The Mission: Protecting the Sea Base

04 December 03
Outline

Introduction
Methodology
Problem Definition
Design & Analysis
Modeling
Conclusion
Introduction

Methodology

Problem Definition

Design & Analysis

Modeling

Conclusion

LCDR Higgs
SEA-4 Team

LCDR Ron Higgs, USN, 1510
LCDR Greg Parkins, USN, 1130
LCDR Eric Higgins, USN, 1510
LT Chris Wells, USN, 1110
LT Vince Tionquiao, USN, 1600
What We Did

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- Used a systems engineering approach to solve a complex multidisciplinary problem
- Took a big picture, overarching look at protecting the Sea Base
- Analyzed future threats to the Sea Base
- Performed deterministic analysis of sensor and weapon systems
- Generated alternative conceptual designs intended to protect the Sea Base
- Used modeling and simulation to assess the performance of the alternative systems
- Identified the most effective system of systems conceptual solution to provide force protection for the Sea Base
- Provided a foundation of data, tools, and methodologies for more detailed studies
Disclaimer

♦ This study was an *academic exercise* used to complete Master’s Thesis requirements for the Systems Engineering and Analysis Curriculum

♦ Results not endorsed by USN or USMC

♦ All information was obtained from open sources

♦ We were not trying to:
  – Generate operational requirements
  – Create doctrine
  – Generate specifications for actual systems
Force Protection
Survivability Design Factors

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Sensor Architecture
- Point
- Distributed

Weapons Architecture
- Point
- Distributed

Force Composition
- CRUDES-based
- LCS-based

Weapons Type
- Current
- Conceptual
Path to Proposed Force Protection Architecture

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Systems Engineering and Management Process

Interceptor-1 vs. ASCM-3
(Point Weapons / Point Sensor Architecture)
(0 sec Reaction Delay)

Force Protection of the Sea Base

Results

Descriptive Scenario
Current State: What is?

Normative Scenario
Desired End State: What should be?

Assessment & Feedback

PROCESS

PROBLEM

SCENARIO

MODEL

Analysis

INTERCEPTOR-1 VS. ASCM-3
(Point Weapons / Point Sensor Architecture)
(0 sec Reaction Delay)
Extensive Modeling Efforts to Analyze Design Alternatives

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Interceptor-1 vs. ASCM-3
(Point Weapons / Point Sensor Architecture)
(1 sec Reaction Delay)

Force Protection of the Sea Base

Modeling Tool Assessment

<table>
<thead>
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<th>JTLS</th>
<th>NSS</th>
<th>EINSTEIN</th>
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<td>Support</td>
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September 2003

DESIGN OF EXPERIMENTS

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<thead>
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<th>Force Composition</th>
<th>Sensor Weapon Architecture</th>
<th>Weapons</th>
<th>Alternate Force Architecture</th>
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<tr>
<td>COA A</td>
<td>Point</td>
<td>Current</td>
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<td>Conceptual</td>
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<td>COA B</td>
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<td>Conceptual</td>
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</table>

EXCEL™

ASSESS

EXTEND™

NSS
Integrated Interdisciplinary Team

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**Force Protection Architecture**

- **SEA-4**
- **TSSE**
- **NPS Theses**
- **TDSI Supporting Studies**

**Sensor/Weapon Architectures**

- **Force Composition**
- **Weapon Types**

**Force Protection Architecture**

- **Overall Integration** – Problem Definition, Modeling and Analysis
- **Requirements Generation** – LCS Attributes

**LCS Design – SEA SWAT**

- **LCS Thesis** – Stealth, Distributed Fires, Helo/UCAV Control
- **SSGN Study** – Battle Space Preparation
- **MSSE Study** – Layered Defense, Hardkill & Softkill Weapons

**Physics Team** – Cooperative Radar Network, Distributed Sensors

**OR Team** – Number and Placement of Assets, Distributed Defenders

**IA Team** – Identification of IW threats to the Sea Base

**ME Team** – Distributed Sensors, Battle Space Preparation

**ECE Team** – Distributed Sensor Network Details
Where We Started: SEI-3 Study

- Foundation for SEA-4 Study
- Developed a sea based conceptual architecture to accomplish the Expeditionary Warfare mission in the 2015-2020 timeframe using the operational tenet of OMFTS
- Focused on logistics and the elimination of the “iron mountain”
- Force protection for the Sea Base identified for further research
SEA-4 Tasking

Official Project Guidance

- **Develop a system of systems conceptual solution to provide force protection for the Sea Base and its transport assets** while performing forced entry and STOM operations in support of the Ground Combat Element of a Marine Expeditionary Brigade.

- Address protection of the ships of the Sea Base while at sea in the operating area
  - Protection of the airborne transport assets moving between the Sea Base and the objective
  - Protection of the surface assets moving between the Sea Base and the beach

- Not required to address protection of the Sea Base assets while in port

- Task does not include addressing the protection of the land force itself or land transport from the beach to the objective
Limitations

- Resources
- Classification
- Experience
- Constraints
- Cost Analysis
Introduction

Methodology

Problem Definition

Design & Analysis

Modeling

Conclusion

LCDR Higgs
Systems Engineering and Management Process

Methodology

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Systems Engineering and Management Process (SEMP) Summary

♦ SEMP is a framework for approaching problems from a systems perspective
♦ SEMP pairs creative thinking with analytical skills
♦ Systems engineering design and management is an iterative process
  – Phases of SEMP, and steps within the phases are repeated as necessary
♦ SEMP may have to be tailored to fit the needs of the project
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LCDR Parkins
Conserve the force’s fighting potential so it can be applied at the decisive time and place. Conserving the force’s fighting potential is achieved through maximizing survivability by minimizing susceptibility and vulnerability.
Scope and Bound the Problem

- Identify issues
- Make assumptions
- Break out the tool bag
  - Functional Analysis
  - Futures Analysis
  - Value System Design
- Generate requirements
Primitive Need

✦ Protect the Sea Base while at sea in the operating area
✦ Protect the airborne transport assets from the Sea Base to the objective
✦ Protect the surface transport assets from the Sea Base to the beach or port
Issues

♦ What is force protection?
♦ What is a Sea Base?
♦ What makes up a Sea Base?
♦ Where does the Sea Base operate?
♦ Is the Sea Base supported by other assets?
♦ What is Ship To Objective Maneuver?
♦ What constraints does this study fall under?
Assumptions

- Marine Expeditionary Brigade (MEB) operations occur in the 2015-2020 timeframe.
- MEB size Marine Air Ground Task Force composition and sustainment requirements remain constant between the present and 2015-2020.
- The USMC adopts Ship To Objective Maneuver doctrine.
- SEI-3’s conceptual expeditionary warfare architecture is operationally available in 2015-2020.
- All current USN and USMC legacy platforms will remain operational through 2015-2020.
- All proposed USN and USMC acquisitions of new aircraft and land vehicles will be operationally available in 2015-2020.
- MEB forces may be projected as far as 200 nm inland. The ships of the Sea Base may be as far as 200 nm offshore, but not to exceed 275 nm from Sea Base to objective.
- A Carrier Strike Group is available for battle space preparation.
- Expeditionary warfare force protection is modeled and analyzed in the SEA-4 Sea Base defined region only.
Force Protection

- Actions taken to prevent or mitigate hostile action against the Sea Base
- These actions conserve the force’s fighting potential so it can be applied at the decisive time and place
- These actions enable effective employment of the joint force while degrading opportunities for the enemy
- Force protection does not include actions to defeat the enemy or protect against accidents, weather, or disease

Adapted from the DOD Dictionary
Sea Base
(Defined by SEI-3)
Sea Base

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Amphibious Force (MEB)

Force Protection Assets

Combat Forces

NESG (MEU)

NESG (MEU)

NESG (MEU)

Combat Support Forces

ExWar Logistics Ship

ExWar Logistics Ship

ExWar Logistics Ship

Air Assets

LRHLAC (3)

MV-22 (14)

AH-1Z (4)

UH-1Y (4)

JSF (6)

Surface Assets

AAAV (18)

HLCAC (3)

LCU(R) (2)
SEI-3 ExWar Ship and Long Range Heavy Lift Aircraft

- **Combat variant**
  - DWL: 990 ft
  - Displacement: 86,000 LT
  - Draft: 42’
  - Flight deck: 770’ x 300’
  - Max speed: 30 Kts
  - Well deck for 3 HLCACs

- **Logistics variant**

Long Range Heavy Lift Aircraft Mission Profile

- Combat radius: 300 nm
- Payload: 37,500 lb
- Speed: 200+ kts
- Shipboard compatible
- Spot factor 1.5 x CH-53E
- Internal / external load capability
- 15 min cargo off-load
Sea Basing…backbone of Ship To Objective Maneuver (STOM).

"From the Sea"

"Forward…From the Sea"

"Operational Maneuver from the Sea"

"STOM"

- Exploit traditional maneuver and naval warfare
- Leverage technical superiority, speed, mobility, communications, navigation, and fire-power
STOM Phases
(Defined by SEA-4)

Phase I
– Staging/Build-up (Operating Area)

Phase II
– Ship-to-Shore Movement (seaborne assets)
– Ship-to-Objective Movement (airborne assets)

Phase III
– Sustainment
Functional Analysis

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Complete Expeditionary Warfare Mission

Conduct Expeditionary Operations

Force Protection

C4ISR

Strategic Sustainment

Survivability

Susceptibility

Prevent

- Air
- Surface
- Subsurface

Defeat

- Air
- Surface
- Subsurface

Withstand

- Above Water
- On Water
- Below Water

$P_{\text{hit}} \rightarrow P_{\text{survival}} \rightarrow P_{\text{kill/hit}}$
Futures Analysis

Surface-to-Surface Missiles

Ballistic Missiles

Unguided Munitions

Anti-Ship Cruise Missiles
(Shore, Ship, Sub, and Air-Launched)

"Double-Digit" SAMs
(Fixed and Mobile)

Submarines

Aircraft/UAV

Small Boats

Unconventional Vessels

Mines
Which Threats Do We Choose?

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**Air Warfare**
- Unmanned Aerial Vehicle (UAV)
- Aircraft (sea based or air assets)
- Anti-Ship Cruise Missile (ASCM)
- Ballistic Missile
- Space-based laser
- Low Slow Flyer

**Surface Warfare**
- Ships and Fast Patrol Boats
- Small Boats (wave rider, jet ski)
- Unconventional ships
- Unmanned Surface Vehicles (USV)

**Undersea Warfare**
- Submarine (diesel, nuclear, mini-sub)
- Mines
- Divers
- Mammals
- Unmanned Underwater Vehicles (UUVs)

**Information Warfare**
- Computer Network Attack (CNA)
- Electronic Attack (EA)
- Chaff / Flares
- Sensor Overload
- Psyops/Deception
- Computer Viruses

**Over Land Threats**
- Surface to Air Missiles (SAM)
- Small Arms
- Anti-Air Artillery (AAA)
- Rockets
- Mortars

**Miscellaneous**
- Land Based Gunfire
- CBR-N
- Land Mines for Craft Landing Zones (CLZ)
Threat Trends

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♦ Technical
  – Faster
  – Smaller
  – Advanced materials
  – Higher explosive yield
  – Lighter
  – Low observable
  – Smarter

♦ Non-technical
  – Cheap
  – Tactics
  – Proliferation

[Diagram showing Unmanned Threat and Manned Threat with categories such as TBM, CM, UAV, Rocket, Attack Helicopter, Aircraft, Low Cost, High Payoff, and Proliferation Trends]
## Most Significant Threats

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<table>
<thead>
<tr>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
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</thead>
<tbody>
<tr>
<td>(Staging / Build-up)</td>
<td>(Assault)</td>
<td>(Sustainment)</td>
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<tr>
<td>◆ ASCM</td>
<td>◆ Small Boats</td>
<td>◆ ASCM</td>
</tr>
<tr>
<td>◆ Small Boats</td>
<td>◆ Mines</td>
<td>◆ Mines</td>
</tr>
<tr>
<td>◆ Unconventional Vessels</td>
<td>◆ SAMs</td>
<td>◆ Unconventional Vessels</td>
</tr>
<tr>
<td>◆ Submarines</td>
<td>◆ ASCM</td>
<td>◆ SAMs</td>
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<tr>
<td>◆ Mines</td>
<td>◆ Aircraft/UAV</td>
<td>◆ Unguided Munitions</td>
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Threat Summary

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Unclassified

Generic

Universal

Capabilities based

<table>
<thead>
<tr>
<th></th>
<th>ASCM - 1</th>
<th>ASCM - 2</th>
<th>ASCM - 3</th>
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<tr>
<td>Length (ft)</td>
<td>12.3</td>
<td>29.2</td>
<td>38.1</td>
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<tr>
<td>Diameter (ft)</td>
<td>1.38</td>
<td>2.2</td>
<td>3.0</td>
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<tr>
<td>Speed (kts)</td>
<td>383</td>
<td>1602</td>
<td>3208</td>
</tr>
<tr>
<td>Max Range (nm)</td>
<td>81</td>
<td>162</td>
<td>540</td>
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<tr>
<td>Cruise Altitude (ft)</td>
<td>15</td>
<td>33</td>
<td>79000</td>
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<tr>
<td>Terminal Altitude (ft)</td>
<td>10</td>
<td>16</td>
<td>75000 (30° dive)</td>
</tr>
<tr>
<td>Seeker Type</td>
<td>Radar / EO / IR</td>
<td>Radar / EO / IR</td>
<td>Radar / EO / IR</td>
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<tr>
<td>Radar Cross Section (RCS) Assumptions*</td>
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</tr>
<tr>
<td>Target Angle = 0° (Nose on)</td>
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<tr>
<td>Radar Freq = 3 GHz</td>
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<tr>
<td>Reflectivity = 0.1</td>
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<td></td>
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<tr>
<td>Total RCS (m²)*</td>
<td>0.014</td>
<td>0.035</td>
<td>0.066</td>
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<tr>
<td>Infrared (IR) Assumptions*</td>
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<tr>
<td>Target Angle = 0° (Nose on)</td>
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<tr>
<td>Emmissivity = 0.9</td>
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<tr>
<td>Radiant Exitance (W/m²-µ*)</td>
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<tr>
<td>Wavelength (λ) = 3 - 5 µm</td>
<td>29.76</td>
<td>3357.22</td>
<td>125130.12</td>
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<tr>
<td>Radiant Exitance (W/m²-µ*)</td>
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<td></td>
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<tr>
<td>Wavelength (λ) = 8 - 12 µm</td>
<td>250.82</td>
<td>2117.78</td>
<td>13599.65</td>
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</table>

Table IV.9  ASCM Threat Representative Characteristics
Scenario: 2016 South China Sea

- PRC invests profits from its booming economy in military
- PRC claims hegemony over entire SCS region
- PRC reinforces presence on Spratly Islands
- PRC / Philippine naval encounter
- PRC invades Kepulalian Natuna and quarantines Palawan
- U.S. / ASEAN attempt FON operations in Sulu Sea
- PRC invades Palawan
- U.S. tasked with restoring regional stability and expelling PRC from Palawan
Value System Design

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Survivability

Susceptibility (0.75)
  - Defeat Attacks (0.75)
  - Prevent Attacks (0.25)

Vulnerability (0.25)
  - Withstand Attacks (1.0)
Capabilities Needed

- Deploy
- Detect
- Defeat
- Prevent
- Withstand
Early Requirements Generation

♦ Overarching
  – Self-defense for ExWar ships
    • Defense against ASCMs
    • Defense against small-boat attack
    • Defense against submarine/UUV attack
  – Robust organic MCM capability
  – Capability to ID and defend against unconventional attacks
  – Highly survivable transport aircraft and landing craft
  – Provide protection for transports from the Sea Base to the objectives

♦ TSSE LCS
  – Operate in deep to very shallow water
  – Direct, support, and/or embark aircraft conducting USW
  – Capability to deploy unmanned vehicles
  – Etc.
Effective Need

Conserve the force’s fighting potential so it can be applied at the decisive time and place. Conserving the force’s fighting potential is achieved through maximizing survivability by minimizing susceptibility and vulnerability.
LT Wells
Design & Analysis
Key Findings

♦ Distributed sensor network offers increased force survivability
  – Greater reaction times
  – More engagement opportunities

♦ Point weapons vs. short-notice threats require
  – Greater weapons speeds
  – Reduced minimum ranges
  – Maximum ranges that are at least equal to maximum detection range

♦ Distributed conceptual weapons offer increased available reaction times
  – Higher weapon speed
  – Increased maximum ranges
Alternatives Generation

♦ Goal: Generate viable alternatives to increase force survivability

♦ Survivability Subfunctions
  – Deploy
  – Detect
  – Defeat
  – Prevent
  – Withstand
<table>
<thead>
<tr>
<th>Detect</th>
<th>Defeat</th>
<th>Prevent</th>
<th>Withstand</th>
<th>Deploy</th>
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<tr>
<td>Radar</td>
<td>Missile</td>
<td>Chaff</td>
<td>Armor</td>
<td>Ship</td>
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<td>Lidar</td>
<td>Gun</td>
<td>Flare</td>
<td>Reactive Armor</td>
<td>Aircraft</td>
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<td>IR</td>
<td>Laser</td>
<td>Decoys</td>
<td>Reflective Armor</td>
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<td>EO</td>
<td>Microwave</td>
<td>Maneuver</td>
<td>Redundant Vital Systems</td>
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<td>Acoustic</td>
<td>Electronic Countermeasures</td>
<td>Quality Construction</td>
<td>Satellite</td>
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<td>SAR/ISAR</td>
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<td>IR Countermeasures</td>
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<td>Submarine</td>
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<td>Hyper spectral</td>
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<td>Acoustic Countermeasures</td>
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<td>UUV</td>
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<td>Sonar</td>
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<td>Signature Management</td>
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<td>Shore</td>
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<td>Seismic</td>
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</tbody>
</table>

Morphological Chart
Threat Model Assumptions: Approximating Threat Shapes

SONAR

- Mine / Torpedo / Submarine
  - 90°
  - 0°

- Small Boat
  - 90°
  - 0°

RADAR / LIDAR / IR

- Surface to Air Missile / Anti-ship Cruise Missile
  - 90°
  - 0°

- Aircraft
  - 0°

- Small Boat
  - 90°
  - 0°
Threat Model Assumptions: Example Effects of Assumptions

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Total RCS = \((\pi r^2 \rho)(\cos \Theta) + (2\pi rl^2 \rho/\lambda)(\sin \Theta)\)

M = \((2\pi c^2h/\lambda^5)(1/e^{(hc/\lambda kT)-1})\)

TS = 10\log\((r^2 \rho \cos \Theta/4) + (2\pi rl^2/4\pi \lambda)(\rho \sin \Theta))\)
Analytical Sensor Models

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- Analyzed inherent trade-offs between targets’ reflectivities and emissivities using radar, lidar, and IR sensors for SUW and AW threats \((\rho + \varepsilon = 1)\)
- Used active and passive sonar models for USW and SUW threats
- Examined threat cross sections and resulting detection ranges from various target angles
- Based on results:
  - Greater target cross section = Greater detection range
  - Sensor horizon limits performance
  - Environment strongly affects lidar and passive sonar
- Excel results indicated benefits of elevated sensor network
Active Sensors: Random Search Theory
\[ P_D(\text{total}) = (1 - e^{-nwvt/A})(1 - (1 - P_D(1))^N) \]

Passive Sensors: ROC detection probability based on CNR
\[ P_D(\text{total}) = (1 - (1 - P_D(1))^N) \]

- \( n \) = number of platforms
- \( w \) = dwell area or volume
- \( v \) = PRF
- \( t \) = search time
- \( A \) = area or volume to be searched
- \( N = nwvt/A \)
- \( P_D(1) \) = ROC detection probability based on CNR
Search Analysis: Point Sensor

Point Sensor Configuration

R = Radius of the area concerned
r = Sensor distance from force center
r' = Radius of sensor coverage
▲ = Notional high value unit

Where r << R
Search Analysis: Distributed Sensor

Distributed Sensor Configuration

Where \( r \approx R \)

\( R \) = Radius of the area concerned
\( r \) = Sensor distance from force center
\( r' \) = Radius of sensor coverage
\( \Delta \) = Notional high value unit
Analytical Search Model

Findings

- Distributed sensor network offers benefits of extended detection ranges and greater reaction times
- Distributed sensor network requires more platforms
- Low-level (surface-based) and elevated (airborne) sensors are complementary
Analytical Search Models: Mines

- Search for mines is different from the other threats considered (a weapon that waits)
- Higher frequencies required for detection
- Relatively poor detection ranges for higher frequency sonars
- May face high reverberation limitations
- Deepwater mine hunting will be very time consuming or platform intensive work
Sensor & Search Trade-Offs

✦ Goals: 1) Minimize number of search platforms  
  2) Minimize search time  
  3) Maximize Probability of Detection

✦ Findings: Based on random search model, for a given sensor and a given area or volume, two of the goals can be met at the expense of the third.
Engagement Analysis: Point Weapons

Point Weapon Configuration

\[ R = \text{Radius of the area concerned} \]
\[ r = \text{Weapon distance from force center} \]
\[ r' = \text{Weapon range} \]
\[ \Delta = \text{Notional high value unit} \]

Where \( r \ll R \)
Engagement Analysis: Distributed Weapons

Distributed Weapon Configuration

R = Radius of the area concerned
r = Weapon distance from force center
r' = Weapon range
▲ = Notional high value unit

Where $r \approx R$
Engagement Model

Interceptor-1 vs. ASCM-3
(Point Weapons-Point Sensor Architecture)
(0 sec Reaction Delay)

1 Successful Intercept
Greater Weapon Speed = Higher Pk

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# Interceptions vs. Reaction Delay
(Point Weapon-Point Sensor Architecture)

More Reaction Time = More Engagement Opportunities

More Engagement Opportunities = Higher Probability of Kill

\[ P_k = 1 - \left(1 - P_{k_{int}}\right)^{\# \text{ interceptors}} \]

- Greater weapon speed = More available reaction time
- More available reaction time = More engagements
- More engagements = Higher Pk
Distributed Sensors = Higher Pk

- Distributed Sensor = More available reaction time
- More available reaction time = More engagements
- More engagements = Higher Pk

More Reaction Time = More Engagement Opportunities

Distributed Sensor = More Reaction Time = More Engagement Opportunities
Dist Weapons-Dist Sensors Pk

$P_k = 1 - (1 - P_{k_{int}})^\#\text{ interceptors}$

- Longer range, higher speed weapons offer increased available reaction times
Design & Analysis

Key Findings

♦ Distributed sensor network offers increased force survivability
  – Greater reaction times
  – More engagement opportunities

♦ Point weapons vs. short-notice threats require
  – Greater weapons speeds
  – Reduced minimum ranges
  – Maximum ranges that are at least equal to maximum detection range

♦ Distributed conceptual weapons offer increased available reaction times
  – Higher weapon speed
  – Increased maximum ranges
Introduction

Methodology

Problem Definition

Design & Analysis

Modeling

Conclusion

LT Tionquiao
## Supporting Studies Overview

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<table>
<thead>
<tr>
<th>Team/Study Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>OR LCS Thesis</td>
<td>Helo/UCAV control, Stealth</td>
</tr>
<tr>
<td>MSSE LCS Thesis</td>
<td>Integration of Hardkill / Softkill Weapons</td>
</tr>
<tr>
<td>TSSE LCS</td>
<td>Sea SWAT design</td>
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<tr>
<td>OR Team</td>
<td>Defender Employment</td>
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<tr>
<td>IA Team</td>
<td>IW threats to the Sea Base</td>
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<tr>
<td>Physics Team</td>
<td>Cooperative Radar Network</td>
</tr>
<tr>
<td>ECE Team</td>
<td>Smart Antennae System</td>
</tr>
<tr>
<td>ME Team</td>
<td>Micro-Air Vehicle</td>
</tr>
<tr>
<td>OR Study</td>
<td>SSGN and battlespace preparation</td>
</tr>
</tbody>
</table>

![Image](image_url)
OR Supporting Study
LCS Force Protection

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“An Exploratory Analysis of Littoral Combat Ships’ Ability to Protect Expeditionary Strike Groups”, LT Efimba, OR Thesis

Purpose: Explore LCS ability to defend an ESG in an anti-access scenario against a high density small boat attack.

Methodology: EINStEin (Agent Based Simulation)
  - Red Force: 30 High-speed small boat agents
  - Blue Force: 3 Amphibs, 0-2 CRUDES, 1-7 LCS
  - MOEs: Amphib survivors, and Amphibs damaged

Conclusion:
  - LCS should have both capability to control a helo/UCAV and have a stealthy hull
  - Use findings to translate into requirements for TSSE LCS design
“MSSE LCS Study” – MSSE Cohort 1, Port Hueneme Division, NSWC

**Purpose:** Develop a concept for an AAW Self Defense Combat System for LCS

**Methodology:**
- Threat identification
- Analyses of sensors, sensor integration, C2, weapons, and manning
- Primary MOP, Probability of Raid Annihilation

**Conclusion:**
- Robust gun system can perform in both AAW and ASUW roles
- Both hardkill and softkill systems in a layered defense scheme is necessary to achieve the required $P_{ra}$
- Layered defense concept still viable in littoral environment
Two types:
- SUW and AW
- SUW and USW

Specifications
- Length: 400 ft
- Beam: 102 ft
- Draft: 14 ft
- Displacement: 3120 LT
- Max Speed: 42 kts
- Sustained Speed: 35 kts

Weapons
- 57mm gun
- SEA RAM
- Harpoon
- Evolved Sea Sparrow
- Mk 50 Torpedo

Sensors
- Towed array sonar
- Multi-Function radar
- ASLS
- Hull mounted sonar

2 Helos (SH-60)
- 2 Hangars, 1 Spot

Unmanned Vehicles
- Air, surface, underwater
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“Defense of Sea Base”, SI4000 - OR TDSI Team

Purpose: Analysis of number and placement of assets defending high value units

Methodology:
- Analytical Model: 3 Models varying HVUs, Defenders, Targets
- Simulation Model: (EINSTein)
  - Red Force: 20 or 40 HSBs or UCAVs
  - Blue Force: 1 or 4 LCS, 1 or 3 HVU
- MOE: HVU survivors

Conclusion:
- 10-13 defenders for 360 deg coverage
- Prob of HVU survival unaffected by # of HVU.
- Defenders employ weapons/sensors at max range
“Information Assurance Plan for the Protection of the Sea Base Information Systems”, SI4000 - IA TDSI Team

Purpose: Establish an IA plan to protect and defend Info Systems of the Sea Base.

Methodology:
- Analysis of current Navy IA policy
- Technology forecast of information systems

Conclusion:
- Nine technology recommendations for the Sea Base
- IW aspects identified in initial threat analysis
- Final threat list did not include IW

Future Technology
1. E-Bomb
2. Biometrics
3. Laser Comms
4. Secure Tunnels
5. Intrusion Prevention
6. Intelligent Software Decoy
7. System Redundancy
8. Security through Obscurity
9. Sim Security
"Cooperative Radar Network (CRANK): Concept Exploration for Defending the Sea Base", SI4000 Sensor (Physics) TDSI Team

**Purpose:** Explore use of bistatic/multistatic radar system to defend Sea Base against airborne attack

**Design:** 360 degree coverage, 200 nm range, .01 m² RCS

**Conclusion:**
- Transmitter power required is too great for performance requirements. Use of pulse compression may reduce
- Use as tripwire sensor network for Sea Base FP w/ existing monostatic capabilities
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“Protection of Sea Base” SI4000 - Sensors (ECE) TDSI Team

**Purpose:** Propose ways to achieve active defense by “out sensing” the enemy

**Methodology:**
- Threat identification: High density, high speed, low signature
- Analysis of data fusion and wireless sensors to improve classification

**Conclusion:**
- Smart Antennae System increases range and reliability of wireless sensors
- Provides insights into distributed sensor network details.
ME (Weapons) Supporting Study MAV

“Exploratory Study of the Operationalization of the Flapping Wing MAV” SI4000 - Weapons (ME) TDSI Team

Purpose: Investigate means to “see first, understand first, strike first”. (MLVs, SpecOps, MAVs)

Methodology:
- Threat identification: Supersonic cruise missiles*, UCAV swarm, torpedoes
- Analysis of defensive systems (FEL / Rail gun, JSF / CSG)

Conclusion:
- Increasing defensive capability decreases logistic capability
- MAVs ideal. (MLVs face land obstacles and SpecOps keeps “man in loop”)
- MAV concept: 100s of micro flapping wings deployed from UAV to find missile launchers under canopy
- Provides insights into a distributed sensor and the importance of battlespace preparation
“Quantifying SSGN Contributions to a Complex Joint Warfare Environment”, LCDR Schoch, JCA White Paper

**Purpose**: Explore increases in force survivability and lethality made possible by SSGN battlespace preparation.

**Methodology**: Circulation Model
- MOEs: 1. Additional Missions per Unit  2. Force Multiplying Factor

**Conclusion**:
- Battlespace preparation reduces enemy lethality thereby increasing force survivability
- Use of SSGN as a means of battlespace preparation will be beneficial for ExWar
Simulation Key Findings

- **Force Composition**
  - CRUDES-based force and LCS-based force are roughly equivalent

- **Sensor / Weapon Architecture**
  - Distributed Architecture improves survivability
  - Distributed Architecture conserves weapons
  - Point and Distributed Architectures are roughly equivalent in Phase II (Assault Phase – close proximity to the threat)

- **Weapon Type**
  - Conceptual weapons require distributed sensor architecture to maximize effectiveness

- **Threats**
  - Distributed Architecture improves survivability particularly against USW threats
Picking the Correct Tool for Simulation

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- **Tools Available**
  - JANUS
  - JTLS
  - NSS
  - EINSTein
  - EXTEND
  - Excel

- **Final Selection**
  - EXTEND
  - NSS

![Comparison Table]

<table>
<thead>
<tr>
<th></th>
<th>JANUS</th>
<th>JTLS</th>
<th>NSS</th>
<th>EINSTein</th>
<th>EXTEND</th>
<th>EXCEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
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<td>(time risk)</td>
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<td>Phase I</td>
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<td>Phase II</td>
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<td>Phase III</td>
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<tr>
<td>Support</td>
<td></td>
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</tr>
</tbody>
</table>
Proposed Architectures

- **Force Composition:**
  - COA A (CRUDES-based w/ SSN)
  - COA B (LCS-based w/ SSGN)

- **Sensor/Weapon Architecture:**
  - Point (ship-based)
  - Distributed (UAV/USV/UUV-based)

- **Weapons:**
  - Current
  - Conceptual

![Design of Experiments Table]

<table>
<thead>
<tr>
<th>Force Composition</th>
<th>Sensor Weapon Architecture</th>
<th>Weapons</th>
<th>Alternate Force Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>COA A</td>
<td>Point</td>
<td>Current</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptual</td>
<td>2</td>
</tr>
<tr>
<td>COA B</td>
<td>Distributed</td>
<td>Current</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptual</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Point</td>
<td>Current</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptual</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Distributed</td>
<td>Current</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conceptual</td>
<td>8</td>
</tr>
</tbody>
</table>
Force Composition

COA A
- 3 CG
- 3 DDG
- 3 FFG
- 1 SSN

CRUDES-based

COA B
- 1 CG
- 1 DDG
- 12 LCS
- 1 SSGN

LCS-based
Point Sensor/Weapon Architecture
Distributed Sensor/Weapon Architecture

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# Weapons

## Current Weapons

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Type</th>
<th>Speed (m/s)</th>
<th>Max Range (km)</th>
<th>Min Range (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interceptor 1</td>
<td>Surface to air missile</td>
<td>825</td>
<td>130</td>
<td>5</td>
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<tr>
<td>Interceptor 3</td>
<td>Air to air missile</td>
<td>1320</td>
<td>56</td>
<td>2</td>
</tr>
<tr>
<td>Torpedo 1</td>
<td>Surface or sub-surface torpedo</td>
<td>20.6</td>
<td>7.3</td>
<td>.1</td>
</tr>
</tbody>
</table>

## Conceptual Weapons

<table>
<thead>
<tr>
<th>Weapon</th>
<th>Type</th>
<th>Speed (m/s)</th>
<th>Max Range (km)</th>
<th>Min Range (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interceptor 2</td>
<td>Surface to air missile</td>
<td>1650</td>
<td>370</td>
<td>5</td>
</tr>
<tr>
<td>Interceptor 4</td>
<td>Air to air missile</td>
<td>1980</td>
<td>93</td>
<td>2</td>
</tr>
<tr>
<td>Free Electron Laser</td>
<td>Directed energy</td>
<td>$3 \times 10^8$</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Torpedo 2</td>
<td>Surface or sub-surface torpedo</td>
<td>25.7</td>
<td>11</td>
<td>.1</td>
</tr>
</tbody>
</table>
Measure Of Effectiveness

◆ Survivability of the Sea Base
  – % of ExWar ships mission capable
  – % of transport aircraft mission capable
  – % of transport surface craft mission capable
EXTEND Modeling

EXTEND Overview: Process based, discrete event modeling and simulation tool. Provides a macro-view of sensor, weapon, and threat interactions.

Design Factors:
- Force Composition: COA A, COA B
- Sensor and Weapon Architecture: Point, Distributed
- Weapons: Current, Conceptual

MOEs: % of assets mission capable


Outputs: # mission kills, # of mission kills by threat
EXTEND Model

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Force Protection of the Sea Base
EXTEND Model

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Above the Water (ATW)

Below the Water (BTW)
EXTEND Model Results

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Current Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Conceptual Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Upper 95% Confidence Interval
Lower 95% Confidence Interval
100 Runs
Distributed Sensors and Weapons Increase Force Survivability

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ExWar  LCU(R)  HLCAC  AAAV  LRHLAC  MV-22

Current Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Conceptual Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Upper 95% Confidence Interval
Lower 95% Confidence Interval

100 Runs
CRUDES-based and LCS-based Forces Roughly Equivalent

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<table>
<thead>
<tr>
<th>Current Weapons</th>
<th>Conceptual Weapons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Point CRUDES</td>
<td>• Point CRUDES</td>
</tr>
<tr>
<td>• Point LCS</td>
<td>• Point LCS</td>
</tr>
<tr>
<td>• Distributed CRUDES</td>
<td>• Distributed CRUDES</td>
</tr>
<tr>
<td>• Distributed LCS</td>
<td>• Distributed LCS</td>
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</table>

Upper 95% Confidence Interval

Lower 95% Confidence Interval

100 Runs

<table>
<thead>
<tr>
<th>ExWar</th>
<th>LCU(R)</th>
<th>HLCAC</th>
<th>AAAV</th>
<th>LRHLAC</th>
<th>MV-22</th>
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</tbody>
</table>

Average Percent of Assets Mission Capable

Distributed CRUDES vs. LCS

Point CRUDES vs. LCS
No Significant Difference Between Current and Conceptual Weapons

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Current vs. Conceptual Weapons

Current Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Conceptual Weapons
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

Upper 95% Confidence Interval
Lower 95% Confidence Interval
100 Runs
Distributed = Increased ExWar Ship Survivability

Average Number of Mission Capable ExWar

- Upper 95% CI
- Lower 95% CI
- Average Mission Capable

CRUDES  LCS

Alternate Force Architecture
100 Runs

1  2  3  4  5  6  7  8
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- ~10% of the threat accounts for ~90% of mission kills
- Distributed architecture mitigates the shooter

![Comparison of TORP and ASCM Threat](chart)

<table>
<thead>
<tr>
<th>Sensor / Weapon Architecture</th>
<th>TORPs Launched</th>
<th>Mission Kills due to TORPs</th>
<th>ASCMs Launched</th>
<th>Mission Kills Due to ASCMs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point</td>
<td>10</td>
<td>5.33</td>
<td>0.36</td>
<td>1</td>
</tr>
<tr>
<td>Distributed</td>
<td>72</td>
<td>24.13</td>
<td>1</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

COA B
Current Weapons
100 Runs
Force Composition
  – CRUDES-based and LCS-based protection forces are roughly equivalent

Sensor / Weapon Architecture
  – Distributed Architecture improves survivability of the Sea Base, particularly against USW threats

Weapon Type
  – No significant difference between current and conceptual weapons with respect to Sea Base survivability
NSS Modeling

NSS Overview: Object oriented, Monte-Carlo modeling and simulation tool. Provides a macro-view of force interactions in a wargame.

Design Factors:
- COAs: A-CRUDES based, B-LCS based
- Sensor / Weapon Architecture: Point, Distributed
- Weapon Type: Current, Conceptual

MOEs: % assets mission capable

Inputs: Platform type and characteristics, asset employment, sensor characteristics

Outputs: # of assets surviving, # of weapon launches
Force Composition in NSS

Palawan Area of Operations

Sea Echelon Area (50 x 50 nm)

South China Sea

LZ Eagle

LZ Hawk

LPS A

LPS B

OBJ A

OBJ B

Sulu Sea

25 nm

75 nm

COA A

COA B

OBJ A

OBJ B

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Distributed Architecture in NSS

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- South China Sea
- Sulu Sea
- Sea Echelon Area
- OBJ A
- Aerostat Coverage
- UAV Perimeter
Confounding Results Between Architectures

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ExWar | LCU(R) | HLCAC | AAAV | LRHLAC | MV-22

Confidence Intervals:
- **Upper 95% Confidence Interval**
- **Lower 95% Confidence Interval**

**Current Weapons**
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

**Conceptual Weapons**
- Point CRUDES
- Point LCS
- Distributed CRUDES
- Distributed LCS

30 Runs
Distributed Architecture Increases Survivability Along Threat Axis

COA A Legend
- Point / Current
- Distributed / Current
- Point / Conceptual
- Distributed / Conceptual

Average Percent of Assets Mission Capable

Threat Axis

OBJ A

OBJ B
Distributed Architecture Provided The Same Level of Force Survivability While Conserving Weapons

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Total Interceptor Launches
(Ship Missile, UAV Missile, FEL)

ExWar Ship Interceptor Launches

CRUDES & Current
CRUDES & Conceptual
LCS & Current
LCS & Conceptual

CRUDES / Current
CRUDES / Conceptual
LCS / Current
LCS / Conceptual

Point
Distributed

CRUDES & Current
CRUDES & Conceptual
LCS & Current
LCS & Conceptual

CRUDES / Current
CRUDES / Conceptual
LCS / Current
LCS / Conceptual

Point
Distributed
Phase I Excursion: Missile Raid

- 800 ASCM-3, 80 ACFT-2
- Alternate Force Architectures 5, 7
- Good Enemy targeting (10 UAVs)
- All landing craft and aircraft remain onboard
NSS Key Findings

Force Composition
– CRUDES-based force and LCS-based force are roughly equivalent.

Sensor / Weapon Architecture
– Distributed Architecture improves survivability
– Distributed Architecture conserves weapons
– Difficult to distinguish between Point and Distributed Architectures in Phase II (Assault Phase – close proximity to the threat)

Weapon Type
– Conceptual Weapons require distributed sensor architecture to maximize effectiveness
## Assessment of Simulation Tools

<table>
<thead>
<tr>
<th>EXTEND</th>
<th>NSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>– Easy to learn</td>
<td>– Detailed, flexible database</td>
</tr>
<tr>
<td>– Easy to model complex processes in detail</td>
<td>– Hi-res wargame simulation</td>
</tr>
<tr>
<td>– Visual representations</td>
<td>– Multiple study replication capability</td>
</tr>
<tr>
<td>– Flexible</td>
<td>– SE management skills learned by working and coordinating with NSS modeler.</td>
</tr>
<tr>
<td>– COTS</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td>– No database</td>
<td>– Requires expertise</td>
</tr>
<tr>
<td>– Difficult to represent every entity</td>
<td>– Long processing time</td>
</tr>
<tr>
<td></td>
<td>– Limited land, amphibious operation capability</td>
</tr>
</tbody>
</table>
Introduction
Methodology
Problem Definition
Design & Analysis
Modeling
Conclusion

LCDR Higgs
Force Protection Study
Key Findings

CRUDES-based and LCS-based force compositions are roughly equivalent

Distributed Architecture improves survivability
  – Greater reaction times
  – More engagement opportunities
  – Particularly effective against USW threats

Distributed Architecture conserves weapons

Point and Distributed Architectures are roughly equivalent in Phase II
(Assault Phase – close proximity to the threat)

Conceptual weapons require distributed sensor architecture to maximize effectiveness

When paired with the distributed architecture, conceptual weapons offer increased reaction time
  – Higher weapon speed
  – Increased maximum ranges
Recommended Architecture

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♦ Distributed Sensors
  - Aerostat
    • High frequency radar (~ 20 GHz)
  - UAVs for 360 degree coverage
    • High frequency radar (~ 20 GHz)
    • 3-5 μm IR
  - UUVs for 360 degree coverage
    • Active Sonar (~1 KHz)

♦ Conceptual Weapons
  - FEL (3 x 10^8 m/s, 10 km)
  - INT-2 (1650 m/s, 370 km)
  - INT-4 (1980 m/s, 93 km)
  - Torpedo 2 (26 m/s, 11 km)

♦ Force Composition
  - LCS-based or CRUDES-based
  - Cost analysis needed to aid in decision making
Expeditionary Warfare Force Protection
System of Systems Conceptual Solution

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Distributed Sensors
• Greater Reaction Times
• More Engagement Opportunities

Distributed Weapons
• Shorter distance to target
• Complement to distributed sensors

Force Composition
• 12 LCS + 1 CG + 1 DDG \cong 3 CG + 3 DDG + 3 FFG
• Unit Cost: 1 DDG-51 \cong 1.37 TSSE LCS

Conceptual Weapons Paired with Distributed Sensors
• Higher Weapon Speeds
• Increased Maximum Ranges