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# Model-Based Methodology for System of Systems Engineering with Application to the Development of the Architecture for the Unmanned Vehicle Sentry

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## Abstract

Unmanned vehicle (UV) systems are a vital part of military operations, performing dull, dirty, and dangerous tasks that are key to achieving the 21<sup>st</sup> Century Maritime Strategy. A major factor which has inhibited unmanned systems from meeting their full potential has been that the majority of architectural developments for their use have principally been *technology* driven, with the developer having a preconceived notion of the solution. Our work shows the development of a method that is *capabilities* driven, based on mission activities, is needed to deliver desired effects. Our model-based architecture development method provides a basis for solution neutral investigation of possible alternative physical architectures to meet overall functional System of Systems (SoS) needs based on a traceable path to the 21<sup>st</sup> Century Maritime Strategy. Key outcomes described in this paper are an architecture generation process (with focus on stakeholder needs and utility) and an example architecture suited to unmanned SoS that integrates the diverse assets involved in this complex system of systems.

# Introduction

The United States Navy is in need of a capabilities-driven development process for the design and acquisition of new systems. The need to design an adequate architecture is key to identifying top-level requirements and their interconnection to both the internal and external system elements that are crucial in meeting the capability need. For this study, a new unmanned vehicle (UV) based capability, the UV Sentry System of Systems (SoS), is used to demonstrate the utility and potential of this method. The UV Sentry is a SoS, and exhibits characteristics as listed in Table 1 (Boardman and Sauser 2006).

**Table 1. Systems and System-of-Systems Characteristics (Boardman and Sauser 2006).**

Element	System	System of Systems	Cross References
<b>Autonomy</b>	Autonomy is ceded by parts in order to grant autonomy to the system	Autonomy is exercised by constituent systems in order to fulfill the purpose of the SoS	Directed [13], Planned [13, 14], Embedded [15], Autonomy [4, 15-17]
<b>Belonging</b>	Parts are akin to family members; they did not choose themselves but came from parents. Belonging of parts is in their nature.	Constituent systems choose to belong on a cost/benefits basis; also in order to cause greater fulfillment of their own purposes, and because of belief in the SoS supra purpose.	Enterprise [14, 18, 19], Shared Mission [20-22], Sharing [14]
<b>Connectivity</b>	Prescient design, along with parts, with high connectivity hidden in elements, and minimum connectivity among major subsystems.	Dynamically supplied by constituent systems with every possibility of myriad connections between constituent systems, possibly via a net-centric architecture, to enhance SoS capability.	Interdependence [23, 24], Distributed [13-15, 21, 25-27], Networked [14, 21, 25], Multiple Solutions [24], Loose Coupling [16], Integration [27-29], Interoperability [29-31], Synergism [4, 30]
<b>Diversity</b>	Managed i.e. reduced or minimized by modular hierarchy; parts' diversity encapsulated to create a known discrete module whose nature is to project simplicity into the next level of the hierarchy	Increased diversity in SoS capability achieved by released autonomy, committed belonging, and open connectivity	Independence [22, 24-27], Diversity [15, 22, 32], Heterogeneous [25, 33]
<b>Emergence</b>	Foreseen, both good and bad behavior, and designed in or tested out as appropriate	Enhanced by deliberately not being foreseen, though its crucial importance is, and by creating an emergence capability climate, that will support early detection and elimination of bad behaviors.	Evolving [14, 16, 23, 25-28], Intelligence [14], Sum is Greater than Parts [24], Behaviors [34], Emergence [4, 14, 16, 25-27], Dynamic [14], Adaptive [19, 31]

The fundamental basis of this capabilities-driven development process is a model-based systems design and engineering methodology that is demonstrated for an early stage concept design, which could be used as the basis for an analysis of alternatives (AoA). Key outcomes described in this paper are an architecting and architecture generation process (with focus on stakeholder needs and utility) ideally suited to unmanned systems complemented by a systems engineering process - from engineering requirements definition to physical architecture integration - for fusing the diverse assets involved in this complex system. The goal of our ongoing work is the development of a systems architecting and engineering process that directly addresses the development of future UV capabilities. Key outcomes described in this study are

- An architecture and architecture-based requirements generation process (with focus on stakeholder needs)
- A concept of operations for a range of military missions in a set of possible operating domains addressed in the UV Sentry concept

- A model-based systems design (MBSD) methodology defined in a larger context of a model-based systems engineering (MBSE) process that combines architecting principles, from engineering requirements definition to physical architecture integration, for fusing the diverse assets involved in this complex system
- An architecture model based on capabilities mapped to mission activities

The end result is a method that enables effective decision-making efforts for the design and acquisition of future classes of Navy systems as well as preventing the expenditure of resources in areas that may not be feasible in the period of development, thus ensuring a sound basis for defining the overall architecture for the future fleet.

**Methodology.** “There is a great need to describe a process to ensure that the architecture, the arrangement of elements and their relationships, is well-defined and addresses the needs of the stakeholders” (DoDAF, 2004). This need is met in this study through the development of a MBSD methodology. It is possible to do either a systems engineering process without producing a systems architecture, or creating an architecture without subjecting it directly to a systems engineering process. However, the quality of the outcome from the two processes done independently will be substantially lower than if the two processes are done in conjunction. This requires consideration of many traditional and newly elucidated aspects related to systems – from systems architecting and engineering, capabilities-based planning, SoS, and architectural frameworks.

## Unmanned Vehicle Introduction

**Background.** Unmanned vehicle (UV) systems have become a vital part of a wide range of military operations, performing tasks that are dull, dirty, and dangerous. Experience gained from warfare operations against asymmetric threats has specifically elucidated the need for versatile UV systems enabling better situation awareness for joint battlefield commanders. Nevertheless, at this time, the majority of developing unmanned systems and robotic technologies have yet to properly meet the rigorous demands and testing for integration into existing system constructs for field utility (OSD, 2007).

As the ability to meet further future warfighting capabilities with unmanned systems increases through operational need identification and technology development, a rigorous method of approaching the development of architectures that define systems and SoS adequately enough for inhibited unmanned systems from meeting their full potential has been that the majority of architectural developments for their use have principally been *technology* driven, with the developer having a preconceived notion of the solution (Bindi, et al, 2008). The driving motivation for our work is the development of techniques that are *capabilities* driven, based on thorough generation and review of mission-based ability to deliver a set of desired effects (Walker, 2005).

The process of identifying a capability gap or need, defining both architectural and engineering requirement specification, analyzing system functions, and allocation to system physical components cannot be satisfactorily completed using existing architecture framework products alone (Richards, et al, 2007) (Bailey, 2007). The result will enable effective focus of future research efforts and prevent the expenditure of resources into areas that are not critical, or that may not be feasible in the period of development, thus insuring a successful long term program for the UV Sentry SoS. The development of an architecture is a key step in defining the “fuzzy front end”

of this SoS.

**UV Sentry SoS Concept.** The UV SoS is designed to fuse various a breadth of surface, sub-surface, and airborne UV elements to accomplish a broad set of capabilities. The overall UV Sentry system will provide situational awareness around assets, both land and sea-based and perform information, surveillance and reconnaissance (ISR) alerts at distances sufficient to neutralize detected threats. Furthermore, the system will, when appropriate, monitor and engage threats, ensure information sharing between forces and operate/manage system assets autonomously with minimal human supervision/control/support. Figure 1, depicts a notional UV Sentry implementation for protecting a seabase (NSWCCD, 2006).

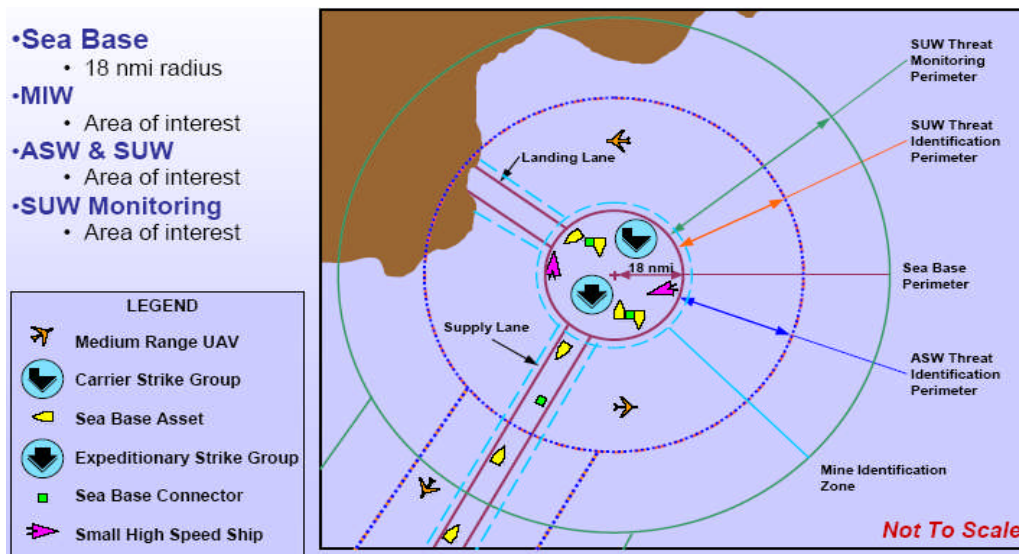


Figure 1. UV Sentry in Defense of a Sea Base (NSWCCD, 2006)

## Mission Analysis

**Background.** For effective systems engineering, accurate problem solving cannot occur without proper problem definition. Preconceived problem solutions or requirements-first systems engineering results in a biased design. The generation of a mission from a desired capability for problem definition will lead to an accurate problem solution to support the range of stakeholders' needs.

The complexity associated with autonomous UV force protection makes knowledge of enemy terrain crucial. The Design Reference Mission (DRM) concept is used in order to establish a warfighting CONOPS for a UV platform trade study baseline context. A DRM defines the operational activities necessary to prove desired capability achievement. "The DRM establishes the baseline for subsequent systems engineering activities - particularly generation of requirements, refining problem definition, development of concepts, and analysis of alternatives, and testing and evaluation. A well developed DRM will facilitate generation of requirements and subsequent system design" (Skolnick & Wilkins, 2000).

"For the government led development process, the DRM feeds the development and certification of a system functional baseline and provides support through the entire life of the

program. Thus the DRM must support the program throughout the systems engineering process” (Skolnick & Wilkins, 2000). To ensure that the final iteration of the DRM is the best solution for capabilities-driven requirements generation, it is important to receive feedback from all stakeholders associated with the system and then to refine the DRM based on that feedback.

Composing a DRM begins with understanding the warfighter’s operational concept and then using this as a simulated environment to let system concept alternatives perform. Once in a mission-executable environment, the capabilities necessary to complete that mission can be exercised. Designing a reference mission begins with understanding the environment surrounding the mission analysis. A scenario includes a goal, a deployment of systems, a physical environment in which the mission takes place or is executed, and whatever changes the environment will undergo as the scenario progresses.

**Stakeholder Need.** The UV Sentry SoS is desired perform the capabilities found in any or all of manned aerial, surface, and underwater platforms, thus it will need the operational capabilities listed below, as defined by the project stakeholders

- Provide situational awareness around sea-based assets at distances sufficient to neutralize detected threats
- Perform ISR alert function and, when appropriate, monitor and engage threats
- Operate and manage system assets autonomously, including autonomous refueling/recharging to minimize human supervision/control/support
- Process data autonomously to provide a knowledge base for the operational force so that they can make informed decisions
- Deploy non-lethal and lethal weapons under human command and control

**Projected Operational Environment (POE).** The POE is the environment in which the system is expected to operate. It provides the necessary details to describe the mission areas, environment, and types of locations to determine the operational capabilities for which the system will be designed. The POE provides information for establishing a context within which tasks will produce their measurable outcomes.

**Potential Targets.** The first phase of the UV Sentry will be primarily deployed for force protecting and so does not include and offensive scenarios.

Some possible defensive scenarios

- Protection of
  - Fixed at-sea platforms
  - Strike groups or sea bases
  - Ports or harbors
  - Possible choke points
- ISR missions to locate enemy forces
- Tracking and interception of suspicious vessels
- Mine location and clearance

**Operational Situations (OPSIT).** The system developer/engineer must go through the planning process to determine “how” the mission will be accomplished. The product of this mission analysis is a plan that details tasks to be assigned to the operational nodes through operational activities in order to complete a mission. A mission consists of multiple operational activities, and its execution typically involves multiple system elements simultaneously conducting a variety of assigned tasks. These tasks are integrated and synchronized in order to accomplish the operational

activities necessary to achieve the mission. OPSITs depict tasks required to perform the mission commander's CONOPS. The commander determines the tasks that are essential to mission success and identifies these as Mission Essential Tasks (MET). The MET are derived from the Universal Joint Task List (UJTL), Universal Naval Task List (UNTL), Navy Tactical Task List (NTTL) and the Naval Mission Essential Task List (NMETL), as appropriate.

OPSITs can be thought of as specific instances of a DRM where the variables can change, creating unique OPSITs for that mission time. OPSIT outcomes based on computational simulation can eventually be compared to developmental test and evaluation (DT&E) in that the system is stressed within a realistic scenario, verifying that the system's operational activities are sufficient to perform the mission effectively. The information and feedback from Subject Matter Experts (SMEs) is imperative for quality OPSIT development. OPSITs should be validated by the SMEs, creating a balance between the average and extreme situations (Skolnick & Wilkins, 2000).

**OPSIT Generation.** For every operational activity achieved by a mission, a set of operational tasks are defined to develop a warfighter CONOPS. Assumptions are made about the environment, logistics, deployment, and time required to achieve the mission. Assumptions are realistic variables meant to provide defined parameters for the scenario keeping it manageable. The systems engineer must determine what variables are key to studying system performance and which can be assumed at certain levels.

The specific mission in this case is to protect a high value asset such as a fixed off-shore platform (oil or gas production or terminal or military operating base). Figure 2 displays the geographical setting for this DRM off the east coast of North Carolina.



**Figure 2. Map of Operating Area (Google, 2009)**

Other information necessary includes maritime and other conditions and potential threats.

### Maritime Conditions

Sea State	<3
Water Temperature	95 F
Bathymetry	Max depth 90 meters, Average depth 50 meters

### Other Conditions

Waters surrounding target are used for commercial fishing and large numbers of small craft are common.

### Threat

Enemy force (conventional or terrorist) that can attack by air, surface, or underwater to damage or destroy target.

### Assumed Threat General Conditions

The attack will be conducted by

- A reasonably sophisticated terrorist organization that is non-state sponsored
- A suicide force capable of a covert, combined air, surface, and underwater attack

Attack platforms are commercially available

- Small commercial aircraft (single or twin engine)
- Surface craft similar in size and appearance to indigenous commercial or pleasure boats (but modified for higher performance)
- Small submersibles designed for sightseeing or covertly built for illegal operations such as smuggling

Conventional explosives only are used.

Minimal early indicators of a pending attack.

Attack occurs near dawn and the weather conditions are clear with low wind speeds.

### Assumed Threat Approach

- Threat surface vehicles transit to the general area of the platform from the direction of a nearby commercial fishing fleet in a boat of similar appearance.
- Threat submersible is transported to the vicinity by a commandeered transiting personal luxury vessel.
- Threat aircraft uses low altitude and deception to approach surveillance area.

### Threat characterization

Threat	Speed	Probability
Surface Vessel	20 knots	Low
	30 knots	Medium
	40 knots	High
Submersible	2.5 knots	Medium
	5 knots	High
	7.5 knots	Low
Aircraft	125 knots	Low
	150 knots	Medium
	175 knots	High

## Threat Tactics

### Raid size (vessels)

- 1
- 5
- 20

## Attack Timing and Coordination

- One at a time
- All at once in a concentrated location
- Surround surveillance area and simultaneous attack

**Mission Success Requirements.** The OPSIT identifies the individual capabilities that need to be accomplished in order to define the success of the mission. The capabilities identified for the success of this DRM will be measured in these categories

- Protect against terrorist threats
- Provide self-defense against surface threats
- Provide self-defense against subsurface threats
- Provide self-defense against air threats
- Provide communications infrastructure
- Provide network protection
- Provide network synchronization
- Provide information transfer
- Conduct sensor management and information processing
- Detect and identify targets
- Provide cueing and targeting info
- Assess engagement results
- Provide mission planning
- Provide battle management synchronization
- Provide common precision navigation and time generation (PNT) and environmental information
- Integrate and distribute sensor information
- Track and facilitate engagement of time sensitive targets
- Track and facilitate engagement of non-time sensitive targets

The mission is divided into these categories based on the specific functions that each individual operational activity is required to perform. Each category must be completed in order to identify the mission as being successful.

**Mission Definition.** In order to complete the mission success levels, all operational activities are utilized. Each mission included within a DRM scenario can be decomposed into the individual operational activities necessary to complete the tasks that the DRM scenario requires. The Joint and Naval Capability Terminology List is a compilation of Joint and Navy capabilities areas. The Joint Capability Areas (JCAs) are broken into Warfighting Mission Areas (WMA) which includes Joint Training, Command & Control, Force Application, Force Protection, Focused Logistics, Battlespace Awareness and Force Management. The Naval capabilities are taken from the Naval Power 21 which is a combination of Sea Power 21 and Expeditionary Maneuver Warfare Capabilities. Naval Power 21 has 5 pillars which are Sea Shield, Sea Strike, Sea Basing,

Expeditionary Maneuver Warfare, and FORCENet. The capabilities that will be focused upon in this case are Sea Shield and FORCENet. The missions within that capability will be focused upon are Force Protection, Surface Warfare, Undersea Warfare, Theater Air and Missile Defense as shown in Table 2, and all mission areas of FORCENet as shown in Table 3.

**Table 2. Sea Shield Pillar from Naval Power 21 (and Naval Capability Terminology List, 2007)**

<b>Sea Shield</b>		
Mission Capability <sup>1</sup>	Definition	Mission Sub-Capability <sup>1</sup>
Force Protection	Preventative measures taken to mitigate hostile actions against Department of Defense personnel, resources, facilities, and critical information. Force Protection does not include actions to defeat the enemy or protect against accidents, weather, or disease. (JP 1-02)	Protect Against SOF and Terrorist Threats
		Mitigate Effects of CBRNE
Surface Warfare	The ability to conduct maritime operations in order to destroy or neutralize enemy naval surface forces and merchant vessels (Modified JP 1-02 by JROC for JCAs)	Provide Self-Defense Against Surface Threats
		Conduct Offensive Operations Against Surface Threats
Undersea Warfare	The ability to conduct operations to establish battlespace dominance in the underwater environment, which permits friendly forces to accomplish the full range of potential missions and denies an opposing force the effective use of underwater systems and weapons. It includes offensive and defensive subsurface, antisubmarine, and mine warfare operations. (Modified JP 1-02 by JROC for JCAs)	Provide Self-Defense Against Subsurface Threats
		Neutralize Open Ocean Submarine Threats
		Neutralize Submarine Threats in the Littorals
		Counter Minefields from Deep to Shallow Water
		Breach Minefields, Obstacles, and Barriers from Very Shallow Water to the Beach Exit Zone
Theater Air and Missile Defense	All defensive measures designed to destroy attacking enemy aircraft or missiles in the Earth's envelope of atmosphere, or to nullify or reduce the effectiveness of such attack (JP 1-02) The integration of joint force capabilities to destroy enemy theater missiles in flight or prior to launch or to otherwise disrupt the enemy's theater missile operations through an appropriate mix of mutually supportive passive missile defense; active missile defense; attack operations; and supporting command, control, communications, computers, and intelligence measures. (JP 1-02)	Conduct Mining Operations
		Provide Self-Defense Against Air and Missile Threats
		Provide Maritime Air and Missile Defense
		Provide Overland Air and Missile Defense
		Conduct Sea-Based Missile Defense

**Table 3. FORCEnet Pillar from Naval Power 21 (and Naval Capability Terminology List, 2007)**

FORCEnet		
Mission Capability <sup>1</sup>	Definition	Mission Sub-Capability <sup>1</sup>
Communication and Networks/Infrastructure	An organization of stations capable of intercommunications, but not necessarily on the same channel. (JP 1-02)	Provide Communications Infrastructure
		Provide Network Protection
		Provide Network Synchronization
		Provide Information Transfer
Battlespace Awareness/Intelligence, Surveillance, and Reconnaissance	The systematic observation of aerospace, surface, or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means to obtain knowledge and understanding of the operational area's environment, factors, and conditions, to include the status of friendly and adversary forces, neutrals and noncombatants, weather and terrain, that enables timely, relevant, comprehensive, and accurate assessments, in order to successfully apply combat power, protect the force, and/or complete the mission. (JP 1-02; Battlespace Awareness, Surveillance, Reconnaissance)	Conduct Sensor Management and Information Processing
		Detect and ID Targets
		Provide Cueing and Targeting Info
		Assess Engagement Results
Command and Control/Decision Support	The exercise of authority and direction by a properly designated commander over assigned and attached forces in the accomplishment of the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of a mission. (JP 1-02)	Provide Mission Planning
		Provide Battle Management Synchronization
		Provide Common PNT and Environmental Information
		Integrate and Distribute Sensor Info
		Track and Facilitate Engagement of Time Sensitive Targets
		Track and Facilitate Engagement of Non-Time Sensitive Targets

The DRM is decomposed into the following operational activities (COAL v2.0, 2007)

- Provide command and control decision support
  - Decide
  - Act
- Conduct ISR/maintain battlespace awareness (Observe)
  - Manage sensors and information processing
  - Develop and maintain shared awareness of the situation
- Execute theater air defense operations
  - Conduct theater air and missile defense
  - Assess information
  - Perform NIFC-CA
- Understand the situation
  - Recognize threats
  - Determine prospective targets

- Prioritize targets prior to attack
- Conduct CBR-D activities
  - Prepare for impending attack
  - Perform operations during attack

Once all operational activities have been identified, the functions necessary to achieve the mission will be identified and documented.

**Mission Execution.** Executing the mission will consist of completing certain tasks that can be traced back to their respective operational activities. Figure 3 shows a notional environment for the UV Sentry system. Possible missions relating to this setting could be intercepting

- a submersible that has come within the observation area
- some surface vessels that have broken away from within a fishing fleet and start heading toward the oil platform
- an aircraft that is suspiciously operating around the airspace directly surrounding the platform

In any of these situations UV Sentry will respond by completing the tasks that it has been programmed to enact when a threat is identified. The tasks taken from the Navy Tactical Task List (NTTL) 3.0 that will be identified for the DRM are

- Collect data and intelligence
- Process and exploit collected information and intelligence
- Produce intelligence
- Disseminate and integrate intelligence
- Acquire, process, communicate information, and maintain status
- Analyze and assess situation
- Determine and plan actions and operations
- Enhance survivability
- Provide security for operational forces and means

Metrics for the above tasks are developed using the Universal Navy Task List (UNTL).

NTA 2.2 Collect Data and Intelligence

M1	Percent	Of targets accurately identified.
M2	Percent	Of targets accurately located.
M3	Percent	Of PIRs have at least one source that yielded intelligence information.
M4	Hours	After PIR satisfied, collection asset is retasked.
M5	Percent	Of the time, operational decisions supported by information not covered by collection plan.
M6	Percent	Of PIRs have more than one source that yielded intelligence information.
M7	Hours	Since most current intelligence information collected.
M8	Percent	Of PIRs collected in time to meet current operational needs.
M9	Number	Images exploited
M10	Time	To exploit images received

NTA 2.3 Process and Exploit Collected Information and Intelligence

M1	Hours	Turnaround to process new intelligence data.
M2	Percent	Of raw information correctly prepared for production phase.
M3	Number	Images exploited per day
M4	Time	To exploit images received

NTA 2.4 Produce Intelligence

M1	Hours	For intelligence information to be prepared in a format suitable for dissemination.
M2	Minutes	After observation of activity, an Intelligence Report is disseminated.

#### NTA 2.5 Disseminate and Integrate Intelligence

M1	Percent	Of time, intelligence disseminated late to units.
M2	Hours	To pass prepared intelligence to the force.
M3	Minutes	To disseminate updates upon receipt of new intelligence.
M4	Minutes	After observation of activity, a report is disseminated.
M5	Hours	To disseminate intelligence updates upon completion of assessment.
M6	Time	To post image to home page or transmit via SIPRNET.
M7	Time	To update data base after receipt of new strike information.

#### NTA 5.1 Acquire, Process, Communicate Information and Maintain Status

M1	Percent	Of units are in communication with commander throughout planning and execution.
M2	Hours	To process status information and disseminate to subordinate units.
M3	Percent	Of critical information acquired and disseminated to subordinate units.
M4	Hours	After arrival within operations area, unit establishes connectivity with the commander and obtains common operating picture.
M5	Hours	Since latest information collected.
M6	Percent	Of available information examined and considered in latest status report.
M7	Percent	Of organizations or units receive latest information.
M8	Time	To restore communications from complete loss of facility control
M9	Time	To restore vital prioritized circuits after DAMA loss
M10	Time	To activate secondary circuits after loss of primary

#### NTA 5.2 Analyze and Assess Situation

M1	Minutes	To complete assessment of latest information (cycle time).
M2	Percent	Of available reports reviewed.
M3	Hours	In advance of execution, decision is made to change plan.
M4	Percent	Of enemy actions or operations (which affected the course of the campaign) not forecast.
M5	Percent	Of time, a political event of interest occurs without options being available.
M6	Percent	Of time, commander/senior staff member made aware by source outside the staff of an emerging political event which could impact the theater.
M7	Hours	Since last update of Force situation.
M8	Percent	Of incoming pieces of information (which could affect outcome of operation) do not get to person needing it.

#### NTA 5.3 Determine and Plan Actions and Operations

M1	Time	Available to complete planning.
M2	Time	To complete planning.
M3	Percent	Of forces available, actually employed in plan.
M4	Modifications	Made to plan in order to attain commander's approval.

#### NTA 6.1 Enhance Survivability

M1	Percent	Of friendly casualties due to enemy actions.
M2	Casualties	To friendly forces due to enemy actions and natural occurrences.
M3	Time	From warning to implementation of protective measures.
M4	Percent	Of casualties due to natural occurrences
M5	Number	Enemy forces retreating from objective due to protection system.

#### NTA 6.3 Provide Security for Operational Forces and Means

M1	Incidents	Of friendly operations degraded due to enemy observation, detection, interference, espionage, terrorism and/or sabotage
M2	Incidents	By enemy troops, or partisans, affecting security of force and means in the operations area.
M2	Percent	Of LOCs used to move logistics in operational area are secure.
M3	Percent	Of total troops, used to secure critical facilities and LOCs in COMMZ.
M4	Percent	Of operationally significant hazards removed or neutralized successfully.
M5	Percent	Of time, primary LOCs within operational area incident free.



**Figure 3. UV Sentry in Defense of a Sea Base**

Simulating the situation shown in Figure 3 will be useful in determining the projected outcome of a threat situation. A simulation tool such as Extend will be used to model this. The metrics derived from the simulation will be used to study the development of requirements that will map to function and eventually the physical form of the system component solution.

## SoS Architecting Process

**Introduction.** The purpose of this section is to describe the steps taken to develop an SoS architecture, from the design reference mission to the system specification, with the aid of an architecting tool, namely CORE as developed by Vitech. The development of an architecture using CORE is described for the future UV Sentry SoS and adequately identifies the capability-based needs in terms of the operational mission objectives.

The MBSE process is used to select the most efficient UV Sentry SoS architecture, specifically using a MBSD method. The identification of the UV Sentry SoS begins with the mission objectives from the CONOPS of the force, to developing a DRM, and leading to an appropriate architecture supported by modeling and simulation. The SoS architecture is modeled in CORE, and is used as a foundation for future capability-based architectural modeling for the future UV Sentry force structure. Key outcomes described in this section are a MBSD method as the basis for an architecture generation process, applied to the UV Sentry SoS (but ideally suited to any system) complemented by a MBSE process—from engineering requirements definition to physical architecture integration—for fusing the diverse assets involved in the complex UV Sentry SoS.

**System Architecture.** We define a system architecture consistent with most defense organizations as: an arrangement of elements and interconnections, and any policy that guides the development and/or operation. The interrelationships among architecture elements are depicted in Figure 4.



linearly, but are performed iteratively using traceability through element relationships from one activity to the next throughout the process.

**Table 4. Systems Architecting & Engineering Activities High Level Outline**

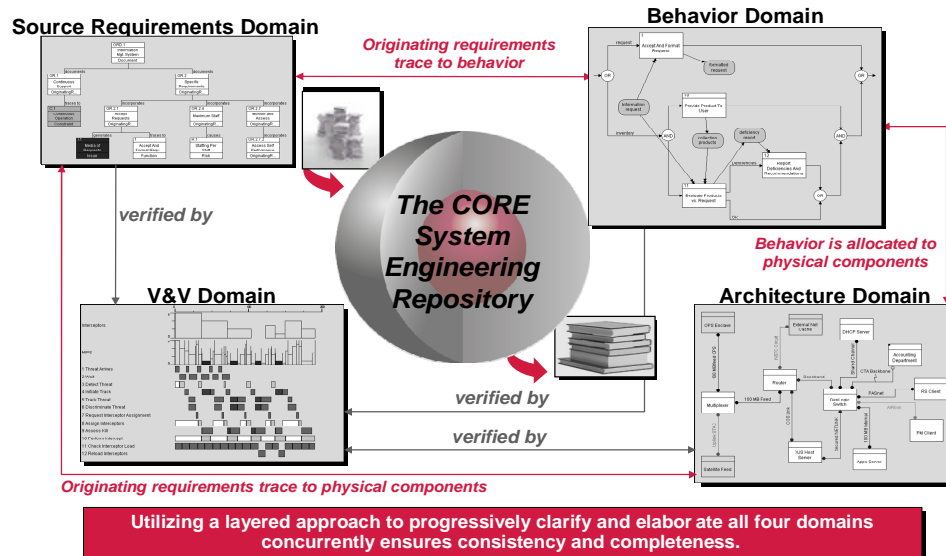
Systems Architecting	Operational Need	Identify pressing need or emerging opportunity as a capability gap Develop concept of operations including existing and planned systems Define operational activities Develop operational nodes and elements Develop operational scenarios Define operational requirements
	Architecture Synthesis	Develop activity models Create functional architecture (hierarchy and flow) Define and characterize functional behavior Run simulations Characterize architecture specifications
Systems Engineering	Requirements Analysis & Definition	Develop “engineerable” requirement specifications
	Functional Analysis of Functional and Non-Functional Requirements & Allocation to Derived Elements	Create derived functional architecture (hierarchy and flow) Derive functional and non-functional requirements Develop system elements Allocate functions Model and simulate behaviors
	Design Synthesis	Create physical architecture (structure) Model and simulate feasibility “physics” Trade off alternatives Select “best” from Pareto optimal set Define system/subsystem specifications
	Test and Evaluation	Continuously validate development

**Core 5 Architecture.** A major challenge in the architecting process is developing an architecture so that the system elements are complete and consistent with one another. A CADM architecting tool is a great asset that is used to verify that the data is consistent and that all element connections remain with their associated counterparts. The amount of data, when complying with architecture standards such as the DoDAF, is too large to manipulate manually.

CORE is based on a unified model that integrates the architectural frameworks with the system development process and an element relationship representation. “The CORE product suite is a fully integrated, flexible approach to a collaborative product design specifically developed by systems engineers for systems engineers” (CORE 5 ADG, 2007). CORE delivers a mutual design-centric approach to product development. “CORE provides comprehensive traceability from need definition through requirements and analysis to architecture and test. Built upon a proven approach and a central integrated design repository, CORE includes a comprehensive behavior modeling notation” (CORE 5 ADG, 2007).

Operational models are developed using MBSE principles. The design activities integrate the operational model and the systems model, and consist of requirements analysis, functional analysis, physical architecture synthesis, and verification and validation (CORE ADG, 2007).

“CORE focuses on an architecture synthesis centric approach rather than a view or document centric approach. This provides traceability from capability through requirements and analysis to testing. The CORE software suite was designed by systems engineers to satisfy diverse civilian and military customer (or stakeholder) needs” (Giammarco, 2007). An overview of the MBSE process is displayed in Figure 5, which shows the stages of the architectural development process.



**Figure 5. CORE Approach Relationships from the CORE Architecture Definition Guide [DoDAF version 1.5], (Vitech, 2007).**

CORE is built around a central integrated design repository. It includes a comprehensive behavior modeling notation to understand the dynamics of a design. CORE is a MBSE tool designed to integrate architectural and engineering activities while developing operational and system models. Documentation, such as the DODAF views, are derived from the basis architecture produced (CORE systems engineering Guided Tour Vitech Corporation, August 2007).

As displayed in Figure 6, the architecture elements from the DoDAF version 1.5 schema are integrated into a database of element classes within CORE to enable the systems engineer to define the element relationships and display the system hierarchies.

The architecture is divided into two behavioral domains: operational architecture and system architecture. “The Operational Architecture Domain captures originating concepts, capabilities, and supporting operational analysis to exploit, whereas the System Architecture Domain expresses the requirements, functions, and components comprising the physical design” (CORE Architecture Definition Guide [DoDAF version 1.5], Vitech Corporation, August 2007). Displayed in Figure 6, the CORE architecting schema separates the systems and operational domains with relationship links connecting the individual elements.

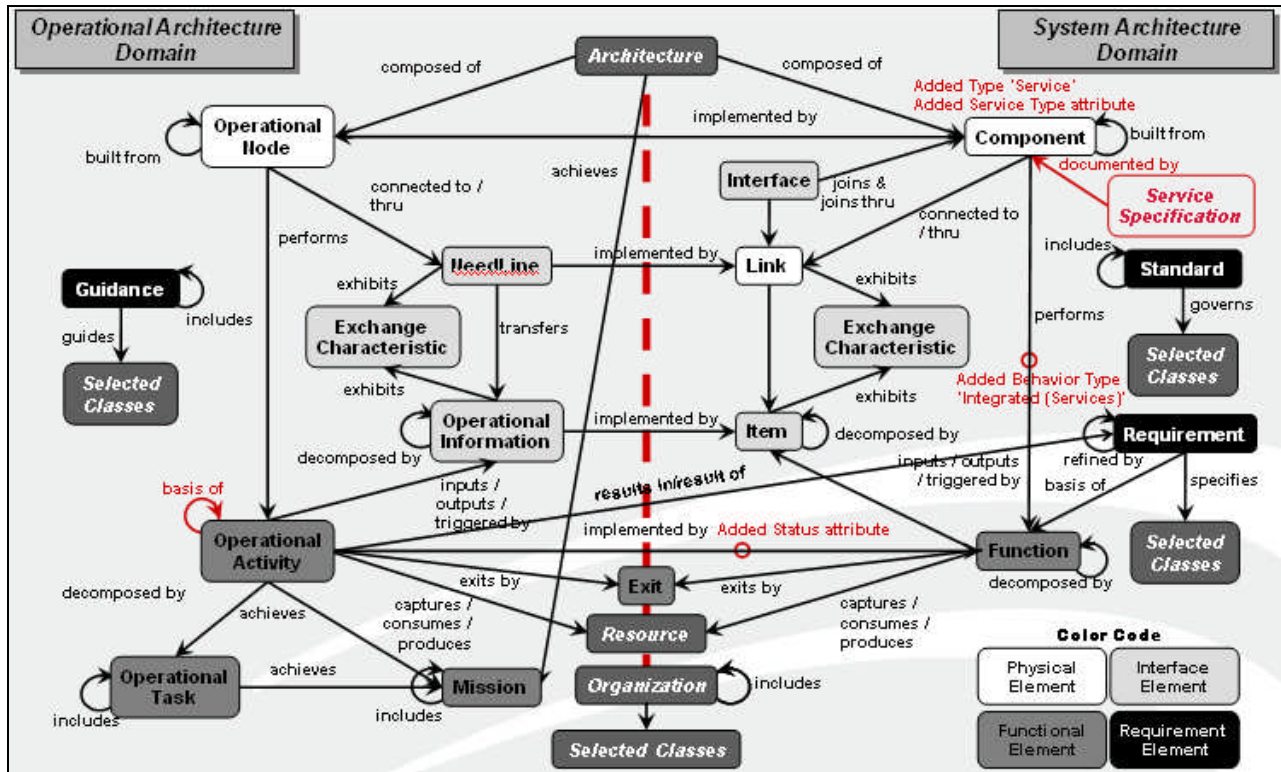


Figure 6. CORE DoDAF Schema (Vitech, 2007)

The CORE architectural elements focused on in this study are the Architecture, Operational Nodes, Operational Activities, Missions, Functions, and Components. From these elements, the necessary DoDAF architectural views and system specification document can be formulated.

**Architecture Implementation.** “Architectures exist for the purpose of achieving a well-defined system in both the operational and system domains, for a specific time frame. The Architecture class is used to identify an architecture and its time frame” (CORE ADG, 2007). Operational nodes in the architecture are implemented by components.

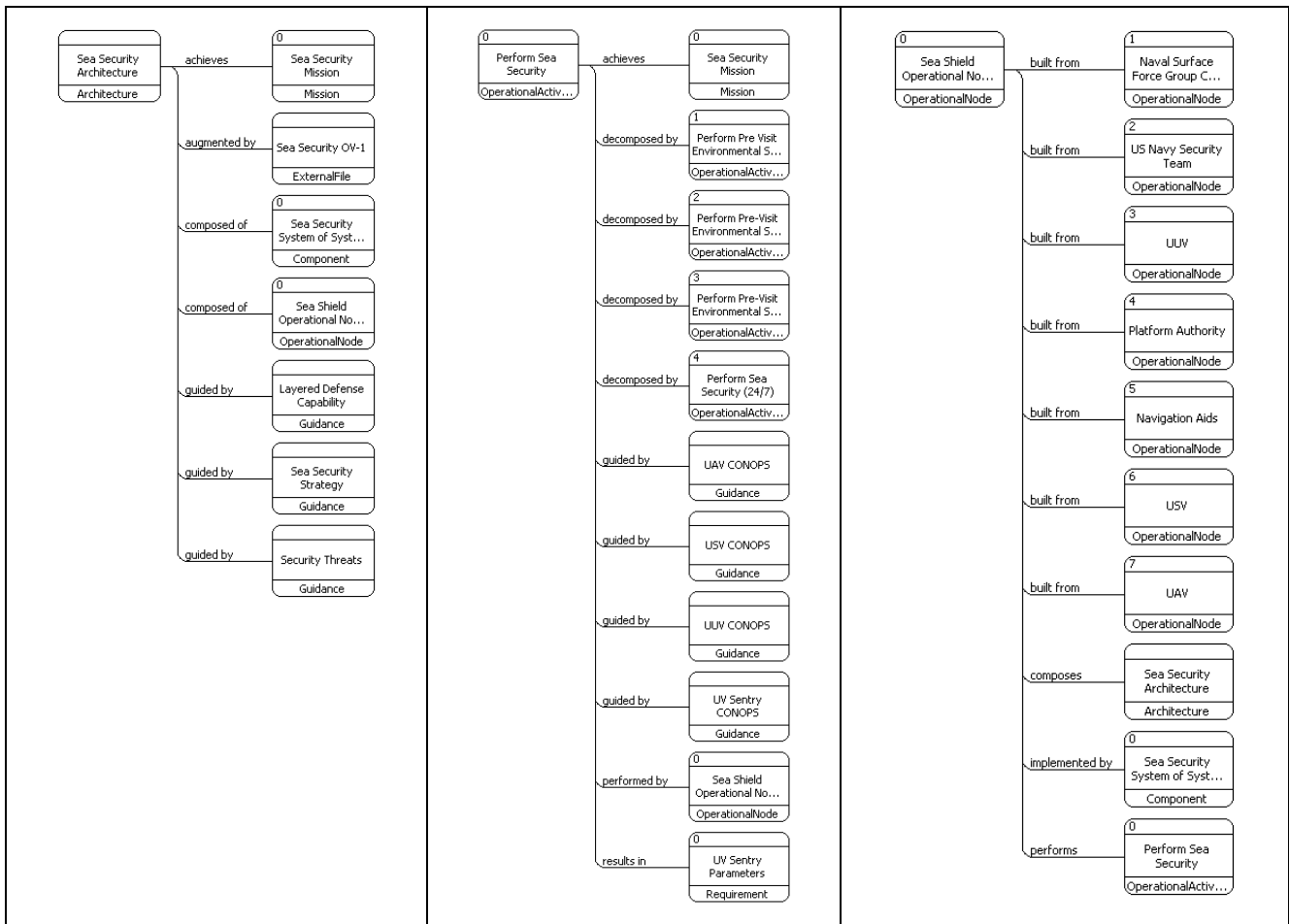
**Operational Architecture.** The operational architecture organizes the architectural elements, which compose the operational behavior of the system. The operational architecture is made up of the operational nodes, operational activities, operational tasks, and missions. Creating an operational architecture begins by first defining the mission, and then by identifying the operational activities needed to accomplish the mission. Once all of the operational activities have been identified, the responsible operational nodes can then be defined. The DRM structure feeds directly into these element definitions and relationships and are captured in the architecture definition using the terminology used by the operators.

**Operational Nodes.** An operational node is a representation of an actor role within an organization that produces or consumes information. The operational nodes for the future UV Sentry platform are all of the actors/organizations that interact with and make decisions for the system. They include:

- Naval Surface Force Group Command
- US Navy Security Team
- UUV

- Platform Authority
- Navigation Aids
- USV
- UAV

The UV Sentry operational nodes can be decomposed and displayed in CORE as a system diagram, as shown in Figure 7. Further breakdown of the operational nodes would characterize operational activities.



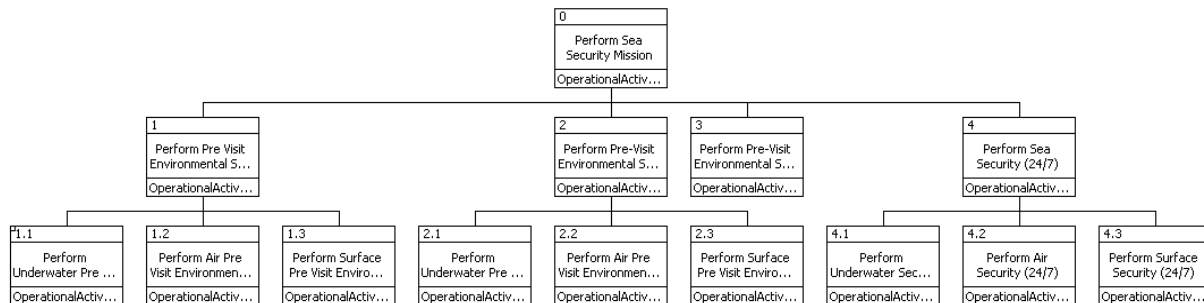
**Figure 7. Top Level UV Sentry Architecture Element Relationships in CORE**

**Operational Activities.** In conjunction with operational architecture synreport, for each layer of operational nodes, operational activities are decomposed until they can be uniquely assigned to the next level of operational node using the performed by relationship. This not only establishes the organization or role that performs the activity, it allows the systems engineer to assess the impact of operational node failures on both mission and operational activities (CORE ADG, 2007).

Operational activities, sometimes called operational scenarios, consist of a sequence of tasks needed to respond to an external stimulus. Each operational activity is performed by an element within the operational node class. Finalized capabilities (as defined by sets of operational activities), are incorporated to become the integrated model for the architecture.

The operational activities are linked to the systems architecture domain through the function element, and are traced from operational nodes and achieve operational tasks and missions, as

displayed in Figure 8. “Operational activity traceability from an appropriate mission element is established using the ‘achieves’ relationship. Establishing this relationship enables one to easily assess what capabilities are impacted by a mission change and what missions are impacted by a capability change or failure” (CORE ADG, 2007).



**Figure 8. CORE systems view of the operational activity “Perform Sea Security Mission”**

**Required Operational Capabilities.** Required Operational Capabilities (ROC), as constituted by mission commanders, detail the capabilities required of ships in various operational situations outlined in the POE. The level of detail is decomposed to outline specific mission areas and component/operator responsibilities. The ROC provides the necessary details of operational capabilities for which the ship class was designed, based on expected missions. It will establish tasking that produces a measurable workload used to compute manpower requirements.

The ROC is further decomposed into operational tasks needed to fulfill the operational activity. For example, the operational activity “Mobility” is composed of lower-level activities such as “move through the water” and “conduct sustained operations underway.” Each of these activities can be further decomposed into individual tasks necessary to achieve the activity “move through the water.”

**Operational Task.** The operational task element decomposes a list of mission-derived tasks with associated conditions and standards that a system architect may select to accomplish a simulated mission. The Universal Naval Task List (UNTL) is a combination of the Navy Tactical Task List (NTTL) and the Marine Corps Task List (MCTL), and was utilized to identify the tasks that the UV Sentry SoS can perform.

The UNTL contains a comprehensive hierarchical listing of the tasks that can be performed by a naval force, describes the variables in the environment that can affect the performance of a given task, and provides measures of performance that can be applied by a commander to set a standard of expected performance (UNTL, 2006).

Along with the UNTL, there are task lists derived from a hierarchy of DoD tasks contained within the Universal Joint Task List UJTL. Depending on the mission level being developed, a certain standard of tasks are required to fulfill that mission-level requirement. If the mission involves joint service cooperation, the tasks would be derived from the UJTL at a higher-level mission perspective.

The following task list definitions were taken from the OPNAV Instruction 3500.38B/ MCO 3500.26A/USCG COMDT Instruction M3500.1B CH-1:

- The Universal Joint Task List (UJTL) (CJCSM 3500.04) is a comprehensive hierarchical listing of the tasks that can be performed by a joint military force. It serves as a common language and reference system for joint force commanders, combat developers, and

trainers. The UJTL also provides a basis for describing joint requirements, capabilities, and combat activities.

- The Universal Naval Task List (UNTL) (OPNAVINST 3500.38/) is a comprehensive hierarchical listing of Navy, Marine Corps, and Coast Guard tasks, at all levels of war (the UJTL plus the Naval Tactical Task List). It includes all those tasks the United States Navy, Marine Corps, and Coast Guard might be required to perform as part of their military missions.
- A Joint Mission Essential Task (JMET) is an activity selected by a joint force commander deemed critical to mission accomplishment. The UJTL (version 4.0) defines essential as “absolutely necessary; indispensable; critical.” The Joint Mission Essential Task List (JMETL) is the joint force commander’s list of joint tasks considered essential for accomplishment of operational plans predicated on the missions assigned and forces apportioned by the JSCP, U.S. alliance or treaty, or by regional initiatives.
- Naval Mission Essential Tasks (NMET) are those tasks considered essential to accomplish and support missions assigned by a naval or joint force commander. NMETs are chosen from the tasks contained in the UNTL.

In order to complete the mission requirements, the type of operation must be considered. Each operation requires a set of operational activities due to the variation of the environment. Task lists are uniquely defined based on a higher-lever mission analysis of the variation in operational objectives. Although many of the tasks within the different lists are similar, task requirements will vary based on the type of operation.

As stated above, the task list identifies “what” is to be performed in terms of the system being designed. These tasks are derived to satisfy the capabilities needed in order to perform the higher-level tasks included in a simulated ROC/POE developed within the DRM. These tasks are used to identify the required operational activities necessary to complete the proposed DRM and further recognize the operational nodes responsible to meet mission needs.

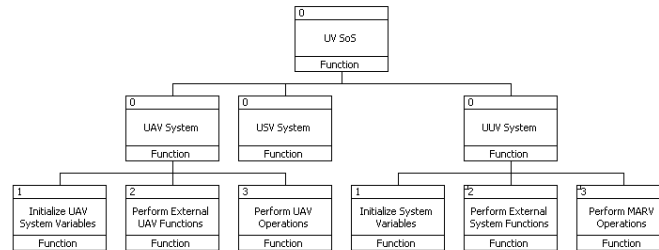
**Missions.** “Missions are hierarchically organized textual descriptions that define the very existence of the enterprise, and that are the ultimate goals and objectives that measure enterprise accomplishment from within different business functions and organizations” (Gorman, 2007). The first step in the architecting procedure is defining the problem(s) it will be built to solve, and ensuring the development and refinement of the correct data necessary to address the problem. The problem definition step in developing a system architecture achieves a reference mission, to which the operational activities of the system will need to be demonstrated within a mission simulation.

The basis for all of the required elements within the architecting model will be developed from a refined DRM. The capabilities from the DRM will drive the functions needed to implement the capabilities, followed by the system components needed to perform the functions. Once these elements have been identified, the architecting data model, CORE, will be utilized.

**Systems Architecture Considerations.** Activities needed to complete the architecture and interrelate the operational and systems domains are developed through the systems performance parameters, with the integration of the component and function elements related to the requirements (CORE ADG, 2007). The components with respective functions are derived from the operational activities needed to perform the mission. The example component type service is built from a system component to perform a service function.

**Functions.** A function is the property of a system that, when performed by a component, will

fulfill a requirement for an objective. Functions are decomposed into lower-level functions (see Figure 9), until the individual components can be traced to a particular function to be performed. Functions are first associated with operational activities and to top level requirements that can be identified in the beginning stages of system architecture development. The functions identified are based on all the operational activities required to achieve the missions that are required to be performed to accomplish the desired capability.



**Figure 9. CORE view of the functional decomposition of UV Sentry SoS**

Functional decomposition refers to the process of organizing functional relationships for the eventual purpose of mapping them to components to define solution specific ways of meeting the “what” of the functions. Specifically, what function must be provided to accomplish the mission activities and how will that function be fulfilled by use of a system component.

**Functional Requirements.** Requirements specify the goals of the system effectiveness or performance related to corresponding functions. “Requirements development occurs when operational activities and performance characteristics serve as sources for system requirements” (CORE ADG, 2007). Operational activities lead to the identification and definition of functional requirements that, when added to the identification of performance characteristics, results in system requirements. Thus, a requirement is a result of an operational activity (that maps to a function) and has with it an associated performance characteristic.

The requirements generated from a capability-need-based, MBSE methodology are a complete set of requirements that will be a basis for the system specification document.

**Nonfunctional Requirements.** Nonfunctional requirements identify criteria used to evaluate the system’s operation characteristics instead of identifying specific functions or behaviors of the system related directly to the operational activities themselves. In general, nonfunctional requirements define how a system is supposed to operate rather than what it is supposed to do. Nonfunctional requirements are sometimes referred to as “ilities,” *e.g.* availability, reliability, maintainability, survivability, interoperability, which describe the criteria upon which the system operation can be evaluated. Within the CORE architecting tool, nonfunctional requirements are not separately defined within the schema, but are created within requirement class with the type attribute set to “Constraint.”

The process starts with extracting the originating requirements into the requirements class and then set the “type” attribute to (Functional, Performance, Constraint, or Verification). A Functional requirement will be modeled with “Function” and the nonfunctional requirements (except for performance) will be addressed by one of the specialty engineering disciplines.

Nonfunctional requirements should be clearly defined and utilized when creating a simulation based on the CORE model. The availability and/or survivability, for example, of a system cannot be determined without being able to simulate all of the components working together within an SoS, to include the environment.

**Components.** An objective of the system architecture is to identify what are its critical components and what are the relationships between all components within the system. “Components are represented in CORE as physical entities, including collections of systems, interfacing systems, and entities within the systems architecture” (CORE ADG, 2007). The components identified in this architecture range from higher-level systems like “ship” to lower-level individual components like “propulsor”. Each component is organized within a hierarchical definition, such as the Ship Work Breakdown Structure (SWBS) to define and categorize boundaries in a system.

A work breakdown structure (WBS) provides a comprehensible framework for system components within a program. It organizes the components in terms of hierarchically-related, product-oriented elements. Improved communication in management practices will be directly correlated to the generation of a WBS throughout the acquisition process.

**Specific Methodology.** The CORE architecture schema has many other elements which connect with and influence the interoperability of the architecture. The focus has been on the major elements which directly influence the capabilities of the system based on the defined DRM. The major elements focused on in this report, when completed, generate the necessary architectural views which will lay the foundation for the UV Sentry SoS architecture.

The proper development of an integrated UV Sentry architecture requires a comprehensive modeling technique based on well-specified, capability-based requirements. To properly guide architecting, design, and integration of this diversity of system elements, a comprehensive UV Sentry SoS MBSD method has been developed that addresses all facets of the mission capabilities of the proposed SoS, such that it will fully meet the needs of the stakeholders (Whitcomb, 2008).

The architecting of the SoS starts with the transformation of an operational capability need, based on mission requirements, into a set of functional and physical requirements that are used to guide the development of operational and system architectures. This process establishes a set of physical requirements to which the future UV Sentry platform can be defined. Essentially, without a comprehensive architecture based on mission requirements that includes a well-developed set of specifications, an integrated SoS cannot be successfully realized (Whitcomb, 2008).

**Naval Architecture Elements Reference Guide.** Architecture implementation is best organized around standard semantics and reference terminology (Ring, 2001). “Every architecture should be constructed from common terms, forming the elemental building blocks of the architecture, standardizing architectural elements” (Naval Architecture Elements Reference Guide, December 2007).

“Architecture elements represent the critical taxonomies, requiring concurrence and standardization for an integrated architecture as described by the DoDAF” (Siel, 2007). They contain the diction for the architectural views and are used to ensure a consistent integration of systems within an SoS architecture. “The data contained in the Navy Architecture Element Reference Guide (NAERG) shall be used for overall architecture framework development, programmatic research, development, and acquisition activities, and related integration and interoperability and capability assessments” (Siel, 2007).

The UV SoS will be described in terms of the NAERG elements, in order to explicitly define the architecture. The NAERG elements are organized into the following lists

- Common System Function List (CSFL)
- Common Operational Activities List (COAL)
- Common Information Element List (CIEL)

- Common Operational Nodes List (CONL)
- Common Systems Nodes List (CSNL)
- Common Systems List (CSL)

The process of identifying capability needs, analyzing system functions, and allocation to system physical components cannot currently be satisfactorily completed given existing architecture framework products alone.

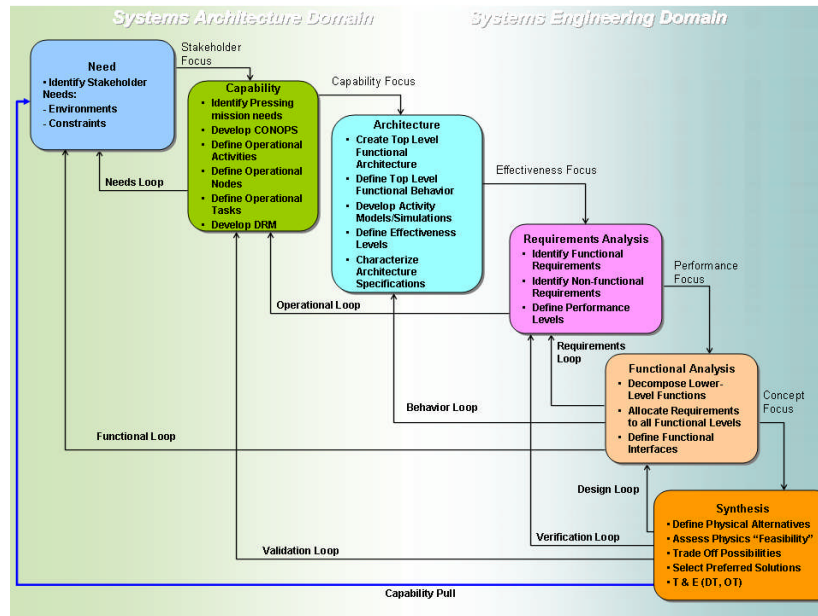


Figure 10. Composite MBSE process

Future UV Sentry SoS operations will require an unprecedented level of integration. The current practice of embedding humans in the operating system must transform to one of effective use of humans-at-a-distance, to avoid dirty, dull, and dangerous missions, leveraging cognitive autonomy in warfighting systems.

## Architecture Results

**DoDAF Views.** The DoDAF displays and organizes a complex systems architecture into user specific views, showing interoperability within the system elements. Representations for the DoDAF products are drawn from through diagramming the Entity-Relationship Diagrams (ERDs) found in the CORE model.

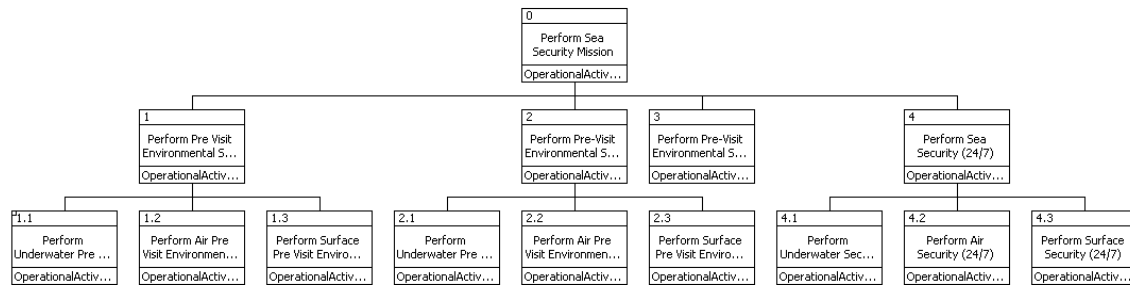
CORE documents the architecture product as a Rich Text Format (RTF) file, via scripts that generate a standard DoDAF diagram. The DoDAF version 1.5 view scripts are designed to be flexible in order to support any later iteration (Vitech, 2007).

From a systems engineering perspective, the DoDAF architecture views OV-2, OV-5, and SV-4 are the important views because they lay the foundation for the operational architecture (structure, behavior, interfaces) and provide a basis for developing the system architecture. For the purpose of this report, the OV-2, OV-5, and SV-4 are developed and discussed.

Operational views detail the user’s operating domain in which the developing system will operate (Zachman, 2007). The OV-2 is an operational node connectivity description, which

displays the relationships between the nodes as well as organizes the nodes into an operational hierarchy.

The OV-5 DoDAF view is an activity model that identifies and displays the hierarchical decomposition of an operational activity, as well as show the relationships between the capabilities and activities in which each activity is interconnected. The OV-5 Activity Model for UV Sentry Sea Security DRM hierarchy is displayed in Figure 11.



**Figure 11. “Perform Sea Security Mission” Hierarchy Diagram**

From the DoDAF views generated in this report, the UV Sentry SoS can begin a preliminary design phase based on the requirements generated with function-to-component relationships defined. The stakeholders’ desires and system requirements are identified and verified to achieve the assigned mission. Lower-level requirements generation must be developed in order to generate a complete analysis of the system options.

**Summary.** The need for MBSE process has been recognized and a MBSD method has been developed based on the fusion of systems engineering and systems architecting. The differences between systems engineering and systems architecting has been established, showing the benefits of what each can bring to a system design. Figure 10 displays the collective approach of the MBSE process developed in this report to include:

- Capability need recognition
- Stakeholder need/desired capabilities input
- Traditional systems engineering process inclusion
- MBSD architecture development method

The architecture demonstrated in this section highlight some of the more important DoDAF views, but they barely scratch the surface of the potential architecture development available in the CORE modeling tool, for a final UV Sentry SoS development.

## Conclusions and Recommendations

**Conclusions.** The MBSE process reported provides a method for solution neutral investigation of possible alternative physical architectures to meet overall functional UV Sentry SoS needs based on a traceable path to the capabilities desired as documented by the stakeholders. One promising first generation alternative physical architecture, especially for the DRM, is a model based on UUV and a UAV mixed with additional UV platforms and legacy systems comprising the UV Sentry. Platform characteristics are derived to accomplish the mission, and a set of postulated future military tasks and force planning scenarios, based on stakeholder capability need via the US NAE and Universal Joint Task List (UJTL) context, can be accomplished using this architecture as

a consistent baseline. This type of analysis provides direction and traceable contribution as part of a structured process; specific objectives; agreed on preconditions; and a clear definition of test and evaluation success derived directly from key metrics associated all the way back to capability need. This becomes the basis for an SoS engineering process with linked analyses will allow the assessment of technologies for future capabilities for the entire life cycle of the program. The MBSE approach provides the best venue to compare alternative architectures and assess technological maturity of critical subsystems. The confluence of these analysis and design techniques leads to an architecture and scheme of integration for UV Sentry, or indeed any combination of SoS components making up the possible physical architecture, incorporating all desired capabilities while maintaining a high level of flexibility to the integration of emerging technologies over the development and operational life cycle.

The Navy has been analyzing the process of how to require open architecture in new contracts. The DoD has changed their philosophy of stove-pipe design to developing integrated architectures based on capability needs. Along with the JCIDS process, the DoDAF and NAERG provide a basis for defining standard architecture elements for future SoS. As the Navy changes its approach to developing new SoSs from capability need, a standard SoS architecting process definition is required.

What has been demonstrated in this study is a MBSE approach that is not only traceable from a realizable mission need, to top-level system requirements, to system function and components, but provides a fully interconnected relationship among all architectural elements. An architecture was created that can be revised, rerun, and moved around in an interactive manner in order to explore the design space of a comprehensive and efficient system design. The architecture development process is implemented as an interactive methodology using the CORE DoDAF 1.5 schema to produce necessary architecture views and design documents. This process provides a useful methodology to demonstrate the capabilities needed by the UV Sentry for joint operations.

This report outlined the first-iteration of a MBSD process, illustrating the manner of how an SoS is engineered in the context of an architecture. The CORE tool was utilized to develop a SDD, as well as key DoDAF views, for consistent and complete requirements generation, based on stakeholder capability needs. High-level functional and nonfunctional requirements were developed and compared with the requirements generated by the stakeholders for optimum future platform performance characteristics. The consolidated requirements could then be used to set the context for proposing alternative technology developments from government labs and warfare centers, as well as the commercial market, for future analytical and real development of future LRIP and full scale production and development strategies.

The U.S. Navy will also benefit from an open, integrated architecture model for this complete SoS, based on the capability-need for mission requirements. Using the information from the UNTL, NAERG, and UV Sentry CONOPS, a combined platform can be realized with a logical and complete set of requirements, modeled after what is needed vice what is already utilized.

**Recommendations.** The need for an analysis of a development strategy substantiates the need for a comprehensive simulation of capabilities. The two main objectives to the analysis are:

1. Determine the technology alternative impacts on effectiveness.
2. Determine the risks associated with uncertainties surrounding the insertion of various technology combinations.

To satisfy the objectives, an analysis of future mission needs must be conducted, along with a technology analysis including technology maturity and cost risk estimates. The need for an architecture model that contains all relevant information, including all required tasks and potential

components, must be developed. Once a comprehensive model has been built, a simulation must be conducted to include scenarios that utilize desired combinations of components. The development of the overall architecture, with the simulation of the use of the architecture implementations, can be used for strategic and operational decision-making. This includes:

Developing an architecture that is populated to the extent that elements include enough description to demonstrate the use for operational and strategic planning, including the need for trade-offs for acquiring new platforms or contracting of outside resources (Whitcomb, 2008).

Exercising the architecture in a dynamic sense to create options for planning and design (Whitcomb, 2008).

Integrating the architecting process using a tool (e.g., CORE) as a basis for input to drive system synthesis with unmanned vehicle and ship design tools (e.g., MATLAB, ASSET, others) and further integrating the analysis results, tying them to specific system physical configurations (e.g., LEAPS) in order to allow a more quantitative, physics-based analysis of platform development, and connect the model-based design process to the stakeholder's need (Whitcomb, 2008).

Expanding the process scope to core warfighting capabilities and business capabilities, such as combatant ships, aircraft, ground vehicles, and system command organizations (Whitcomb, 2008).

Utilizing and incorporating all task lists to include the UNTL, UJTL, and NMETL, with real-time updates as missions get redefined.

Revising the CORE schema to include a separate capabilities element, which links operational activities to the architecture illustrating the process; the architecture is composed of capabilities that achieve operational activities.

Continuing the development of a standard architecting process, which will facilitate the implementation of a future capability, is critical to acquiring an efficient system built specifically to meet the stakeholders' needs. The success of a standard architecting process will lead to more successful Navy-wide open architecture implementations for system development, thus reducing costs and maximizing efficiency throughout the Fleet.

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