AY 2004 Spring Integrated Project
Maritime Dominance in the Littorals
3 June 2004
Presentation Purpose

Final Review
by SEA5
of the AY2004 Spring Integrated Project
Agenda

- Maritime Dominance in the Littorals Brief ........................................0900-1145
  - Executive Overview .........................................................LCDR Tran
  - SoS Development ............................................................ENS Tsikalas
    - Functional Analysis ....................................................ENS Tubbs
    - Value Systems Design ................................................ENS Tubbs
    - Architectures .............................................................ENS Peterson
    - Threats & Scenarios ....................................................LT Holmes
    - TDSI Integration .........................................................ENS Hartling
    - Cost Analysis .............................................................LT Julien
    - Simulative Study ........................................................ENS Abbott
      - Engineering Physics Models .........................................ENS Poitevent
      - Platform/Combat System Models ....................................ENS Poitevent
      - Force/Theater Models ................................................ENS Smith
    - Architecture Ranking ................................................LT Graham
    - Configuration Selection Validation .................................LT Winslow
  - Concluding Remarks .....................................................LCDR Tran

- Lunch Break ........................................................................1145-1300

- Breakout Session at Bullard 100 (Including Temasek Defense System Institute Poster Session) ..................................................1300-1400
Executive Overview

LCDR Quoc Tran
Executive Overview

- Project Overview
- Project Description
- Project Results
- Project Team Organization
- Project Schedule
- Project Effective Need
Project Overview

- Tasked to Develop a System of Systems Conceptual Solution For Maritime Dominance in the Littorals
- Developed a Project Management Plan
- Used a Systems Engineering Design Process
- Analyzed Threats and Defined Littoral Scenarios
- Generated Conceptual SoS Architecture Alternatives
- Used Modeling and Simulation
- Ranked SoS Architecture Alternatives According to Their Maritime Dominance Effectiveness and Cost
- Delivered The Final Recommendation
Project Description

- Execute Tasking from Deputy Chief of Naval Operations (CNO) for Warfare Requirements (OPNAV 7)
- Develop a Conceptual System of Systems (SoS) for Maritime Dominance that Enables SEA BASING and SEA STRIKE in the Littorals
  - Generate Alternatives Using Existing Systems, Current Programs of Record, and Future Systems
  - Recommend Cost Effective Conceptual SoS That Minimizes Risk To Allied Personnel While Accomplishing Objectives
- Deliver Results in a Final Briefing and Technical Report
SoS Focus and Constraints

• **SoS Architectural Focus**
  – Combination of both Manned and Unmanned Systems
  – Surface, Subsurface, Air and Space Systems
  – Employment of Forces From All Services

• **Constraints**
  – Scenario Constraints
    • Land Forces Deployed up to 200 nm Inland
    • Striking/Supporting Maritime Forces Deployed up to 200 nm Offshore
  – Timeframe Constraint
    • Concepts of Operations Applicable within 2020 Timeframe
  – Cost Being a Necessary Selection Variable
Recommended System of Systems for Maritime Dominance in Littorals

• Unmanned Vehicles Complement But Cannot Replace Manned Platforms

• Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe
  – Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1
  – Utilizes Distributed Communications with 100nm Physical Platform Distribution
  – Employs Decentralized Command & Control Structure
  – Is Cost Effective Relative to Other Alternatives

• Distributed Communications
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures

• Decentralized Command and Control
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance

• 100 nm Platform Distribution
  - Superior Overall Performance
Project Schedule

Phase 0: Planning/SEDP Quicklook
- Operational Concepts 03Nov
- SEDP Quicklook 07Nov
- IPR 25Nov

Phase 1(SEDP): Problem Definition & Effective Need Gen
- PMP Completed 15Dec
- TDSI Letter 15Dec

Phase 2(SEDP): Alternative Generation
- Team Kickoff Mtg 15Jan

Phase 3: Decision & Recommendation
- Preliminary Design Review 05Mar

TDSI Results 15APR

Final Design Selection 21May

Final Project Review 03Jun

Technical Report 15 Jun

Major Phases
Completed Tasks
Today
Deliverable
Effective Need

Develop a SoS Solution to Enable SEA BASING and SEA STRIKE by Providing Maritime Dominance in the Littoral Environment Through Cooperative Surveillance, Threat Analysis and Evaluation, Battle Management, and Engagement
SoS Development

ENS Manny Tsikalas
Problem Definition

• Define and Select a Cost Effective System of Systems Architecture Consisting of Sea-Based, Land-Based, and Airborne Sensor and Weapon Systems that Are
  – Both Manned and Unmanned
  – In Existence, in Development, and Future Concepts
  – Networked Via Communication Links and Space Systems to Achieve Success of the Following Littoral Missions with Minimum Risk to Allied Personnel
    - Identification and, If Necessary, Reduction of Hostile Threats to Within Defensive Capability of the Sea Base
    - Enabling Projection of Offensive Capabilities From the Sea Base
SoS Development Process

NEEDS ANALYSIS

Mission
Scenarios
Threat Analysis

Value System Design
Effective Need

Functional Analysis
Requirements Flow Down

ARCHITECTURE RANKING

Develop MOEs
Cost
Technology Risk

Perform Simulative Study

Outputs (MOEs)
Rank Options
Develop Weighting Matrix
SoS Development Overview

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Functional Analysis and Value Systems Design

ENS Cavan Tubbs
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Functional Analysis

- **SoS Design Requires**
  - Identification of Functions to be Performed in Support of Mission Accomplishment
  - Decomposition of Identified Functions
- **Four-Level Depth Functional Decomposition Embodies SoS Functionality**
Functional Hierarchy

SoS

Surveillance
Threat Analysis and Evaluation
Battle Management
Engagement

Observe Orient Decide Act
Surveillance Functional Decomposition

- **Detect**
  - Process Signal
  - Transmit

- **Locate**
  - Scan
  - Determine Range
  - Determine Altitude/Depth

- **Track**
  - Receive
  - Determine Bearing
  - Determine Course

- **Reconnoiter**
  - Determine Speed
Threat Analysis & Evaluation

Functional Decomposition

- Identify
  - Reference Database
- Classify
  - Reference Intel
- Assess
  - Determine Intent
    - Observe Declaration
  - Observe Actions
  - Solicit Intelligence
  - Determine Capability
    - Battle Damage Assessment
BMC4I Functional Decomposition

Battle Management Means Battle Management, Command, Control, Communications, Computers, and Intelligence (BMC4I)
Engagement Functional Decomposition

- Engagement
  - Survive
    - Endure
  - Avoid
  - Render Threats Ineffective
    - Disable
      - Target
      - Fire
      - Disrupt
      - Deny
Value Systems Design
Implementation

Mission
Scenarios
Threat Analysis

System Needs
System Functions

• Objectives
• MOEs
• MOPs

Balance System Needs and Functions in Support of SoS Missions of Enabling SEA BASE and SEA STRIKE

MOE – Measure of Effectiveness
MOP – Measure of Performance
# Functional Decomposition

## Surveillance Function

<table>
<thead>
<tr>
<th>Objectives</th>
<th>MOE</th>
<th>MOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection</td>
<td>Coverage Capability</td>
<td>Average Time to Establish Complete Area Coverage</td>
</tr>
<tr>
<td></td>
<td>Ratio Area Covered / Total Search Area</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coverage Factor (Confidence)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Probability of Detection</td>
<td>Average System Probability of Detection</td>
</tr>
<tr>
<td>Tracking</td>
<td>Tracking Capability</td>
<td>Ratio Contact of Interest (COI) Tracked / Total COI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average Number of Visits per COI</td>
</tr>
</tbody>
</table>
## Threat Analysis & Evaluation Function

<table>
<thead>
<tr>
<th>Objectives</th>
<th>MOE</th>
<th>MOP</th>
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</thead>
<tbody>
<tr>
<td>Identification</td>
<td>ID Capability</td>
<td>Ratio COIs Identified / Total COI</td>
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<tr>
<td></td>
<td>Probability of False ID</td>
<td>Ratio of Incorrect Identifications / Total Identifications</td>
</tr>
<tr>
<td>Minimize Risk</td>
<td>Reduced Exposure to Risk Capability</td>
<td>Ratio of Personnel Exposed to Risk / Total Personnel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ratio of Casualties / Total Personnel</td>
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## Battle Management Function

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<thead>
<tr>
<th>Objectives</th>
<th>MOE</th>
<th>MOP</th>
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<tbody>
<tr>
<td>Recognized Maritime Picture</td>
<td>RMP Capability</td>
<td>Average Time to Establish 80% of RMP</td>
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<tr>
<td></td>
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<td>Ratio Correct COI IDs / Total COI</td>
</tr>
<tr>
<td>Maximize Communication</td>
<td>Communication Capability</td>
<td>Ratio of Number of Assets Lost Comms / Total Assets</td>
</tr>
</tbody>
</table>
# Functional Decomposition

## Engagement Function

<table>
<thead>
<tr>
<th>Objectives</th>
<th>MOE</th>
<th>MOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Destroy/Disable Targets</td>
<td>Engagement Capability</td>
<td>Average Time to Kill 80% of Targets</td>
</tr>
<tr>
<td></td>
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<td>Ratio Targets Engaged / Total Targets</td>
</tr>
<tr>
<td>Endure Combat</td>
<td>Endurance Capability</td>
<td>Ratio Friendly Assets Survived / Total Friendly Assets</td>
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<tr>
<td></td>
<td></td>
<td>Ratio Enemy Assets Survived / Total Enemy Assets</td>
</tr>
</tbody>
</table>
Value Systems Design

LITTORAL MARITIME DOMINANCE

Function
- SURVEILLANCE
- THREAT ANALYSIS and EVALUATION
- BATTLE MANAGEMENT
- ENGAGEMENT

Objective
- MOE
- MOP

Local Weight
- DETECTION
- TRACKING
- IDENTIFICATION
- MINIMIZE RISK
- RMP
- MAXIMIZE COMMS
- DESTROY TARGETS
- ENDURE COMBAT

Global Weight
- PROBABILITY of DETECTION
- Average System Probability of Detection
- Ratio of Incorrect IDs / Total IDs
- Ratio of Assets Lost Communications / Total Assets
- Ratio Correct COIs ID / Total COIs
- Ratio of Assets Lost Communications / Total Assets
- Ratio of Friendly Assets Survived / Total SoS Assets
- Ratio of Enemy Assets Survived / Total Enemy Assets
- Avg Time to Establish Area Coverage
- Ratio Area Covered to Total Search Area
- Avg Number of Visits per COI
- Coverage Factor
- Avg Time to Kill 90% of Targets
- Ratio of Targets Engaged / Total Targets
- Avg Time to Kill 90% of Targets
- Coverage Factor
Architectures

ENS Bryan Peterson
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Topics

- SoS Architecture Overview
- SoS Architecture Assumptions
- SoS Architecture Definition Process
- Functional Embedding
- UV Types and Functions
- Architectures
- Architecture Summary
SoS Architecture Overview

• Ensured Gradual Increase of Unmanned Vehicles with Architectures
  – Manned Only (Architecture 1)
  – Balanced Hybrid (Architecture 2)
  – Primarily Unmanned (Architecture 3)

• Ensured Architecture 1 Consisted of Current Systems Only

• Accounted for 2020 Timeframe Technology

• Named Unmanned Vehicles According to Size and Functions
SoS Architecture
Assumptions

• Manned Systems Still Required For Air to Air Combat in 2020 Timeframe

• Carrier-Launched and Recovered Medium-Sized UAVs Exist
  – Number of UAVs Determined by Size and Space Available on Carrier

• Availability of Postulated Systems in 2020 Timeframe
  – DDX, CGX, LCS, etc.
SoS Architectures
Definition Process

1. SoS Objectives
2. Identify Physical Element Categories
3. Perform Functional Analysis
4. Embed Functions into Physical Systems
5. Perform Gap Filler Analysis
6. Identify Programs of Record
7. Identify Physical Elements
8. Postulate Future Physical Elements
9. Identify SoS Architectures

Wayne E. Meyer Institute of Systems Engineering
Naval Postgraduate School, Monterey, CA
### Functional Embedding

<table>
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<tr>
<th>Functions</th>
<th>S-3</th>
<th>P-3</th>
<th>EA-6B</th>
<th>AH-1</th>
<th>B-2</th>
<th>F-14</th>
<th>FA-18</th>
<th>JSF</th>
<th>C-2</th>
<th>E-2C</th>
<th>MH-53</th>
<th>SH-60</th>
<th>Strike UAV</th>
<th>Surv UAV</th>
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**Notes:**
- **Architecture 1**: Common to all Architectures
- **Architecture 2**: Architecture 1 and 2
- **Architecture 3**: Architecture 2 and 3

Wayne E. Meyer Institute of Systems Engineering
Naval Postgraduate School, Monterey, CA
## Unmanned Vehicle Types and Functions

<table>
<thead>
<tr>
<th>Unmanned Vehicle Type</th>
<th>Sensors/Weapons/Functions</th>
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<tbody>
<tr>
<td>Large Surveillance UAV</td>
<td>Air/Surface Search Radar</td>
</tr>
<tr>
<td>Medium-Sized Surveillance UAV</td>
<td>TDSI FOPEN Radar, Infrared (IR) Sensor</td>
</tr>
<tr>
<td>Medium-Sized Strike UAV</td>
<td>Harpoon, JSOW</td>
</tr>
<tr>
<td>Medium-Sized Multi-Mission UAV</td>
<td>TDSI FOPEN Radar, Hellfire</td>
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<tr>
<td>Small Surveillance UAV</td>
<td>IR Sensor</td>
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<tr>
<td>Mine Warfare UUV</td>
<td>Sonar</td>
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<tr>
<td>Anti-Submarine Warfare UUV</td>
<td>Sonar, Torpedo</td>
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<tr>
<td>Unmanned Vehicle Insertion UUV</td>
<td>TDSI Unmanned Insertion Vehicle</td>
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<tr>
<td>Surveillance USV</td>
<td>Surface Search</td>
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<tr>
<td>Multi-Mission USV</td>
<td>Surface Search, Hellfire</td>
</tr>
</tbody>
</table>
Communications to All Surface Platforms

Common to Architecture 1 and 2
- 2 DDG
- 2 CG
- 2 SSN
- 4 E-2C
- 36 F-18
- E-8 JSTARS

Common to All Architectures
- 10 SH-60
- 10 AH-1
- 5 E/A 6B
- 14 F-14
- 2 P-3
- 8 S-3
- 2 F-117
- 1 B-2

- E-3 AWACS
- 6 MH 53
- 5 CH 53
- CVN
- 10 AH-1
- 2 DDG
- 2 FFG
- LHA
- MHC
- MCM

- CVN
- Manned Only
- Current Systems
- Carrier Air Wing
- Based Off Carrier Battle Group
Surveillance to All Manned Platforms

- Programs of Record
- Existing Systems
- Surveillance UAVs and USVs
- Surveillance and Attack UUVs

Communications to All Platforms

Common to Architecture 1 and 2
- 2 DDG
- 2 CG
- 2 SSN
- 4 E-2C
- 24 F-18
- E-8 JSTARS

Common to All Architectures
- 6 SH-60
- E-3 AWACS
- CVN
- 6 F-16
- 6 F/A-22

Common to Architecture 2 and 3
- 2 MIW LCS
- 2 ASW LCS
- 2 ASuW LCS
- 20 Small Surveillance UAVs
- 70 Medium-Sized Surveillance UAVs
- 4 MIW UUV
- 4 ASW UUV
- 2 Large Surveillance UAVs
- 18 JSF

Architecture 2
Balanced Hybrid
Communications to All Platforms

Surveillance to All Manned Platforms

- Programs Of Record
- Future Systems
- Unmanned Vehicles
  Perform Strike, Surveillance Or Multi-Mission Roles

Common to All Architectures

- 6 SH-60
- E-3 AWACS
- CVN
- TDSI Insertion UUV

Common to Architecture 2 and 3

- 2 MIW LCS
- 2 ASuW LCS
- 2 ASW LCS
- 2 CGX
- 2 DDX

- 20 Small Surveillance UAVs
- 8 Large Surveillance UAVs
- 14 JSF
- 30 Medium-Sized Surveillance UAVs

- 30 Medium Sized Strike UAVs
- 50 Medium Multi-Mission UAVs
- 4 Multi-Mission USVs
- 10 ASW UUV
- 4 MIW UUV
## Architecture Composition

<table>
<thead>
<tr>
<th>MANNED ONLY (ARCH 1)</th>
<th>BALANCED HYBRID (ARCH 2)</th>
<th>PRIMARILY UNMANNED (ARCH 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CVN</td>
<td>1 CVN</td>
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<tr>
<td>1 E-8 JSTARS</td>
<td>1 E-8 JSTARS</td>
<td>50 MEDIUM-SIZED MULTI-MISSION UAV</td>
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<td>6 LCS</td>
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<td>4 MIW UUV</td>
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<td>18 JSF</td>
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<td>2 LARGE SURVEILLANCE UAVS</td>
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<td>5 E/A-6B</td>
<td>70 MEDIUM-SIZED SURVEILLANCE UAVS</td>
<td>30 MEDIUM-SIZED SURVEILLANCE UAVS</td>
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<td>10 AH-1</td>
<td>20 SMALL SURVEILLANCE UAVS</td>
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<tr>
<td>1 B-2</td>
<td>6 F/A-22</td>
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<tr>
<td>2 B-52</td>
<td>2 MULTI-MISSION MARITIME AIRCRAFT (MMA)</td>
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<td>2 F-117</td>
<td>2 SSGN</td>
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<td>2 FFG</td>
<td>4 SURVEILLANCE USV</td>
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<tr>
<td>1 MHC</td>
<td>6 F-16</td>
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</tbody>
</table>

**All Architectures** **Arch1 and Arch 2** **Arch 2 and Arch 3**
Architecture Summary

• Three Architectures With Progressing Reliance on UVs
  – Architecture 1: Manned Only
  – Architecture 2: Balanced Hybrid
  – Architecture 3: Primarily Unmanned

• Architecture Effectiveness Modeled in Simulative Study Against Test Scenarios
Threats & Scenarios

LT Matt Holmes
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Topics

• Joint Campaign Analysis
• South China Sea Scenario
• Scenario Development Criteria
• Tactical Scenarios
JCA Referenced US Force Composition Criteria

• Joint Campaign Analysis as Point of Reference for Scenario Analysis
• Warfare Threats to NESG Prioritized
  – ASCM
  – ASW
  – MIW
  – ASuW
• JCA Study Format
  – Officers
  – Baseline Architecture
  – Lanchester Attrition Models
  – Larger Group Broken Into Mission Groups
  – Estimate of SoS Baseline Architecture Performance vs. Threat
South China Sea Scenario

• PRC Warship Strafes by Philippines Fighter

• PRC Naval Blockade of Puerta Princesa
  – Historical Rights and Economic Requirements
  – Need to Establish Safety Perimeter Around South China Sea

• PRC Reinforcement of Presence in the Spratly Islands
  – Paved Runways
  – Pier and Maintenance Facilities
  – ADA Batteries and Ballistic Missile Sites.

• PRC Invasion of Kepulauan Natuna (Indonesia)

• PRC Invasion of Palawan After a 30-day Blockade
  – Land, Air, Sea, and Missile Forces Moved to Island
Scenario Criteria

- Tactical Littoral Environments
- Scenario Definition Guided By Complexity
  - Mission
  - Enemy Force Structure
  - Level of Hostility

### PRC Invasion Force

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<th>Aircraft</th>
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<td>Surface</td>
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<td>3 SOVREMMENY DDG</td>
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**MARDIV** 1

**ARTDIV** 1

**INFDIV** 7*

*3 Additional Reserve (Guangzhou)

No Heavy Armor Division

Light Armor Units With MANPADS

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Enemy</th>
<th>Conflict</th>
<th>Escalation</th>
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<td>Aggressive</td>
<td>Medium</td>
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<td>Stressing</td>
<td>Hostile</td>
<td>High</td>
<td>Medium</td>
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</table>
Scenario 1 - Benign

Specific Scenario Elements
Day (-3): PRC Submarines Sweep Sulu
Day (0): PRC Maritime Division (MARDIV) Secures Capital City
         : PRC Naval Forces Blockade Harbor
Day (1): PRC Reinforces Spratly Isles

SoS Mission Considerations
• Unlimited US Force Movement
• US Tasking: Reconnaissance (RECCE)
Scenario 2 - Nominal

Hostility Level 2

Specific Scenario Elements
Day (2): PRC Artillery/Inf. FWD Staged
PRC Fortifies Palawan Airport
Day (3): PRC Naval Forces Mine Harbor
PRC TU-16s Begin Maritime Patrol
Day (12): PRC Reinforces Naval Presence

SoS Mission Considerations
• Restricted US Movement Outside 12 nm
• US Forces Actively Tracked
• US Tasking: RECCE and Targeting

Sulu Sea: PRC Sub Op Area
Scenario 3 - Stressing

Hostility Level 3

Day (13): PRC MARDIV Fortifies Puerta Princessa
Day (15): PRC INFDIV Disperse Into Terrain
    PRC Air Corps Commence Aggressive Patrols
Day (16): SOVREMENNY Steam to North Rendezvous
    Subs Deploy to Surf/Sub-surf Operating Areas
Day (18): PRC Surface Fleet Patrol/Interdict SSOA2

SoS Mission Considerations

• Enemy Hostile (Active Patrol Zones)
• Denial of US Assets to Littoral Region
• US Tasking: RECCE, Targeting, and Strike
Threats & Scenarios Summary

- Quantifying Capability vs. Risk
- Building the Operating Environment
- Identifying Future Threats
- Evaluating SoS Performance with Scenarios
TDSI Integration

ENS Kara Hartling
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
TDSI Requirements Process

SEA5
Maritime Dominance in the Littorals

Requirements

Results

COMMUNICATIONS
Conceptual Communications Network

INFORMATION ASSURANCE
Technology Exploitation Study and Limitation Parameters

LAND SYSTEMS
Submersible UV Craft Carrier

SENSORS
In Depth Sensor Study for Operation in Littorals

OR
Analytical Support Conceptual Modeling
Communications Track

Architecture Needs

- Distributed
- Wireless
- High Data Rates

Comms Outputs

- Developed a Conceptual Inter-platform Communications Network
- Provided Interoperability and Bandwidth Constraints
- Focused on Emerging Technologies such as
  - Mobile *ad hoc* Networking
  - Adaptive Communication Software for Multi-platform System Interoperability (Software Defined Radio)
Information Assurance Track

Architecture Needs

- Comparative Analysis on Information Security of Manned Versus Unmanned System

Information Assurance Outputs

- Performed Information Security Study on Means of Securing and Authenticating UV Communications
- Defined Inherent Organic Capabilities of UVs That Could Be Exploited
- Defined Ways to Minimize Enemy Exploitation of Captured UVs
Land Systems Outputs

- Designed UV Craft Carrier
  - Submersible
  - Deployed from Surface Platform
  - Capable of Deploying and Recovering Mini UVs
  - Multi Mission Capable (MIW, ASW)
  - Extended Reach into Littorals

Architecture Needs
- Link Blue Water Platforms with Littoral Platforms (Long Range UV Insertion)

Primarily Unmanned
Sensors Track

**Architecture Needs**

- Capability of Detecting and Tracking Land Targets in the Littorals
- Capability of Detecting and Tracking Submerged Threats
- Timely Detection of Contacts

**Sensors Outputs**

- Performed In-depth Environmental Analysis of Littorals
- Defined Requirements for Sensor Network to Detect Land Based Anti-Access Defensive Systems (FOPEN)
- Determined Means to Maximize Probability of Detection of Submerged Threats
- Developed Approaches to Detect Contacts That Operate on and Above the Sea in a Timely Manner
Operations Research Track

Simulative Study

Inputs
- Scenario
- SoS Architecture

Models
- Surveillance/Threat Analysis & Evaluation
- Detection
- Localization
- Tracking
- Kill Assessment
- Battle Management Coordination Command
- Communications
- Engagement Engage Threats Attrition

Outputs
- Performance Measures
- Recognized Maritime Picture
- Engagement Risk to Personnel Endurance
- Post Processor SoS Ranking Cost Effectiveness

OR Outputs
- Develop Sensor Fusion Model (Quality Versus Quantity of UAVs)
- Determine Optimal Search Patterns for UAVs
- Determine Optimal Number of Comms Nodes for Undersea Network
- Provide Support to TDSI Tracks

Modeling/Simulation Needs
- Performance Analysis
- Analytical Support for TDSI Tracks
TDSI Inputs to Integrated Project

COMMUNICATIONS
Conceptual Communications Network

INFORMATION ASSURANCE
Technology Exploitation Study and Limitation Parameters

LAND SYSTEMS
Submersible UV Craft Carrier

SENSORS
In Depth Sensor Study for Operation in Littorals

OR
Analytical Support Conceptual Modeling

Extend™
Link Capacity 24 Mbps
Max. Comm. Range 60 km

Littoral Deployment CONOPS

Littoral Deployment CONOPS

ALWSE-MC
• 5 Golden Eye UAVs
• 20 iSTAR UAVs
• 4 REMUS UUVs
• 6 TALON Robot UGV

Excel
• Center Frequency 440 MHz
• BW 19.38 MHz
• Peak Power 1000 W
• Average Power 19 W
• Azimuth 3dB Beam Width 19°
• Elevation 3dB Beam Width 38°
• Nominal Gain 14 dB
Cost Analysis

LT Rene Julien
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Cost Analysis Preview

- Results
- Assumptions
- Methodology
- Process
- Data Collection
- Tools
## Cost Estimation Results

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<th>Purchase Cost</th>
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* Per 1-year Basis
** Per 10-year Basis Including Inflation
System of Systems Cost Estimation

- **Architecture 1** (Manned Only)
- **Architecture 2** (Balanced Hybrid)
- **Architecture 3** (Primarily Unmanned)

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Architecture 1 (Manned Only)</th>
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<td>Total Ownership Costs</td>
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Platform Cost Assumptions

- Fiscal Year Estimates
  - Not Available From Open Sources
  - Based on Proprietary Sources
- Future Manned and Unmanned Systems Equivalent in Cost to Manned Systems
  - UAV2-1 Cost Equivalent to E-2C
  - F-35 (Joint Strike Fighter) Based on F/A-18F O&S Data
- Current UAV O&S Costs Approximately 10% of Manned Equivalents
  - Based on Air Force Predator O&S Costs
Cost Process Methodology

- Platform Purchase Cost
- Platform Operating & Support Cost
- Architecture Composition
- Inflation Indices
- Architecture Cost

Cost Model
Cost Estimation Methodology

- All O&S Costs in FY2003 From VAMOSC, AFTOC and OSMIS Databases
- Costs for Future Systems (i.e., UVs and (X) Ships) Estimated Using Analogy Technique
- Derivation of Proposed Future System Unit Cost Using Cost Factors
  - Complexity
  - Miniaturization
  - Productivity Improvement
Cost Organizations

- Navy Center for Cost Analysis (NCCA)
- Air Force Cost Analysis Agency (AFCAA)
- US Army Cost and Economic Analysis Center (USACEAC)
- Defense Cost and Research Center (DCARC)
- Tecolote Research (ACEIT Software)
Cost Estimation Tools

Microsoft Excel

Advanced Cost Estimating Integrated Tools (ACEIT) from Tecolote Research
Simulative Study

ENS Bryce Abbott
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Simulative Study Overview

Method
- Important Questions and Sensitive Design Variables Identified
- Comprehensive Modeling Framework Developed to Answer the Important Questions

Result
- Quantitative Data Provided to Answer Important Questions

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Simulative Study

- Objective
- Design
- Modeling Framework
- Modeling Tools
- Modeling Output
Simulative Study Objective

• Conduct a Simulative Monte Carlo Analysis to Quantify the Effectiveness of Alternative SoS Architectures by Answering
  – How Much Time Does the SoS Require to Establish the Recognized Maritime Picture?
  – How Well Does the SoS Engage Threats?
  – How Well Does the SoS Protect Personnel From Risk?
  – How Well Does the SoS Endure Combat?
Simulative Study Design

Inputs
- Scenario
- SoS Architecture

Models
- Surveillance/Threat Analysis & Evaluation
- Detection
- Localization
- Tracking
- Kill Assessment
- Battle Management Coordination Command
- Communications Establish Link Transmit
- Engagement Engage Threats Attrition

Outputs
- Performance Measures
  - Recognized Maritime Picture
  - Engagement
  - Risk to Personnel
  - Endurance
- Post Processor
  - SoS Ranking
  - Cost Effectiveness
Simulative Study Design

Variables

- SoS Architecture
  - Communications Network Architecture
  - Command and Control
  - Platform Physical Distribution
- Scenario
Simulative Study Design – SoS Architecture Variable

SoS Architecture Variable

- Manned Only
- Balanced Hybrid
- Primarily Unmanned

Manned Platform

Unmanned Platform

Manned Only

Balanced Hybrid

Primarily Unmanned
Simulative Study Design - CNA Variable

Communications Network Architecture (CNA)

- Enclave
- Hybrid
- Distributed

- Manned Platform
- Unmanned Platform
- Line of Communication
Simulative Study Design - C2 Variable

Command and Control (C2)

- Centralized
- Decentralized

- Manned Platform
- C2 Node
- Unmanned Platform
- Line of Communication
Simulative Study Design - PPD Variable

Platform Physical Distribution (PPD)

- Small
- Medium
- Wide

- Manned Platform
- Unmanned Platform
Simulative Study Design - Scenario Variable

Scenario
- Benign
- Nominal
- Stressing

- Friendly Platform
- Hostile Platform
Modeling Framework

Force/Theater Model (Extend™)

Platform/Combat System Model (ALWSE-MC)

Engineering Physics Based Models (Excel/SWAT)

Lower Levels Interface With & Support Upper Levels

Flow of Results
Modeling Tools Interface

Excel/SWAT

ALWSE-MC

Lateral Range Detection Curves

Extend™

Database Tables

Time To Detection Data

Wayne E. Meyer Institute of Systems Engineering
Naval Postgraduate School, Monterey, CA
Modeling Output

Extend™

Quantitative Data Provided to Fulfill Simulative Study Objective

Simulation Output Table
Engineering Physics Models (Excel/SWAT)

ENS Scott Poitevent
Modeling Framework

- Engineering Physics Based Models (Excel/SWAT)
- Platform/Combat System Model (ALWSE-MC)
- Force/Theater Model (Extend™)
• Provide Flexible Tool for Detection Simulation with Sensor/Target Pairs
• Implement Physical Laws for Analytical Application
• Generate $P_{\text{det}}$ vs Range Curves
Engineering Analysis Models (Excel/SWAT)

• Engineering Physics Based Modeling Performed to Create Database Tables and Lateral Range Detection Curves for Sensors / Threats Pairs

• Sensor-Target Models
  – Probability of Detection (P_det) vs Range Curves

• Physics Models*
  – Radar Based on Swerling II
  – Acoustic Based on Manning P_det
  – Infrared (IR) Based on Johnson’s Criteria

- Sensor Parameters
- TDSI FOPEN Radar Performance Parameters
- Specific Enemy Threat Characteristics From Scenario
- Environmental Parameters

### IR Input Table

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<th>Reflect</th>
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<th>Sensor Freq(M)</th>
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### RF Input Table

\[
R = \frac{\pi P_i D^2 \sigma}{64 \lambda^2 k T BF (CNR)}
\]

- \( P_i = 3.14 \)
- \( \text{Reflect} = 0.0100 \)
- \( \text{Emissivity} = 0.9900 \)
- \( \text{Sensor Freq(M)} = 3.0E+09 \)

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- \( \text{RCS} = 0.0100 \)
- \( \text{Detection Range (m)} = 9.0E-05 \)
- \( \text{Detection Range (nm)} = 1.6E-01 \)
- \( \text{Detection Range (m)} = 9.0E-05 \)
- \( \text{Detection Range (nm)} = 1.6E-01 \)
Engineering Model Outputs

- Threat Signatures (Radar, IR, Acoustic)
- $P_{\text{det}}$ vs. Range for Sensor-target Pairings

Threat Signatures

**EF Band vs ASCM**

![Graph showing the relationship between Threat Detection Range (m) and Broadside P_Det for various threat signatures.](image)
Engineering Models – SWAT

- Shallow Water Acoustics Toolset (SWAT) - NAVSEA
  - Inputs
    - Environment
    - Sensor Parameters
    - Target Parameters
  - Outputs
    - $P_{\text{det}}$ vs. Range

P_det vs Range Output Chart
Platform/Combat System Model (ALWSE-MC)

ENS Scott Poitevent
Modeling Framework

- Force/Theater Model (Extend™)
- Platform/Combat System Model (ALWSE-MC)
- Engineering Physics Based Models (Excel/SWAT)
ALWSE-MC

- Simulate Tactical Level Employment of Sensors Against Threats
- Make Use of Sensor $P_{\text{det}}$ vs Range Curves in Performance Analysis

Time-to-Detect Distribution

Wayne E. Meyer Institute of Systems Engineering
Naval Postgraduate School, Monterey, CA
ALWSE-MC

- Discrete Event Simulation Tool Developed by NAVSEA Panama City, FL
- Integration of Engineering Level Detection Curves Into Tactical Simulation
- Simulation of Vehicle Characteristics, Sensor, and Employment for a Variety of Unmanned Systems
ALWSE-MC Inputs

- P_det vs. Range Curves
- Vehicle Parameters
- Threats
- Environment

ALWSE P_det Input Chart

ALWSE Vehicle Editor
ALWSE-MC Outputs

- Effective Probability of Detection
- Vehicle Tracks
- Time to Detection
- Area Covered
ALWSE-MC Utilization

- Platform/Combat System Modeling Performed to Incorporate Operational Implementation of Sensors/Threats Pairs and Produce Time to Detection Data
- Monte Carlo Analysis (200 Runs per Sensor/Target Pair)
- ALWSE-MC Simulation Missions
  - Surface (ASuW) Threats: DD, FFG, PGM
  - Anti-submarine (ASW) Threats: Diesel, Mini, Nuclear
  - Air (AW) Threats: Fighter, Bomber
  - Mine (MIW) Threats: Moored/Bottom (25 Each)
  - Land Threats: 50 SAM Launchers
- Use of P\_det Curves For Each Sensor/Target Pairing
- Generation of Distributions of Average Detection Time For Sensor–Target Pairings Used As Input Into Extend™
Force/Theater Model (Extend™)

ENS Rob Smith
Force/Theater Model (Extend™)

Platform/Combat System Model (ALWSE-MC)

Engineering Physics Based Models (Excel/SWAT)
Force/Theater Model Overview

- Process Model of Maritime Dominance Concept
- High Level Interactions Between Opposing Forces
- Effects of Changing SoS Force Structure and Architecture Attributes on Outcome

SoS Architecture
Scenario

Extend™ Model

Simulative Study Performance Measures
Modeling Tool: Extend™

- Discrete-Event Simulation Tool
- Multi-Layer Simulation
- Object-Oriented Design
- Extensive Libraries of Alterable Icons Representing Simulation Processes
- Integrated Database Utility
Extend™ Model Design

Surveillance/Threat Analysis & Evaluation
- Target
- SoS Sensor
- Process Delay: Detection, Localization, & Tracking
- Target
- SoS Weapon
- Battle Management
- Batch Target and Weapon Resources
- Paired Target/Weapon
- Engagement
- Process Delay: Time to Engage
- P(K)
- Attrition: Destroyed Targets & SoS Platforms Exit Model

Communications
- Assign Message Attributes
- Batch Comm Link Resources
- Process Delay: Transmission
- Track Report
- Engagement Order
- Track Report
- Engagement Order
- Engagement Order
Experiment Design

- Full-Factorial Design With Configurations For All Combinations of Design Variables
  - 3 Scenarios (Benign, Nominal, Stressing)
  - 3 Architectures (Manned Only, Balanced Hybrid, Primarily Unmanned)
  - 3 Communications Network Architectures (Enclave, Hybrid, Distributed)
  - 2 C2 Structures (Centralized, Decentralized)
  - 2 Physical Platform Distributions (Small, Medium, Large)
- Run Matrix (162 Configurations with 50 Monte Carlo Runs Each) – 8100 Runs
Inputs

Attributes

- **SoS Objects**
  - Platform Types
  - Sensor/Weapon Capabilities
  - Sensor Performance
  - Communications Capability
  - Mission Area

- **Scenario Objects**
  - Threat Types
  - Mission Area
  - Arrival Times

Process Model Parameters

- **Surveillance/Threat Analysis & Eval**
  - ALWSE-MC Time To Detect Data
  - Sensor Availability

- **Battle Management**
  - Weapon Availability

- **Communications**
  - Network Architecture
  - Link Availability
  - Link Data Rates

- **Engagement**
  - \( P_{SoS}(K) \)
  - Time To Engage
  - \( P_{enemy}(K) \)
Simulation Outputs – Performance Measures

• Recognized Maritime Picture
  – Time to Develop RMP

• Engagement
  – Targets Killed / Targets Engaged
  – Targets Killed / Total Targets

• Risk to Personnel
  – Number of Personnel Exposed to Risk
  – Number of Casualties

• Combat Endurance
  – Number of Surviving SoS Platforms

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<th>Config</th>
<th>SoS Arch (1,2,3)</th>
<th>CNA (1,2,3)</th>
<th>C2 (1,2)</th>
<th>PPD (1,2,3)</th>
<th>Scenario / Hostility (1,2,3)</th>
<th>Total COIs</th>
<th>COIs Detected</th>
<th>COIs Localized &amp; Enemy Targets Killed</th>
<th>Weapons Fired</th>
<th>Total Personnel</th>
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<th>Casualties</th>
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Simulative Study Design

Models

Surveillance/Threat
Analysis & Evaluation
Detection
Localization
Tracking
Kill Assessment

Battle Management
Coordination
Command

Communications
Establish Link
Transmit

Engagement
Engage Threats
Attrition

Performance Measures
Recognized Maritime Picture
Engagement
Risk to Personnel
Endurance

Post Processor
SoS Ranking
Cost Effectiveness

Inputs
Scenario
SoS Architecture

Outputs
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Topics

- Data Analysis
- Architecture Ranking Process
- Architecture Ranking Results
- Configuration Ranking Process
- Configuration Ranking Result
Data Analysis

Extend Outputs
- Total Contacts of Interest
- Enemy Targets Killed
- Avg Time to Establish RMP
- Sos Platforms Killed
- Casualties
- Personnel Exposed to Risk
- Avg Message Transmission Time
- Total Personnel

Data Analysis Process
- Averaged 50 Runs of Output Data Per Configuration
- Extracted Averages for Every MOE for 162 Configurations
- Imported Averages Into Excel Data Sheet for Further Manipulation
- Processed Data Output to Match Total Utility Inputs

Extend Data Table

Data Outputs
- Surveillance
- Risk Exposure
- Casualties
- Communication Capability
- Combat Endurance
- Engagement Capability
- Recognized Maritime Picture Capability

Extend Processed Data Output

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Architecture Ranking Process

- Extend Data
- Post Extend Data Analysis & Trade Space Determination
- Calculating Normalized Utility Score
- Utility Scores By Scenario
- Architecture Average Utility Score by Scenario
- Determination Of Utility Score For Scenario Arch pairs
- Partition of Configurations By Scenario
- Outputs
- Processes
- Inputs

Legend:

{Sc} - Set of Scenarios
{Arch} - Set of Architectures
{Comms, C^2, PPD} - Set of Attributes
Architecture Ranking Summary

• Balanced Hybrid Architecture With Unmanned/Manned Ratio of 1.5:1 is Selected Based on Overall Performance

• UV to Manned Ratio Greater Than 1.5:1 Decreases Overall SoS Performance

• These Results Are Based on Defined Scenarios With Weights Provided by Primary Stakeholder

• Architecture Ranking is Insensitive to Scenario Weights
Configuration Ranking Process

- Extend Data
- Post Extend Data Analysis & Trade Space Determination
- Extend Analysis Results
- Utility Score Matrix
- Calculation of Normalized Utility Score
- Partition of Configurations By Scenario
- Utility Scores By Scenario
- Selection of Best Configuration Per Architecture
- Determination Of Configuration Utility Scores Across Scenarios
- Configuration Utility Scores Across Scenarios
- Configuration Ranking
- Configuration Ranking Results

Legend:
- Processes
- Inputs
- Outputs

Scenarios \{Sc\} - Set of Scenarios
Architectures \{Arch\} - Set of Architectures
Attributes \{Comms, C^2, PPD\} - Set of Attributes

Processes:
VSD Weights
Scenario Weights

Inputs:
Extend Data
Scenario Weights

Outputs:
Best Configuration Per Architecture
Configuration Ranking Results
Utility Scores By Scenario
Partition of Configurations By Scenario
Selection of Best Configuration Per Architecture
Calculation of Normalized Utility Score
Configuration Ranking Results

Best Configuration

• Balanced Hybrid Unmanned/Manned Architecture (Architecture 2)
• Distributed Communication
• Decentralized Command & Control
• 100-nm Platform Distribution

• Distributed Communications
  - Faster Dissemination of Information
    • Average Message Delay 1/10th Hybrid’s & 1/100th Enclave’s
  - Minimum Impact on Throughput with Node Failures

• Decentralized Command and Control
  - Faster Dissemination of Command Messages
    • Average Message Delay 1/10th Centralized C2’s
  - Faster Reaction Times
  - Less Network Demand
  - Reduced Single C2 Node Workload
  - Single C2 Node Failure Avoidance

• Platform Distribution
  - 100-nm Platform Distribution
  Exhibiting Superior Performance Albeit Statistically Insignificant
Configuration Selection Validation

LT Jeff Winslow
SoS Development

- Functional Analysis
- Value Systems Design
- Architectures
- Threats & Scenarios
- TDSI Integration
- Cost Analysis
- Simulative Study
- Architecture Ranking
- Configuration Validation
Selected Configuration Validation

- Comparison of CDF for Time-to-RMP for Best Configuration from 162 Configurations to CDFs for Selected Configurations
- Excellent Agreement between Best-Configuration CDF and CDF for Selected Architecture 2-Best Configuration Thus Validating Chosen Configuration
- Comparison of CDFs for Other MOEs Also Validating Chosen Configuration

CDF: Cumulative Distribution Function
Effects of Configuration Attributes On RMP

- Significant Effects of Unmanned/Manned Ratio on Time-to-RMP
- Insignificant Effects of Command and Control Structure & Communication Network Architecture

95% Confidence Interval Plot

Scenario 3 (Stressing) UV Mix

Time to Establish RMP (Hours)

Enclave  Hybrid  Distributed
Effects of Configuration Attributes On Communications Performance

- Significant Effects of Unmanned/Manned Ratio, Command & Control and Communication Network Architecture on Communication Performance (Message Delay)
Cost Effectiveness Curve for Architecture Recommendation

- Balanced Hybrid (Architecture 2) Cost Effective & Cost Efficient
- Manned Only (Architecture 1) Cost Effective Not Cost Efficient
- Primarily Unmanned (Architecture 3) Dominated (Neither Effective or Efficient)

Architecture 2 Recommended Based on Cost & Performance
Recommended SoS Configuration

- **Recommended SoS Configuration**
  - Balanced Hybrid Unmanned/Manned Architecture (Architecture 2)
  - Distributed Communication
  - Decentralized Command & Control
  - 100-nm Platform Distribution

- **Recommended Configuration Validated**
  - Based On Independent Statistical Analysis
  - Involving All MOEs

- **Balanced Hybrid Unmanned/Manned Architecture**
  - Recommended Based on Cost & Performance
  - Cost Effective and Cost Efficient
Project Conclusion

LCDR Quoc Tran
Project Overview

- Tasked With A Complex Problem of Maritime Dominance in the Littoral
- Developed a Project Management Plan
- Executed The Plan Using Systems Engineering Design Process
- Generated Conceptual SoS Architecture Alternatives
- Used Modeling and Simulation to Assess Architecture Performance
- Ranked SoS Architecture Alternatives
Recommended System of Systems for Maritime Dominance in Littorals

• Unmanned Vehicles Complement But Cannot Replace Manned Platforms

• Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe
  – Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1
  – Utilizes Distributed Communications with 100nm Physical Platform Distribution
  – Employs Decentralized Command & Control Structure
  – Is Cost Effective Relative to Other Alternatives

• Distributed Communications
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures

• Decentralized Command and Control
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance

• 100 nm Platform Distribution
  - Superior Overall Performance
Acknowledgments

- Family and Friends
- Project Advisor – Dr. Huynh
- Military Advisor – CAPT Kline
- Supporting Temasek Defense Systems Institute Teams
- Department of Defense Organizations and Defense Industry
- Professors
Questions and Answers

Questions May Be Reserved for the Break Out Session at 1300 in the Bullard Hall Computer Lab (If So Desired)

• Report and Presentation Will Be Available After 18 June 2004

http://www.nps.navy.mil/SEA/MaritimeDominance
Backup Slides
# Differences in Architectures

<table>
<thead>
<tr>
<th>Architecture 1</th>
<th>Architecture 2</th>
<th>Architecture 3</th>
</tr>
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<tbody>
<tr>
<td>CVN</td>
<td>CVN</td>
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<tr>
<td>SH-60</td>
<td>SH-60</td>
<td>SH-60</td>
</tr>
<tr>
<td>E-3 AWACS</td>
<td>E-3 AWACS</td>
<td>E-3 AWACS</td>
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<tr>
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<tr>
<td>DDG</td>
<td>DDG</td>
<td>CGX</td>
</tr>
<tr>
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<td>SSN</td>
<td>Insertion UUV</td>
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<td>E2-C</td>
<td>E2-C</td>
<td>Multi-Mission USV</td>
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<td>F/A-18</td>
<td>F/A-18</td>
<td>Strik UAV</td>
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<td>E-8 JSTARS</td>
<td>E-8 JSTARS</td>
<td>Medium-Sized Multi-Mission UAV</td>
</tr>
<tr>
<td>P-3</td>
<td>LCS</td>
<td>LCS</td>
</tr>
<tr>
<td>CH-53</td>
<td>MIW UUV</td>
<td>MIW UUV</td>
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<td>ASW UUV</td>
<td>ASW UUV</td>
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<td>JSF</td>
<td>JSF</td>
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<tr>
<td>S-3</td>
<td>Large Surveillance UAVs</td>
<td>Large Surveillance UAVs</td>
</tr>
<tr>
<td>E/A-6B</td>
<td>Medium-Sized Surveillance UAVs</td>
<td>Medium-Sized Surveillance UAVs</td>
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<td>AH-1</td>
<td>Small Surveillance UAVs</td>
<td>Small Surveillance UAVs</td>
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<tr>
<td>B-2</td>
<td>F-16</td>
<td></td>
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<tr>
<td>B-52</td>
<td>F/A-22</td>
<td></td>
</tr>
<tr>
<td>F-117</td>
<td>Multi-Mission Aircraft</td>
<td></td>
</tr>
</tbody>
</table>

## All Architectures

## Arch1 and Arch 2

## Arch 2 and Arch 3
TDSI Inputs to Integrated Project

**Communications**
- MANET Parameters
  - Link Capacity 24 Mb/s
  - Range 60 km
  - Delay 4.37*10^-3 s
- Sea web Parameters
  - Link Capacity 600 bps
  - Range 10 km
  - Delay 6.7 s
- Advantages/Disadvantages of MANET and SDR
- Performance
- Security Details

**Information Assurance**
- Threats to UAVs
- Means to Mitigate Threats

**Operations Research**
- Fusion Model
- Description of Quality vs. Quantity for Search/Detection with UAVs
- Optimization of Search Patterns
- Effects of Increasing # of UAVs
- Optimization # of Communications Nodes for Underwater UV Network

**CONOPS**
- Simulative Study

- ✔️
- ✔️
- ✔️
# TDSI Inputs to Integrated Project

**SENSORS**

## Surveillance Gaps

**Recommended Sensors to fill specific Gaps**

**Parameters of FOPEN/SAR**
- Center Frequency 440 MHz
- BW 19.38 MHz
- Peak Power 1000 W
- Average Power 19 W
- Azimuth 3dB Beam Width 19°
- Elevation 3dB Beam Width 38°
- Nominal Gain 14 dB

## Parameters of UV craft carrier
- Length 11.08 m
- Width 2.286 m
- Height 2.238 m
- Weight <15,000 kg
- Max Depth 50 m
- Range 150 nm
- Average Speed 6 kts
- Endurance 72 hrs
- Deployment methods:
  - LPD well deck
  - Helo drop
  - Submarine launch
- Number/type of UVs carried:
  - 5 Golden Eye UAVs
  - 20 iSTAR UAVs
  - 4 REMUS UUVs
  - 6 TALON Robots UGV

<table>
<thead>
<tr>
<th>CONOPS</th>
<th>Simulative Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>✓</td>
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</tbody>
</table>

**LAND SYSTEMS**
Cost Analysis Databases

- Visibility and Management of Operating and Support Costs (VAMOSC) Database from NCCA
- Air Force Total Ownership Cost (AFTOC) Database from AFCAA
- Operating and Support Management Information System (OSMIS) Database from USACEAC
- Jane’s Online
- Navy and Air Force Online Fact Files
- Federation of American Scientists (FAS)
- Defense Automated Cost Information System (DACIMS) Database from DCARC
Platform Cost Assumptions

- O&S Costs for USVs and UUVs Not Available
- Total Ownership Costs (TOC) Based on 10 year Service Life
Surveillance Algorithm
Communications Algorithm

- Track Report or Engagement Order
- Sending / Receiving Platforms (Sensor / Weapon Node & C2)
- Number Hops & Link Length (Platform Type, CNA & C2)
- Link Type (Platform Type & CNA)
- Collision Avoidance Queue
- Batch Comm Link Resource
- Transmit
- Battle Management Model

Comm Link Resource Pool
Battle Management Algorithm

Weapon Nodes
(Sorted by Mission Area & Prioritized by P(K))

Pair Weapon & Threat

Threat

Issue Order

Comms Model

Platform Receives Order

Engagement Model
Engagement Algorithm

Scenario Object* → Number of Chances to Engage (Threat Type) → Time to Engage (SoS Platform & Target Type) → SoS P(K) → Scenario Object Destroyed

Time to Engage (Scenario Object & SoS Platform Type) → Enemy P(K) → SoS Platform Destroyed (Attrition Model)

*SoS Engages Enemy Targets First in Most Cases
(Missile Threat Represents Enemy First Strike)
Bounded and Weighted VSD

1. Maritime Dominance
   a. Surveillance (.3)
      i. Detection (.6 / .18)
         1. Coverage Capability (.4 / .072)
            a. Average Time to Establish Complete Area Coverage
            b. Ratio Area Covered / Total Search Area
            c. Coverage Factor (Confidence)
         2. Probability of Detection (.6 / .108)
            a. Average System Probability of Detection
   ii. Tracking (.4 / .12)
      1. Tracking Capability (1 / .12)
         a. Ratio Contacts of Interest (COI) tracked / Total COI
         b. Average Number of Visits per COI
   b. Threat Analysis and Evaluation (.2)
      i. Identification (.7 / .14)
         1. ID Capability (.6 / .084)
            a. Ratio COI’s ID’d / Total COI
         2. Probability of False ID (.4 / .056)
            a. Ratio of Incorrect ID’s / Total ID’s

ii. Minimize Risk (.3 / .06)
   1. Reduced Exposure to Risk Capability (1 / .06)
      a. Ratio of Personnel Exposed to Risk / Total Personnel
      b. Ratio of Casualties / Total Personnel
   c. Battle Management (.2)
      i. Recognized Maritime Picture (RMP) (.6 / .12)
         1. RMP Capability (1 / .12)
            a. Average Time to Establish 80% of RMP
            b. Ratio Correct COI’s ID’d / Total COI
      ii. Maximize Communication (.4 / .08)
         1. Communication Capability (1 / .08)
            a. Ratio of Number of Assets Lost Communications / Total Assets
   d. Engagement (.3)
      i. Destroy / Disable Targets (.4 / .12)
         1. Engagement Capability (1 / .12)
            a. Average Time to Kill 80% of Targets
            b. Ratio of Targets Engaged / Total Targets
      ii. Endure Combat (.6 / .18)
         1. Endurance Capability (1 / .18)
            a. Ratio of Friendly Assets Survived / Total SoS Assets
            b. Ratio of Enemy Assets Survived / Total Enemy Assets
Assumptions and Constraints

• Calculations were done by approximating relative sizes of the UAVs to the manned systems they would be replacing.
• The calculations on the number UAVs capable of fitting on a carrier is based off the size of the predator UAV.
• We assumed that it would be possible to fold the wings in 2020 and that they would be capable of launching off and landing onto a carrier.
# UV Calculations

<table>
<thead>
<tr>
<th>Arch 3</th>
<th>Wingspan</th>
<th>Length</th>
<th>Area</th>
<th>Total</th>
<th>Arch 2</th>
<th>Wingspan</th>
<th>Length</th>
<th>Area</th>
<th>Total</th>
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<tbody>
<tr>
<td>25 Med Surveillance</td>
<td>40</td>
<td>25</td>
<td>1000</td>
<td>25000</td>
<td>58 Med Surveillance</td>
<td>40</td>
<td>25</td>
<td>1000</td>
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<tr>
<td>25 Med Strike</td>
<td>50</td>
<td>30</td>
<td>1500</td>
<td>37500</td>
<td>14 JSF</td>
<td>30</td>
<td>45</td>
<td>1350</td>
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<tr>
<td>25 Med Multi</td>
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<td>27</td>
<td>1296</td>
<td>32400</td>
<td>4 E-2</td>
<td>42</td>
<td>60</td>
<td>2520</td>
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</tr>
<tr>
<td>14 JSF</td>
<td>30</td>
<td>45</td>
<td>1350</td>
<td>18900</td>
<td>7 Sh-60</td>
<td>15</td>
<td>50</td>
<td>750</td>
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</tr>
<tr>
<td>4 E-2</td>
<td>42</td>
<td>60</td>
<td>2520</td>
<td>10080</td>
<td>24 FA 18</td>
<td>29</td>
<td>55</td>
<td>1595</td>
<td></td>
</tr>
<tr>
<td>7 Sh-60</td>
<td>15</td>
<td>50</td>
<td>750</td>
<td>5250</td>
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129130 sq ft

<table>
<thead>
<tr>
<th>Current Carrier</th>
<th>Area</th>
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<tbody>
<tr>
<td>8 S-3</td>
<td>39</td>
<td>53</td>
</tr>
<tr>
<td>36 F/A-18 E/F</td>
<td>29</td>
<td>55</td>
</tr>
<tr>
<td>4 E-2</td>
<td>42</td>
<td>60</td>
</tr>
<tr>
<td>14 F-14</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>5 EA-6B</td>
<td>30</td>
<td>59</td>
</tr>
<tr>
<td>7 Sh-60</td>
<td>15</td>
<td>50</td>
</tr>
</tbody>
</table>

131120 sq ft Approx. Carrier space

Assume that with Wing Fold the wingspan is approximately 2/3 the size

<table>
<thead>
<tr>
<th>Arch 3</th>
<th>Wingspan</th>
<th>Length</th>
<th>Area</th>
<th>Total</th>
<th>Arch 2</th>
<th>Wingspan</th>
<th>Length</th>
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<tr>
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<td>27</td>
<td>810</td>
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<tr>
<td>30 Med Strike</td>
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<td>27</td>
<td>864</td>
<td>25920</td>
<td>14 JSF</td>
<td>30</td>
<td>45</td>
<td>1350</td>
<td></td>
</tr>
<tr>
<td>50 Med Multi</td>
<td>32</td>
<td>27</td>
<td>864</td>
<td>43200</td>
<td>4 E-2</td>
<td>42</td>
<td>60</td>
<td>2520</td>
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</tr>
<tr>
<td>14 JSF</td>
<td>30</td>
<td>45</td>
<td>1350</td>
<td>18900</td>
<td>7 Sh-60</td>
<td>15</td>
<td>50</td>
<td>750</td>
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</tr>
<tr>
<td>4 E-2</td>
<td>42</td>
<td>60</td>
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<td>10080</td>
<td>24 FA 18</td>
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<tr>
<td>7 Sh-60</td>
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<td>750</td>
<td>5250</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

129270 sq ft

26.66667 17.77777778
Changes In Sub & Surface Vessels

Arch 1
- 1 CVN
- 2 CG
- 4 DDG
- 2 FFG
- 2 SSN
- 1 MHC
- 1 MCM
- 1 LHA

Arch 2
- 1 CVN
- 2 CG
- 2 DDG
- 6 LCS
- 2 SSN
- 2 SSGN
- 4 USV
- 4 MIW UUV
- 4 ASW/ASUW UUV

Arch 3
- 1 CVN
- 2 CGX
- 2 DDX
- 6 LCS
- 4 Multi-Mission USV
- 4 MIW UUV
- 4 ASW/ASUW UUV
- 1 Long Range UV Insertion Platform
# Changes In Air Assets

<table>
<thead>
<tr>
<th>Arch 1</th>
<th>Arch 2</th>
<th>Arch 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4 E2-C</td>
<td>• 4 E2-C</td>
<td>• 6 SH-60</td>
</tr>
<tr>
<td>• 10 SH-60</td>
<td>• 7 SH-60</td>
<td>• 14 JSF</td>
</tr>
<tr>
<td>• 36 F/A-18</td>
<td>• 24 F/A-18</td>
<td>• 1 E-3 AWACS</td>
</tr>
<tr>
<td>• 2 P-3</td>
<td></td>
<td>• 8 Large Surveillance UAVs</td>
</tr>
<tr>
<td>• 5 CH-53</td>
<td>• 18 JSF</td>
<td>• 30 Medium Surveillance UAVs</td>
</tr>
<tr>
<td>• 2 MH-53</td>
<td>• 1 E-3 AWACS</td>
<td>• 20 Small Surveillance UAVs</td>
</tr>
<tr>
<td>• 14 F-14</td>
<td>• 1 E-8 JSTARS</td>
<td>• 30 Medium Strike UAVs</td>
</tr>
<tr>
<td>• 8 S-3</td>
<td>• 6 F-16</td>
<td>• 50 Medium Multi Mission UAVs</td>
</tr>
<tr>
<td>• 5 E/A-6B</td>
<td>• 6 F/A-22</td>
<td></td>
</tr>
<tr>
<td>• 10 AH-1</td>
<td>• 2 Large Surveillance UAVs</td>
<td></td>
</tr>
<tr>
<td>• 1 E-3 AWACS</td>
<td>• 70 Medium Surveillance UAVs</td>
<td></td>
</tr>
<tr>
<td>• 1 E-8 JSTARS</td>
<td>• 20 Small Surveillance UAVs</td>
<td></td>
</tr>
<tr>
<td>• 1 B-2</td>
<td>• 2 Multi-Mission Aircraft (MMA)</td>
<td></td>
</tr>
<tr>
<td>• 2 B-52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 2 F-117</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Land Forces Estimate in JAOA

• Estimate of PRC forces
  – 3 Infantry Divisions  =  45K
  – 1 Arty Division      =  15K
  – Total               =  60K

• Estimate of JUMPVISA Coalition forces
  – 1 MEB                 =  17K
  – 1 OFB                =  3K
  – 1 Airborne Division =  12K
  – 1 Infantry Division =  11K
  – Total                =  43K
## Game Theory Definitions

### IMPACT Table Breakdown

<table>
<thead>
<tr>
<th>Mission Area Def</th>
<th>Key</th>
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<tbody>
<tr>
<td>1</td>
<td>TBMD</td>
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<tr>
<td>2</td>
<td>AAW</td>
</tr>
<tr>
<td>3</td>
<td>Land Warfare</td>
</tr>
<tr>
<td>4</td>
<td>SUW/USW</td>
</tr>
<tr>
<td>5</td>
<td>LOC</td>
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</table>
### Probability of Kill:

<table>
<thead>
<tr>
<th>Displacement</th>
<th>Multiple</th>
<th>Number</th>
<th>Wt Mult</th>
<th>P(H)</th>
<th>Hits to Kill</th>
<th>P(k)</th>
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</thead>
<tbody>
<tr>
<td>LPD-17</td>
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<td>147.43</td>
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<td>13.00</td>
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<td>220.2857</td>
<td>1</td>
<td>15</td>
<td>0.288413</td>
</tr>
</tbody>
</table>

P(MA) = Probability of Missile Acquire
P(MH) = Probability of Missile Hit; standard measure of missile accuracy
P(SHMK) = Probability of Single Hit Missile Kill (per ship class)
Multiple = The number of times that a ship is more likely to be targeted than an LCS positioned near it based on size difference
Number = Number of ships in that class that are in the targeting area simultaneously
Wt Mult = Likelihood that a particular ship class will be targeted based on the number of ships in that class that are present
P(H) = Weighted probability of hit for each ship class based on the numbers of that ship class in the area
Hits to Kill = Number of hits required per class of ship to achieve mission kill
P(k) = Weighted total probability, adjusted by number of ships per class present, of mission kill per class

Non-selective
Game Theory Calculations:

<table>
<thead>
<tr>
<th>POA 1</th>
<th>US wins; No WFA losses</th>
<th>China wins; Loss 2 WFA</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COA 1</th>
<th>US wins; China @ 55%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COA 2</th>
<th>US wins; China @ 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-2.0</td>
</tr>
</tbody>
</table>

POA 1 – Repeated 150-200 missile raids (A/C)
POA 2 – Coordinated raid attacks at key assets
COA 1 – US waits for Chinese first strike
COA 2 – US first strike → reduce Chinese 50%

China is 96% likely to adopt
POA 1; Weaken US AAW

US 76.78% likely to use some form of COA 2.

*Table is viewed from the Chinese perspective

END RESULT: US is unable to defend vs. ASM threat after 2 raids/SAG
Modeling Tools Description

Higher Level Models Build on Lower Level Models

Excel/SWAT
- Based on Physical Laws
  - High Fidelity
  - Limited Fidelity
- Establishes Fundamental Physical Characteristics for all Other Models

ALWSE-MC
- Implements Concepts of Operation
  - Less Depth
  - Consideration of “Real World” Effects
  - Application of Tactical Environment
- Provides Performance Characteristics for Higher Level Models

Extend™
- Implements Process Algorithms to Provide
  - Increased Breadth
  - Abstraction
  - Assessment of Multiple Configurations of Variable Parameters
- Produces Comprehensive and Quantitative Results for Decision Making
Modeling Outputs

Excel/SWAT

• Engineering Physics Based Modeling Performed to Create Database Tables and Lateral Range Detection Curves for Sensors/Threats Pairs

ALWSE-MC

• Platform/Combat System Modeling Performed to Incorporate Operational Implementation of Sensors/Threats Pairs and Produce Time to Detection Data

Extend™

• Force/Theater Modeling Performed to Incorporate Multiple Architectural and Scenario Parameters and Provide the Necessary Outputs to Fulfill the Simulative Study Objectives
Land Systems Unmanned Vehicle Carrier Analysis

- Used ALWSE-MC to evaluate the area coverage by payload of the TDSI Land Systems Unmanned Vehicle Carrier
- 10 nm x 10 nm
- 4 UUV (search speed 3 kts)
- 5 Crawler UGV (search speed 1.3 ft/sec)
- 20 iStar UAV (search speed 30 kts)
- 6 Goldeneye UAV (search speed 30 kts)
- Area split horizontally between water and land
- UUVs conducted ladder search of area, UAVs/UGVs conducted random search patterns
Area Covered

- Area divided into 25 ft x 25 ft squares
- Color scheme scaled according to number of times square was visited
- 98.43% area covered in 22 hrs (maximum endurance of UV)
Results

• Significant littoral surveillance capability can be achieved at distance with reduced risk to personnel
• Rapid, Modular Deployment options
• 150 nm operating range of Unmanned Vehicle Carrier
• 98.43% area (10 nm x 10 nm) covered in 22 hrs of operation
### Mach Conversion Table

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### Engineering Models – Threat Signature Tool

**Assumptions:**
- Broadside Aspect
- Reflectance 1/0.1
- Ogive/Cylinder
- Ships: Displacement
- Raleigh Atmospherics
- Johnson’s Criteria (IR Resolution)
Engineering Models – Representative P_det Curves

• Acoustic/RADAR/EO-IR Longitudinal Probability of Detection Curves
• SA/SS/AS Envelopes Characterized By Unclassified Physics Models
• Swerling II Detection Model / NVESD ACQUIRE Algorithm

Phased Array RADAR E/F Band
LOWTRAN Model 1
Sea Level
Standard Atmosphere
Visibility: Light Haze
Mach 1 = 330 m/s
Concept of Operations 1

• Employment of UV Assets
  – Introduce Less Capable/less Costly Assets First
  – More Advanced Assets Follow

• Search Pattern
  – Alternating Waffle Search
Concept of Operations 2

- Distributed Communications
  - All Platforms Have Communication Capability
- Decentralized Command and Control
  - Performed by Manned Platforms
Concept of Operations 3

- Medium Platform Distribution
  - 150 Nautical Mile Distance

Wayne E. Meyer Institute of Systems Engineering
Naval Postgraduate School, Monterey, CA
Global Weight Sensitivity Analysis

- Insensitivity of Global Weights within Measures of Effectiveness
- Measures of Effectiveness Were Within Insensitivity Range
Scenario Weight Sensitivity Analysis BU

Insensitivity of Architecture Selection to Scenario Weights
Model Development Process

- Allowed Efficient Extend™ Model Development in Compliance with Schedule
- Focused and Standardized Programmer/Modeler Efforts
- Coordinated Modeling Efforts With Data Collectors and Post-Processors
Extend™ Model Design

**Scenario Physical Objects**

**Surveillance Threat Analysis & Evaluation**
- Detection
- Localization
- Tracking
- Kill Assessment

**Battle Management**
- Coordination - Prioritize & Pair Weapons
- Command - Issue Orders

**Engagement**
- Engage Threats
- Attrition

**Communications**
- Sensor Nodes
- Info Flow
- SoS Physical Objects

**SoS Architecture**
- Info Flow
- Perform
- Weapons Nodes
Recommended System of Systems for Maritime Dominance in Littorals

- Unmanned Vehicles Complement But Cannot Replace Manned Platforms
- Recommended System of Systems Enabling SEA BASING and SEA STRIKE in 200 nm by 200 nm Littoral Operation Area in 2020 Timeframe
  - Consists of Unmanned/Manned Vehicle Ratio of Approximately 1.5 to 1
  - Utilizes Distributed Communications with 100nm Physical Platform Distribution
  - Employs Decentralized Command & Control Structure
  - Is Cost Effective Relative to Other Alternatives

- Distributed Communications
  - Faster Dissemination of Information
  - Minimum Impact on Throughput with Node Failures
- Decentralized Command and Control
  - Shorter Reaction Times
  - Less Network Demand
  - Single C2 Node Failure Avoidance
- 100 nm Platform Distribution
  - Superior Overall Performance
Surveillance

• Programs of Record
• Existing Systems
• Surveillance UAVs and USVs
• Surveillance and Attack UUVs

Architecture 2
(Balanced Hybrid)