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Executive Summary
Expeditionary Warfare — Force Protection

by

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January 2004

Prepared for: Deputy Chief of Naval Operations for Warfare Requirements and Programs (OPNAV N7), 2000 Navy Pentagon, Rm. 4E392, Washington, DC 20350-2000

EXEPEDITIONARY WARFARE FORCE PROTECTION
EXECUTIVE SUMMARY

The 2003 Expeditionary Warfare Force Protection Integrated Project represents the combined efforts of approximately 60 students and 15 faculty members from different Naval Postgraduate School departments. The Systems Engineering and Analysis (SEA-4) Team integrated these efforts into the final product, a system of systems conceptual solution for expeditionary warfare force protection. The project began in 2002 with the office of the Deputy Chief of Naval Operations for Warfare Requirements and Programs (OPNAV N7) requesting an examination of future expeditionary warfare operations in terms of current and emerging operational concepts. The 2002 study identified and defined capability gaps, developed platform solutions, and generated conceptual design requirements for an expeditionary warfare family of ships, a heavy lift aircraft, and other systems designed to be capable of fully implementing the Ship to Objective Maneuver and Sea Basing doctrines identified as the future concepts of operation. The 2003 Expeditionary Warfare Force Protection Integrated Project was tasked to develop a system of systems conceptual solution to provide force protection for the Sea Base developed in the 2002 study. SEA-4 accomplished the task by employing a distinct Systems Engineering methodology, defining the problem, creating a scenario, conducting analyses, and using modeling and simulation tools to draw conclusions and determine the results.

Conclusions, results, and recommended system architecture were based on the attributes of force composition, sensor architecture, weapons architecture, and weapons type. The key findings of this study were:

- ***The distributed sensor and weapons architectures improve force survivability*** by providing increased available reaction times and more engagement opportunities. These architectures are particularly effective against Undersea Warfare (USW) threats because submarines can be detected and engaged prior to closing within effective torpedo ranges. Limited torpedo defense capabilities were identified as the primary cause of mission kills in the point sensor architecture.
- ***Conceptual weapons when paired with distributed sensors, improve survivability*** by increasing available reaction time. Conceptual weapons included higher-speed, longer-range variants of existing weapons, and a free-electron laser.

Detecting threats at greater ranges provides commanders with more time to evaluate threats before committing weapons.

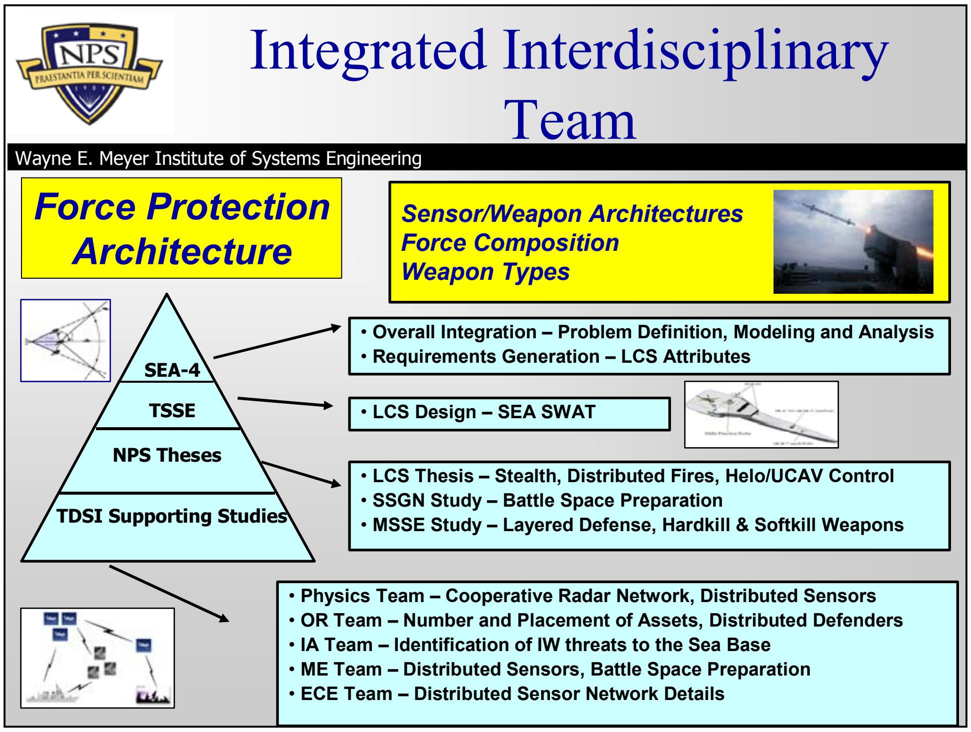
- ***The distributed architecture conserves weapons*** by detecting targets at ranges close to the maximum range of the interceptor. The longer detection ranges, in conjunction with the increased maximum ranges of the conceptual weapons, allow threat platforms to be engaged before they can launch their weapons. For example, if an aircraft capable of launching four anti-ship cruise missiles is destroyed before launching those missiles, then only one interceptor is used instead of four. Also, the greater reaction time provided by the distributed sensors allows for improved targeting, which contributes to the conservation of weapons.
- ***The selected cruiser-destroyer (CRUDES)-based and the Littoral Combat Ship (LCS)-based force compositions were tactically equivalent.*** Ultimately, another measure of effectiveness, such as manning, life cycle costs, etc., would have to be used to select a preferred concept.

The Systems Engineering and Management Process was used as the primary methodology to complete this multidisciplinary task and is an iterative, four-phase process designed as an organized approach to solving complex engineering problems. The four phases are: problem definition, design and analysis, decision-making, and implementation. Within each phase there are several iterative steps. Because this study was an academic exercise, the implementation phase was omitted.

Defining the problem was the most critical task in this study. In defining the problem, the team outlined critical assumptions, identified the primary functions of the system, addressed critical issues, assessed the threat environment, and generated system requirements. Survivability was determined to be the most critical factor in the protection of the Sea Base and its transport assets. Survivability is the measure of all defensive actions and consists of two components: susceptibility and vulnerability. Survivability can be increased by reducing susceptibility (probability of being hit) and reducing vulnerability (probability of kill given a hit). Threats to the Sea Base were reviewed, analyzed, and prioritized. The problem was scoped by generalizing threats in the form of threat categories, and by identifying and focusing force protection efforts on the primary threats identified by the analysis. Due to resource limitations, the threat analysis did not encompass the full range of threats that the Sea Base might face in the future, but it was able to provide a realistic basis, with regards to the capabilities and characteristics, of the types of threats that future architectures will have to counter in order to be successful.

After defining the problem, system design and analysis focused on detailed analyses of sensor concepts, search concepts, and weapons engagement concepts. An important part of effectively countering any threat is the ability to detect it. The analysis began by assessing the ability of various sensors (radar, lidar, infrared, and sonar) to detect threats as the first step in defending the Sea Base. Analysis of sensors showed that a distributed sensor network offers greater detection ranges by extending the sensors' horizons and by achieving greater target aspects. The analysis also provided insight into which sensors were best in detecting a specific threat. For example, the infrared sensor performed better than radar when detecting a high-diving, supersonic, anti-ship cruise missile. From this, various threat-sensor pairs were developed, studied, and analyzed in order to determine potential detection ranges of the sensors against associated threats. The search analysis applied search detection models based on area or volume covered and beam spread or field of view for each sensor to determine probabilities of detection for each threat-sensor pair. First principal probability of detection equations were applied in addition to the detection ranges calculated in the sensor analysis to provide insight into the type of sensor architecture needed to best protect the Sea Base. These preliminary analyses identified a capability gap that drove the need for a sensor system that would be capable of detecting threat platforms at long range and with ample time to counter them before reaching their weapons' maximum effective ranges. The functional analysis identified the basic functions of deploy, detect, defeat, prevent, and withstand as individual capabilities needed to protect the Sea Base. Using these factors, the team proposed architectures based on characteristics of force composition, sensor architecture, weapons architecture, and weapons type.

Supporting studies from individual student theses and student faculty teams, including those from the Temasek Defense Systems Institute, were used as a basis for developing these characteristics and the associated architectures. A breakdown of the teams and brief descriptions of their contributions is shown in Figure I-1.



Integrated Interdisciplinary Team

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Force Protection Architecture

Sensor/Weapon Architectures
Force Composition
Weapon Types

SEA-4
TSSE
NPS Theses
TDSI Supporting Studies

- 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

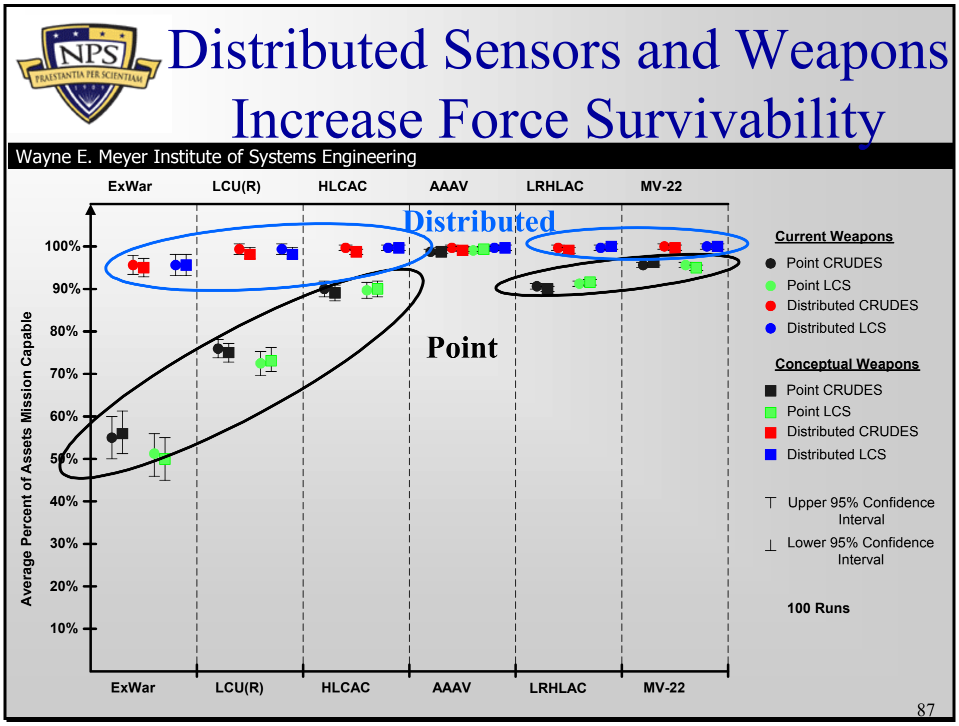
Figure I-1 Overview of Supporting Studies

Understanding the complex nature of force protection of the Sea Base required the use of modeling and simulation tools. The tools initially assessed included: Joint Army Navy Uniform Simulation (JANUS), Joint Theater Level Simulation (JTLS), Naval Simulation System (NSS), Enhanced ISSAC (Irreducible Semi-Autonomous Adaptive Combat) Neural Simulation Toolkit (EINSTein), EXTEND, and Microsoft Excel. After completing a detailed risk analysis, the team decided to include NSS, EINSTein, EXTEND, and Microsoft Excel as parts of the study.

In order to adequately determine the relative performance of the proposed architectures developed by the team, a thorough and systematic design of experiments was developed to maximize the model runs. The primary characteristics of the proposed architectures are force composition, sensor and weapons architecture, and weapon types. Using the notion of a 2^n factorial design, two levels of each characteristic were developed. The force composition levels are courses of action (COA) A and B. COA A is a CRUDES-based protection force comprised of three CGs, three DDGs, three FFGs, and one SSN. COA B is a LCS-based force protection force comprised of one CG, one DDG, 12 LCSs, and one SSGN. The sensor and weapons architecture are point and distributed. Weapon types are current and conceptual weapons.

From the functional analysis, survivability was determined to be the key function in force protection of the Sea Base. The primary measure of effectiveness (MOE) of protecting the Sea Base, therefore, was determined to be the survivability of the Sea Base and its transport assets. The output of each of the models was designed to facilitate the collection of information needed to determine the survivability of the Sea Base and its transport assets.

EXTEND, a process-based, discrete-event modeling and simulation tool, provided a macro-view of sensor-weapon architecture-threat interactions. Results from the EXTEND model (see Figure I-2) demonstrated that distributed sensors increase the survivability of the Sea Base and its transport assets, that an LCS-based protection force is tactically equivalent to a CRUDES-based protection force; and that current weapons are not statistically different with respect to survivability when compared to conceptual weapons. Additionally, the submarines and torpedoes were by far the highest threats to the Sea Base. Torpedoes, which in this model made up roughly 10% of the threat, caused approximately 90% of the mission kills (see Figure I-3).



Distributed Sensors and Weapons Increase Force Survivability

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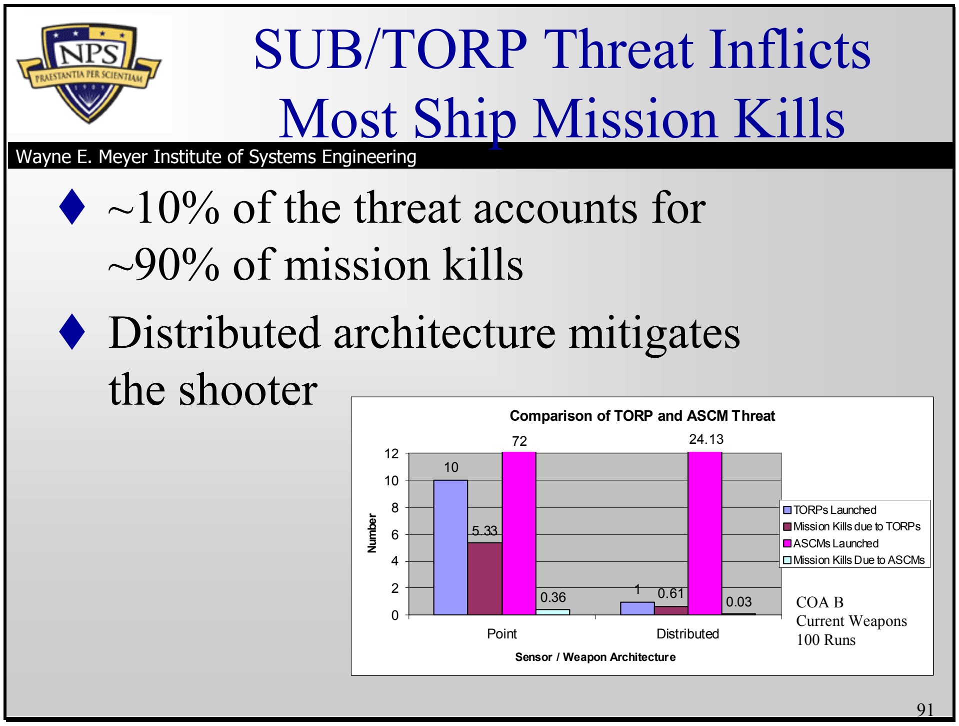
Figure I-2 Comparison of Alternate Force Architectures



SUB/TORP Threat Inflicts Most Ship Mission Kills

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- ~10% of the threat accounts for ~90% of mission kills
- Distributed architecture mitigates the shooter

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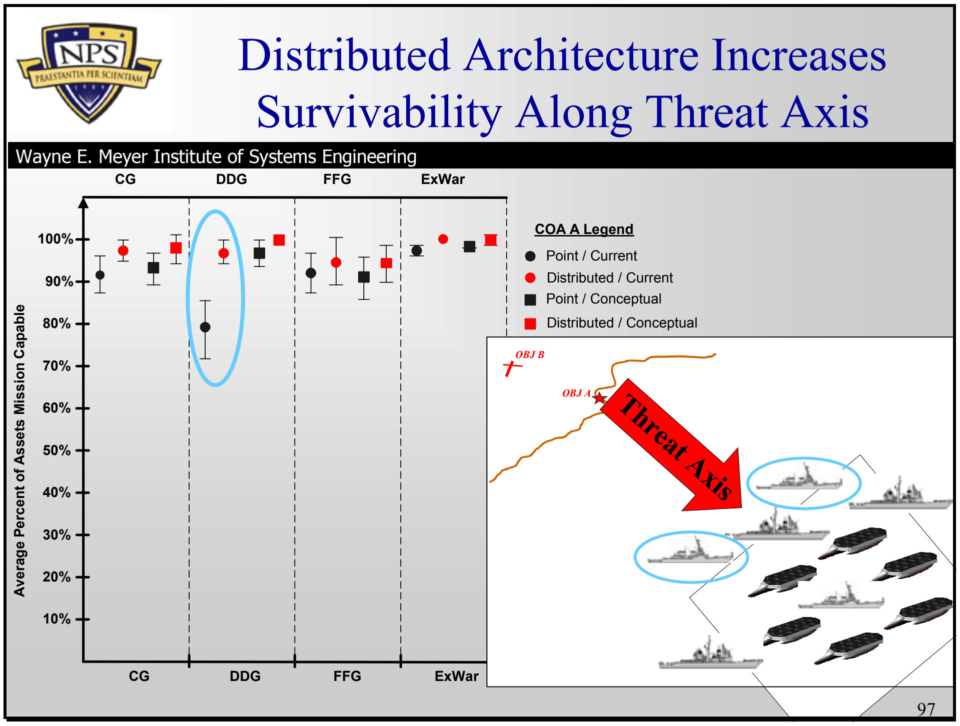
Figure I-3 Comparison of Torpedo and ASCM Threats

NSS, an object-oriented Monte Carlo modeling and simulation tool, provided a means of analyzing the characteristics of the two proposed force protection architectures. NSS model results showed that the distributed architecture provides improved survivability for defending assets placed along the threat axis (see Figure I-4). The model also showed that the distributed architecture seems to facilitate a quicker drawdown of threats. Additionally, the NSS model showed that the distributed architecture is more effective in its use of weapons because of its ability to provide better targeting information and more effective threat-weapon assignments. Furthermore, the distributed architecture was able to detect and defeat threat platforms before they were able to launch their weapons.



Distributed Architecture Increases Survivability Along Threat Axis

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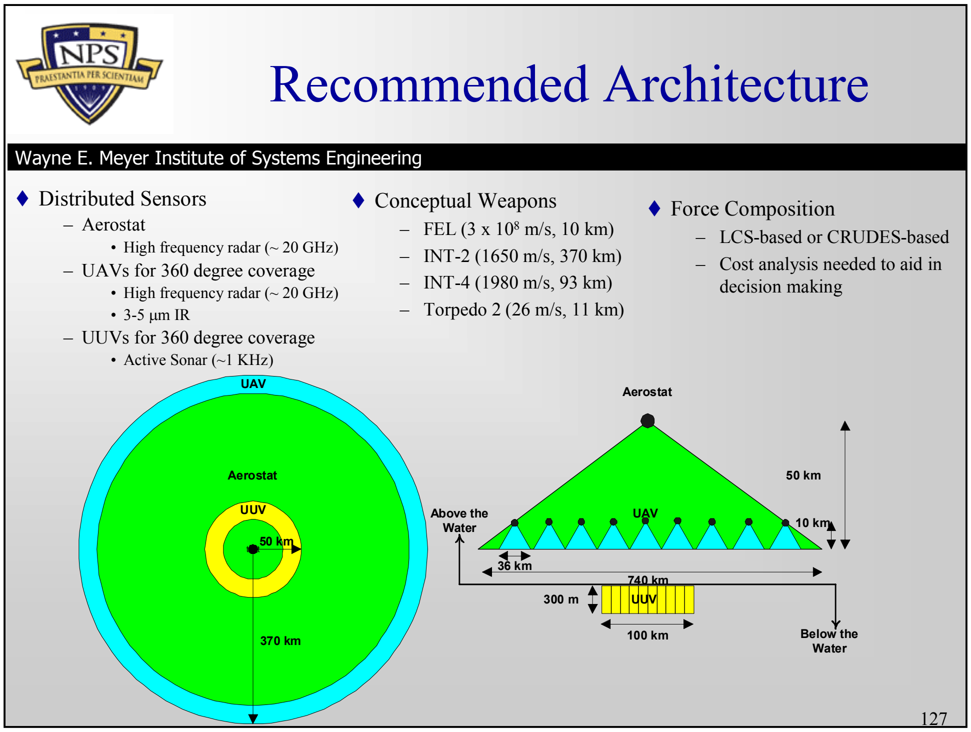
COA A Legend

- ● Point / Current
- ● Distributed / Current
- ■ Point / Conceptual
- ■ Distributed / Conceptual

Figure I-4 Distributed Architecture Increases Survivability Along Threat Axis

From the models analyzed, the key factor in attaining higher survivability for the Sea Base and its transport assets was the ability of the sensor system to provide more reaction time, and therefore more engagement opportunities, to the weapons systems. The distributed sensor architecture allows the weapons systems to take fewer shots, thereby conserving the force's fighting potential. As a result of these analyses, the proposed architecture can be either LCS- or CRUDES-based and possess either current or conceptual weapons. Ultimately, the decision to use an LCS-based or CRUDES-based force and the decision to use the given current or conceptual weapons must be based on a measure of effectiveness other than survivability. Figure I-5 summarizes the system of systems conceptual solution for Sea Base force protection.



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

Figure I-5 Proposed System Solution for Sea Base Force Protection

Because the analysis itself was broad, the results are broad-based as well. Further study efforts should be conducted to provide more thorough analyses of areas of particular concern. Some suggested areas include actual sensor and weapon capabilities, emerging technologies, reliability and maintainability factors, acquisition strategies, realistic timelines for deployment, associated trade-offs, and COA analyses. Finally, research into existing classified systems, emerging technologies, and non-lethal weapons technologies is recommended to provide additional options for protecting the Sea Base.