementation is an integration and management challenge.
  - Critical need to manage interfaces well.
  - Metrics can support but existing metrics are less useful at SoS then System level
- SRL Methodology has been shown to be highly adaptable and applicable to a wide variety of PMS 420 SoS development efforts but like all metrics can mislead if used beyond its capabilities
  - If TRL & IRL are not correct then GI=GO.
  - The math can hide the impact of a single technology
  - Use for insight & trends –another tool in a PM's toolbox
  - Supports PM with I&W data and insight into trades and impacts of technology options

QUESTIONS?

Abstract

Abstract: Over the last several decades, the nature of acquisition has changed. The delivery of capabilities has shifted from a systems focus to the development and fielding of system-of-systems (SoS). The Littoral Combat Ship (LCS) Mission Modules Program Office (PMS 420) is an example of this shift in that PMS 420 was charted to develop, integrate, modularize, deploy, and sustain focused warfighting capabilities by combining existing systems into a system of systems for Surface Warfare, Anti-Submarine Warfare, and Mine Countermeasure missions. To help control this development and understand the state of capability maturation and integration, PMS 420 has worked collaboratively with the Stevens Institute of Technology and Northrop Grumman on the development and implementation of the System Maturity Model. The System Maturity Model uses the traditional Technology Readiness Level and an Integration Readiness Level to calculate a value defined as System Readiness Level. The System Readiness Level provides the Program Manager with a single point value used to define the state of the System of System combined maturity. This methodology is built upon a defined architectural representation of the capability and provides the Program Management team with insight into the probability that the focused warfighting capability can be delivered when the development of the individual system capabilities are not within the Program Managers direct control. PMS 420 has been using this tool over the past several years. From its conception to the present significant lessons have been learned by Stevens and PMS 420 in the application of the SMM. This briefing will provide and overview of the methodology used by PMS 420 in implementing the SMM and review lessons learned from that implementation.