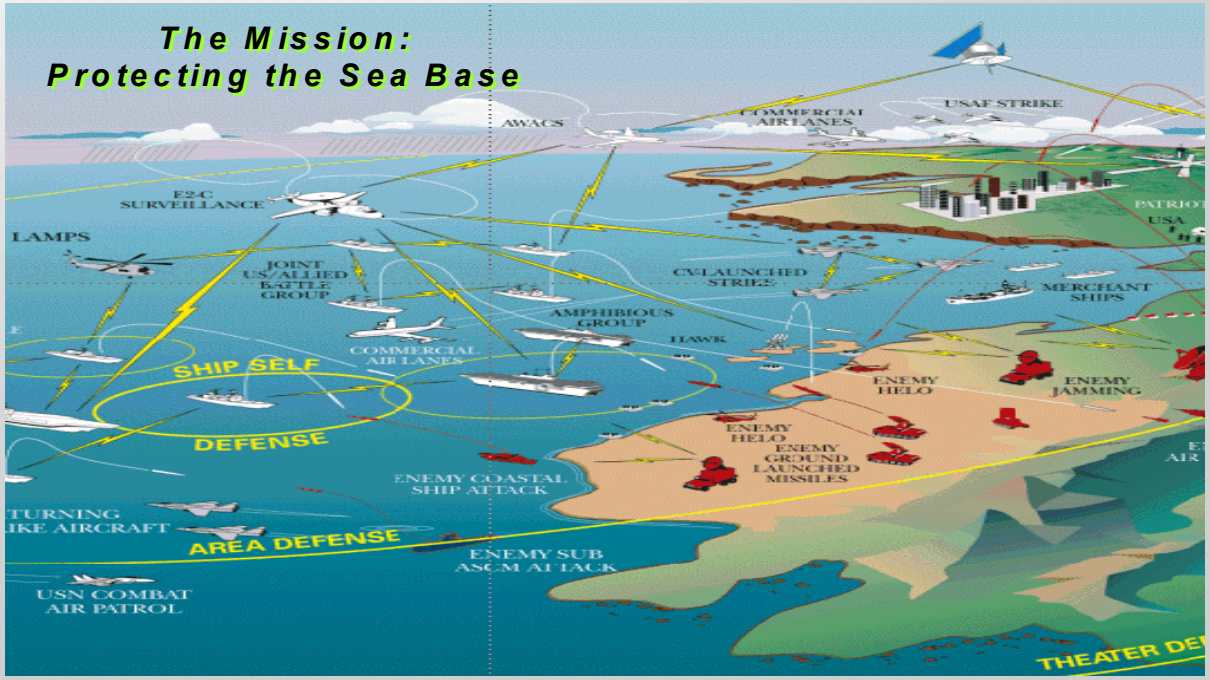
Naval
Postgraduate
School

Wayne E. Meyer Institute of Systems Engineering

SEA-4
Expeditionary Warfare Force Protection



04 December 03

What We Did

- 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

Where We Started: SEI-3 Study

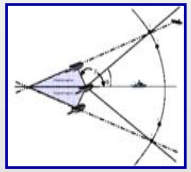
- Foundation for SEA-4 Study
- Developed a sea based conceptual architecture to accomplish the Expeditionary Warfare mission in the 2015-2020 timeframe using the operational tenet of OMFTS
- Focused on logistics and the elimination of the "iron mountain"
- Force protection for the Sea Base identified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

Integrated Interdisciplinary Team

Wayne E. Meyer Institute of Systems Engineering

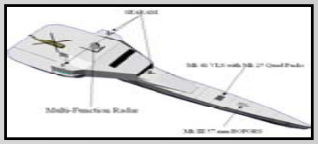
Force Protection Architecture

Sensor/Weapon Architectures
Force Composition
Weapon Types

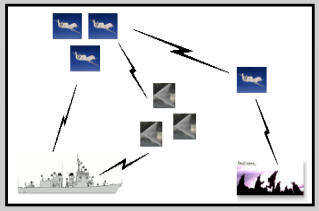


- Overall Integration – Problem Definition, Modeling and Analysis
- Requirements Generation – LCS Attributes

- 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

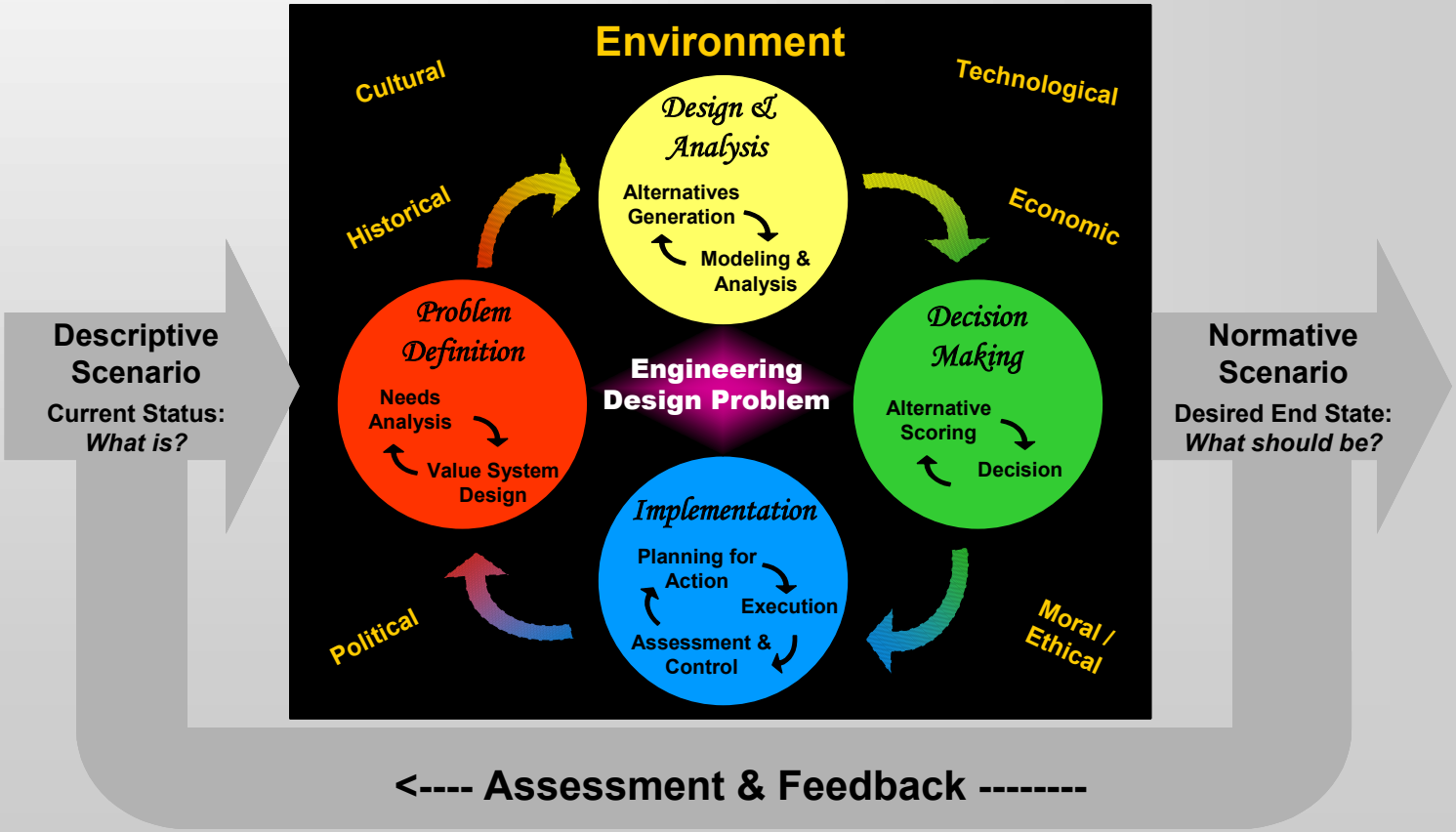
SEA-4 Tasking

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

Methodology

Systems Engineering and Management Process



Primitive Need

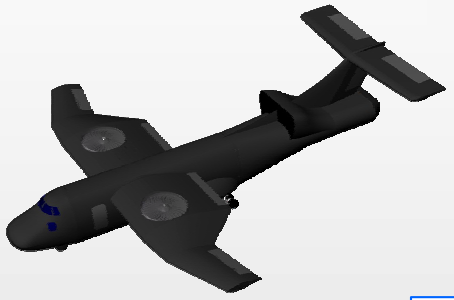
- Protect the Sea Base while at sea in the operating area
- Protect the airborne transport assets from the Sea Base to the objective
- Protect the surface transport assets from the Sea Base to the beach or port

Force Protection

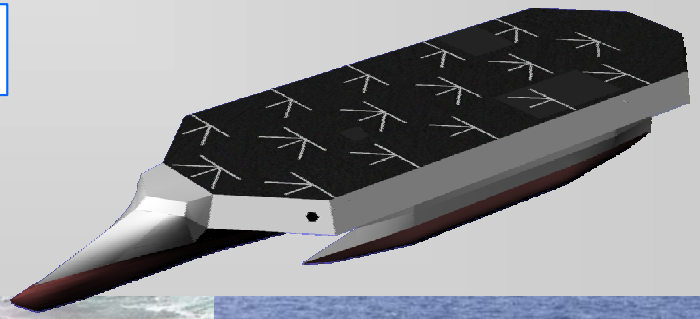
- Actions taken to prevent or mitigate hostile action against the Sea Base
- These actions conserve the force's fighting potential so it can be applied at the decisive time and place
- These actions enable effective employment of the joint force while degrading opportunities for the enemy
- Force protection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

Adapted from the DOD Dictionary

Sea Base



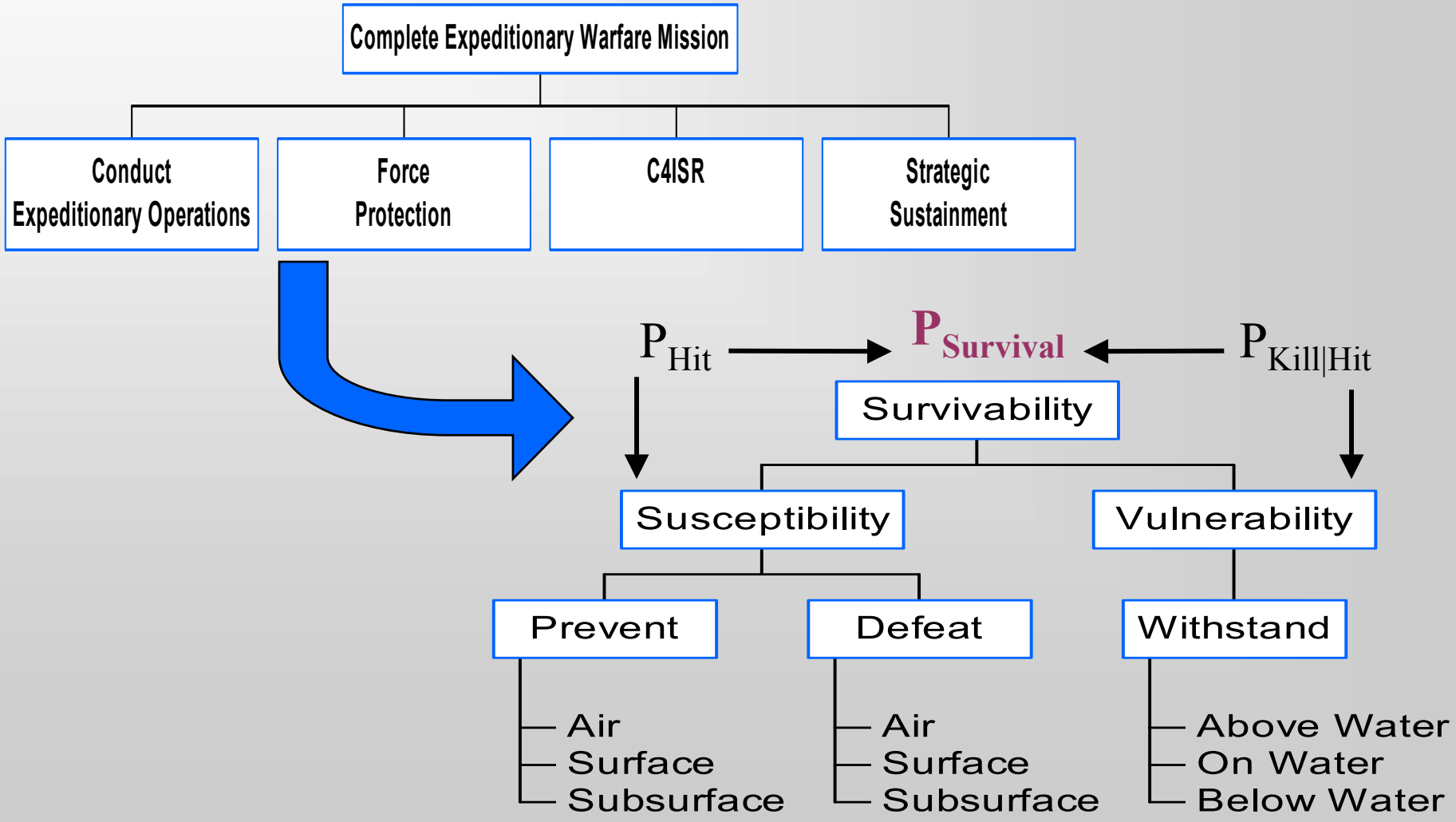
- Amphibious Force (MEB)
  - Force Protection Assets
  - Combat Forces
    - NESG (MEU)
      - ExWar Ship
        - Air Assets
          - LRHLAC (3)
          - MV-22 (14)
          - AH-1Z (4)
          - UH-1Y (4)
          - JSF (6)
        - Surface Assets
          - AAAV (18)
          - HLCAC (3)
          - LCU(R) (2)
      - ExWar Ship
    - NESG (MEU)
      - ExWar Ship
      - ExWar Ship
    - NESG (MEU)
      - ExWar Ship
      - ExWar Ship
  - Combat Support Forces
    - ExWar Logistics Ship
    - ExWar Logistics Ship
    - ExWar Logistics Ship



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

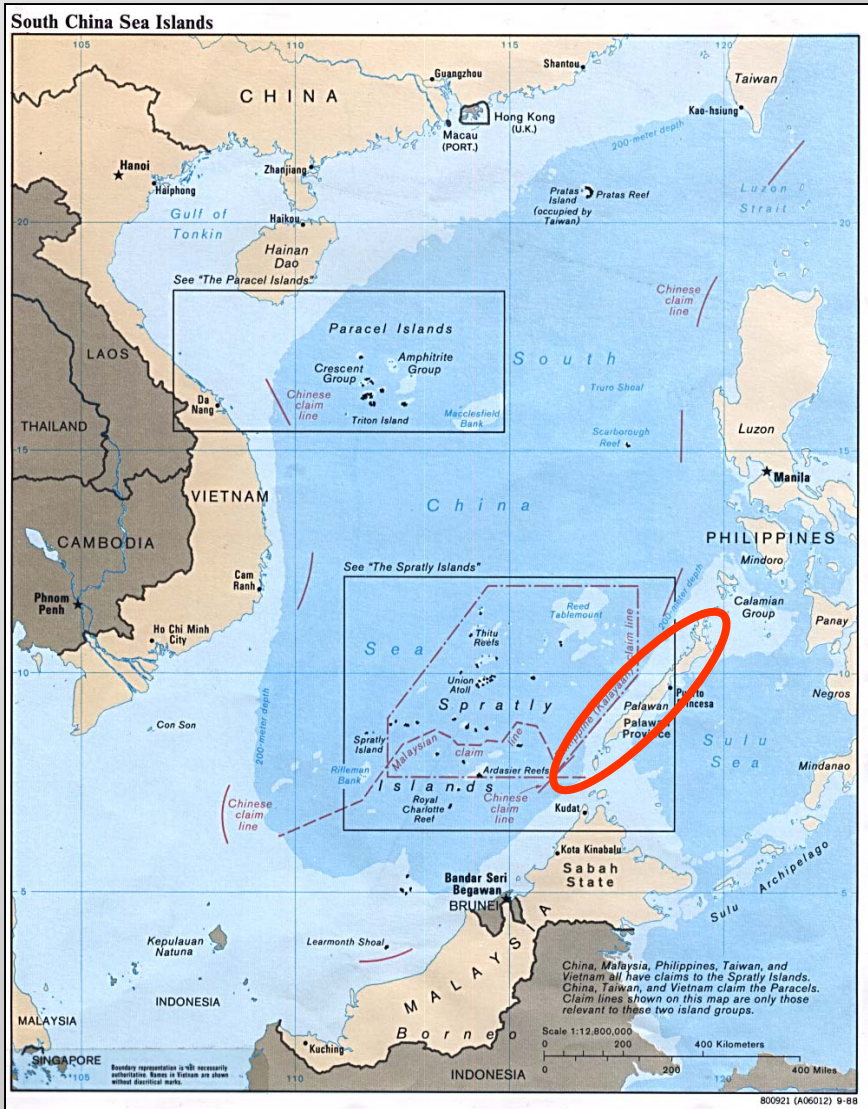
Functional Analysis



Scenario:
2016 South China Sea

Wayne E. Meyer Institute of Systems Engineering

- 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



Most Significant Threats

Phase I (Staging / Build-up)	**Phase II** (Assault)	**Phase III** (Sustainment)
♦ ASCM	♦ Small Boats	♦ ASCM
♦ Small Boats	♦ Mines	♦ Mines
♦ Unconventional Vessels	♦ SAMs	♦ Unconventional Vessels
♦ Submarines	♦ ASCM	♦ SAMs
♦ Mines	♦ Aircraft/UAV	♦ Unguided Munitions

Effective Need

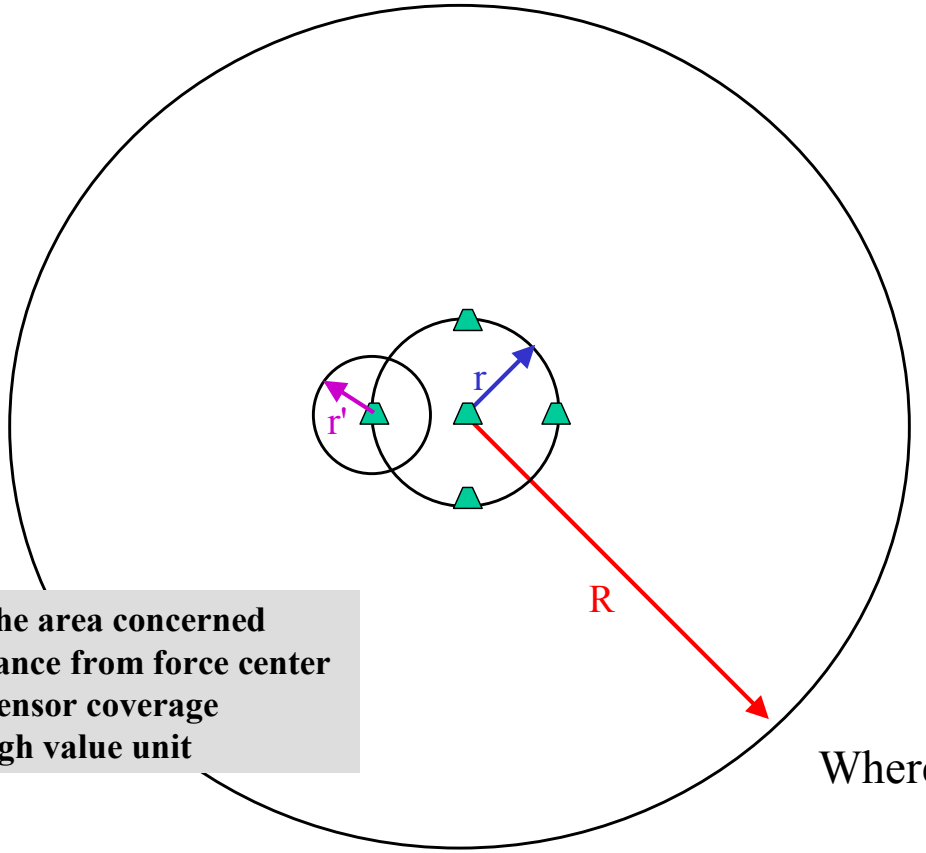
Conserve the force's fighting potential so it can be applied at the decisive time and place. Conserving the force's fighting potential is achieved through maximizing survivability by minimizing susceptibility and vulnerability.

Analytical Sensor Models

- 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

Search Analysis: Point Sensor

Point Sensor Configuration

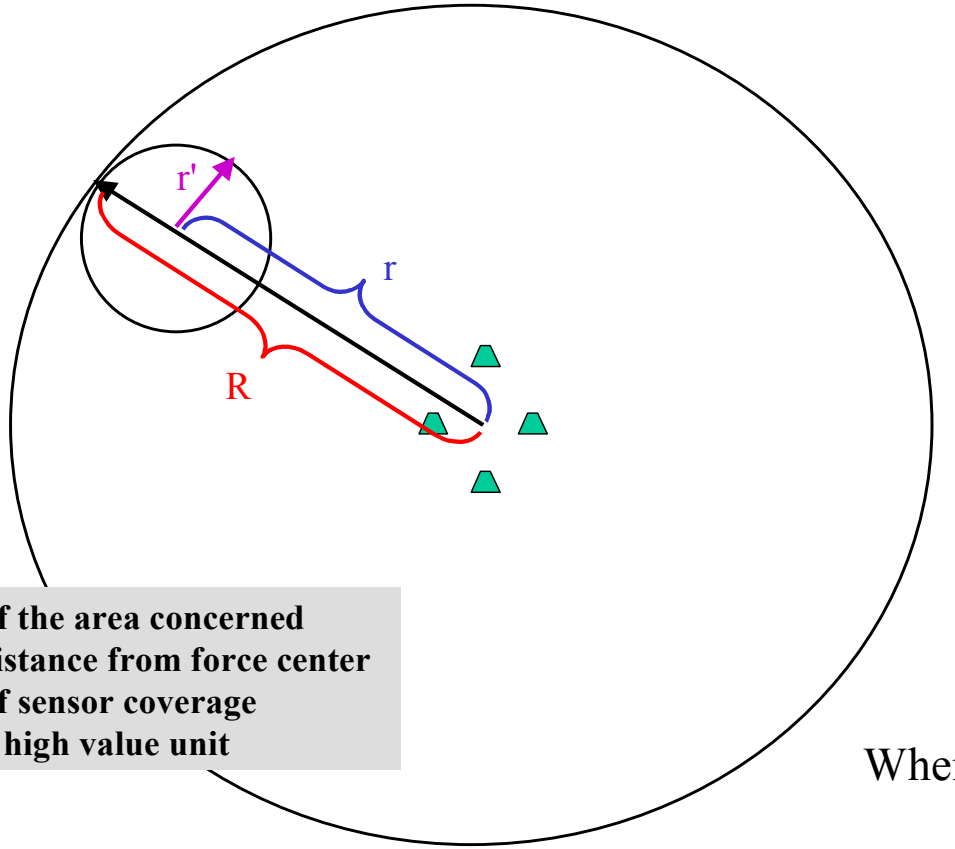


R = Radius of the area concerned
r = Sensor distance from force center
r' = Radius of sensor coverage
▲ = Notional high value unit

Where r << R

Search Analysis: Distributed Sensor

Distributed Sensor Configuration



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

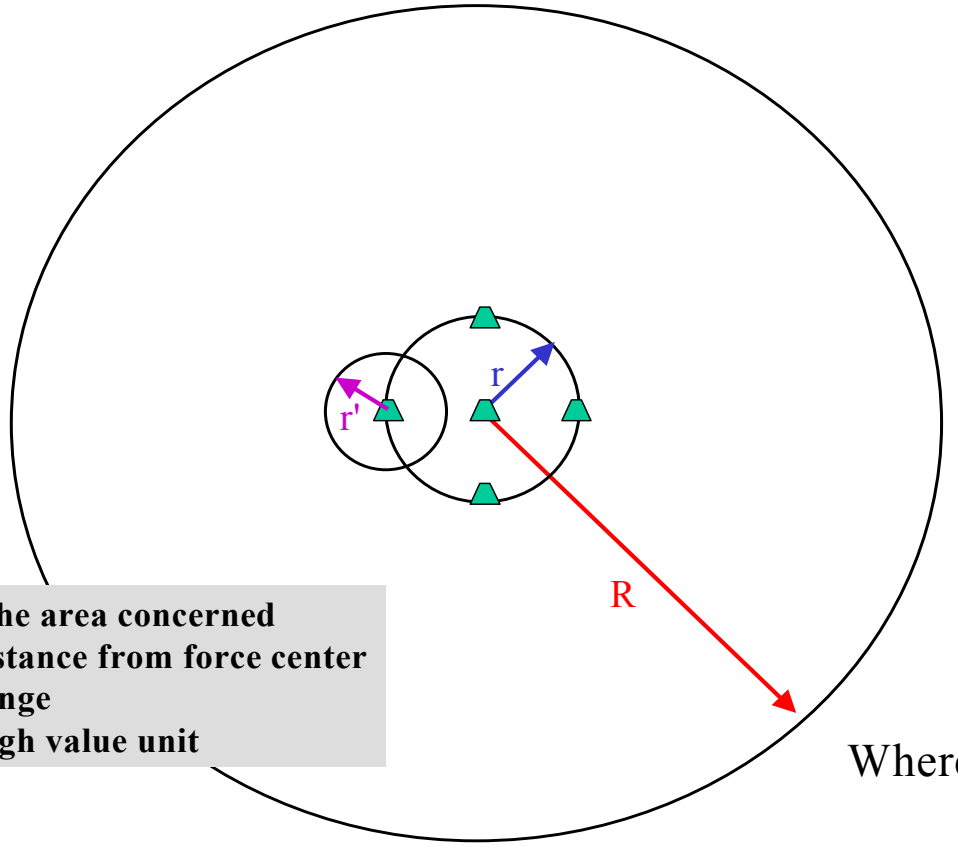
Where $r \approx R$

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

Engagement Analysis: Point Weapons

Point Weapon Configuration

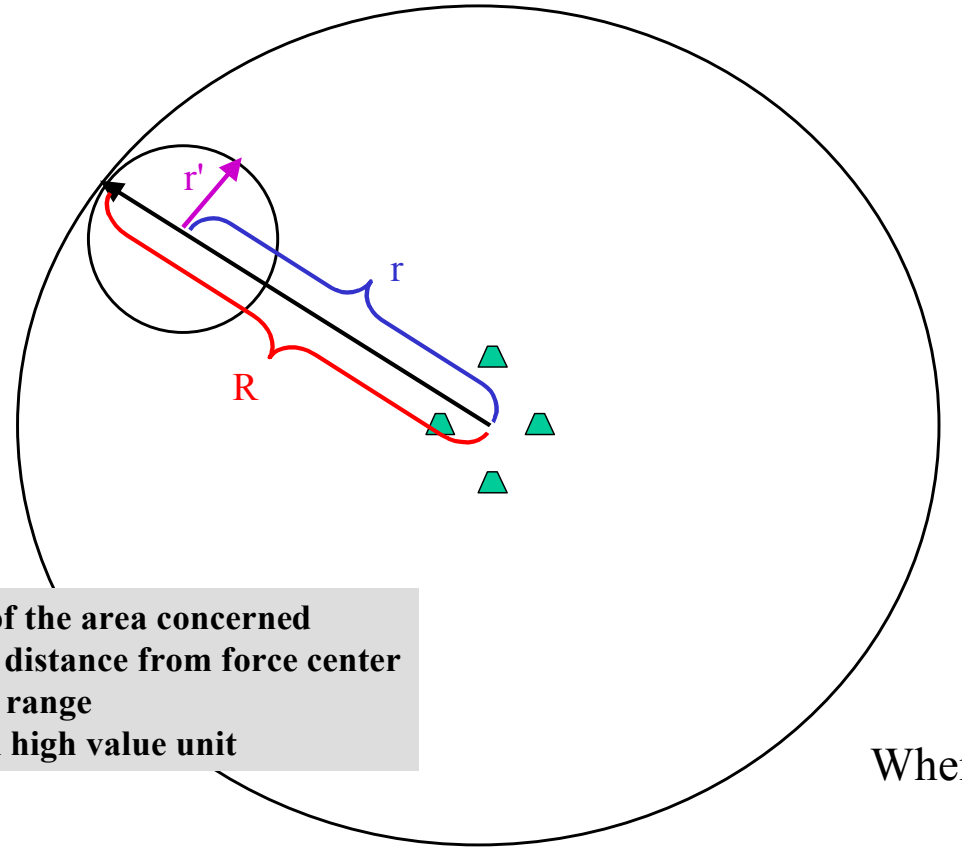


R = Radius of the area concerned
r = Weapon distance from force center
r' = Weapon range
▲ = Notional high value unit

Where r << 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 $r \approx R$

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

Measure Of Effectiveness

- Survivability of the Sea Base
  - % of ExWar ships mission capable
  - % of transport aircraft mission capable
  - % of transport surface craft mission capable

Proposed Architectures

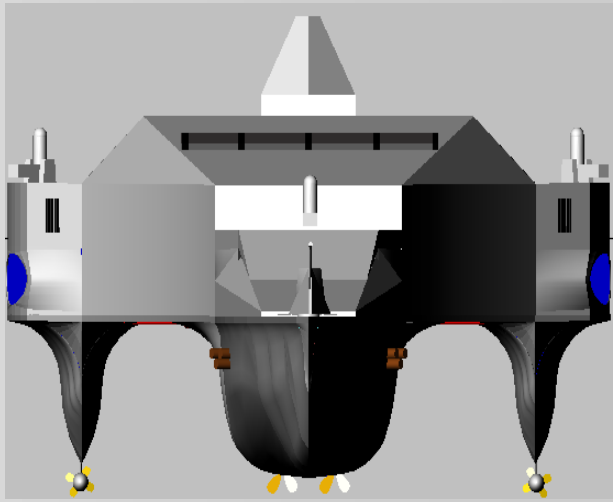
- Force Composition:
  - COA A (CRUDES-based w/ SSN)
  - COA B (LCS-based w/ SSGN)
- Sensor/Weapon Architecture:
  - Point (ship-based)
  - Distributed (UAV/USV/UUV-based)
- Weapons:
  - Current
  - Conceptual

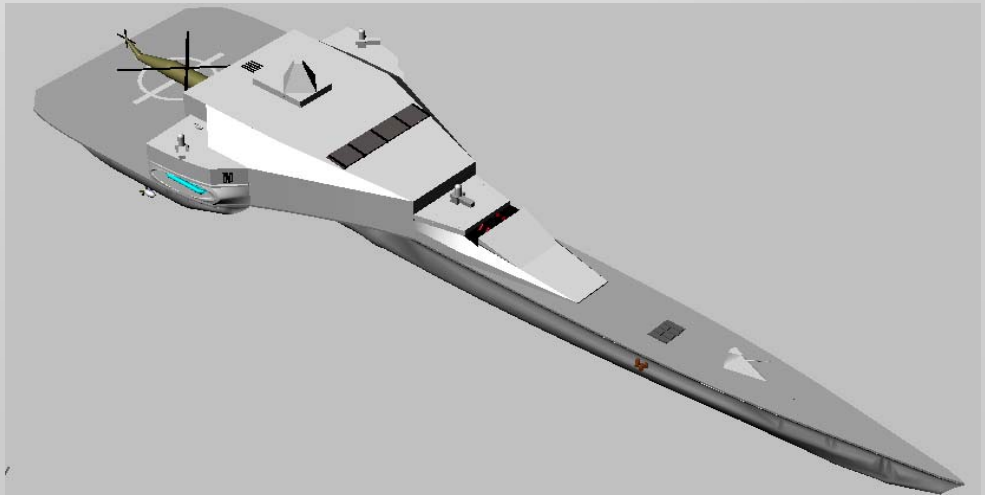
DESIGN OF EXPERIMENTS			
Force Composition	**Sensor Weapon Architecture**	**Weapons**	**Alternate Force Architecture**
COA A	Point	Current	1
		Conceptual	2
	Distributed	Current	3
		Conceptual	4
COA B	Point	Current	5
		Conceptual	6
	Distributed	Current	7
		Conceptual	8

TSSE Supporting Study
LCS Design: Sea SWAT

Wayne E. Meyer Institute of Systems Engineering

- 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

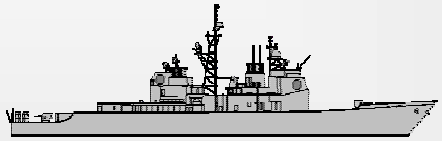




Force Composition

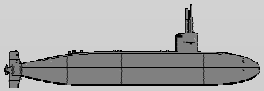
Wayne E. Meyer Institute of Systems Engineering

COA A

3 CG 

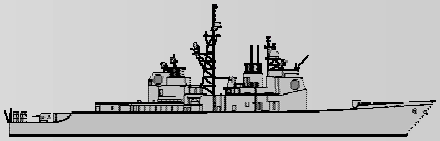
3 DDG 

3 FFG 

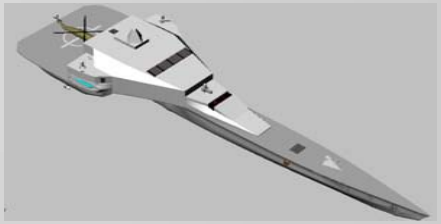
1 SSN 

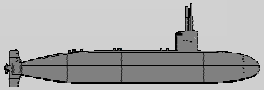
CRUDES-based

COA B

1 CG 

1 DDG 

12 LCS 

1 SSGN 

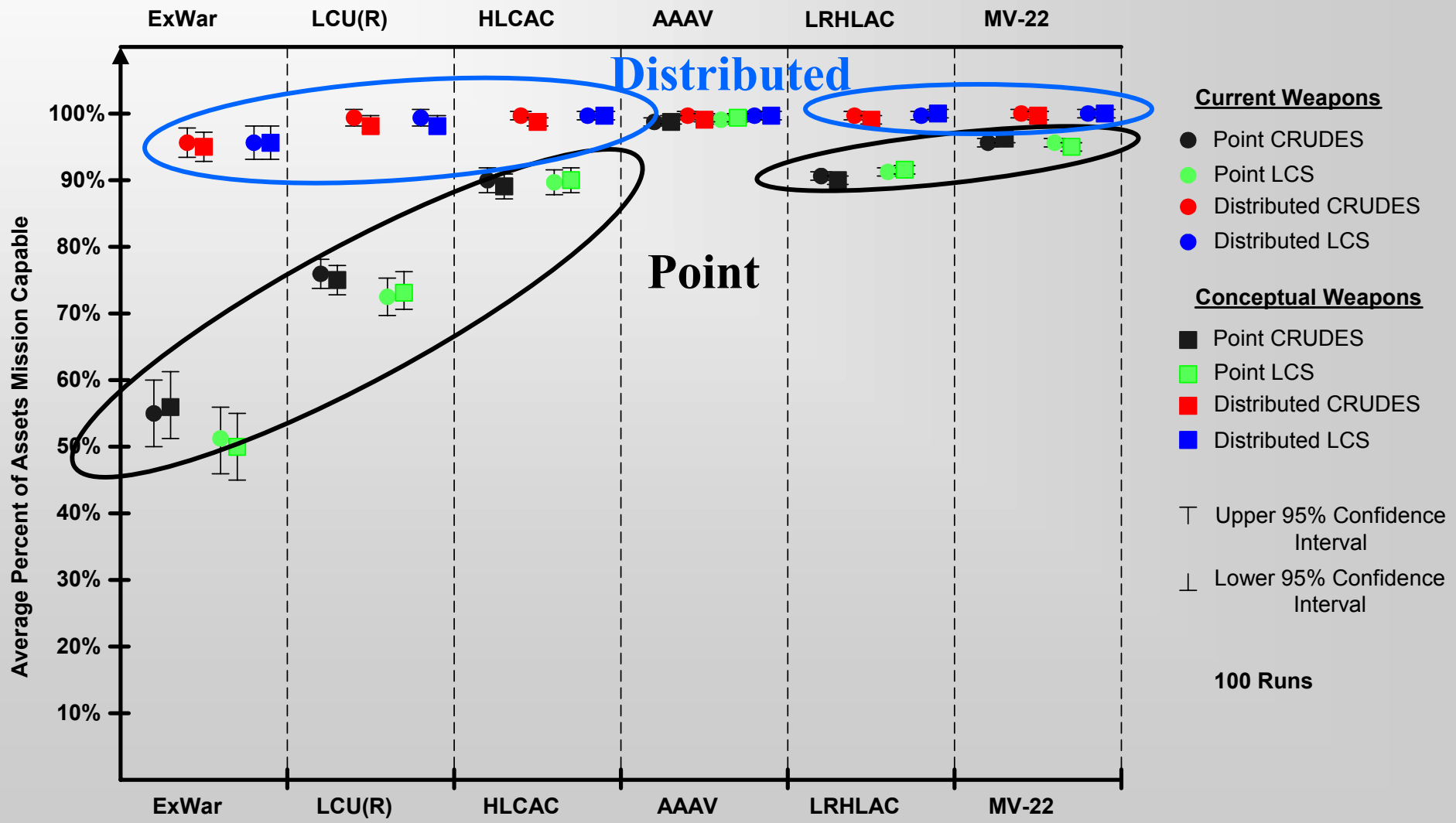
LCS-based

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
- **Inputs:** Sensor and search model calculations. Characteristics of weapons, platforms, and sensors.
- **Outputs:** # mission kills, # of mission kills by threat

Distributed Sensors and Weapons Increase Force Survivability

Wayne E. Meyer Institute of Systems Engineering



EXTEND Key Findings

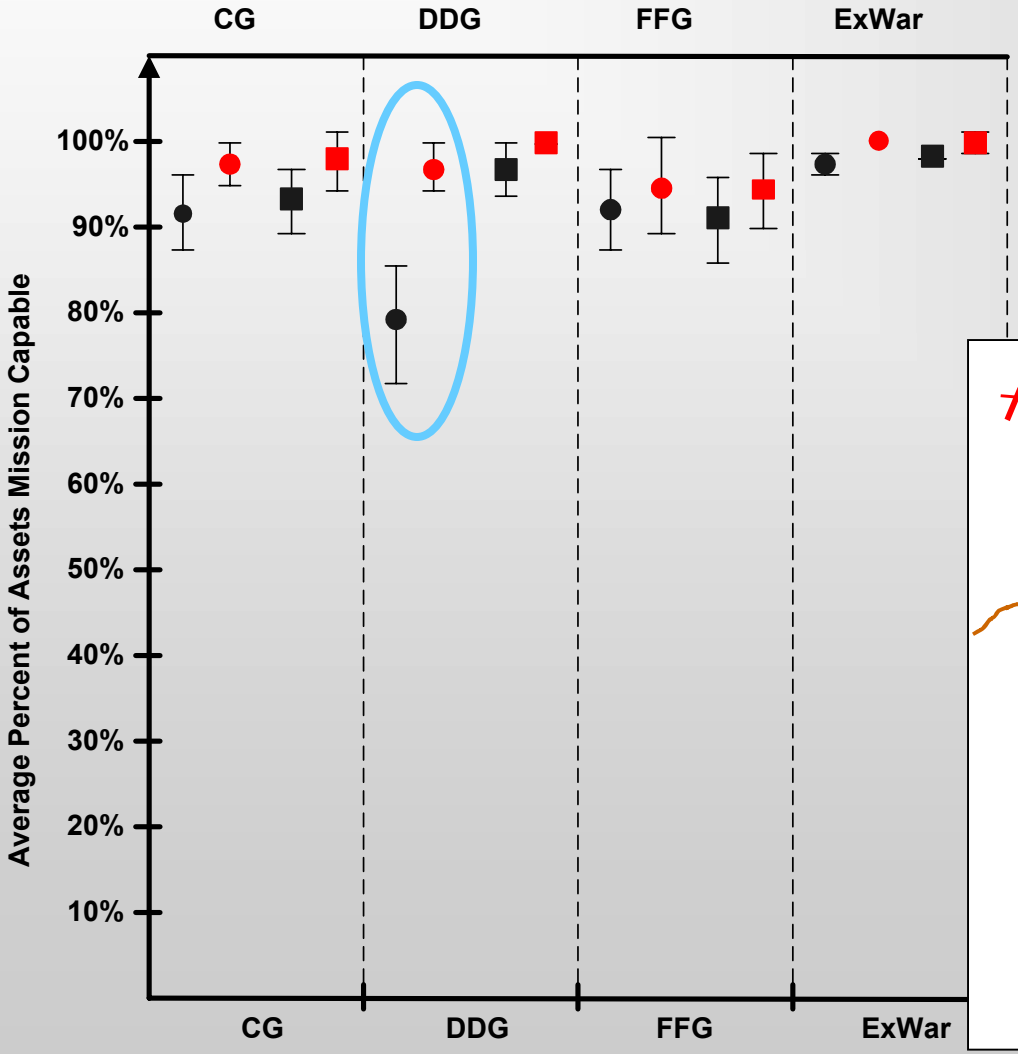
- Force Composition
  - CRUDES-based and LCS-based protection forces are roughly equivalent
- Sensor / Weapon Architecture
  - Distributed Architecture improves survivability of the Sea Base, particularly against USW threats
- Weapon Type
  - No significant difference between current and conceptual weapons 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

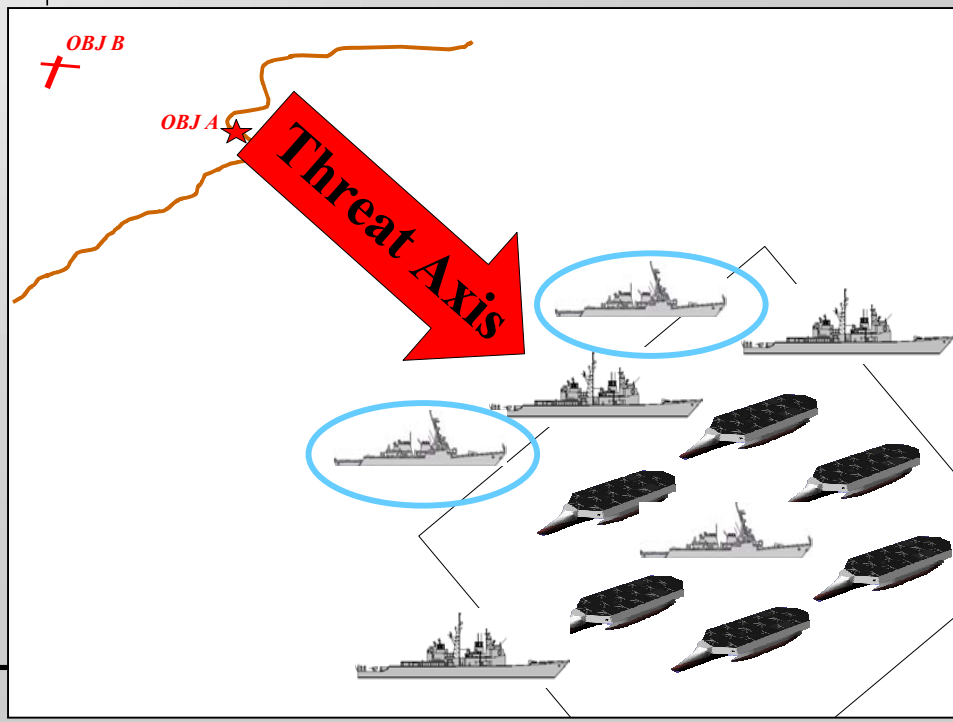
Distributed Architecture Increases Survivability Along Threat Axis

Wayne E. Meyer Institute of Systems Engineering



COA A Legend

- Point / Current
- Distributed / Current
- Point / Conceptual
- Distributed / Conceptual



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

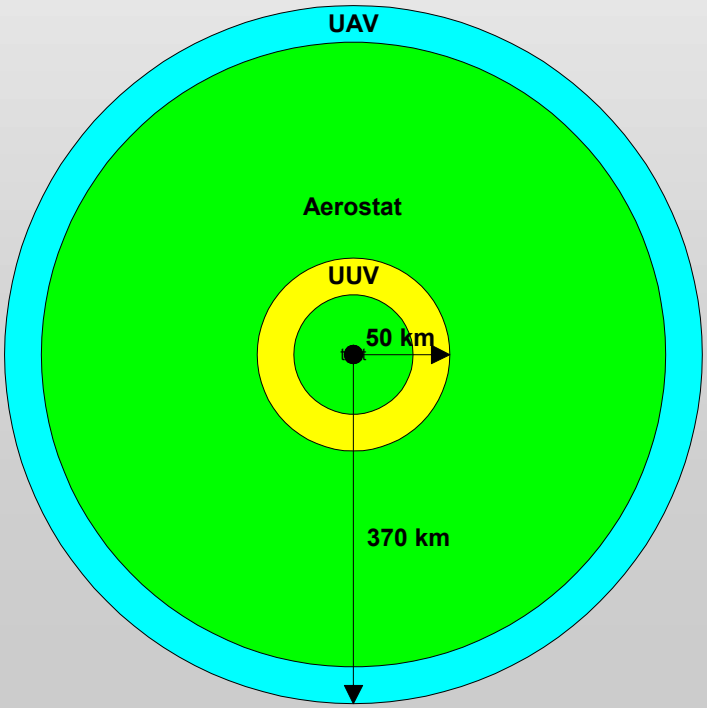
Force Protection Study
Key Findings

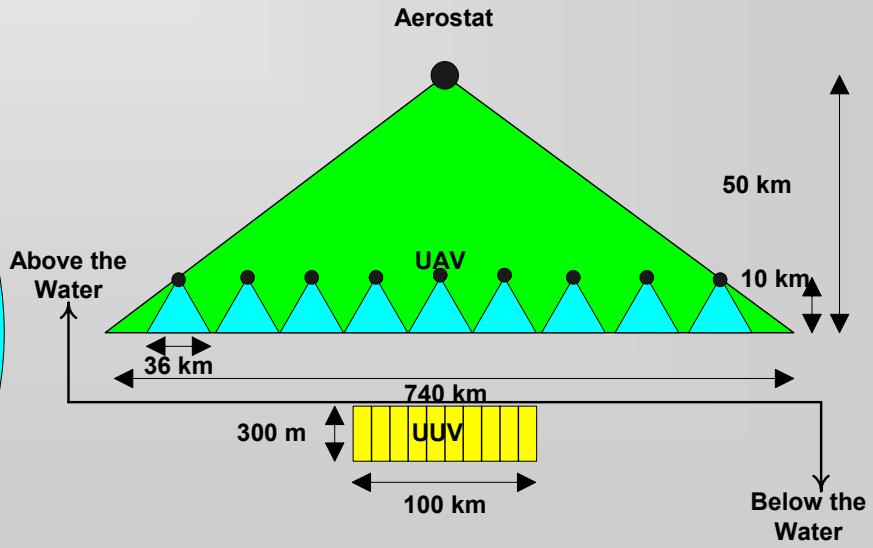
- CRUDES-based and LCS-based force compositions are roughly equivalent
- Distributed Architecture improves survivability
  - Greater reaction times
  - More engagement opportunities
  - Particularly effective against USW threats
- Distributed Architecture conserves weapons
- Point and Distributed Architectures 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

Wayne E. Meyer Institute of Systems Engineering

- 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

Wayne E. Meyer Institute of Systems Engineering

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 ≅ 3 CG + 3 DDG + 3 FFG
- Unit Cost: 1 DDG-51 ≅ 1.37 TSSE LCS

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