Achieving MBSE Benefits amidst Multiple Government Program Office System of System Challenges

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LCS Mission Modules Systems Engineering & Integration
Agenda/Objective

- LCS Mission Module Challenges
- Submarine and LCS synergy
- Come as you are benefit/challenge
- LCS Model based SoS SE&I approach summary
- Interface model SoS analysis schema
- Data concordance analysis capabilities
- Model benefits
- Conclusion
LCS Mission Modules Challenge: Sheer Complexity

LCS Mission Capabilities
- Multiple Mission Packages
- Multiple Mission Modules & Multiple Increments
- Multiple Mission Systems

Mine Countermeasures Mission Package
- Remote Minehunting Mission Module
- Multiple Mission Systems
- Multiple Development Organizations

RMH Mission Systems

<table>
<thead>
<tr>
<th>System</th>
<th>PM</th>
<th>OEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMS</td>
<td>PMS 420</td>
<td>LM</td>
</tr>
<tr>
<td>Ships LH&amp;R</td>
<td>PMS 501</td>
<td>LM (FRE), GD (IND)</td>
</tr>
<tr>
<td>Mission Bay Stations</td>
<td>PMS 501</td>
<td>LM (FRE), GD (IND)</td>
</tr>
<tr>
<td>MVCS</td>
<td>PMS 420</td>
<td>NSWC-PCD</td>
</tr>
<tr>
<td>Ship C2</td>
<td>IWS-8</td>
<td>LM (FRE), GD (IND)</td>
</tr>
<tr>
<td>Mission Package C2</td>
<td>PMS 420</td>
<td>NSWC-PCD</td>
</tr>
<tr>
<td>MCM Analysis</td>
<td>PMS 495</td>
<td>SAIC, NSWC-PCD</td>
</tr>
</tbody>
</table>

LCS mission modules have both system- and organizational-complexity which results in formidable integration challenges
LCS MP Model Based SoS SE Analysis
History & Submarine Reuse

Submarine SoS SE & I (SWFTS/NPES SE&I) : Thought Leader, Steve Lose
- **Big System**: Multiple PEOs and program offices, 4 ship classes, 4 Million lines of SW code, 65 cabinets
- **Complex interfaces**: 30 subsystems, 2800 interface requirements, 25 OEMs
- **Fast Update Pace**: Yearly alternating capability / technology updates

Point to Point IRS Documents ➔ Centrally managed interface requirements ➔ MDA Prototype ➔ Model based Systems Engineering (MBSE)

LCS Mission Module SoS SE & I, Thought Leader, George Saroch
- **Big System**: 12 Mission modules, 2 class variants
- **Complex interfaces**: 25 subsystems in RMH MM alone
- **Fast Update Pace**: 4 planned increments / RTI updates

Remote Minehunting MBSE SoS Pilot ➔ Come as you are ➔ Gaps ➔ MP Common interface Products

PMS 420 sponsored SoS LCS Interface Model Pilot
- Interface MBSE model development – Significant Submarine Reuse
- RMH Mission Module Interface Requirements Generation
- Multiple RMH MBSE-enabled issues identified

SoS Tasking Details ➔ RMH Mission Module SE Analysis

Significant Submarine Methodology and Tool benefits to LCS
LCS Mission Modules Challenge: Come-As-You-Are Reuse

<table>
<thead>
<tr>
<th>“Come as you are” attribute</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability is already developed and tested on another platform, theoretically being reused for “Pennies on the dollar”</td>
<td>Generally, core capability IS available on the cheap, but integration with the platform and adjacent systems quickly eats into the savings</td>
</tr>
<tr>
<td>Interface requirements are individually developed and tested by each “come-as-you-are” mission system developer</td>
<td>Key interface functions are designed out of sync and while initial individual system development costs are less, SoS integration costs can be very high</td>
</tr>
<tr>
<td>Mission level operational specifications are not reflected coherently in the interface requirements</td>
<td>Each system has gaps and inconsistent requirements relative to the mission level specs, and as a result, mission level performance is unpredictable and KPPs are often not met</td>
</tr>
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The “come-as-you-are” (low-cost-capability) benefit does not have to come at a high platform integration cost → *A better approach is needed*
SoS MBSE Integration Methodology
MBSE Interface Model Architecture / Process

- Stakeholder developed requirements
- Structured entry into model
- Jointly reviewed model products

SoS MBSE Integration Methodology starts with a collaborative framework to develop solid interface requirements and ends with SoS thinking amongst all participants
SoS MBSE Interface Model manages the complex system information in a structured manner
Structured and Regimented Nesting of Architecture and Interface Decomposition
### Requirement Text

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement</th>
<th>Realized by</th>
<th>Used by</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYS 8.8</td>
<td>The MCM Analysis to RMS System interface shall support the transfer of sensor data from a ( y ) hour mission in ( z ) minutes or less (threshold), ( x ) minutes or less (objective). (1.5)</td>
<td>Mine Analysis System</td>
<td>RMS</td>
</tr>
<tr>
<td>SUB 10.5</td>
<td>The RDR to PMA Workstation interface shall support a minimum data transfer rate of 1 Gbit/s (threshold), 10 Gbit/s (objective) for each storage media.</td>
<td>PMA Workstation</td>
<td>RDR</td>
</tr>
<tr>
<td>CI 1.6</td>
<td>The PMA Workstation OE - RDR OE data transfer ports shall be implemented using the Gigabit Ethernet standard (threshold), or the 10 Gigabit Ethernet standard (objective).</td>
<td>PMA Workstation OE</td>
<td>RDR OE</td>
</tr>
</tbody>
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**Model Schema synchronizes and structures the decomposition of architecture, interfaces, and Interface Requirements**
LCS SoS MBSE End to End Analysis

Data Thread View
- CSCI only
- End to End data flow
- Process to process message Flow

Mechanical Thread View
- HWCI Only
- Touch Points
- Complex mechanical Interactions

Electrical Thread View
- HWCI Only
- ANSI and custom interfaces

Software Allocation View
- CSCI Only
- SW Hosting
- Basis to manage OS Environment

Network View
- HWCI Only
- Network Topology
- Network standards
- Throughput “choke point” analysis

Interface model provides an end-to-end viewpoint in the data, electrical and mechanical domains to engage the appropriate SME discipline.
MP ICD Content: Operational Analysis Artifacts

Activity Diagrams
- Flow of activities for decomposing operational information
- Lowest level activity becomes sequence diagram

Sequence Diagrams
- Provides means to ensure operations between subsystems are covered by requirements
- Provides baseline for additional operational analysis

<table>
<thead>
<tr>
<th>Operation</th>
<th>Reqt ID</th>
<th>Requirement Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMMV Position, Heading, and Speed</td>
<td>CI 68.16</td>
<td>The RMMV CTL CSCI shall send RMMV position (latitude and longitude) to the DLI-R CSCI to support MVCS automatic link management.</td>
</tr>
<tr>
<td>RMMV Position, Heading, and Speed</td>
<td>CI 68.17</td>
<td>The RMMV CTL CSCI shall send RMMV heading to the DLI-R CSCI to support MVCS automatic link management.</td>
</tr>
<tr>
<td>RMMV Position, Heading, and Speed</td>
<td>CI 68.18</td>
<td>The RMMV CTL CSCI shall send RMMV speed to the DLI-R CSCI to support MVCS automatic link management.</td>
</tr>
</tbody>
</table>

Linked Interface Requirements
- Thread function integrity in requirements baseline
- Objective test checklist

SoS MBSE Interface model provides a solid foundation to ensure operational architecture to interface requirements integrity
Structured SoS Thread Integration Maturity model provides a means to objectively and thoroughly plan platform integration.
**MBSE Thread Integration Maturity Support**

Automated *Thread level* Interface-RVM status

**Legend:**
- **Tested** Requirements
  - Tested by any of the following:
    - RM5/LM Val/Ver testing
    - MVCs/PCD Throughput testing
    - MVCs/PCD SRS testing
    - RMS/LM Integration testing
- **Untested Requirements**
  - High: Requirements failure results in Pri 1 or 2 SPR
  - Med: Requirements failure results in Pri 3 SPR
  - Low: Requirements failure results in Pri 4 or 5 SPR

PRE-PLATFORM per thread Risk Mitigation

**Expected Risk Levels after mitigation**

MBSE SoS Thread Integration Maturity → Predictable Platform Performance
## LCS SoS MBSE Integration Methodology
### RMH Benefit / ROI

<table>
<thead>
<tr>
<th>SoS MBSE Activity</th>
<th>Approach</th>
<th>Benefit / Result</th>
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</table>
| 1. Maximize RMH Q20 Sensor Thread Performance | Defined the RMH sensor thread architecture, end-to-end performance requirements for the Q20-B sensor information movement/processing. | • Technical: Established initial NSAM performance requirements for Q20B sensor  
• Technical: Developed RMH sensor thread end-to-end architecture to maximize TPM adherence |
| 2. Define RMH MM Orphaned Hardware | Developed PMS 420/403 “Orphan MOA” which adjudicated technical (spec) and programmatic ($$) ownership with 420/501/503/495 for 41 configuration items | • Cost/Schedule: Avoided cost and schedule churn 41 tactically required configuration items  
• Defined full set of capability required to transition the RMH MM to production |
| 3. Mitigate RMH Comms (RMS / MVCS) Interface Risk | Generated MVCS/RMS interface requirements verification matrix (I-RVM) identifying 62 high-priority interface requirements which had not been adequately tested. | • Cost/Schedule: Drove RMS/MVCS integration problems to be found and fixed much earlier in the lifecycle  
• Risk Mgt: Provided objective information manage IOT&E integration risk |
| 4. Mitigated RMH on FRE interface risk | Developed performance-requirements based approach to buy-down RMH on FRE risk well ahead of on-platform timeframe | • Risk Mgt: Mitigation plans developed for 4 high priority and 5 medium priority MCM on FRE risks  
• Risk Mgt: Options developed for wake flow-field analysis to benefit multiple UxV L&R  
• Risk Mgt: Options developed for seaframe information exchange risk |

Model and Methodology investment recouped .. And counting
SoS MBSE ROI Foundation

“Come-As-You-Are” Approach
- Interface Specs Generated by each PARM
- Very few interface problems solved early
- Most interface problems solved on-platform (8x)

Cost, Schedule, Performance unpredictable

SoS MBSE Integration Methodology
- IPT-generated Interface Requirements
- More Interface problems solved early
- More predictable platform tests
  - Fewer “new” problems
  - Significant cost reduction
  - Improved Schedule, Technical Performance

SoS MBSE Integration Methodology enables Rapid Capability Insertion

LCS SoS MBSE Integration Methodology

Conclusion / Takeaway

• Enables the “come-as-you-are” approach to be rapidly acquiring capability from other Navy programs

• Has been proven with the RMH MM pilot to avoid costs and manage risks at the mission module / platform integration level

• Scales to multiple mission modules and multiple platforms

• Enables all stakeholders to manage their own systems and their own role in mission module / platform integration to cohesively satisfy the LCS fleet and sponsor

The Glue for the LCS MP Engineering Enterprise