Using UPDM for Defense Architectures

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Lockheed Martin Master Architect

UPDM – It’s Not Just for Acquisition Milestones Anymore
Why Architect?

• Architecting is an Integral Part of Systems and Software Engineering
  – Starts with understanding stakeholder concerns
  – Extends through requirements analysis and derivation
  – Relevant at multiple levels of abstraction

• Architecture Definition generates and evaluates multiple candidate architectures that frame stakeholder concerns and meet system requirements, then down-selects the architectural basis for Design Definition

*It is critical NOT to select an architecture just because you did it that way on the last project*
Why Use UPDM?

• UPDM provides a reasonably concise language to capture stakeholder concerns and to express high level architectures that address them
  – Standardization reduces ambiguity in communicating, particularly with external stakeholders
  – Simplifies source selection all along the supply chain

• Integrates cleanly with SysML and UML to support refining the architecture and to enable design
LM DoDADF Architecting Methodology

• Object-oriented Model-Based Systems Development evolved from OMG OOSEM using UPDM for the ‘upper architecture’, SysML for most systems engineering and design, augmented by UML where needed for software and services

• DoDADF is used to frame (not dictate) the set of architectural viewpoints modeled – but NOT to drive the process of architecting
  – Viewpoints are selected or defined to address specific concerns, not checklists
  – Note that for US DoD programs, the JCIDS process requires specified DoDADF views for key milestone documents (ICD/CDD/CPD)

Methodology applicable at each level in the supply chain
Worked Example

Notional Combat System for New Conventional Attack Submarine (NAS)
Notional Missions, Capabilities and Architecturally Significant Requirements adapted from Wikipedia Collins Class and Virginia Class descriptions, and RAN Whitepaper on SEA-1000

This notional architecture was developed for training purposes only.
• “9.3 For the reasons spelled out in Chapter 8, the Government has decided to acquire 12 new Future Submarines, to be assembled in South Australia. This will be a major design and construction program spanning three decades, and will be Australia's largest ever single defence project. The Future Submarine will have greater range, longer endurance on patrol, and expanded capabilities compared to the current Collins class submarine. It will also be equipped with very secure real-time communications and be able to carry different mission payloads such as uninhabited underwater vehicles.

• 9.4 The Future Submarine will be capable of a range of tasks such as anti-ship and anti-submarine warfare; strategic strike; mine detection and mine-laying operations; intelligence collection; supporting special forces (including infiltration and exfiltration missions); and gathering battlespace data in support of operations.

• 9.5 Long transits and potentially short-notice contingencies in our primary operational environment demand high levels of mobility and endurance in the Future Submarine. The boats need to be able to undertake prolonged covert patrols over the full distance of our strategic approaches and in operational areas. They require low signatures across all spectrums, including at higher speeds. The Government has ruled out nuclear propulsion for these submarines.”
Understanding Stakeholders Concerns
OV-1 Operational Concept

[Map showing operational concepts involving Hostile Submarine, Hostile Ship, New Australian Submarine, Strike Missile, Hostile ASW Helo, Coastal Facility, Battlespace, Background Maritime, Conduct Intelligence Preparation, COMSAT, Maritime Patrol Aircraft, SBS deploy, recover, detect, surveil, deploy, mine, detect, evade, engage, communicate, detect, track, track, engage, Surveil, employ, detec, evade, engage.]

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NAS Operational Use Cases

• Anti-Submarine Warfare
• Anti-Surface Warfare
• Combat Search and Rescue
• Damage Control
• Engage Hostile ASW Aircraft
• Experimentation
• Force Protection
• Indications and Warning
• Intelligence Preparation of the Battlespace
  – Clandestine Survey
  – Coastal Surveillance
  – Maritime Surveillance
• Mine Warfare
  – Lay Minefield
  – Chart Minefield
• Recharge Batteries
• Special Boat Squadron (Special Forces) Support
• Strike Warfare
  – Strike using Missile
  – Strike using SBS
• Transit
  – Harbor Transit
  – Hostile Waters Transit
  – Surface Transit
  – Submerged Transit
• Team Training
Use Cases Analyzed to Derive Requirements

- **Engage ASW Aircraft with SAM**
  - **Id**: "10"
  - **Text**: "The NAS shall be able to shoot down an airborne target at a range of 10 nm and at an altitude of 5,000 feet flying at a speed not more than 400 kts."
  - **verifyMethod**: Demonstration

- **Sonar Track Hovering Helo**
  - **Id**: "44"
  - **Text**: "The sonar system shall be capable of detecting and tracking a helicopter flying within 75 meters of the surface of the ocean below sea state 3."

- **Launch SAM While Submerged**
  - **Id**: "45"
  - **Text**: "The NAS shall be capable of launching a surface-to-air missile while submerged at periscope depth."

**Extension Points**
- Engage Hostile ASW Helo
  - **Include**
    - Detect and Track ASW Helo
  - **Extend**
    - Target Aircraft with SAM
Use Cases Refine Driving Requirements

- **Surface Transit**
- **Harbor Transit**
- **Submerged Transit**
- **Hostile Waters Transit**

**Transit Operations**

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**Submerged Speed without Snorkeling**
- \( \text{Id} = "4" \)
- \( \text{Text} = "\text{The NAS shall sustain a submerged speed through the water of not less than 20 kts for not less than 6 hours without snorkeling.}" \)
- \( \text{verifyMethod} = \text{Test} \)

---

**Indiscretion Ratio**
- \( \text{Id} = "5" \)
- \( \text{Text} = "\text{The NAS shall maintain main battery charge state during submerged operations while snorkeling not more than 30 minutes in any 24 hour period.}" \)
- \( \text{verifyMethod} = \text{Demonstration} \)

---

**Submerged Endurance**
- \( \text{Id} = "2" \)
- \( \text{Text} = "\text{Submerged endurance shall be at least 14 days at a speed through the water of not less than 5 kts without snorkeling.}" \)
- \( \text{verifyMethod} = \text{Demonstration} \)

---

**Reduced Power Operations**
- \( \text{Id} = "43" \)
- \( \text{Text} = "\text{During transit operations, the NAS combat system shall support all combat system functionality with only two consoles powered up.}" \)

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**Minimum Watch Size**
- \( \text{Id} = "42" \)
- \( \text{Text} = "\text{The NAS combat system shall be operable with a minimum watch of two operators during transit operations.}" \)
Operational Activities may be modeled at the UJTL level, or down to whatever level is needed to flesh out the architecture and design.
Strike Requirements Refinement

«functionalRequirement»
Engage with Strike Missile
Id = "3"
Text = "The NAS shall be able to plan and execute a missile strike ashore using a land attack missile launched from a 21" hydraulic ram weapon launcher while submerged at a depth of at least 20 meters and at a speed through the water of not less than 5 kts."
nvMethod = Demonstration

«functionalRequirement»
Support Special Forces
Id = "11"
Text = "The NAS shall be able to carry up to 18 special forces operators on a 90 day mission without hot-bunking."
nvMethod = Analysis

«extendedRequirement»
Plan Strike Missile Engagement
Id = "46"
Text = "The NAS shall provide the capability to plan missile strikes ashore using targeting data received over the Strike Targeting Network."
nvMethod = Demonstration

«extendedRequirement»
Use GFI Strike Planner
Id = "48"
Text = "The NAS combat system shall use the GFI strike missile planning system."
nvMethod = Inspection

«requirement»
SOF Mission Planning
Id = "47"
Text = "The NAS combat system shall support the GFI SOF mission planning software."
OV-4 Command Relationships

OV-2 Operational Resource Flow Description

- **Definition**: May be RAN, Joint, Allied or Coalition Commander

- **Performer**: Australian Submarine Group
  - Operational Control
  - Mission Report, Logistics Requirements
  - WSM Request
  - WSM Assignment
  - Mission Orders

- **Performer**: Operational Command
  - Operational Control
  - Strike Targeting
  - Operational Tasking

- **Performer**: New Australian Submarine
  - Strike Targeting
  - Operational Tasking
OV-2 Resource Flows
OV-2 Information Flows

- **Port**
  - Logistics Request, Arrival Notice, AIS Message, AIS Report
  - NAV Update, AIS Message, Harbor Clearance

- **Fleet Command Ashore**
  - Minefield Map, Logistics Request, Track Coordination, ISR Report, Contact Report, Casualty Report, Movement Report, I&W Report, OPSTAT CASREP, Operational Summary, Arrival Notice
  - Strike Targeting, INTEL Report, SUBOPAUTH, NAV Update, OPTASK, ASW Targeting, ROE, Track Coordination, ASUW Targeting, Minefield Map, SUBNOTE, METOC

- **Friendly Helo**
  - IFF, ASW Targeting, OPS Coordination, Distress Signal

- **Friendly MPA**
  - Distress Signal, ASW Targeting, IFF, OPS Coordination

- **NAS**
  - OPTASK, Contact Report, Distress Signal, Minefield Map, Track Coordination, OPS Coordination, IFF, Strike Targeting, ASUW Targeting

- **Civilian Shipping**
  - OPS Coordination, Distress Signal

- **NAVSAT**
  - NAV Message, Time Reference

- **Friendly Military Ship**
  - OPS Coordination, Distress Signal, Contact Report, Track Coordination, Minefield Map, ASUW Targeting, I&W Report, IFF

- **Hostile Platform**
  - Distress Signal, OPS Coordination

- **SOF**
  - I&W Report, OPS Coordination, ISR Report
<table>
<thead>
<tr>
<th>Exchange ID</th>
<th>Exchange Name</th>
<th>Operational Exchange Item</th>
<th>Sending Performer</th>
<th>Receiving Performer</th>
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<tbody>
<tr>
<td>OE9</td>
<td>LOG-00001</td>
<td>IE15 Combat System Problem Reports</td>
<td>New Australian Submarine</td>
<td>Combat System Provider</td>
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<tr>
<td>OE7</td>
<td>LOG-00002</td>
<td>Combat System Spares, Software Update</td>
<td>Combat System Provider</td>
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<td>OE5</td>
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<td>IE7 Strike Targeting</td>
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<td>TAC-00002</td>
<td>IE1 Mission Orders</td>
<td>Australian Submarine Group</td>
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<td>ADM-00001</td>
<td>IE6 Mission Report, E2 Logistics Requirements</td>
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<td>Australian Submarine Group</td>
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<td>TAC-00003</td>
<td>IE38 ISR Collection Data</td>
<td>New Australian Submarine</td>
<td>RAN Intelligence</td>
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<td>OE16</td>
<td>TAC-00004</td>
<td>IE16 Intelligence Report</td>
<td>RAN Intelligence</td>
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<tr>
<td>OE15</td>
<td>NAV-00001</td>
<td>IE19 Electronic Chart Update</td>
<td>RAN METOC</td>
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<td>OE14</td>
<td>LOG-00003</td>
<td>21&quot; UUV, Anti-Ship Missile, Large UUV, Strike Missile, Torpedo, Food, Medical Supplies, Ammunition, Ship Systems Spares</td>
<td>Fleet Logistics</td>
<td>New Australian Submarine</td>
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<td>Fleet Logistic</td>
<td>New Australian Submarine</td>
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<td>TAC-00005</td>
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<td>New Australian Submarine</td>
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<td>OE10</td>
<td>TAC-00006</td>
<td>IE16 Intelligence Report</td>
<td>New Australian Submarine</td>
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<td>OE18</td>
<td>NAV-00002</td>
<td>IE39 WSM Assignment</td>
<td>SUBOPAUTH</td>
<td>New Australian Submarine</td>
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<td>OE19</td>
<td>NAV-00003</td>
<td>IE40 WSM Request</td>
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<td>OE24</td>
<td>TAC-00008</td>
<td>IE49 SAS Tactical Coordination</td>
<td>New Australian Submarine</td>
<td>Special Forces Operators</td>
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<td>OPS-00001</td>
<td>IE52 Operational Control</td>
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<td>Operational Command</td>
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<td>IE52 Operational Control</td>
<td>Operational Command</td>
<td>Australian Submarine Group</td>
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<td>OE27</td>
<td>TAC-00009</td>
<td>IE53 Operational Tasking</td>
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<td>New Australian Submarine</td>
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<tr>
<td>OE28</td>
<td>NAV-00004</td>
<td>IE54 Chart Updates</td>
<td>New Australian Submarine</td>
<td>RAN METOC</td>
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## NAS Architecturally Significant Requirements

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Text</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Range</td>
<td>Unrefueled range shall be at least 12,000 nm.</td>
<td>P</td>
</tr>
<tr>
<td>2</td>
<td>Submerged Endurance</td>
<td>Submerged endurance shall be at least 14 days at a speed through the water of not less than 5 kts without snorkeling.</td>
<td>PR</td>
</tr>
<tr>
<td>3</td>
<td>Engage with 21&quot; Torpedo</td>
<td>The NAS shall be able to engage one target with at least two wire- or fiber-optic guided 21&quot; torpedoes simultaneously.</td>
<td>SAD</td>
</tr>
<tr>
<td>4</td>
<td>Submerged Speed without Snorkeling</td>
<td>The NAS shall sustain a submerged speed through the water of not less than 20 kts for not less than 6 hours without snorkeling.</td>
<td>PC</td>
</tr>
<tr>
<td>5</td>
<td>Indiscretion Ratio</td>
<td>The NAS shall maintain main battery charge state during submerged operations while snorkeling not more than 30 minutes in any 24 hour period.</td>
<td>PS</td>
</tr>
<tr>
<td>6</td>
<td>Large Diameter UUV Operations</td>
<td>The NAS shall be able to launch and recover a large diameter UUV (not less than 2 meters diameter, not less than 6 meter length) while submerged.</td>
<td>YPS</td>
</tr>
<tr>
<td>7</td>
<td>Built in Australia</td>
<td>To the maximum extent practical, the NAS shall be built in Australia of Australian components</td>
<td>KCD (A?)</td>
</tr>
</tbody>
</table>

**Key** Architecture Design Cost Platform Combat_System PAYloads Crew
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Text</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Engage with ASM</td>
<td>The ASM shall be able to engage and sink a surface ship with an anti-ship missile launched from a 21&quot; hydraulic ram weapons launch tube while submerged at a depth of at least 20 meters and at a speed through the water of not less than 5 kts.</td>
<td>PSA</td>
</tr>
<tr>
<td>9</td>
<td>Engage with Strike Missile</td>
<td>The NAS shall be able to plan and execute a missile strike ashore using a land attack missile launched from a 21&quot; hydraulic ram weapon launcher while submerged at a depth of at least 20 meters and at a speed through the water of not less than 5 kts.</td>
<td>PSA</td>
</tr>
<tr>
<td>10</td>
<td>Launch and Recover UAV</td>
<td>The NAS shall be able to launch and recover a hatchable UAV while surfaced.</td>
<td>S</td>
</tr>
<tr>
<td>11</td>
<td>Engage ASW Aircraft with SAM</td>
<td>The NAS shall be able to shoot down an airborne target at a range of 10 nm and an altitude of 5,000 feet flying at a speed not more than 400 kts.</td>
<td>PSR</td>
</tr>
<tr>
<td>12</td>
<td>Support Special Forces</td>
<td>The NAS shall be able to carry up to 18 special forces operators on a 90 day mission without hot-bunking.</td>
<td>P</td>
</tr>
<tr>
<td>13</td>
<td>Submerged Lock-Out</td>
<td>The NAS shall be able to lock-out 18 special forces operators in not more than 12 minutes while the top of the sail is submerged to a depth of at least 5 meters.</td>
<td>P</td>
</tr>
</tbody>
</table>

**Key**

Architecture  Design  Cost  Platform  Combat_System  Payloads  Crew
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Text</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Weapons Load-out</td>
<td>The NAS shall carry a weapons load-out of not less than 36 heavyweight 21&quot; torpedo equivalents.</td>
<td>P</td>
</tr>
<tr>
<td>15</td>
<td>Large Payload Tubes</td>
<td>The NAS shall have at least two payload tubes capable of launching and recovering a large UUV at least 2 meters in diameter and at least 6 meters long.</td>
<td>PSA</td>
</tr>
<tr>
<td>16</td>
<td>Large Payload Tube Power Interface</td>
<td>Each large payload tube shall be capable of providing at least 10 amps of power at 120 VAC inductively coupled at 1 meter from the bottom of the tube.</td>
<td>P</td>
</tr>
<tr>
<td>17</td>
<td>Large Payload Tube Data Interface</td>
<td>Each large payload tube shall be capable of supporting an IEEE 802.11n wireless data interface sustaining at least 54 Mbps coupled through 1 cm of sea water at the bottom of the tube.</td>
<td>SP</td>
</tr>
<tr>
<td>18</td>
<td>Number of 21&quot; Weapons Launchers</td>
<td>The NAS shall have at least 6 21&quot; hydraulic ram weapon launchers capable of accommodating any of a UUV, Stonefish Mark III mine, Sub-Harpoon ASM, strike missile, or Mk.48 CBASS heavyweight wire-guided torpedo.</td>
<td>PSR</td>
</tr>
<tr>
<td>19</td>
<td>Control Six Torpedoes Simultaneously</td>
<td>The NAS shall be able to simultaneously control at least six 21&quot; wire- or fiber-optic guided torpedoes.</td>
<td>SAD</td>
</tr>
</tbody>
</table>

**Key:** Architecture, Design, Cost, Platform, Combat Sistema, Payloads, Crew
Identifying Needed Capabilities
CV-2 Capabilities Taxonomy

- **Operate Independently**
  - Exhibit Extended Underwater Endurance
  - Autonomous Navigation: Navigate Autonomously
  - Extended Operational Range: Extended Operational Range

- **Operate with Stealth**

- **Support Special Forces**

- **Manage Off-board Assets**
  - Employ large diameter Unmanned Underwater Vehicle
  - Employ 21st Unmanned Underwater Vehicle
  - Employ Unmanned Air Vehicle

- **Employ Weapons**
  - Employ Torpedo
  - Employ Strike Weapon
  - Employ Anti-Ship Missile

- **Provide Situational Awareness**
  - Conduct Clandestine Survey: Conduct Clandestine Survey
  - Conduct Clandestine Maritime Surveillance: Conduct Clandestine Maritime Surveillance
  - Conduct Clandestine Coastal Surveillance: Conduct Clandestine Coastal Surveillance

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The Objective of “Monitoring the Ocean Environment” has been used as the basis for the capability “Monitor Ocean Environment”

Notice the link to the mission, and to the operational activities that make up the operational thread for this capability.

A sample of the type of Operational Activities that support the capability is shown. These will be further elaborated through System Services and Functions later.
CV-1 NAS Vision – Phased Implementation

CV-1 Vision [New Australian Submarine Vision]

- Maritime Dominance
- Persistent ISR
- Power Projection

New Australian Submarine

- endDate = 2060
- startDate = 2025

- Initial Operational Capability
- East-Coast Deployment
- Midlife Upgrade
Defining the Solution Architecture
Solution Architecture Considerations

• Foregoing analysis has defined the problem we need to solve

• Multiple paths forward lead to good, compliant solutions
  – Analysis methods like structured decomposition and object oriented analysis
  – Design techniques like functional integration and SOA

• The best solution almost always requires tradeoffs and compromises

Consider alternatives and avoid the temptation to dive down to a point solution
Generating Candidate Architectures

• There are almost always multiple valid approaches to designing a combat system. Differentiating factors include:
  – Services decompositions
  – Computational architectures
  – Re-use strategies
  – Decompositions induced by the core competencies of alternative partners

• Each approach has its own strengths and weaknesses, and may be appropriate in some application

*It is critical NOT to select an architectural approach just because you did it that way on your last project, or even on the last combat system.*
Multiple architectures SHALL be constructed and traded!!!
SvcV-2 Service Resource Flows
• System functions are the foundation for services
• Based on all of the analysis up to this point, we identify the system functions needed to support the identified activities and services
• *Come up with at least two different functional decompositions – don’t lock in the first one suggested*
• Requirements, new data elements, and additional services will be exposed by this process – update the model to capture all of them as you go along!
• Iterate, Iterate, Iterate, …
SV-4 Combat System Functional Decomposition

- Monitor Ship Status
  - Monitor Ownership Signature
  - Track Expendables
- Navigate the Ship
  - Plan Course
  - Determine Position Inertially
  - Determine Position using Optical Fix
  - Measure Location using NAVSAT
  - Update Charts
- Maintain Tactical Picture
  - Automatically Fuse All-Source Tracks
  - Identify Maritime Track
  - Project Maritime Track
  - Report Tactical Situation
  - Track Air Target
  - Track Maritime Target
  - Manually Reclassify Tracks
  - Record Track Histories
- Plan Operations
  - Plan ASM Engagement
  - Plan Missile Strike
  - Plan Torpedo Engagement
  - Plan UUV Mission
  - Plan SOF Operation
  - Monitor Tactical Environment
    - Process Acoustic Data
    - Conduct SIGINT
    - Employ Photonics
    - Monitor Ocean Environment
    - Monitor Towed Array
    - Deploy and Recover Towed Array
- Conduct Operations
  - Launch Wire-guided Torpedo
  - Guide Torpedo
  - Launch Countermeasure
  - Launch 21" UUV
  - Recover 21" UUV
  - Launch Strike Missile
  - Recover Large Diameter UUV
  - Launch Large Diameter UUV
  - Launch Anti-Ship Missile
  - Engage MPA with SAM
  - Engage ASW Holo with SAM
  - Launch Environmental Probe
SV-4 Sonar Functional Decomposition

SV-4 Functionality Description

- **Process Acoustic Data**
  - **Function** Detect Mines
  - **Function** Measure Velocity
  - **Function** Measure Depth Below Keel
  - **Function** Range Target Using Active Sonar

- **Model Acoustics**
  - **Function** Model Acoustic Propagation
  - **Function** Calculate Sound Velocity Profile

- **Process Passive Sonar Data**
  - **Function** Process Towed Array Data
  - **Function** Perform Adaptive Beamforming
  - **Function** Detect ASW Helo Acoustically
  - **Function** Process Bow Array Data
  - **Function** Process Flank Array Data
  - **Function** Perform Passive Ranging
SV-1 Combat System Interfaces On-Platform

SV-1 Systems Interface Description

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## SV-3 System to System Mapping

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SV-4 Physical Architecture

Show only those elements of the NAS HM&E relevant to the combat system architecture.

- **domain** NAS
  - **system** HM&E
    - **block** 21″ Launcher
    - **block** Large Payload Tube
    - **block** Countermeasure Launcher
    - **block** Signal Launcher
    - **block** Mast Elevation Mechanism
    - **block** Towed Array Handler
  - **block** ASM Controller
  - **block** Strike Missile Controller
  - **block** Sonar Hull Arrays
  - **block** Torpedo Control Unit

- **system** Combat System
  - **block** Common Console
  - **block** Vertical Large Screen Display
  - **block** Photonic Mast
  - **block** Antenna Mast
  - **block** ASM Controller
  - **block** Strike Missile Controller
  - **block** Sonar Hull Arrays
  - **block** Torpedo Control Unit

- **domain** Payloads
  - **block** Heavyweight Torpedo
  - **block** Signal Flares
  - **block** Anti-Ship Missile
  - **block** Strike Missile
  - **block** Mine
  - **block** Hatchable UAV
  - **block** Surface to Air Missile
  - **block** Expendable Bathythermograph
Summary

• UPDM is a useful language for developing and communicating solution and product family architectures
  – LM architcturing methodology has been applied on multiple successful programs
  – Downside of UPDM + SysML + UML + DoDAF + powerful OO and analytic modeling tools is steep learning and knowledge/skill maintenance curve

• UPDM does help bridge the gap between enterprise architecture and solution design