Naval
Postgraduate
School

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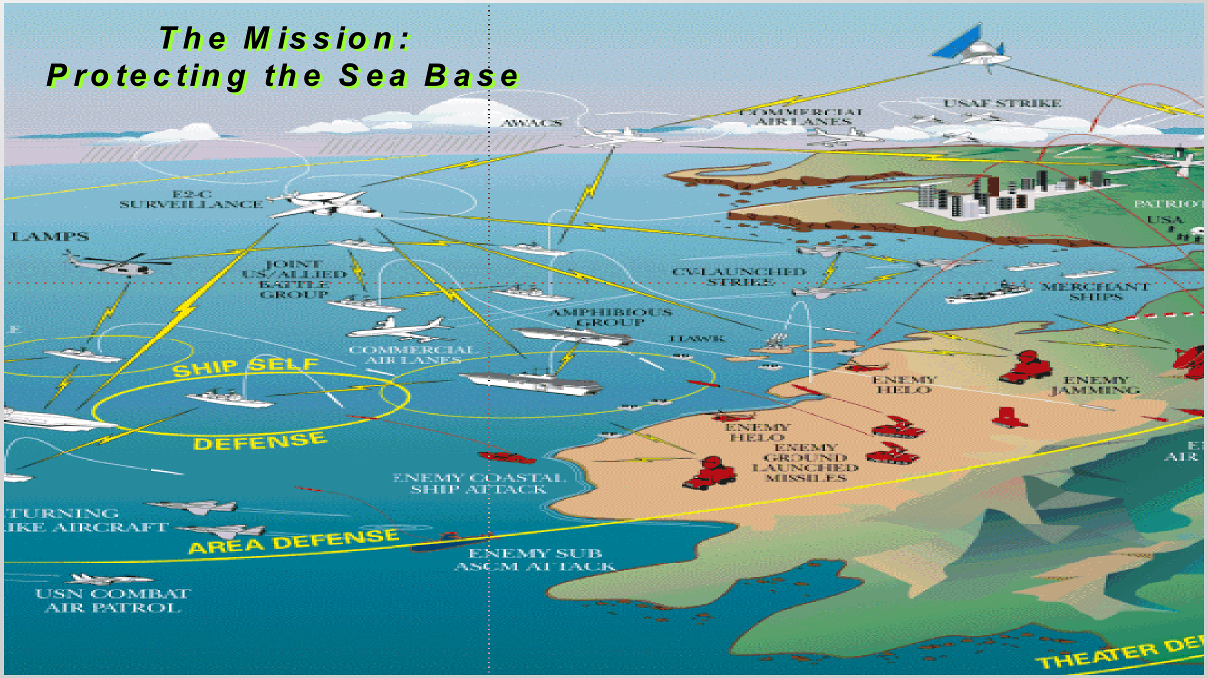
SEA-4
Expeditionary Warfare Force Protection



04 December 03

Outline

- 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

- 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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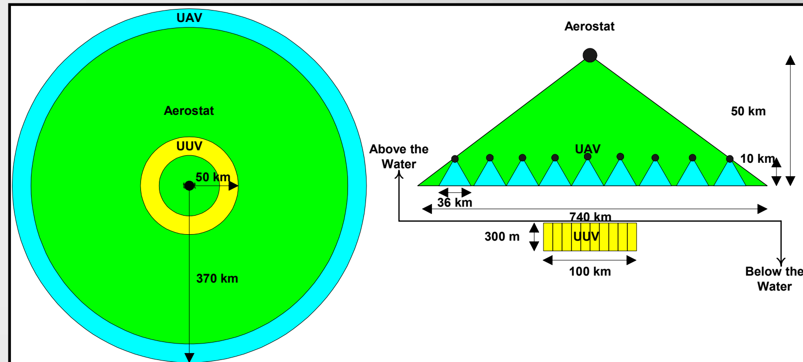
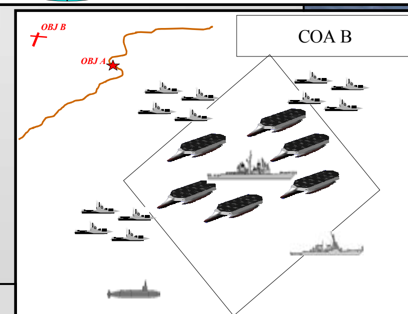
Sensor Architecture
- Point
- Distributed

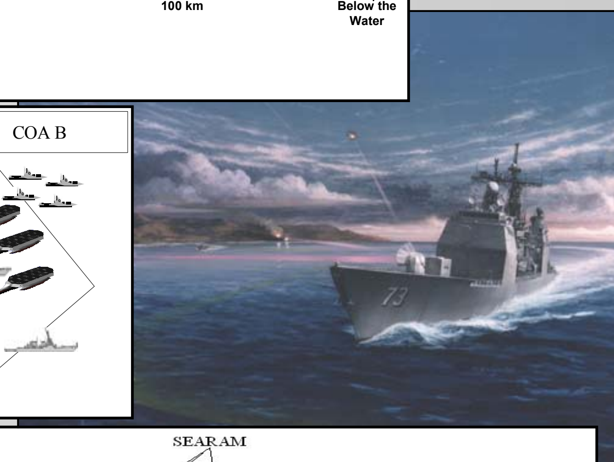
Weapons Architecture
- Point
- Distributed

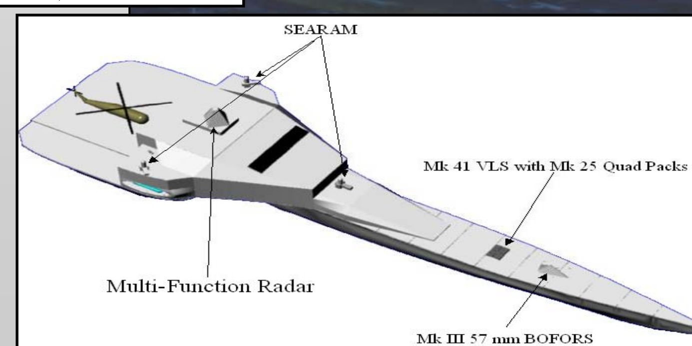
Force Composition
- CRUDES-based
- LCS-based

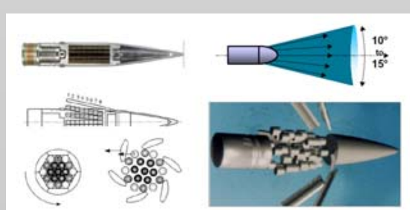
Weapons Type
- Current
- Conceptual











Path to Proposed Force Protection Architecture

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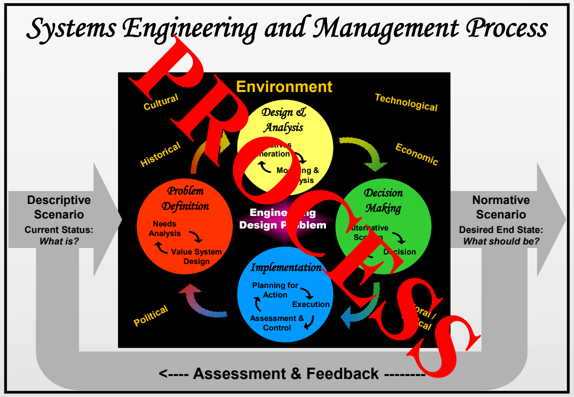

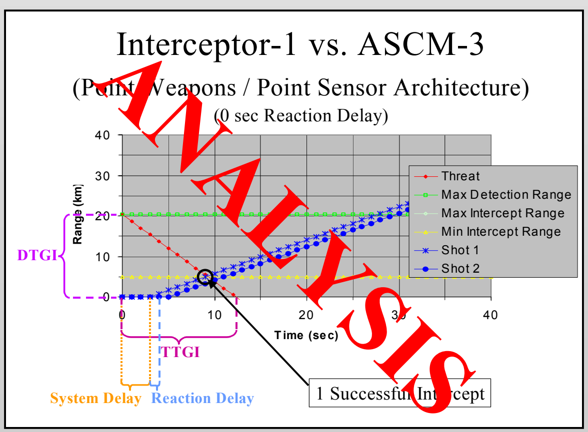

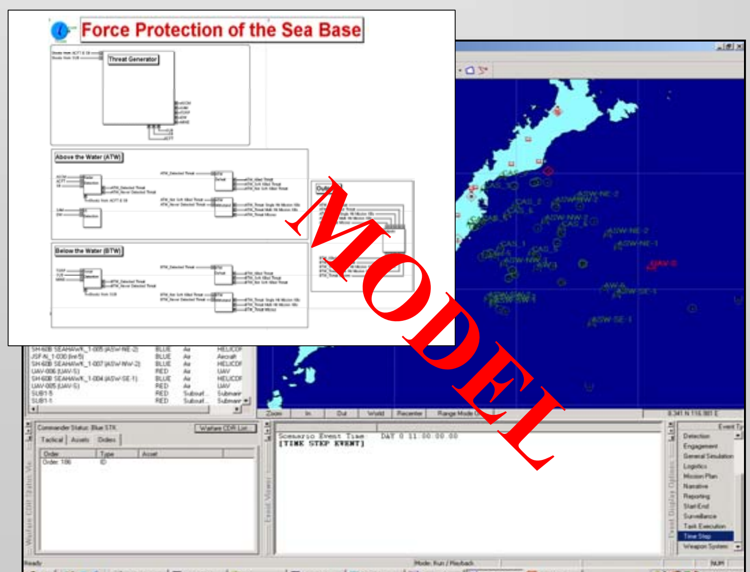

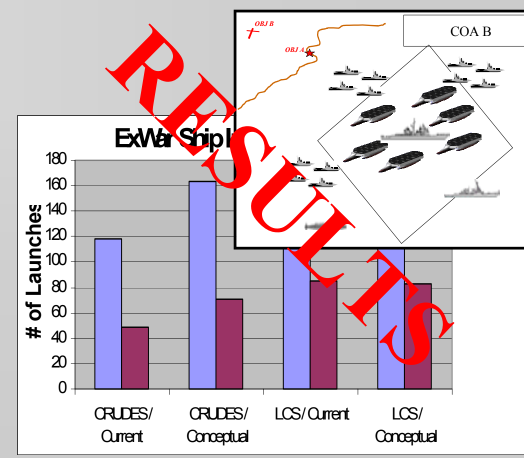

Extensive Modeling Efforts to Analyze Design Alternatives

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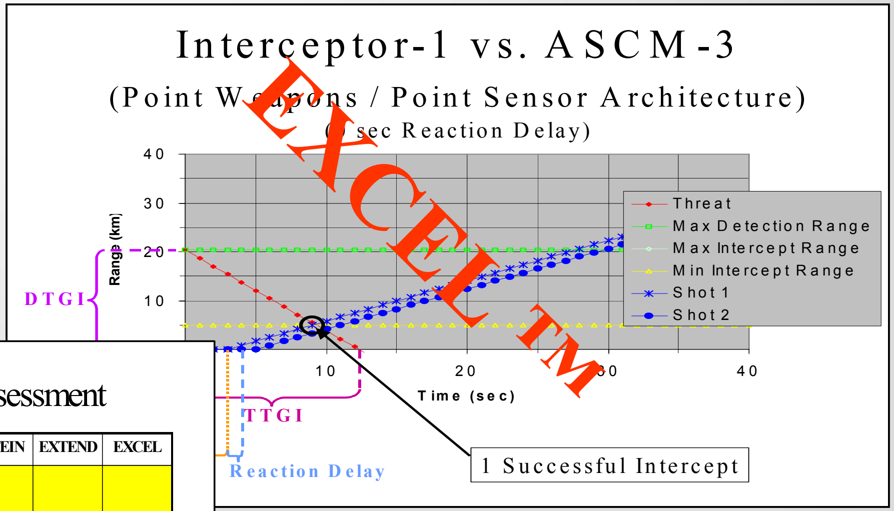


DESIGN OF EXPERIMENTS			
Force Composition	Sensor Weapon Architecture	Weapons	Alternate Force Architecture
COA A	Point	Current	1
		Conceptual	2
	Distributed	Current	3
		Conceptual	4
COA B	Point	Current	5
		Conceptual	6
	Distributed	Current	7
		Conceptual	8

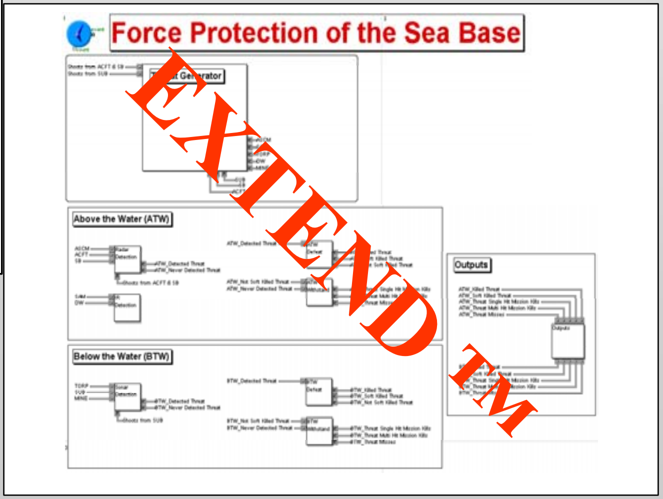
DESIGN

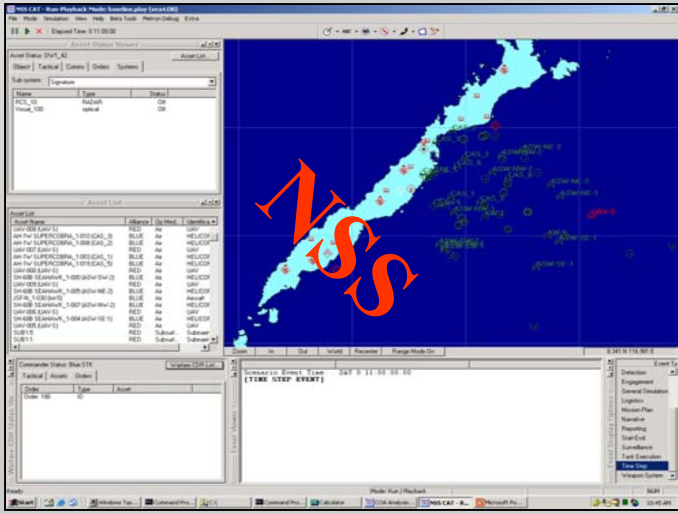
Modeling Tool Assessment

	JANUS	JTLS	NSS	EINSTEIN	EXTEND	EXCEL
Ease of use (time risk)						
Analysis						
Database						
Cost						
State I						
State II						
State III						
Support						

ASSESS

September 2003





Integrated Interdisciplinary Team

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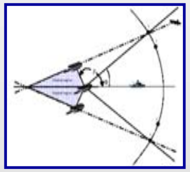
Force Protection Architecture

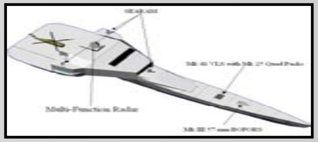
Sensor/Weapon Architectures
Force Composition
Weapon Types



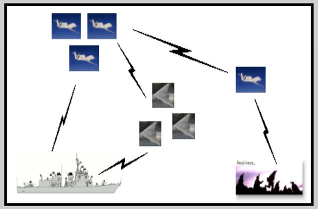
SEA-4
TSSE
NPS Theses
TDSI Supporting Studies

- **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**

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

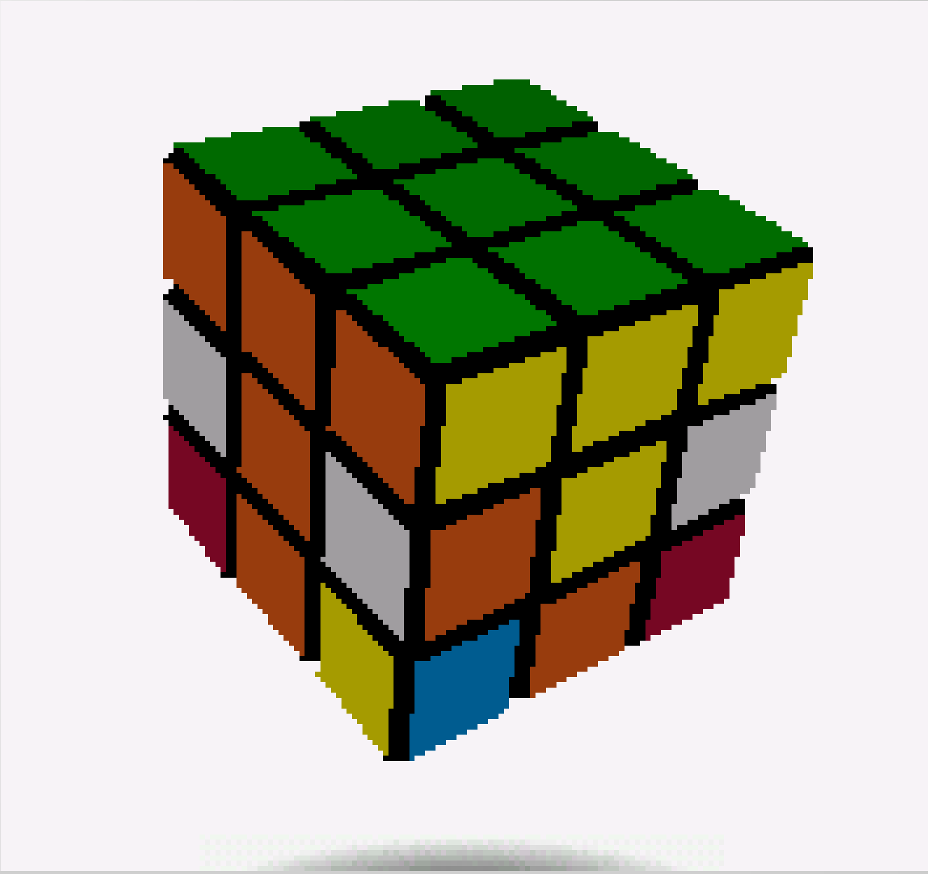
SEA-4 Tasking

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



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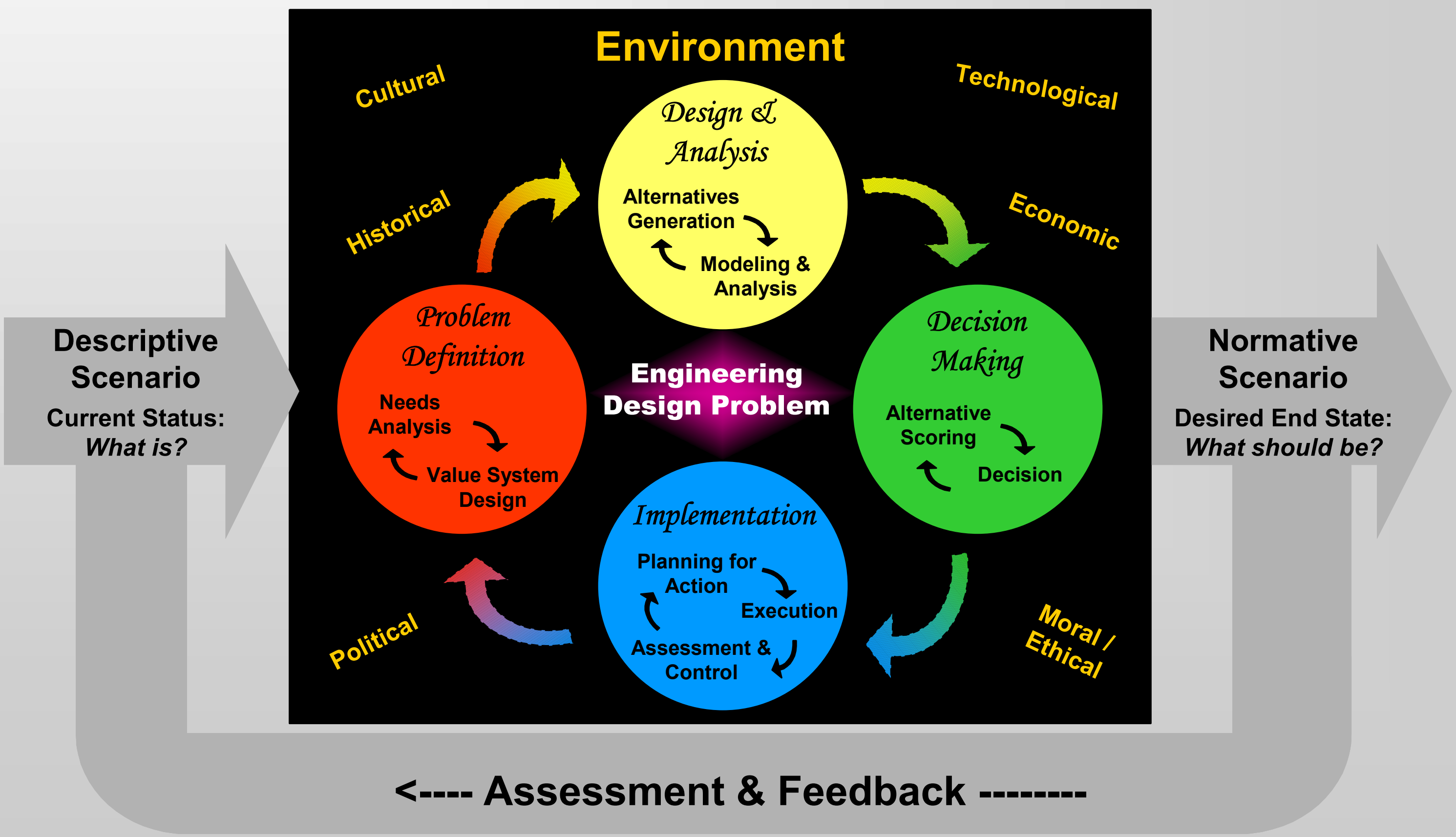
Methodology

Systems Engineering and Management Process



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

LCDR Parkins

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.

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

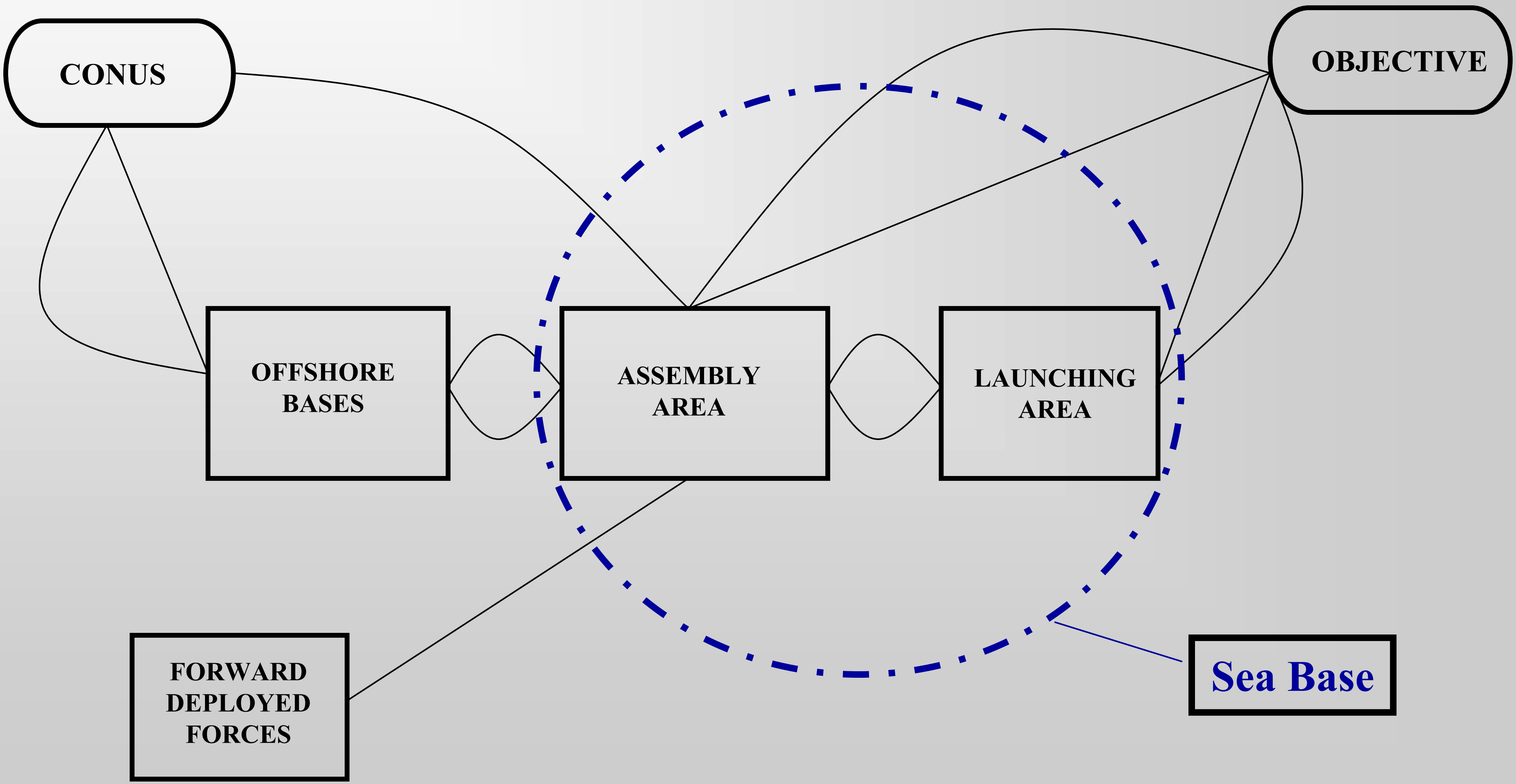
- Marine Expeditionary Brigade (MEB) operations occur in the 2015-2020 timeframe.
- MEB size Marine Air Ground Task Force composition and sustainment requirements remain constant between the present and 2015-2020.
- The USMC adopts Ship To Objective Maneuver doctrine.
- SEI-3's conceptual expeditionary 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

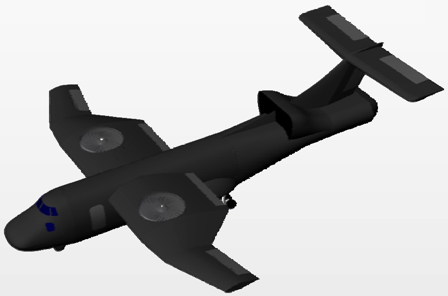
- Actions taken to prevent or mitigate hostile action against the Sea Base
- These actions conserve the force's fighting potential so it can be applied at the decisive time and place
- These actions enable effective employment of the joint force while degrading opportunities for the enemy
- Force protection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

Adapted from the DOD Dictionary

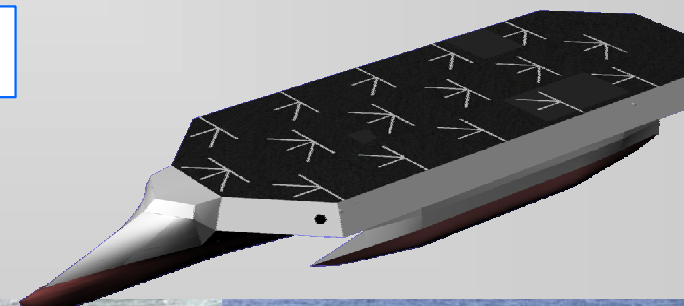
Sea Base
(Defined by SEI-3)



Sea Base



- 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



SEI-3 ExWar Ship and Long Range Heavy Lift Aircraft

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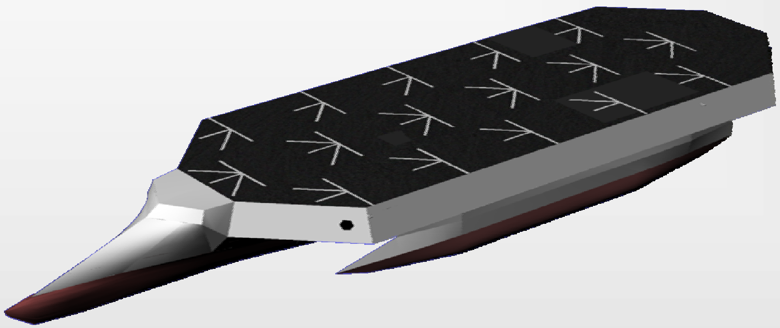
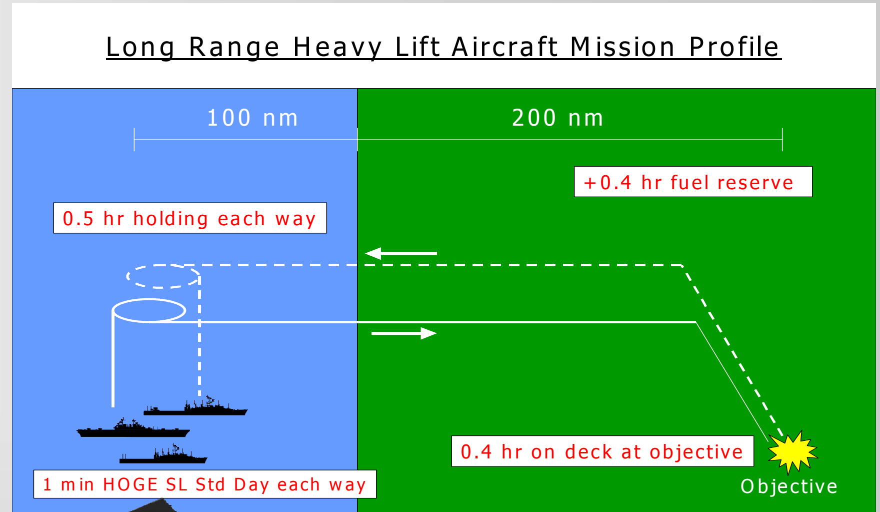
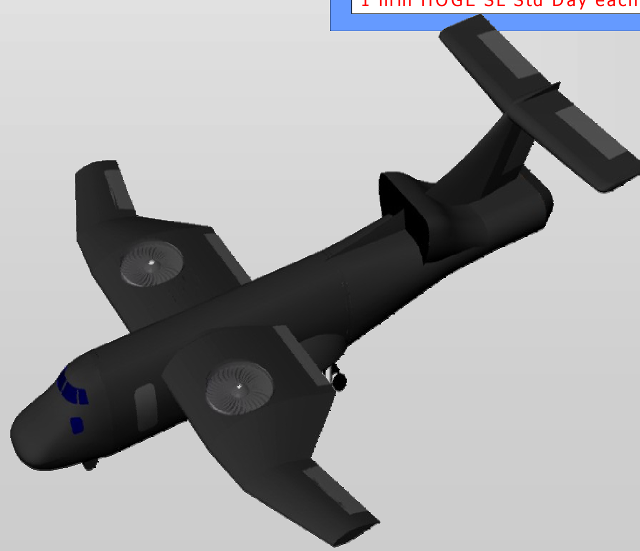




- Combat variant
- Logistics variant
  - DWL: 990 ft
  - Displacement: 86,000 LT
  - Draft: 42’
  - Flight deck : 770’ x 300’
  - Max speed: 30 Kts
  - Well deck for 3 HLCACs



- 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

Expeditionary Maneuver Warfare

- 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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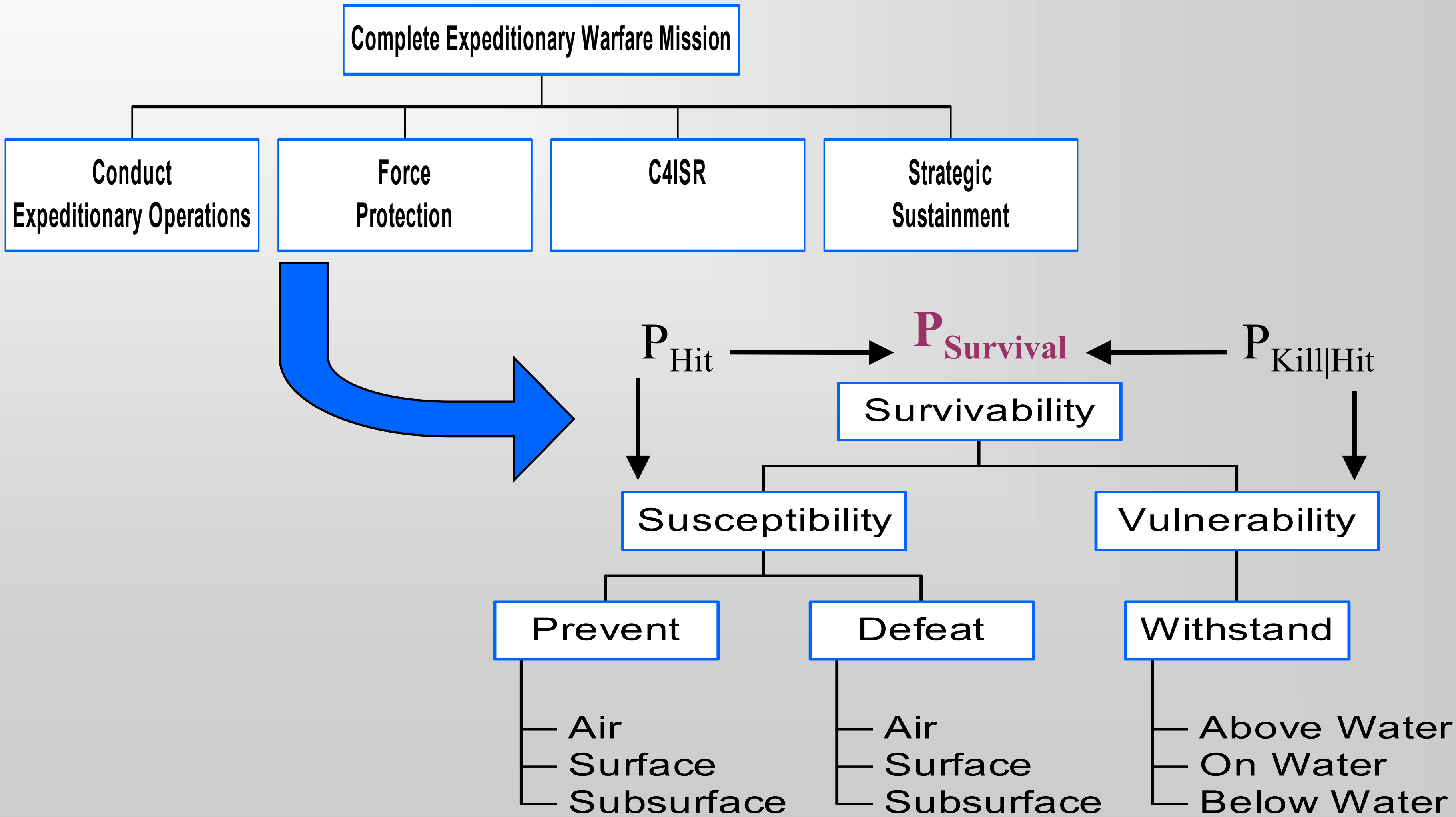

Futures Analysis

Which Threats Do We Choose?

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

- Technical
  - Faster
  - Smaller
  - Advanced materials
  - Higher explosive yield
  - Lighter
  - Low observable
  - Smarter
- Non-technical
  - Cheap
  - Tactics
  - Proliferation

Most Significant Threats

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

Threat Summary

- Unclassified
- Generic
- Universal
- Capabilities based

	ASCM - 1	ASCM - 2	ASCM - 3
Length (ft)	12.3	29.2	38.1
Diameter (ft)	1.38	2.2	3.0
Speed (kts)	583	1602	3208
Max Range (nm)	81	162	540
Cruise Altitude (ft)	16	33	79000
Terminal Altitude (ft)	10	16	79000 (30° dive)
Seeker Type	Radar / EO / IR	Radar / EO / IR	Radar / EO / IR
Radar Cross Section (RCS) Assumptions* Target Angle = 0° (Nose on) Radar Freq = 3 GHz Reflectivity = 0.1			
Total RCS (m^2)*	0.014	0.035	0.066
Infrared (IR) Assumptions* Target Angle = 0° (Nose on) Emissivity = 0.9			
Radiant Exitance (W/m^2-μ)* Wavelength (λ) = 3 - 5 μm	29.76	3357.22	125130.12
Radiant Exitance (W/m^2-μ)* Wavelength (λ) = 8 - 12 μm	250.82	2117.78	13599.65

Table IV-9 ASCM Threat Representative Characteristics

Scenario:
2016 South China Sea

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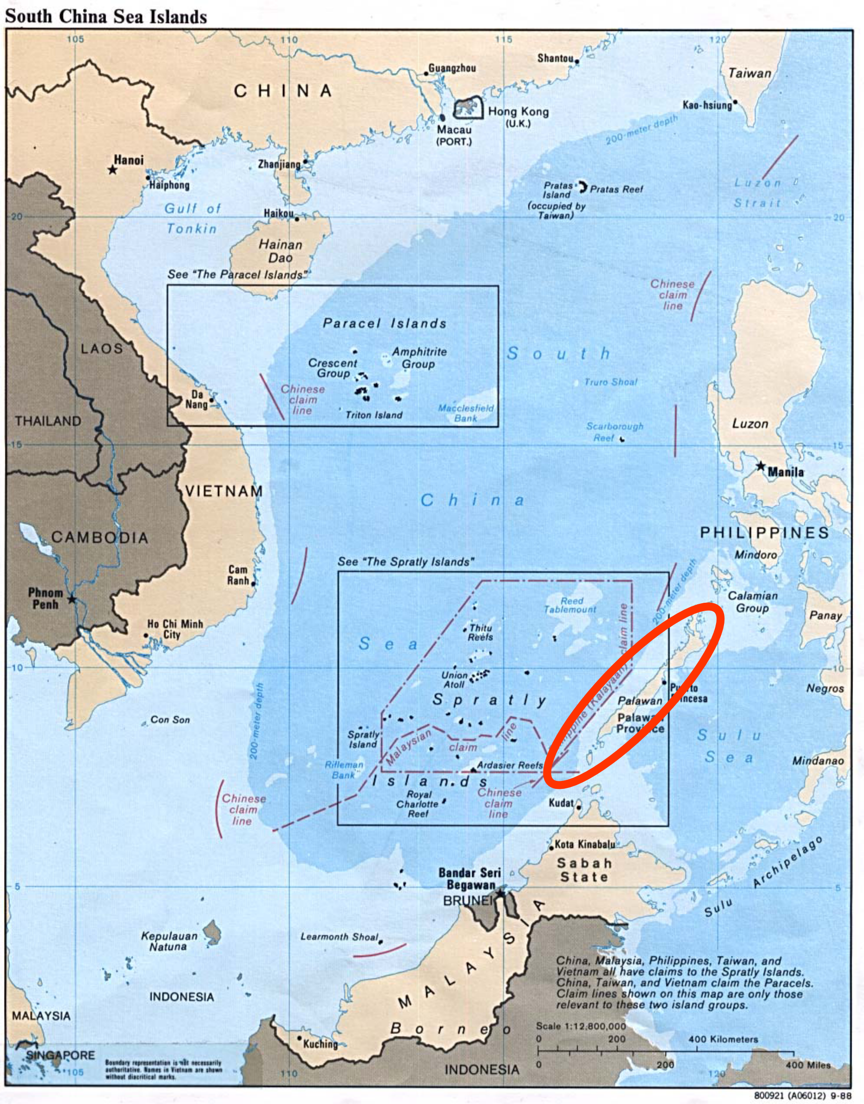
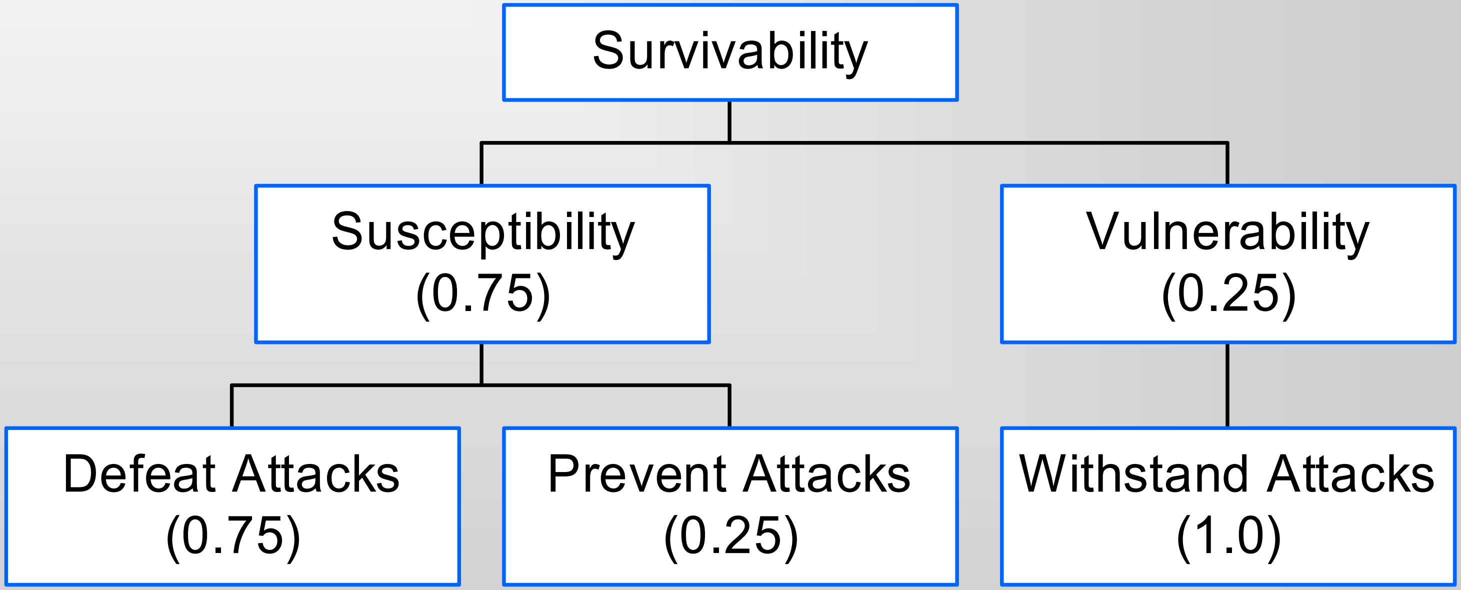
- PRC invests profits from its booming economy in military
- PRC claims hegemony over entire SCS region
- PRC reinforces presence on Spratly Islands
- PRC / Philippine naval encounter
- PRC invades Kepulalian Natuna and quarantines Palawan
- U.S. / ASEAN attempt FON operations in Sulu Sea
- PRC invades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

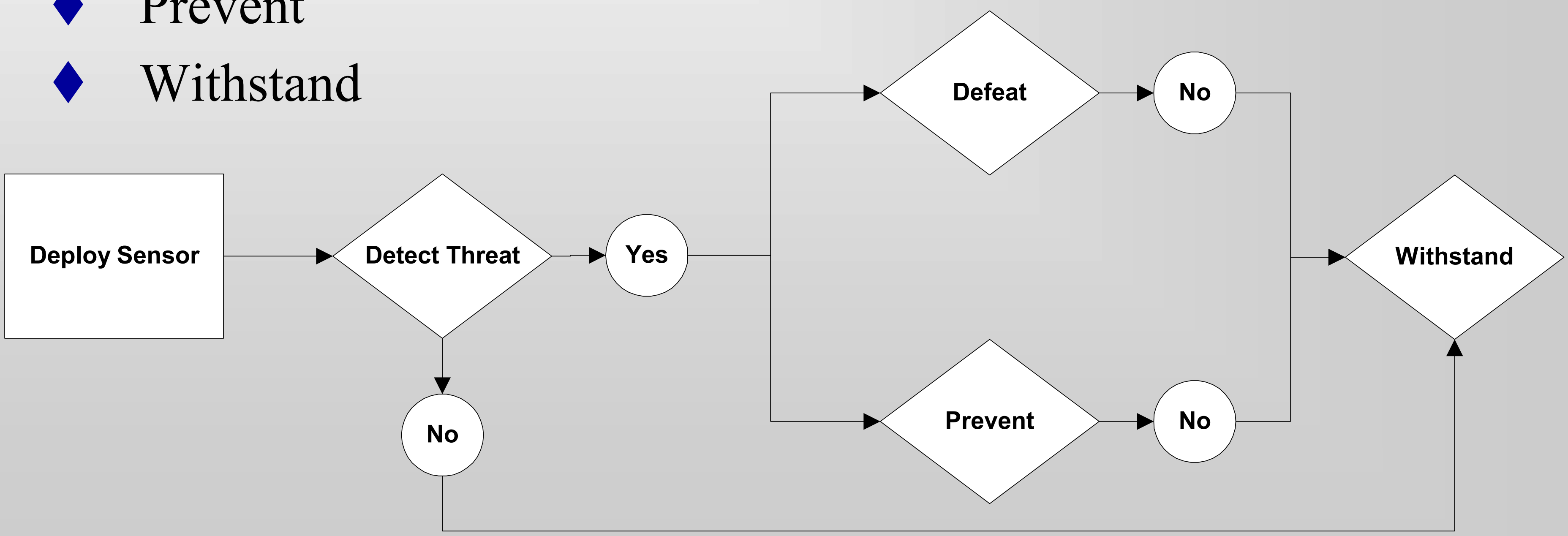


Value System Design



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

Alternatives Generation

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Detect	Defeat	Prevent	Withstand	Deploy
Radar	Missile	Chaff	Armor	Ship
Lidar	Gun	Flare	Reactive Armor	Aircraft
IR	Laser	Decoys	Reflective Armor	UAV
EO	Microwave	Maneuver	Redundant Vital Systems	Aerostat
UV	Acoustic	Electronic Countermeasures	Quality Construction	Satellite
SAR/ISAR		IR Countermeasures		Submarine
Hyper spectral		Acoustic Countermeasures		UUV
Sonar		Signature Management		Shore
Seismic				

Morphological Chart

Threat Model Assumptions:
Approximating Threat Shapes

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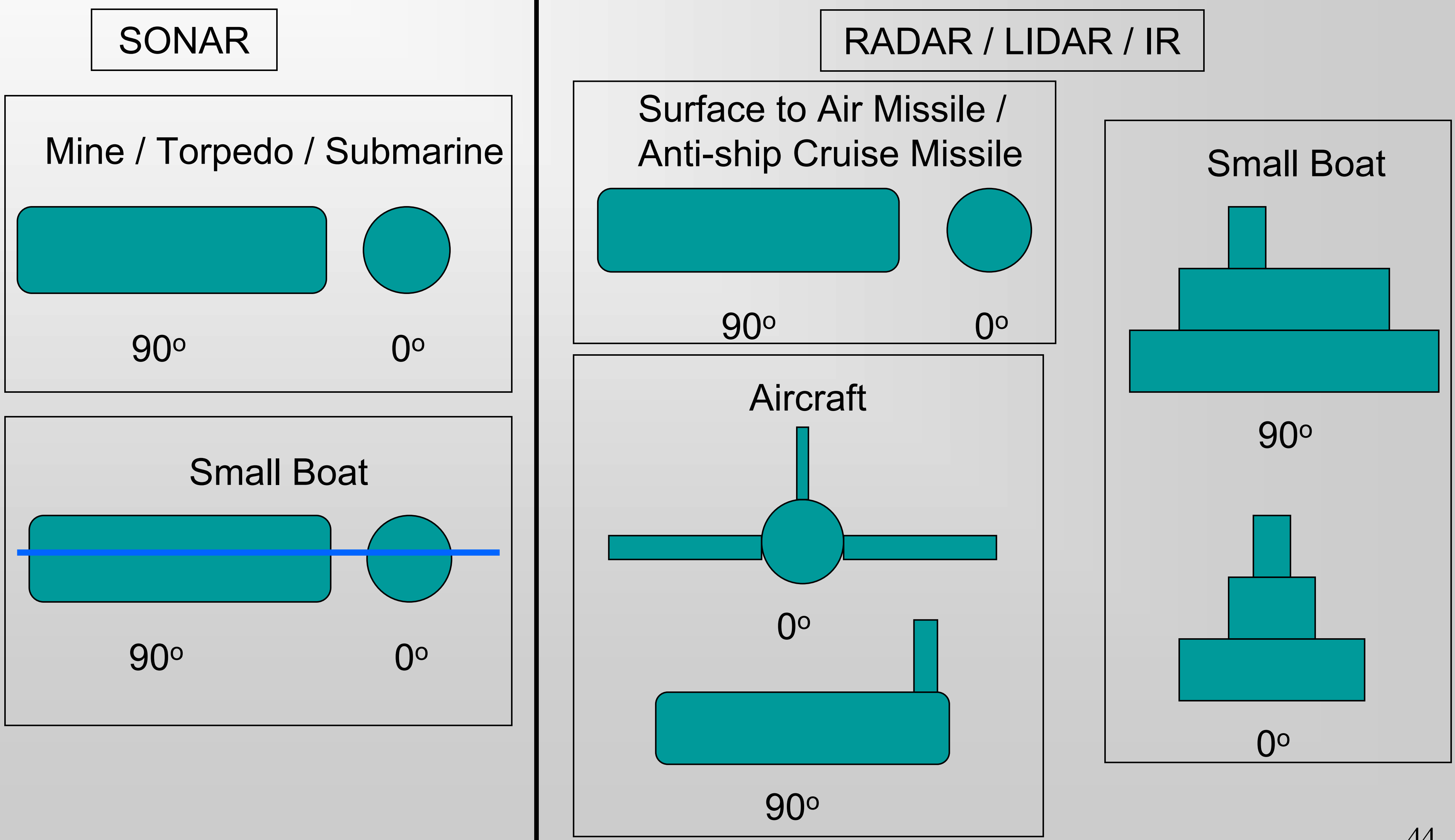
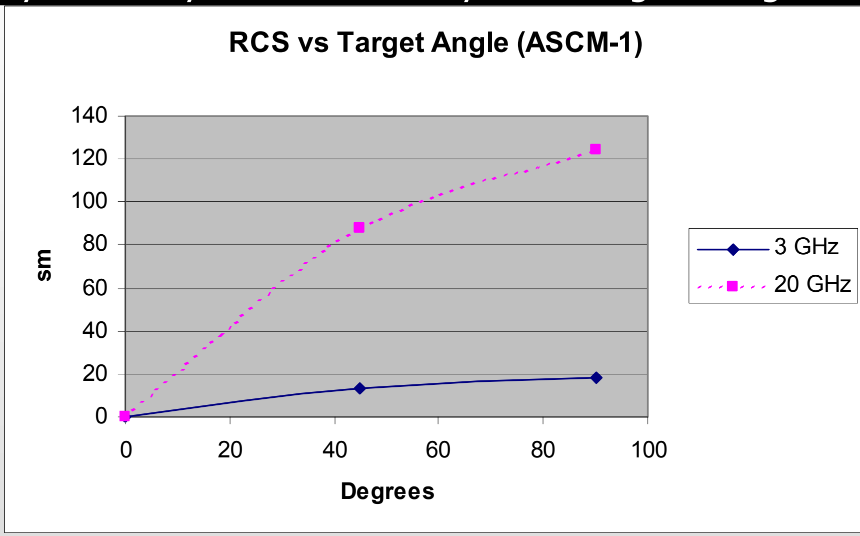
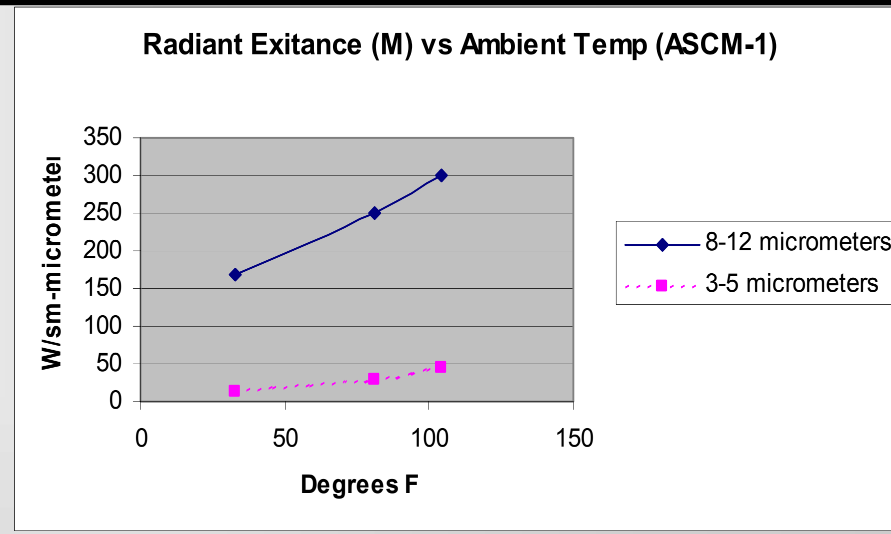


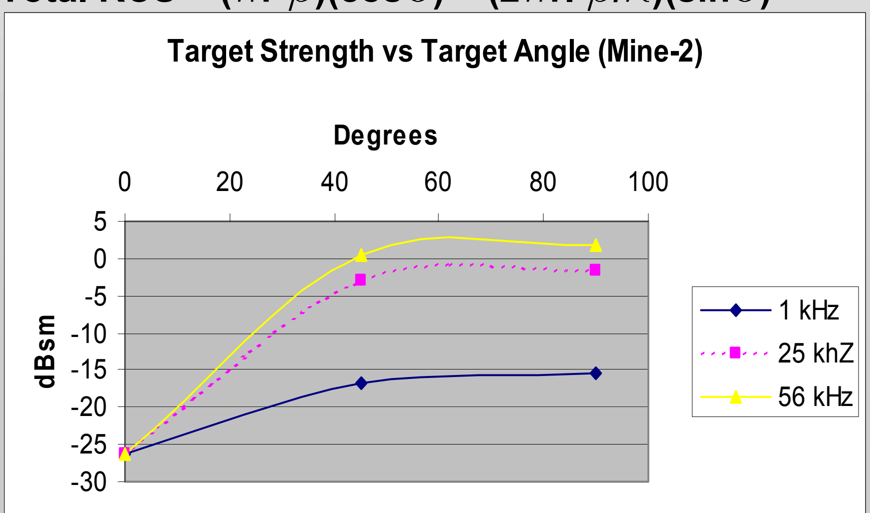
Threat Model Assumptions:
Example Effects of Assumptions





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

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



TS = $10\log((r^2 \rho \cos\Theta/4) + (2\pi r l^2/ 4\pi\lambda)(\rho \sin\Theta))$

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

Analytical Search Models

- Active Sensors: Random Search Theory

  $$P_D(\text{total}) = (1\text{-}e^{(-nwvt/A)})(\ 1\text{-}(1\text{-}\ P_D\ (1))^N)$$

- Passive Sensors: ROC detection probability based on CNR

  $$P_D(\text{total}) = (\ 1\text{-}(1\text{-}\ P_D\ (1))^N)$$

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

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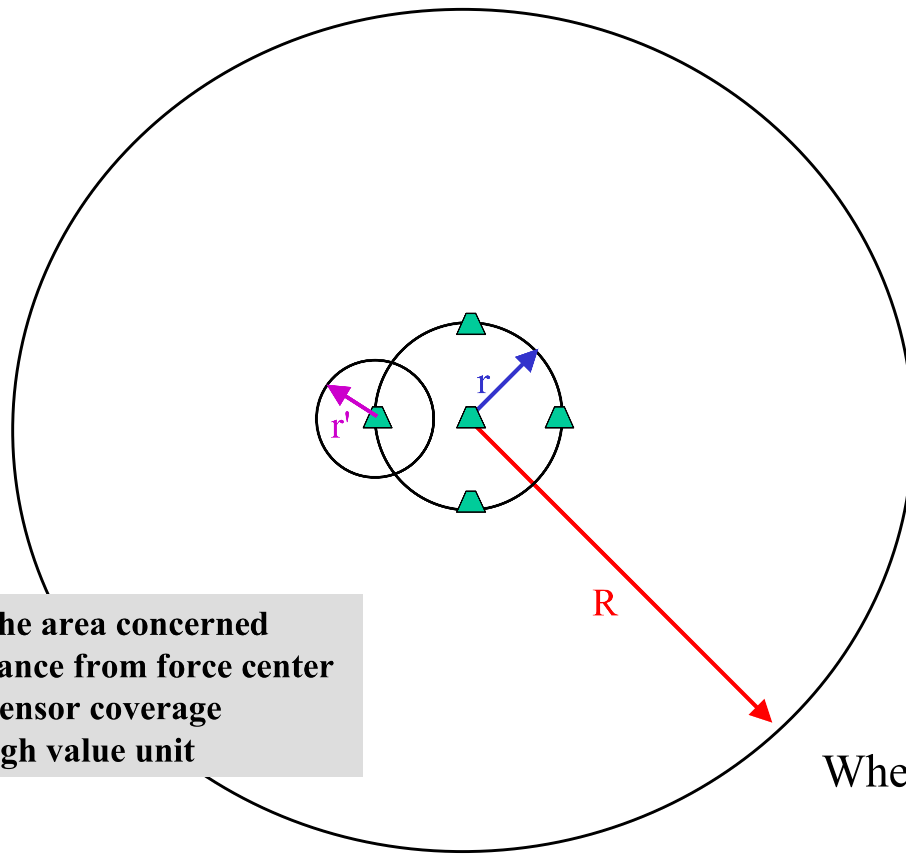
Point Sensor Configuration



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

Where $r \ll R$

Search Analysis: Distributed Sensor

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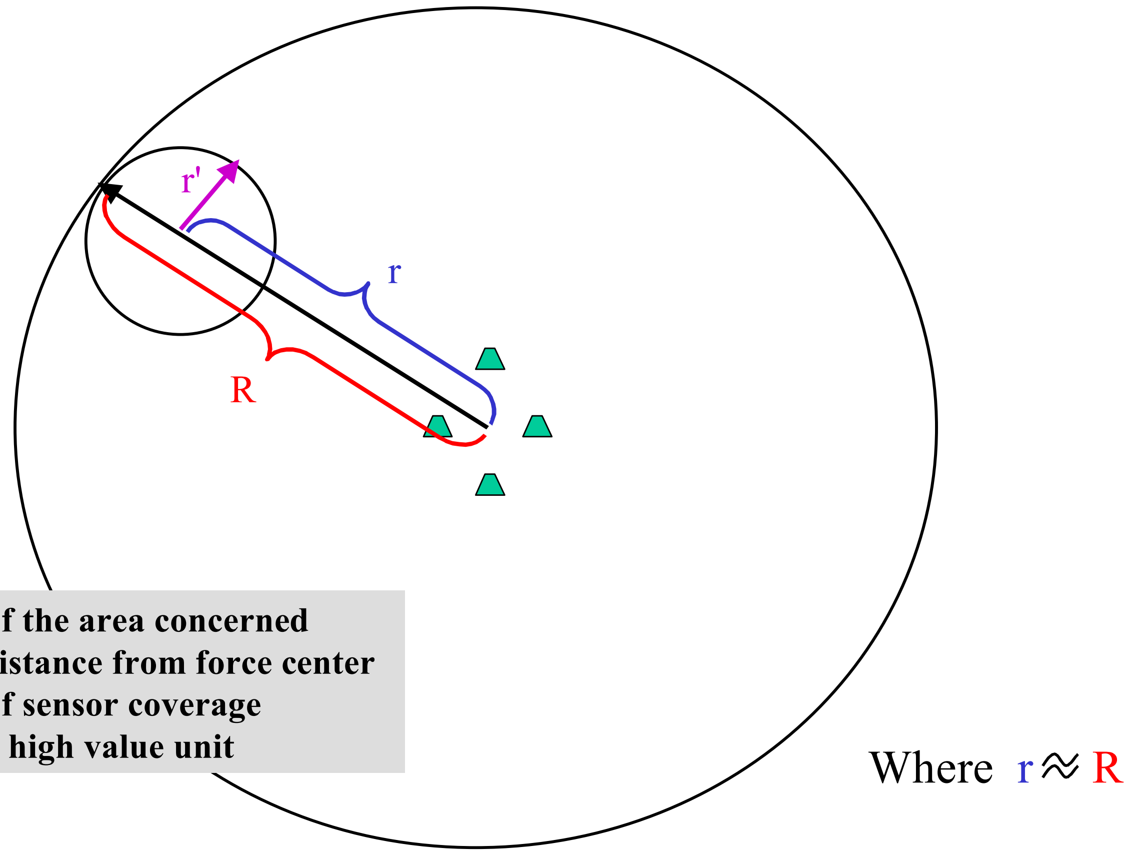
Distributed Sensor Configuration



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

Analytical Search Model Findings

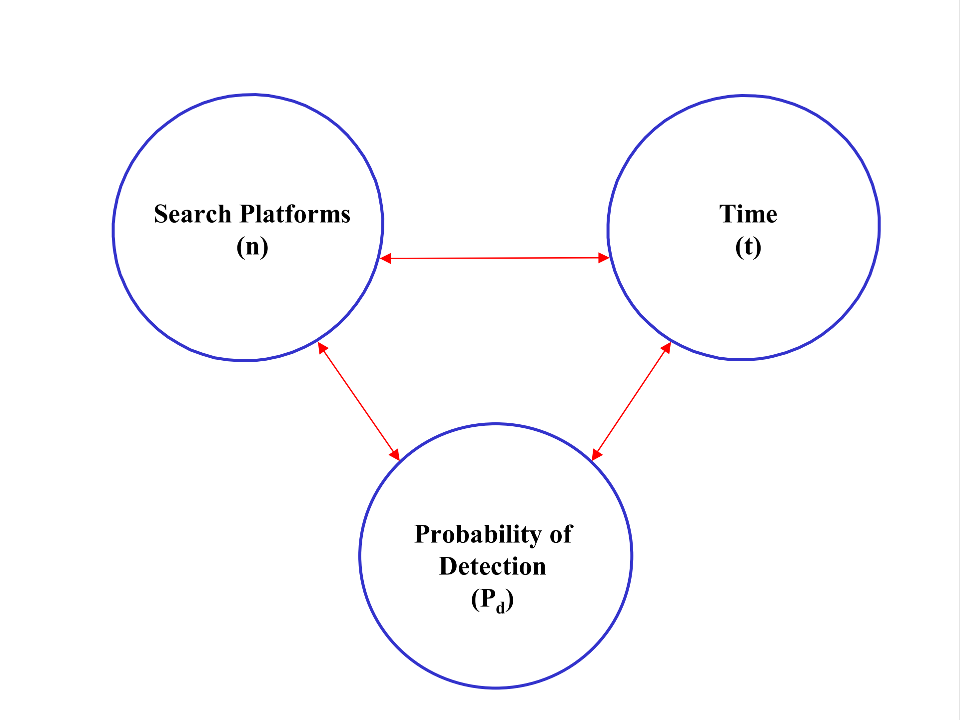
- Distributed sensor network offers benefits of extended detection ranges and greater reaction times
- Distributed sensor network requires more platforms
- Low-level (surface-based) and elevated (airborne) sensors are complementary

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

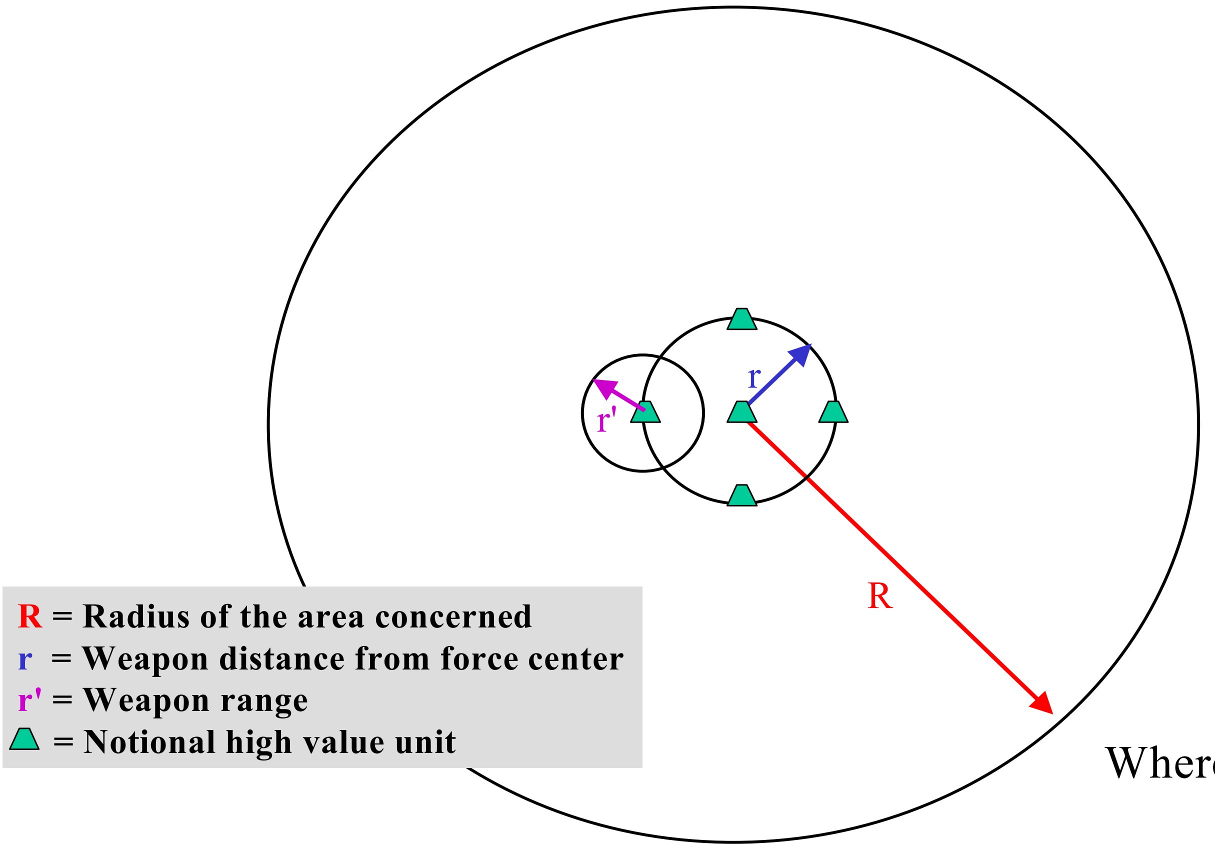
Sensor & Search Trade-Offs

- 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



Where r << R

Engagement Analysis: Distributed Weapons

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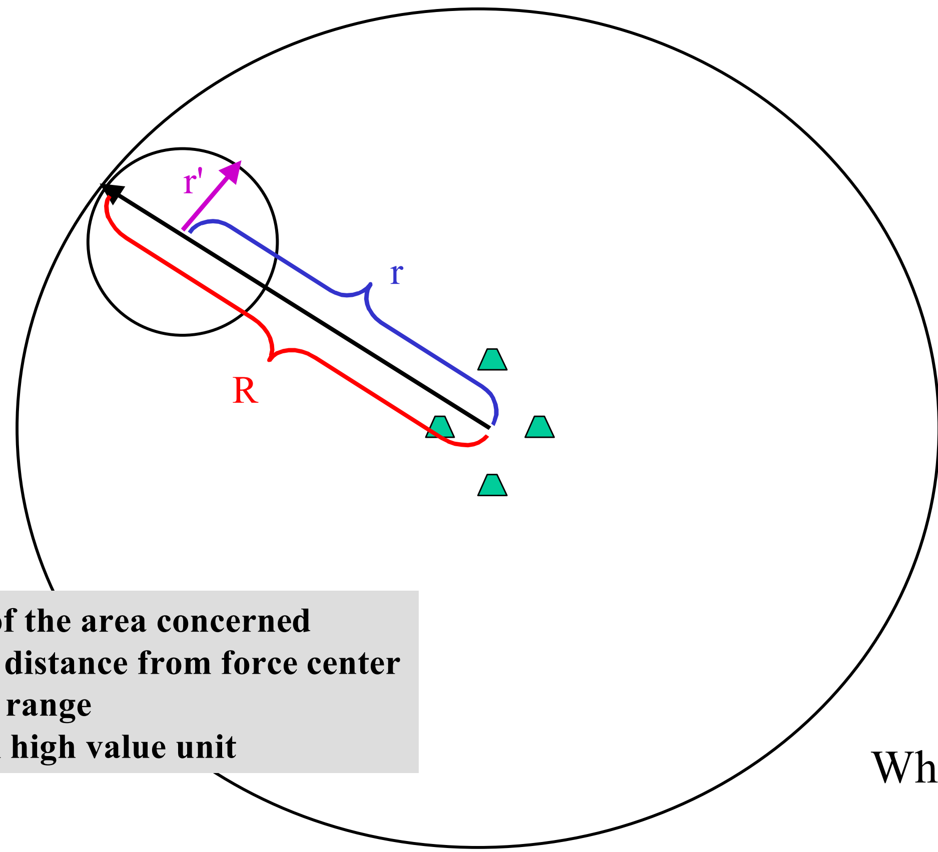
Distributed Weapon Configuration



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

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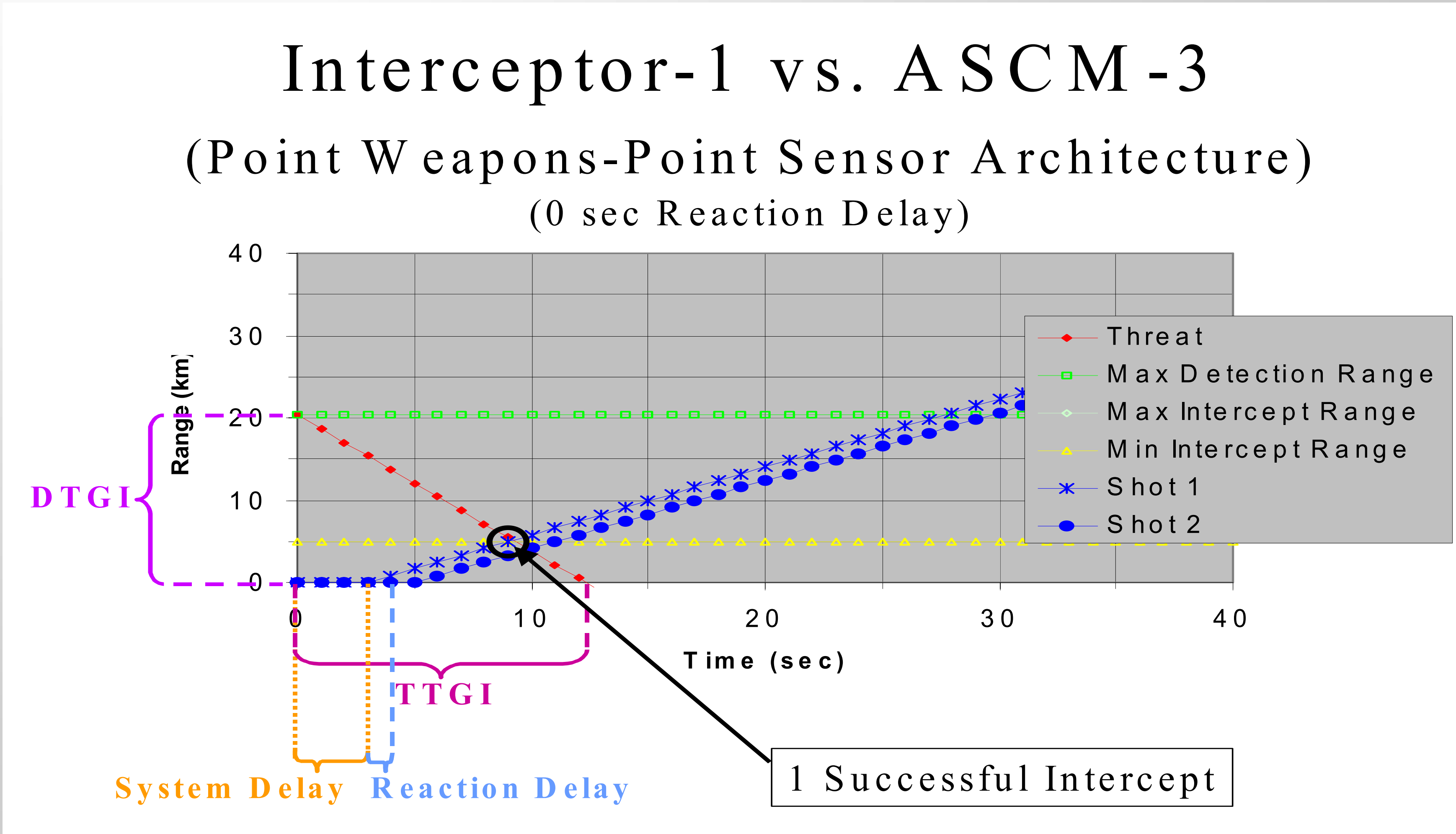

Greater Weapon Speed = Higher Pk

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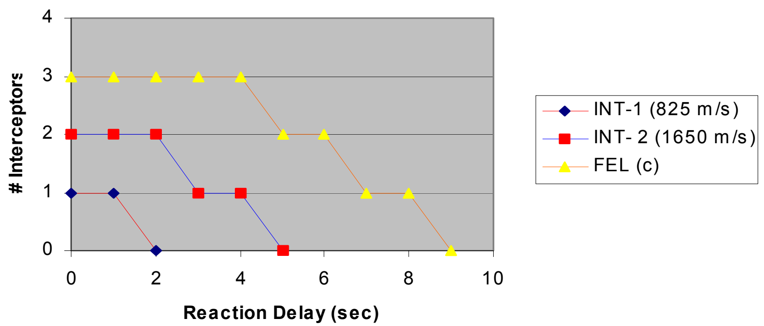
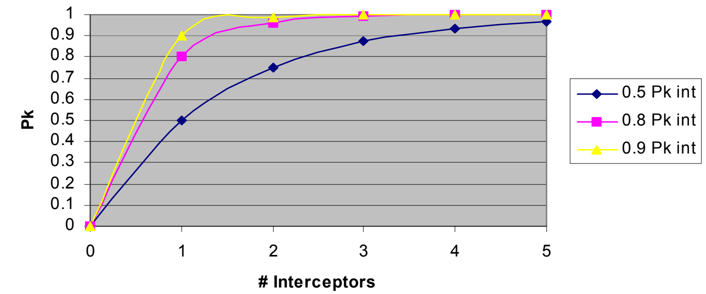
Interceptions vs. Reaction Delay
(Point Weapon-Point Sensor Architecture)



More Reaction Time = More Engagement Opportunities

P_k vs. # Interceptors



More Engagement Opportunities = Higher Probability of Kill

$$Pk=1-(1-Pk_{int})^{\#\ interceptors}$$

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

Distributed Sensors = Higher Pk

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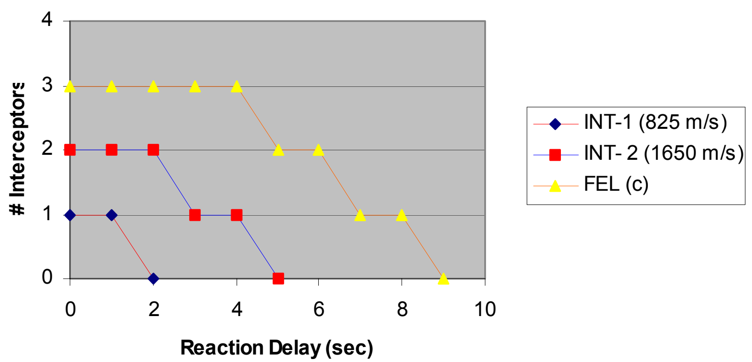
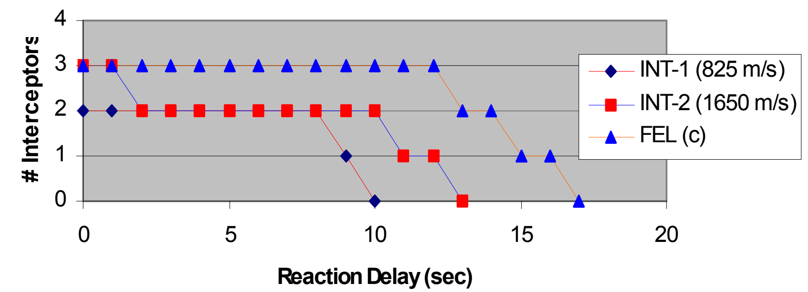
Interceptions vs. Reaction Delay
(Point Weapon-Point Sensor Architecture)



More Reaction Time = More Engagement Opportunities

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



Distributed Sensor = More Reaction Time = More Engagement Opportunities

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

Dist Weapons-Dist Sensors Pk

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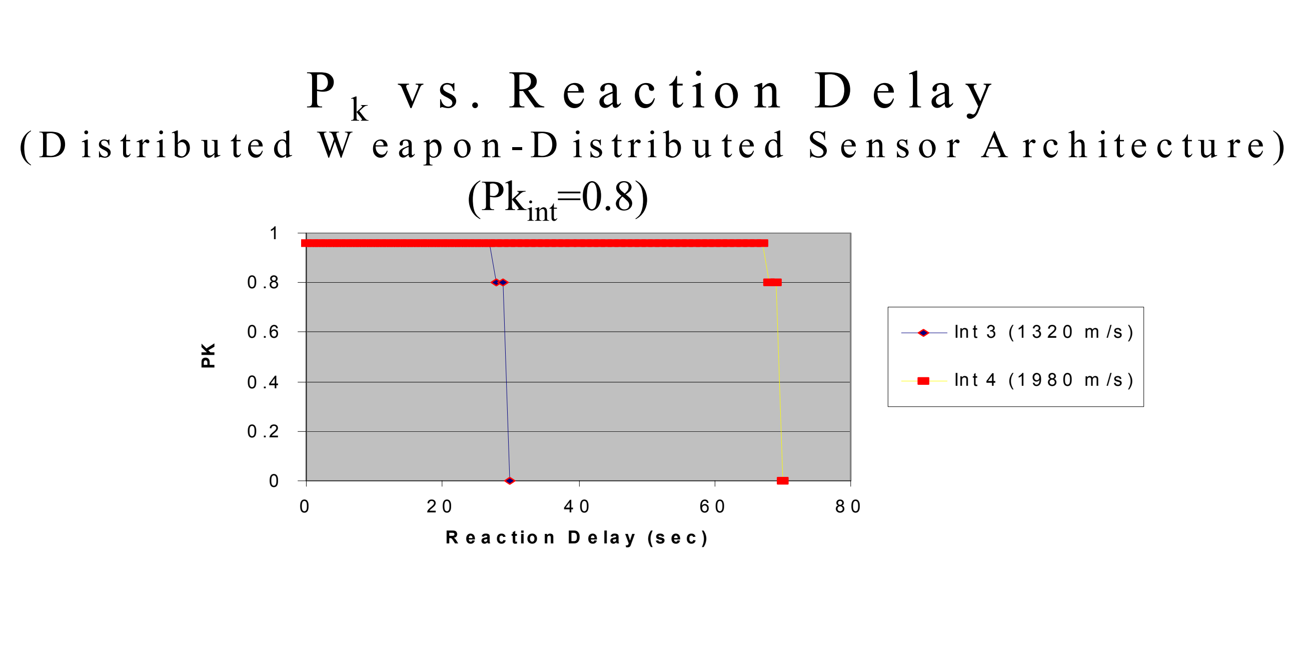


- $Pk=1-(1-Pk_{int})^{\#\ interceptors}$
- Longer range, higher speed weapons offer increased available reaction times

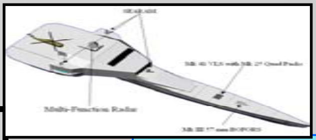
Design & Analysis Key Findings

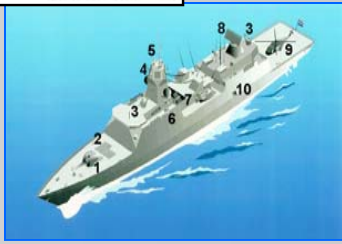
- Distributed sensor network offers increased force survivability
  - Greater reaction times
  - More engagement opportunities
- Point weapons vs. short-notice threats require
  - Greater weapons speeds
  - Reduced minimum ranges
  - Maximum ranges that are at least equal to maximum detection range
- Distributed conceptual weapons offer increased available reaction times
  - Higher weapon speed
  - Increased maximum ranges

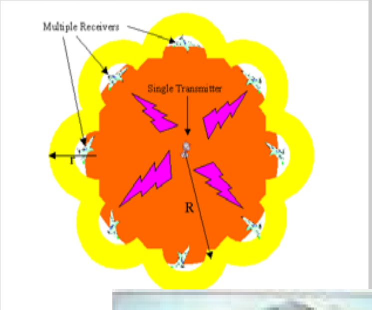
LT Tionquiao

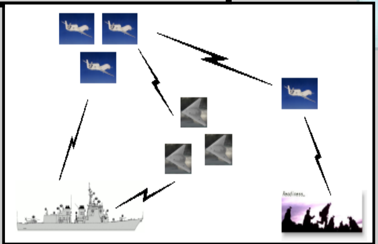
Supporting Studies Overview

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









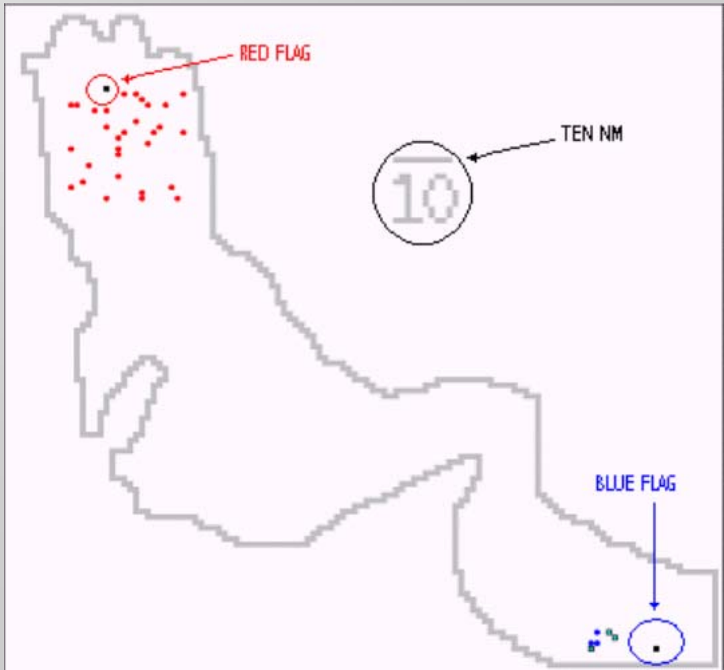
OR Supporting Study LCS Force Protection

- **"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.
  - LCS design factors: 1. Helo / UCAVs 2. Stealth 3. Firepower 4. Speed

- **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 Supporting Study
LCS AAW Self-Defense

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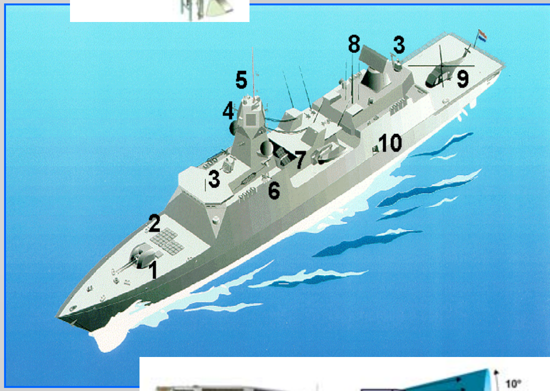
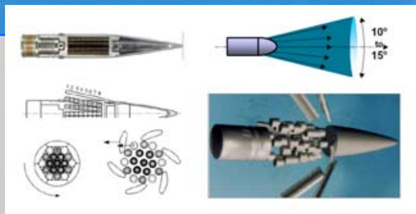
- **"MSSE LCS Study"** – MSSE Cohort 1, Port Hueneme Division, NSWC
- **Purpose**: Develop a concept for an AAW Self Defense Combat System for LCS

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

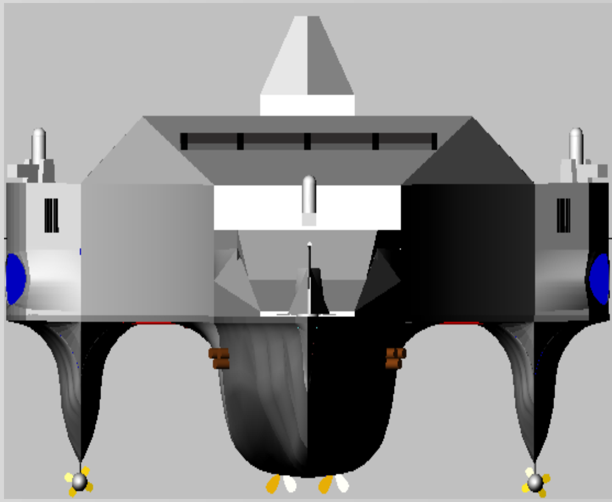


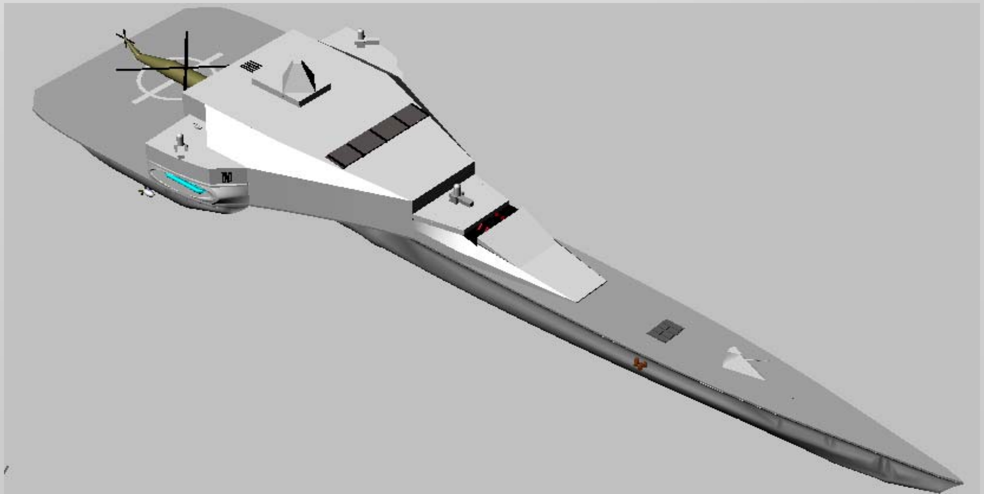
- **Conclusion**:
  - Robust gun system can perform in both AAW and ASUW roles
  - Both hardkill and softkill systems in a layered defense scheme is necessary to achieve the required P_{ra}
  - Layered defense concept still viable in littoral environment



TSSE Supporting Study
LCS Design: Sea SWAT

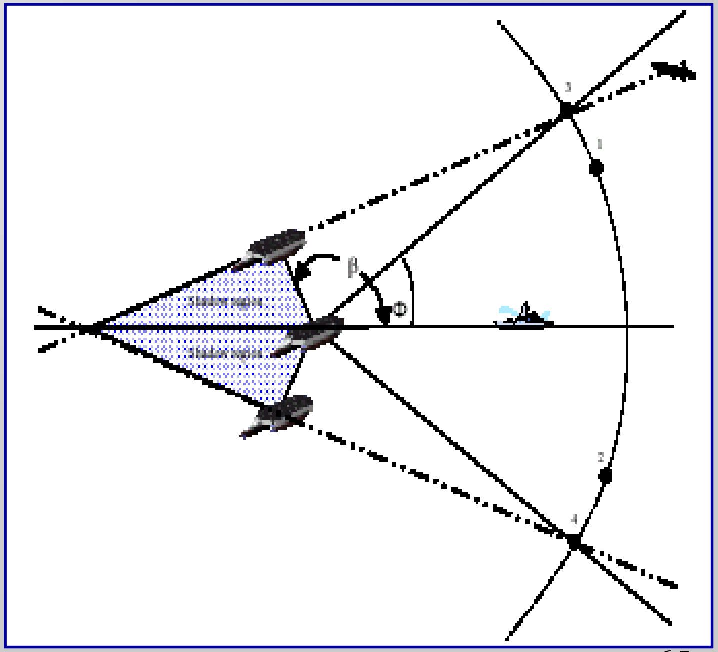
- Two types:
  - SUW and AW
  - SUW and USW
- Specifications
  - Length: 400 ft
  - Beam: 102 ft
  - Draft: 14 ft
  - Displacement: 3120 LT
  - Max Speed: 42 kts
  - Sustained Speed: 35 kts
- Weapons
  - 57mm gun
  - SEA RAM
  - Harpoon
  - Evolved Sea Sparrow
  - Mk 50 Torpedo
- Sensors
  - Towed array sonar
  - Multi-Function radar
  - ASLS
  - Hull mounted sonar
- 2 Helos (SH-60)
  - 2 Hangars, 1 Spot
- Unmanned Vehicles
  - Air, surface, underwater





OR Supporting Study Defender Employment

- **"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



CS Supporting Study Information Assurance

- **"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

Physics Supporting Study CRANK

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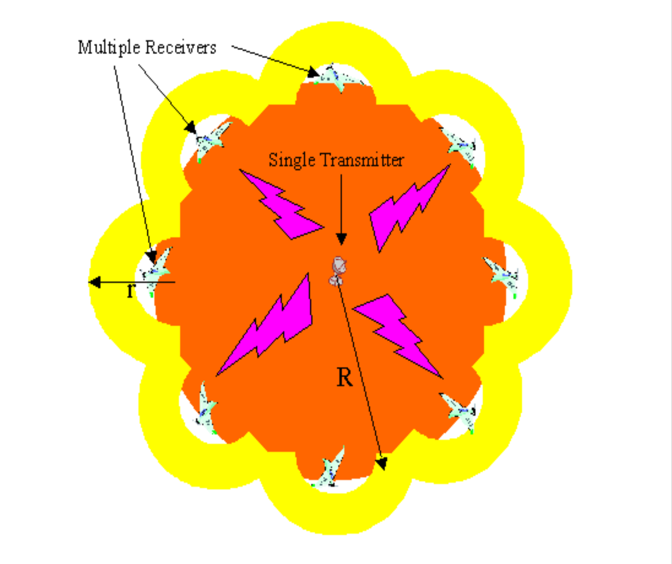
- **"Cooperative Radar Network (CRANK): Concept Exploration for Defending the Sea Base"**, SI4000 Sensor (Physics) TDSI Team

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

- **Design**: 360 degree coverage, 200 nm range, .01 m^2 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



ECE Supporting Study
Smart Antennae System

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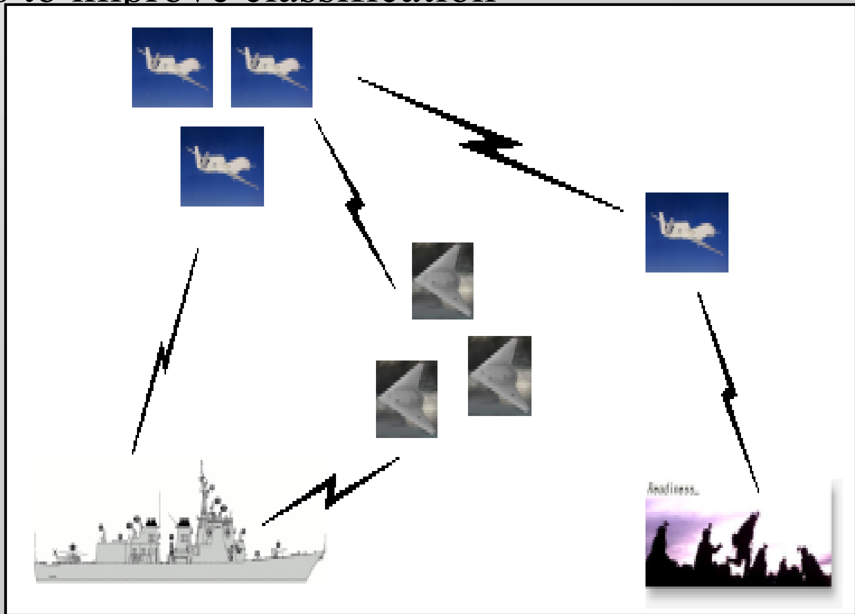
- **"Protection of Sea Base"** SI4000 - Sensors (ECE) TDSI Team
- **Purpose**: Propose ways to achieve active defense by "out sensing" the enemy
- **Methodology**:
  - Threat identification: High density, high speed, low signature
  - Analysis of data fusion and wireless sensors to improve classification
- **Conclusion**:
  - Smart Antennae System increases range and reliability of wireless sensors
  - Provides insights into distributed sensor network details.



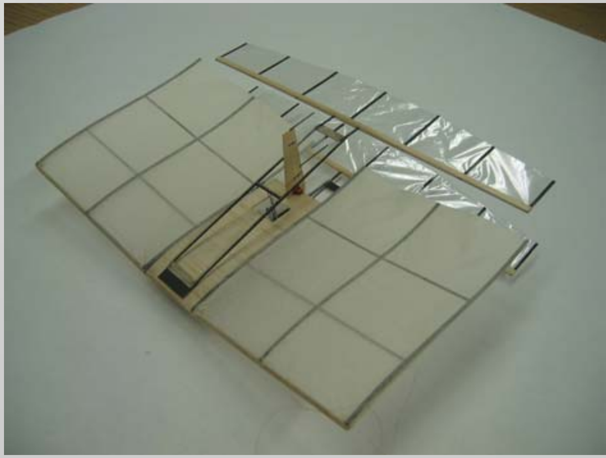
ME (Weapons) Supporting Study MAV

- **"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



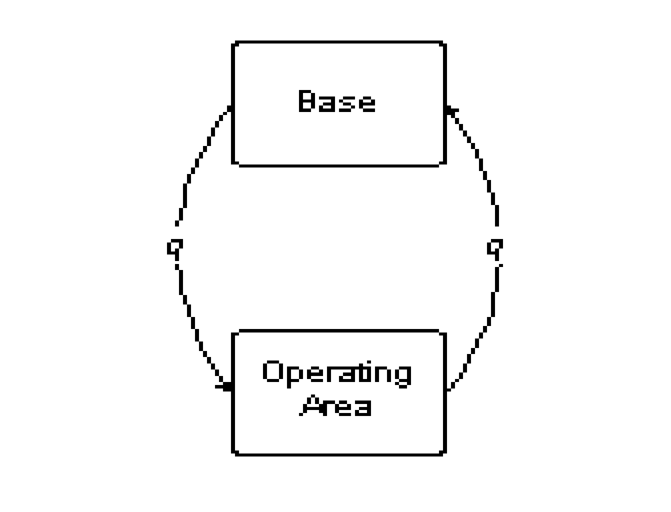
OR Supporting Study SSGN

- **"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



LCDR Higgins

LT Tionquiao

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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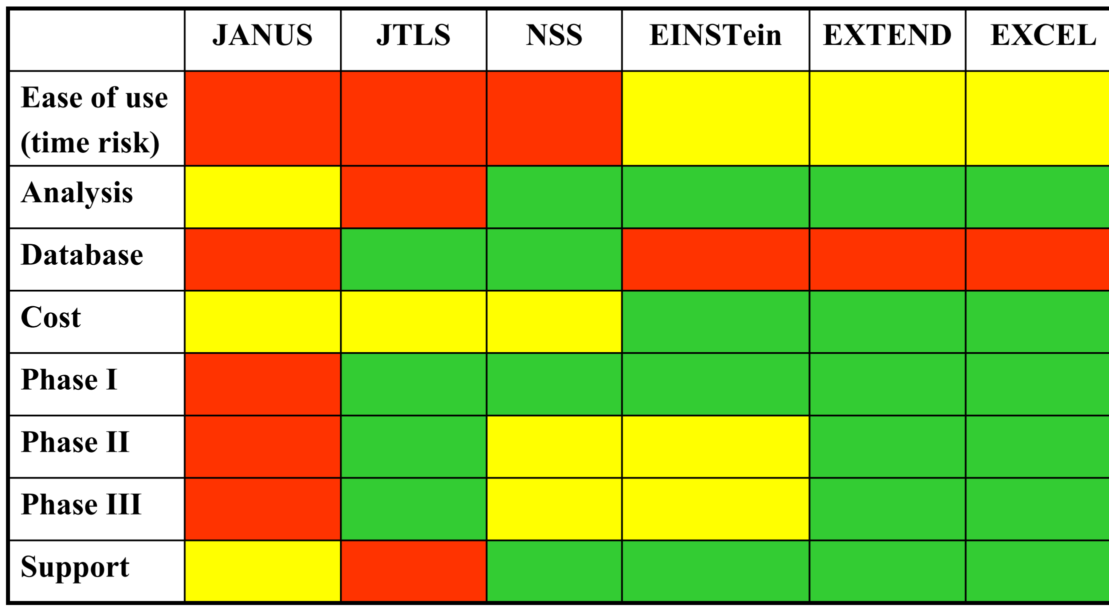
- Tools Available
  - JANUS
  - JTLS
  - NSS
  - EINSTein
  - EXTEND
  - Excel
- Final Selection
  - EXTEND
  - NSS



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

Force Composition

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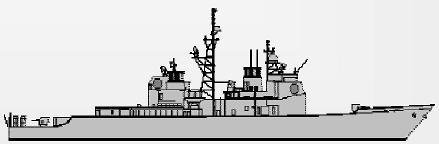
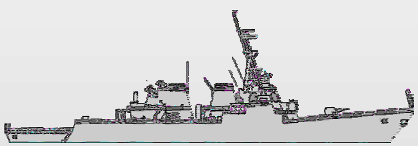
COA A

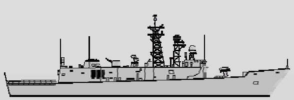
3 CG



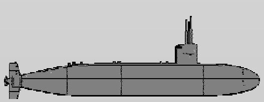
3 DDG



3 FFG



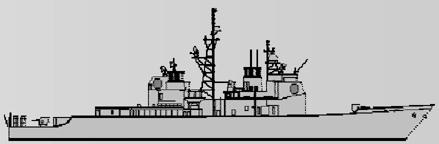
1 SSN



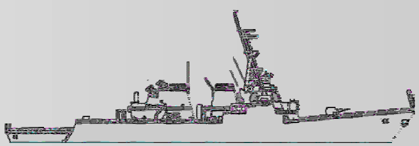
CRUDES-based

COA B

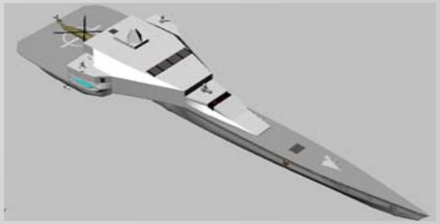
1 CG



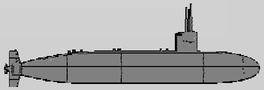
1 DDG



12 LCS

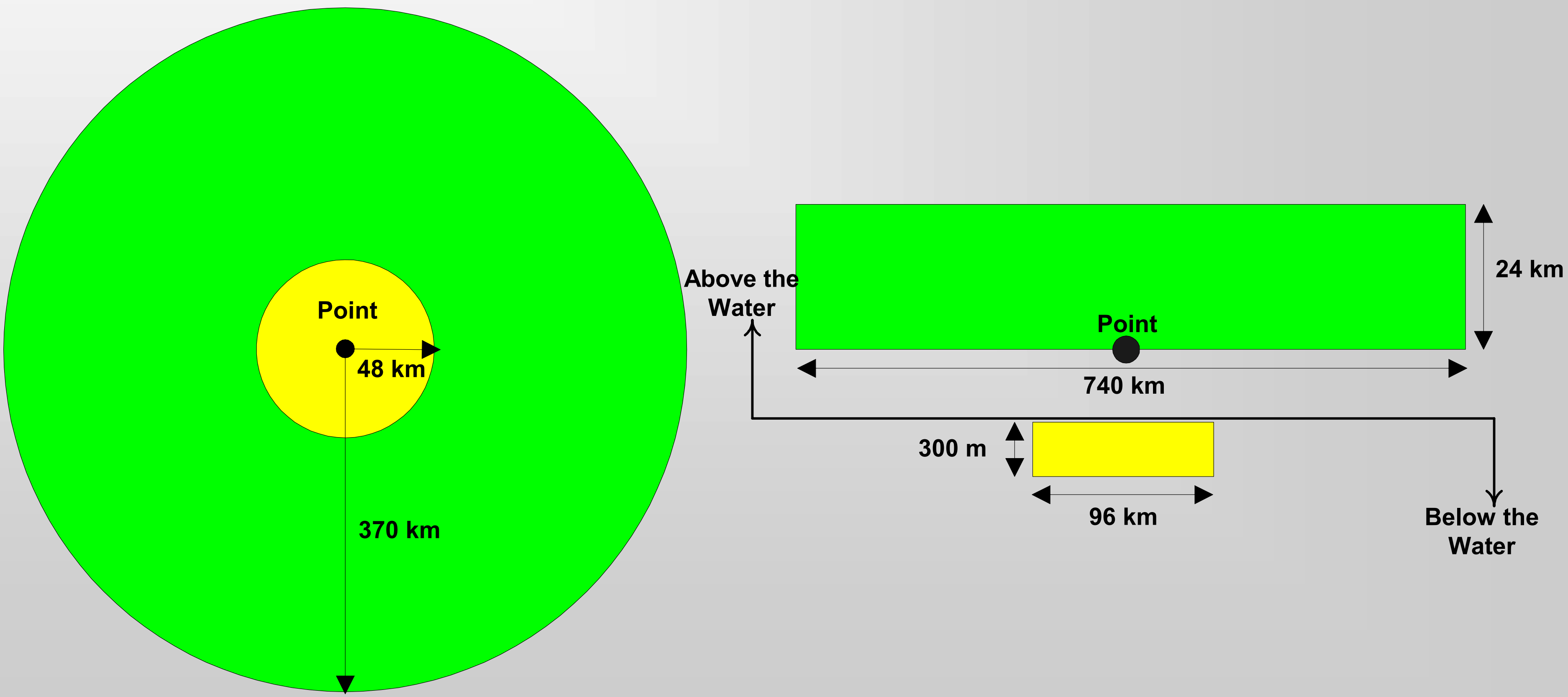


1 SSGN

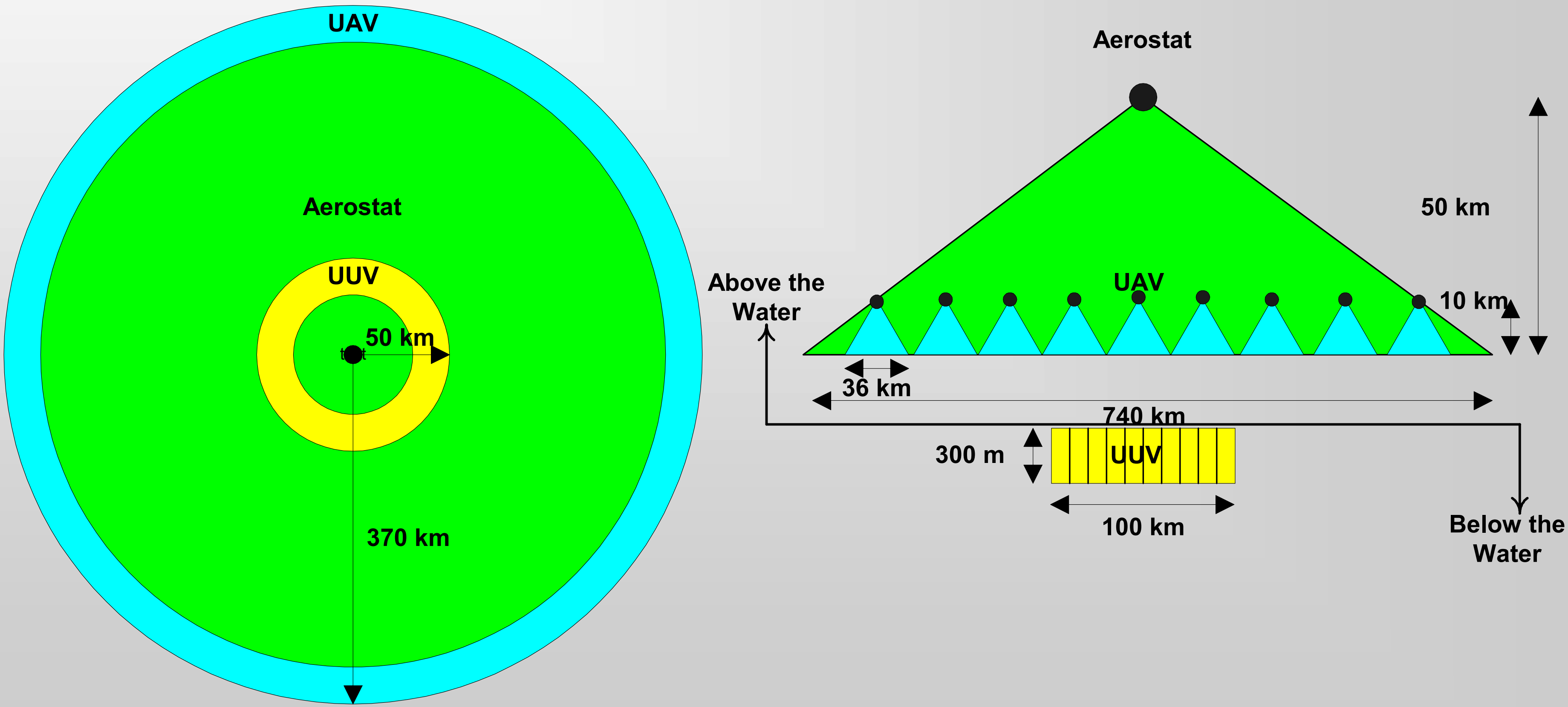


LCS-based

Point Sensor/Weapon Architecture



Distributed Sensor/Weapon Architecture



Weapons

Weapon	Type	Speed (m/s)	Max Range (km)	Min Range (km)
Current Weapons				
Interceptor 1	Surface to air missile	825	130	5
Interceptor 3	Air to air missile	1320	56	2
Torpedo 1	Surface or sub-surface torpedo	20.6	7.3	.1
Conceptual Weapons				
Interceptor 2	Surface to air missile	1650	370	5
Interceptor 4	Air to air missile	1980	93	2
Free Electron Laser	Directed energy	$3x10^8$	10	2
Torpedo 2	Surface or sub-surface torpedo	25.7	11	.1

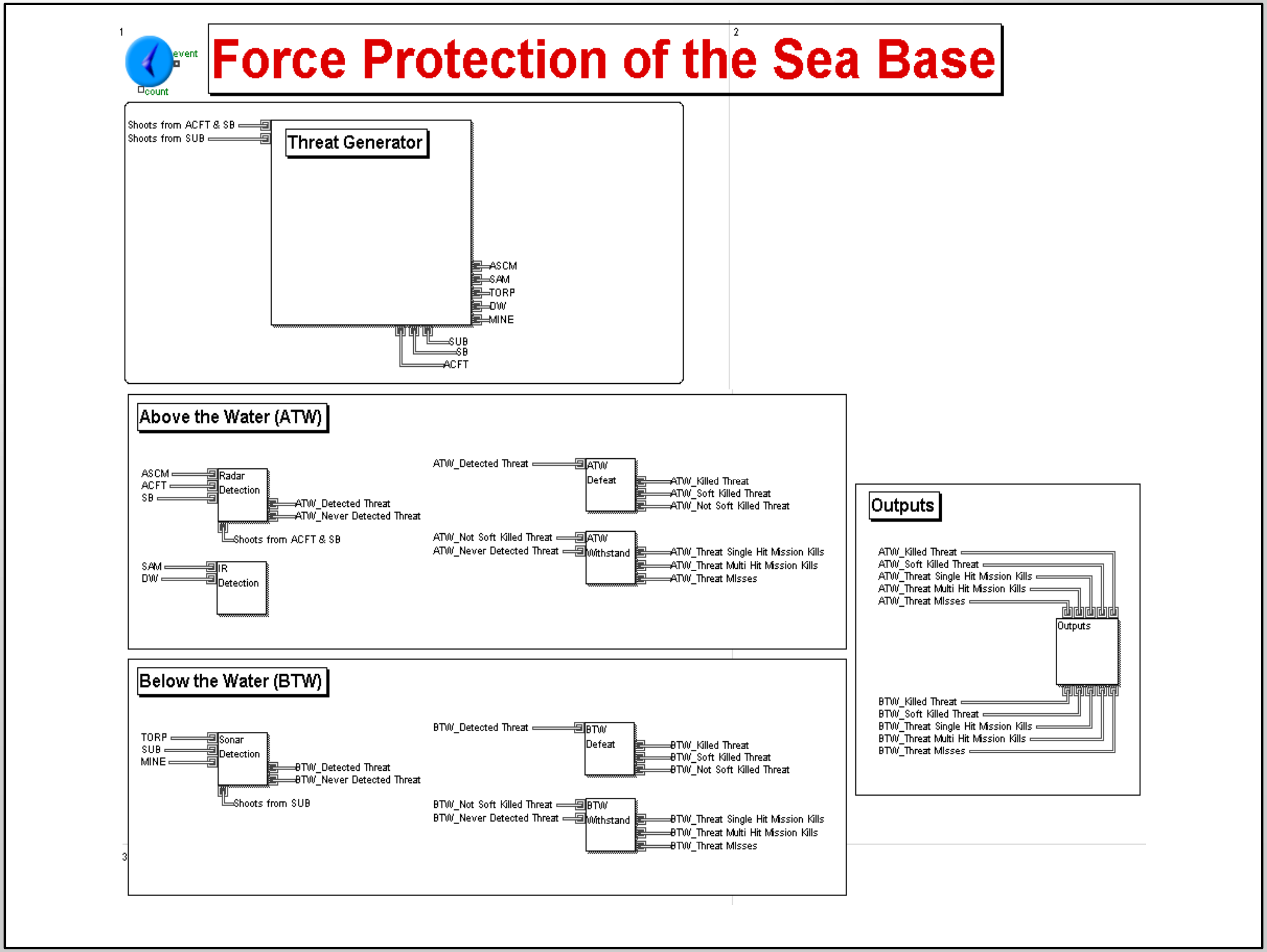
Measure Of Effectiveness

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

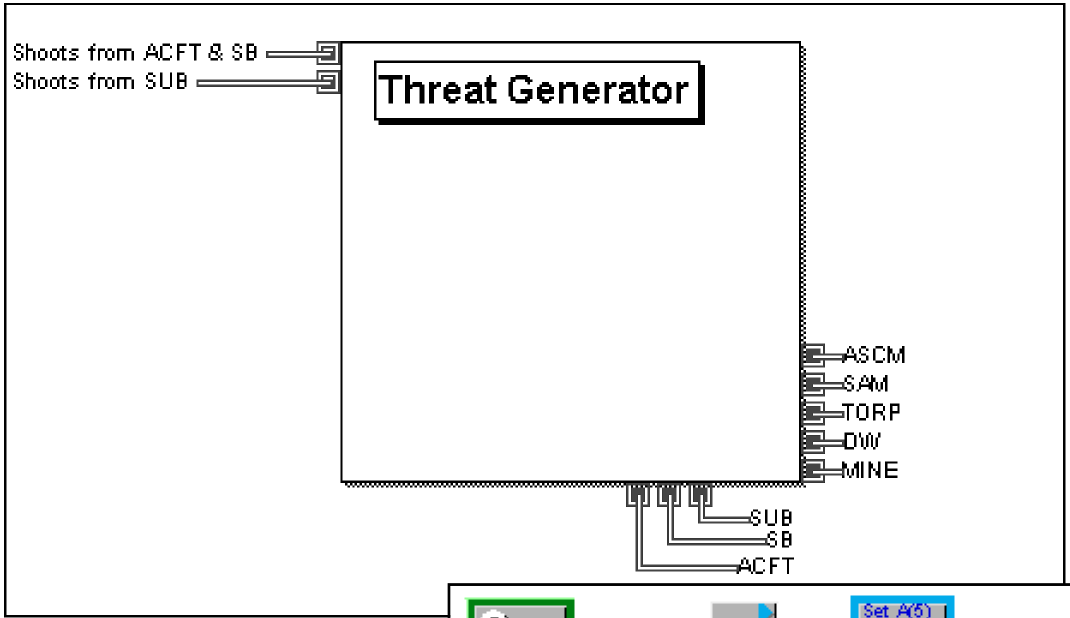
EXTEND Modeling

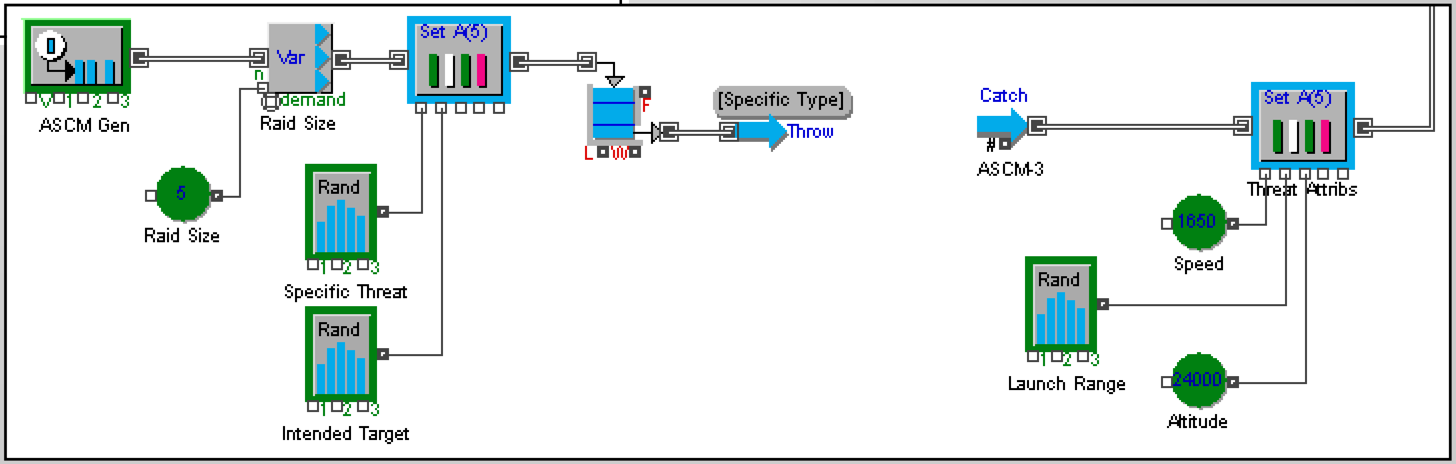
- **EXTEND Overview:** Process based, discrete event modeling and simulation tool. Provides a macro-view of sensor, weapon, and threat interactions.
- **Design Factors:**
  - **Force Composition:** COA A, COA B
  - **Sensor and Weapon Architecture:** Point, Distributed
  - **Weapons:** Current, Conceptual
- **MOEs:** % of assets mission capable
- **Inputs:** Sensor and search model calculations. Characteristics of weapons, platforms, and sensors.
- **Outputs:** # mission kills, # of mission kills by threat

EXTEND Model

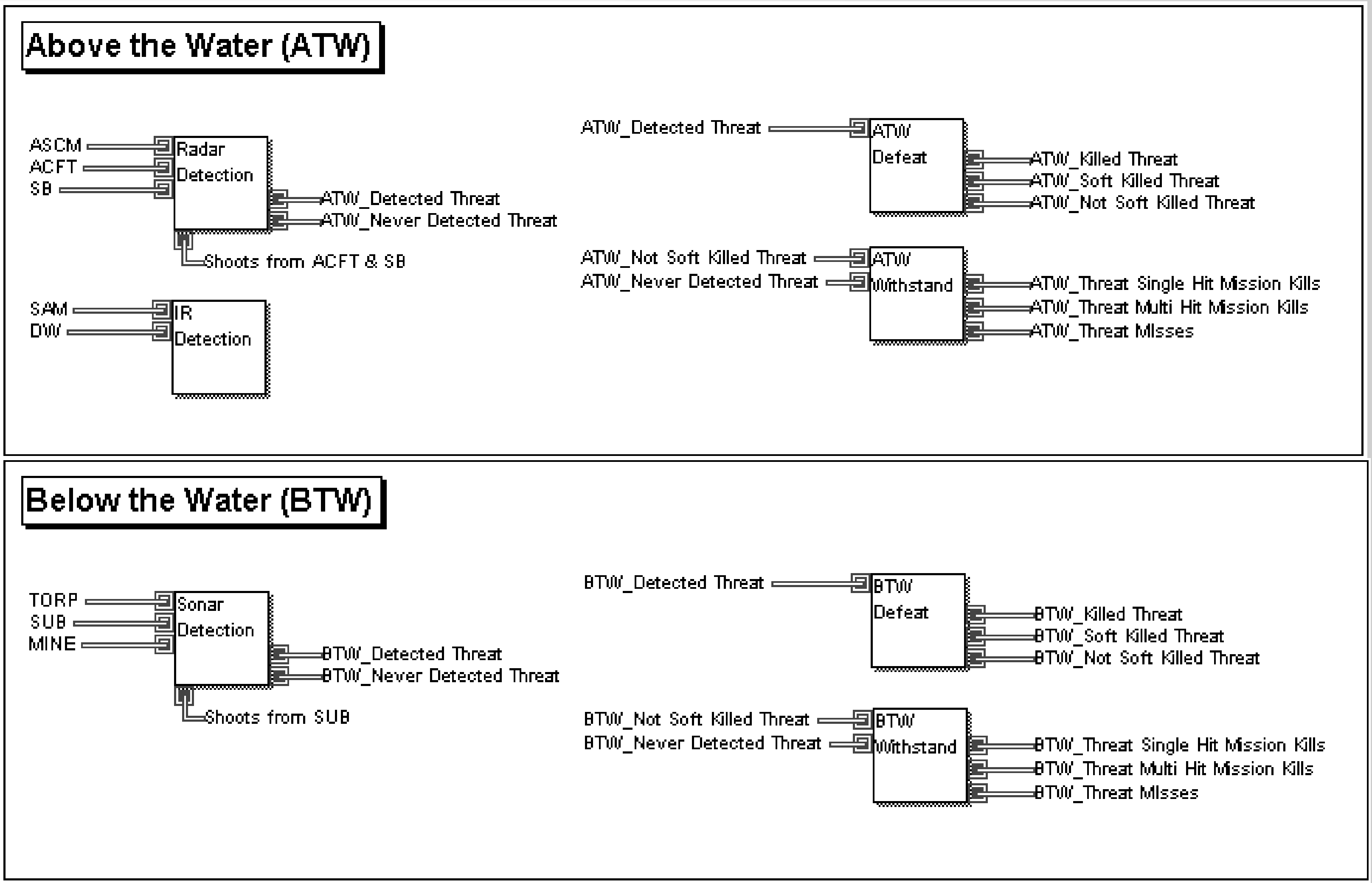


EXTEND Model





EXTEND Model



EXTEND Model

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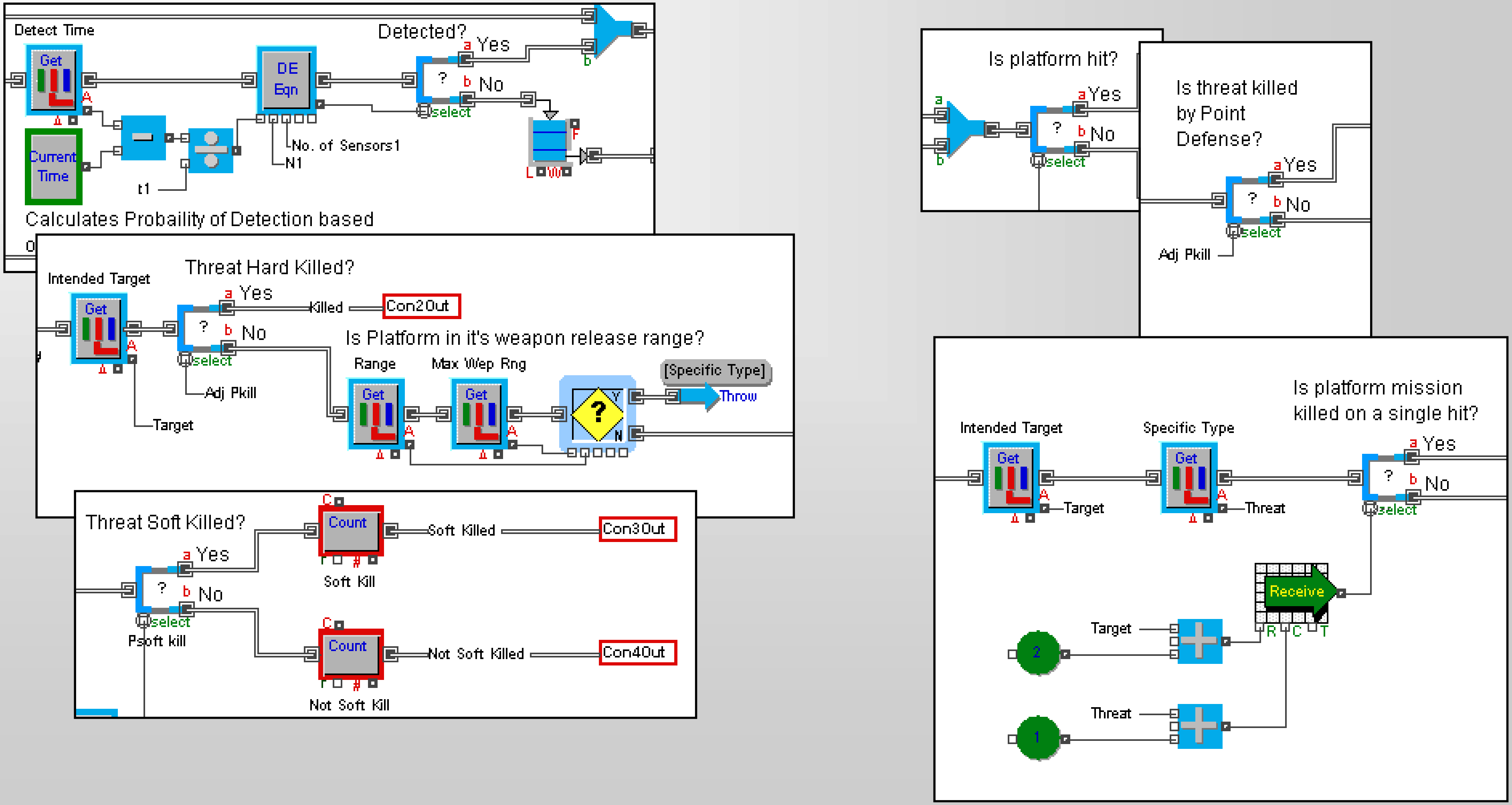

EXTEND Model

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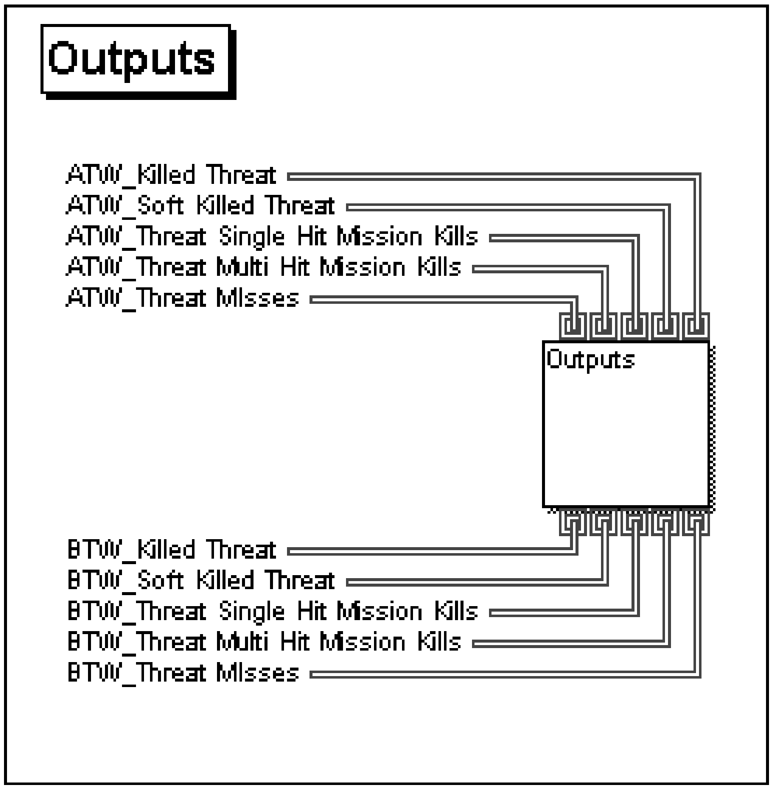

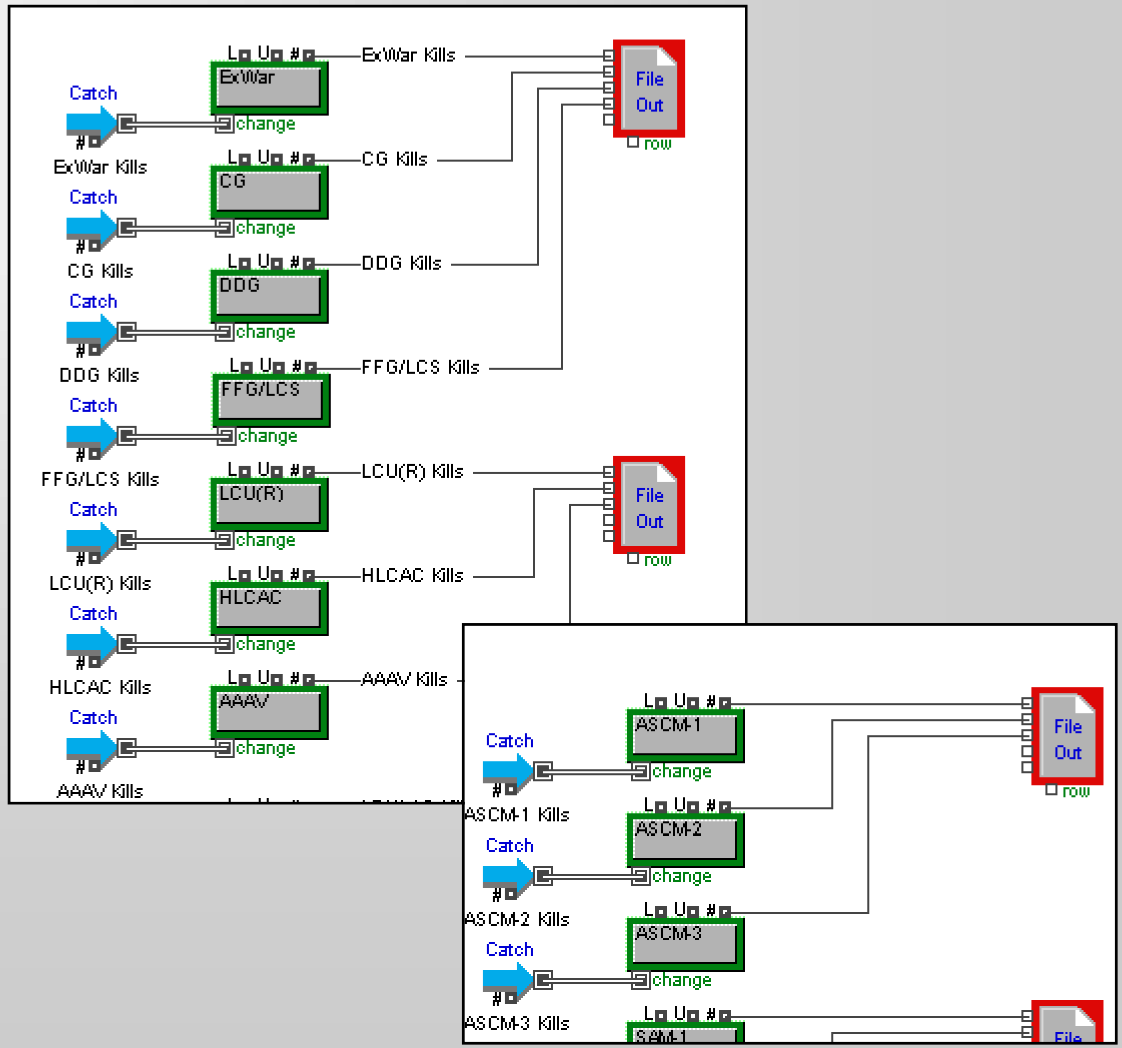

EXTEND Model Results

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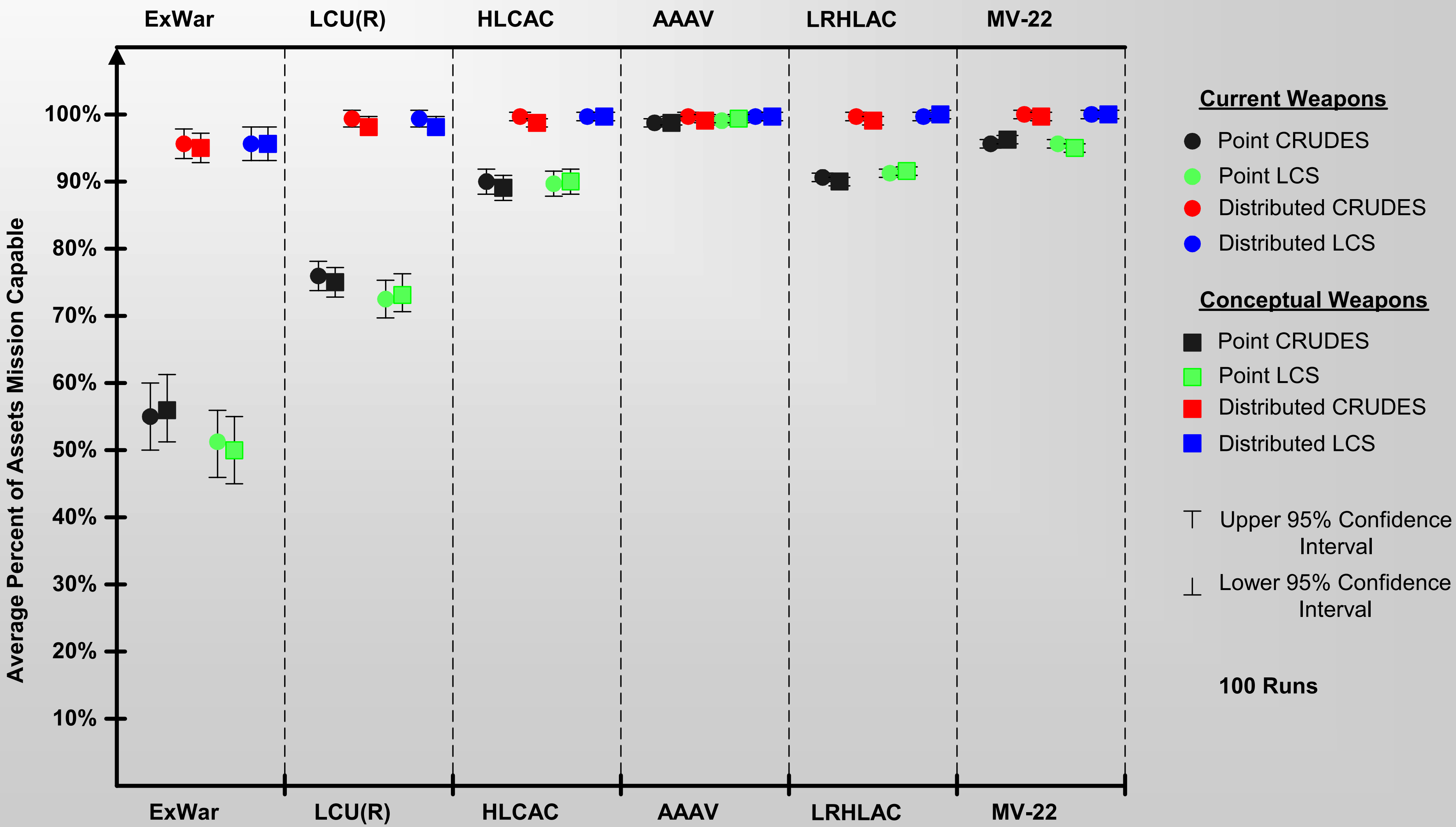

Distributed Sensors and Weapons Increase Force Survivability

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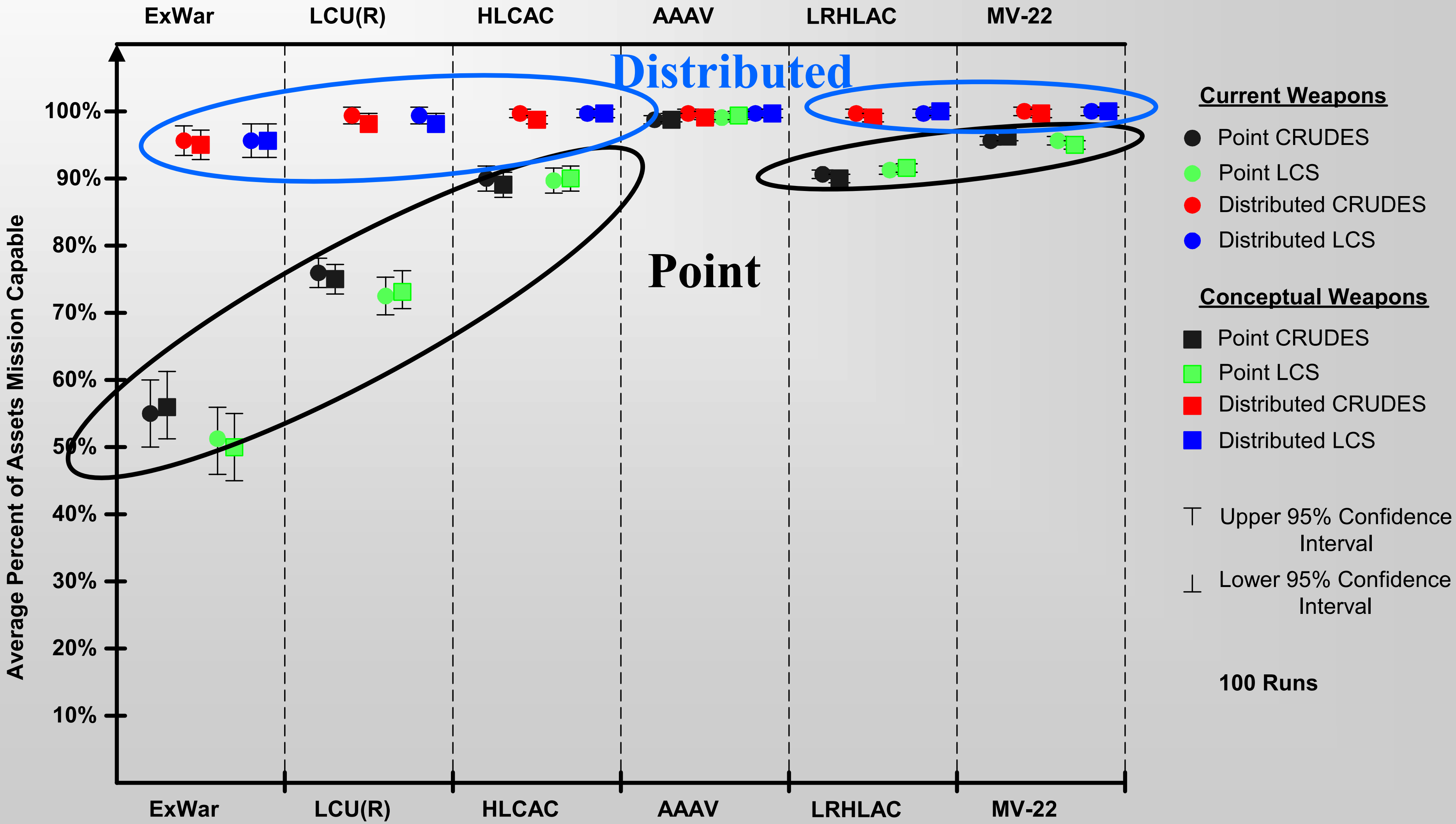
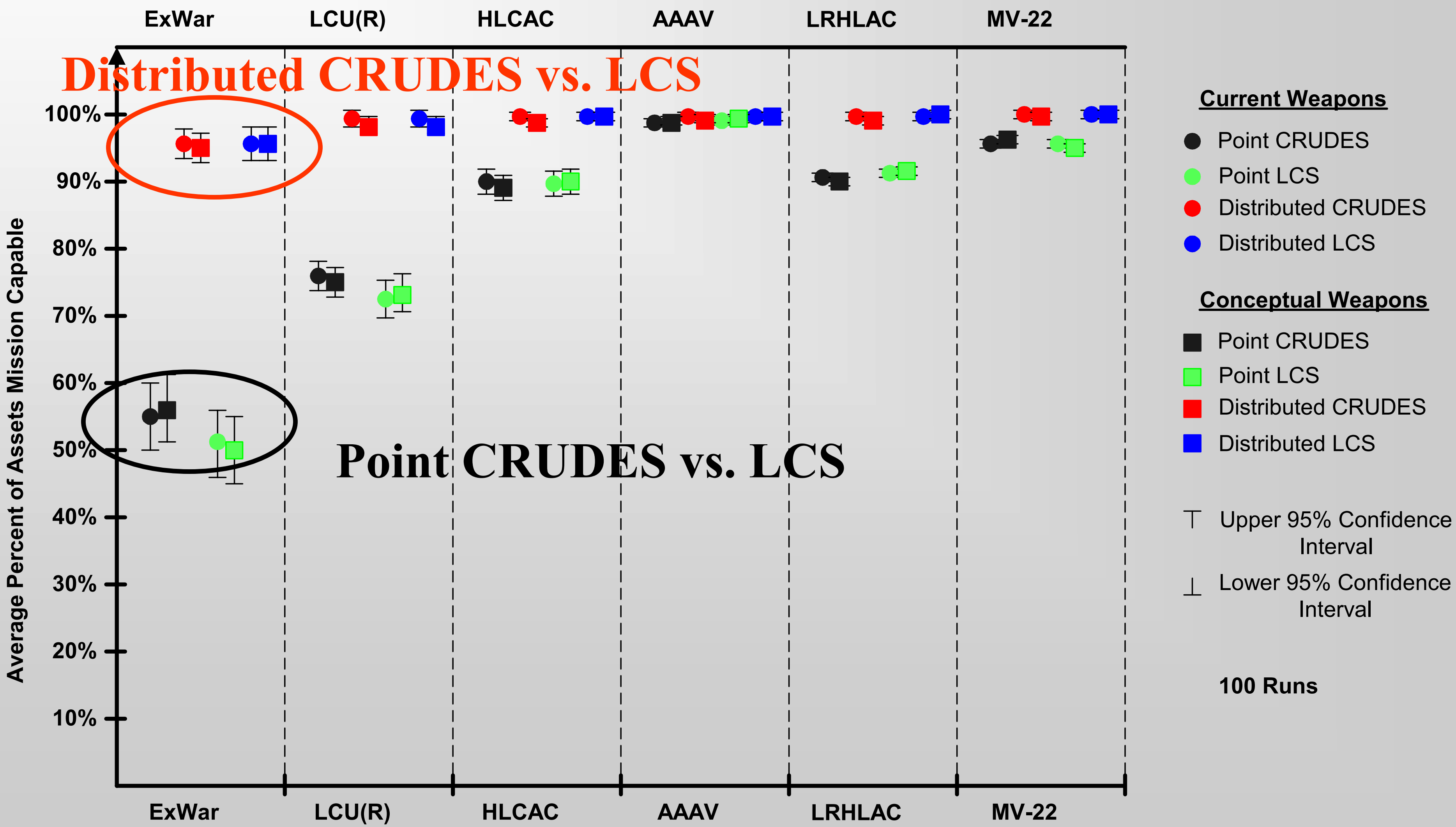


CRUDES-based and LCS-based Forces Roughly Equivalent



No Significant Difference Between Current and Conceptual Weapons

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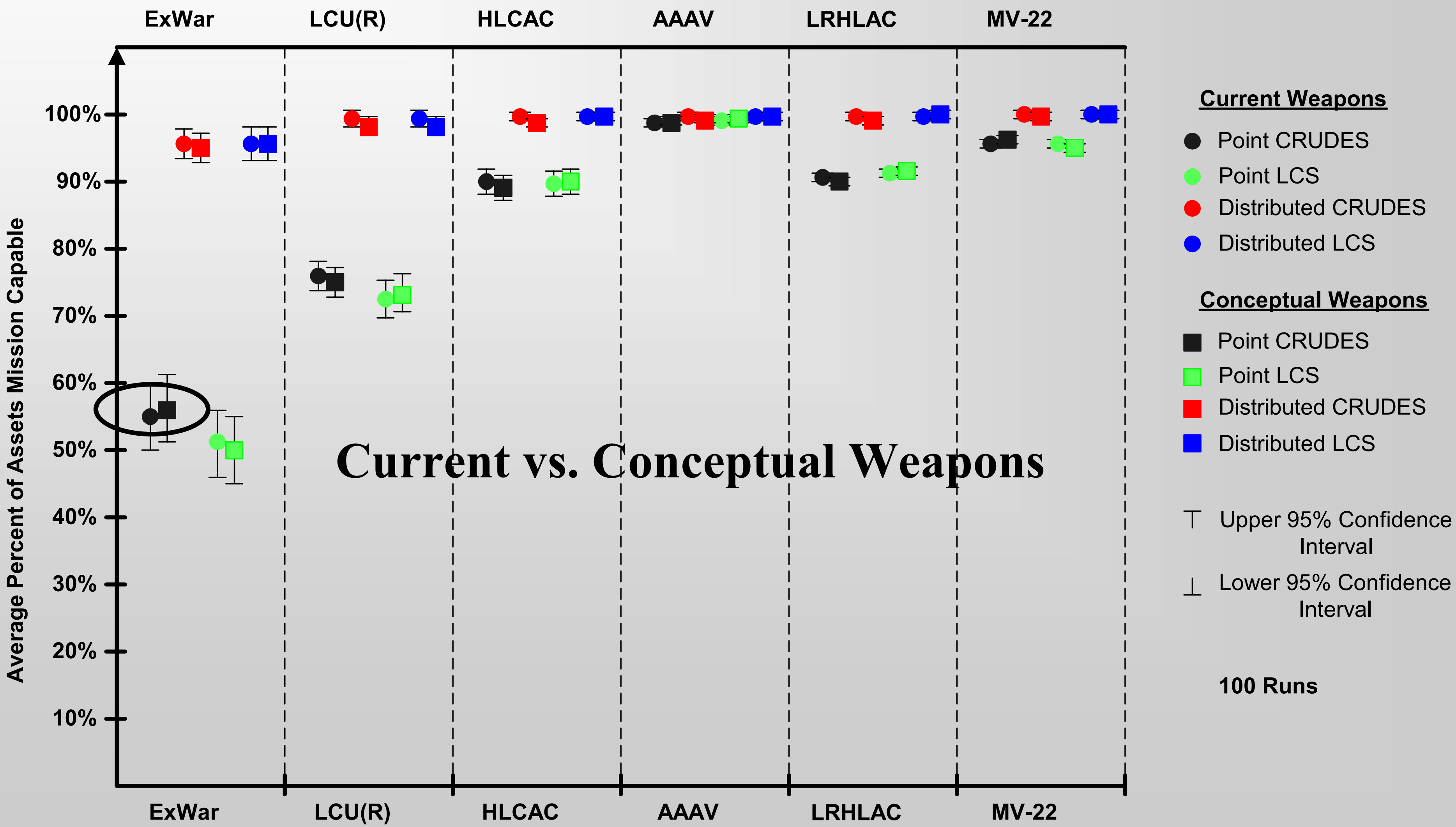

Distributed = Increased ExWar Ship Survivability

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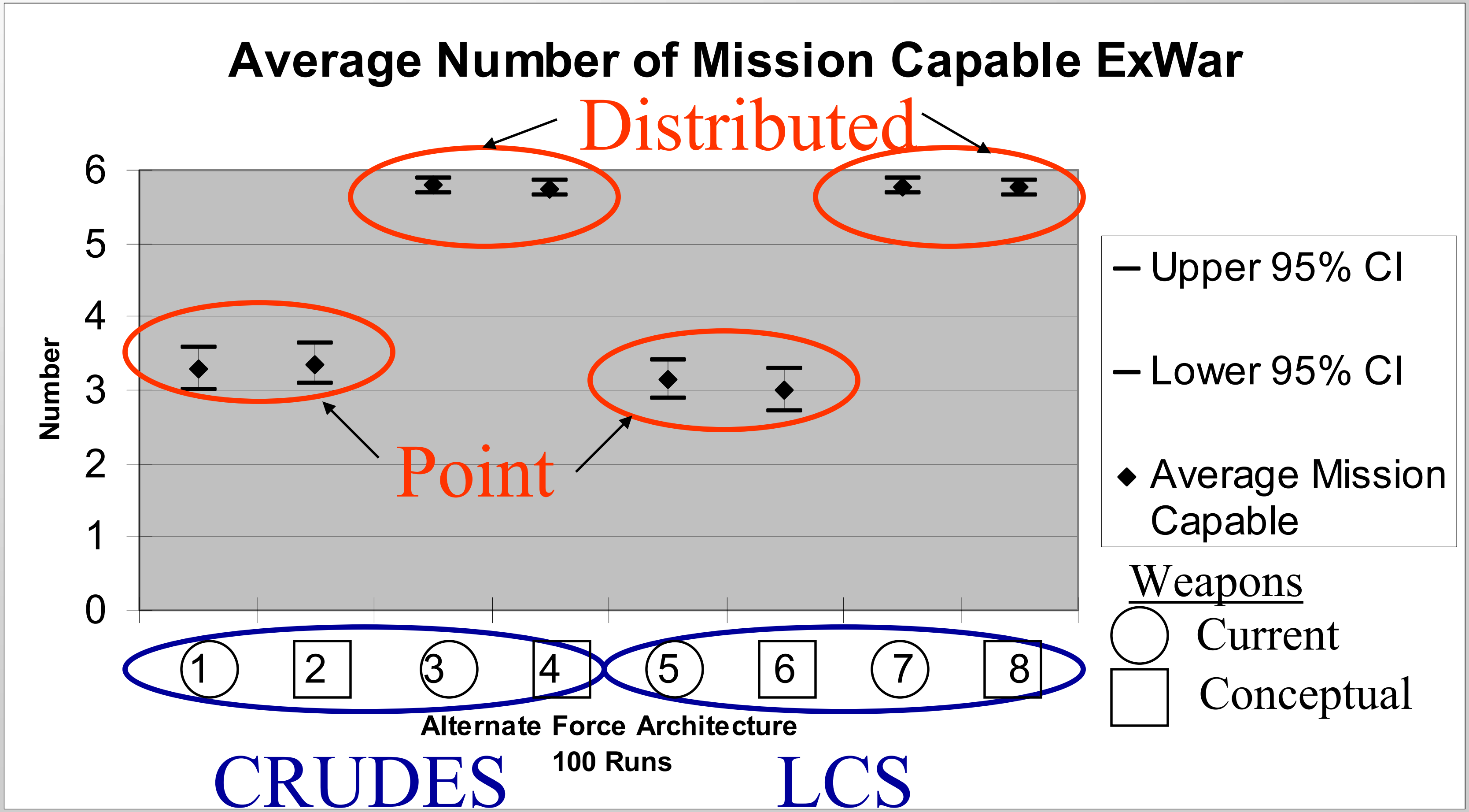
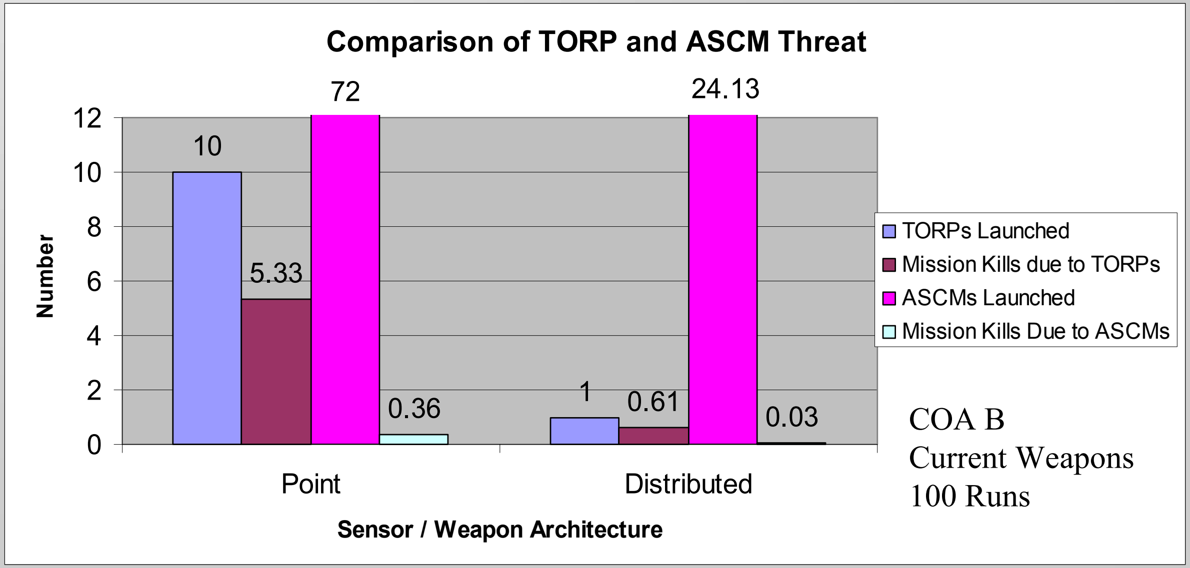


SUB/TORP Threat Inflicts Most Ship Mission Kills

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



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

Force Composition in NSS

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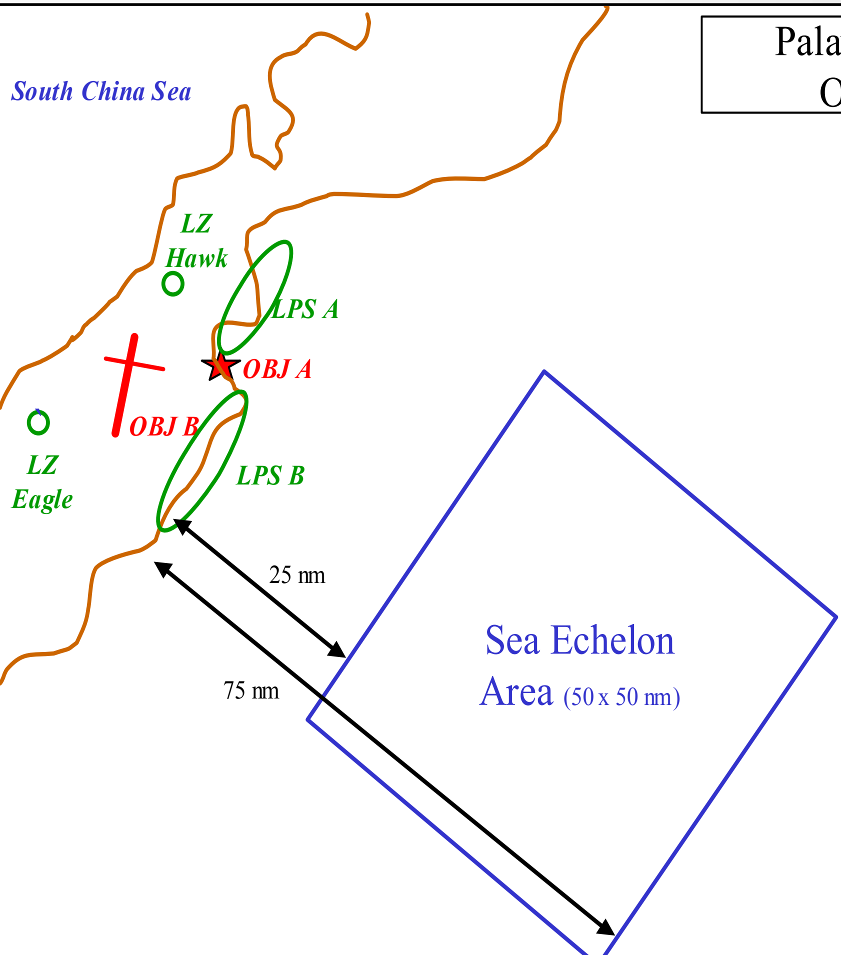

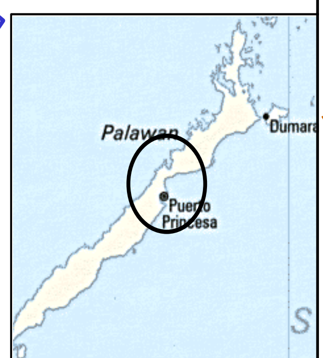

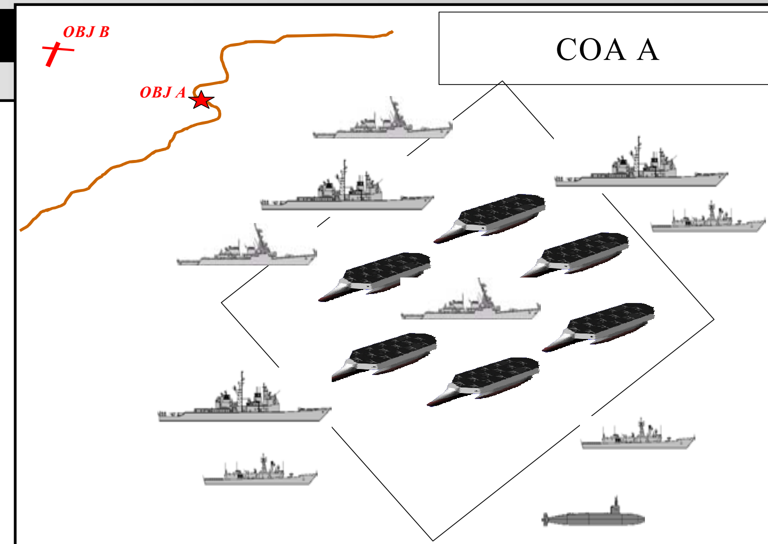

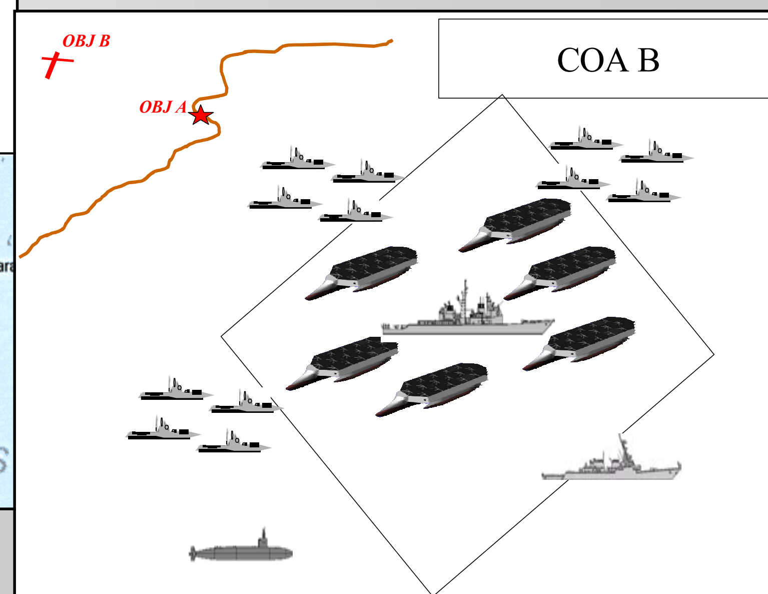

Distributed Architecture in NSS

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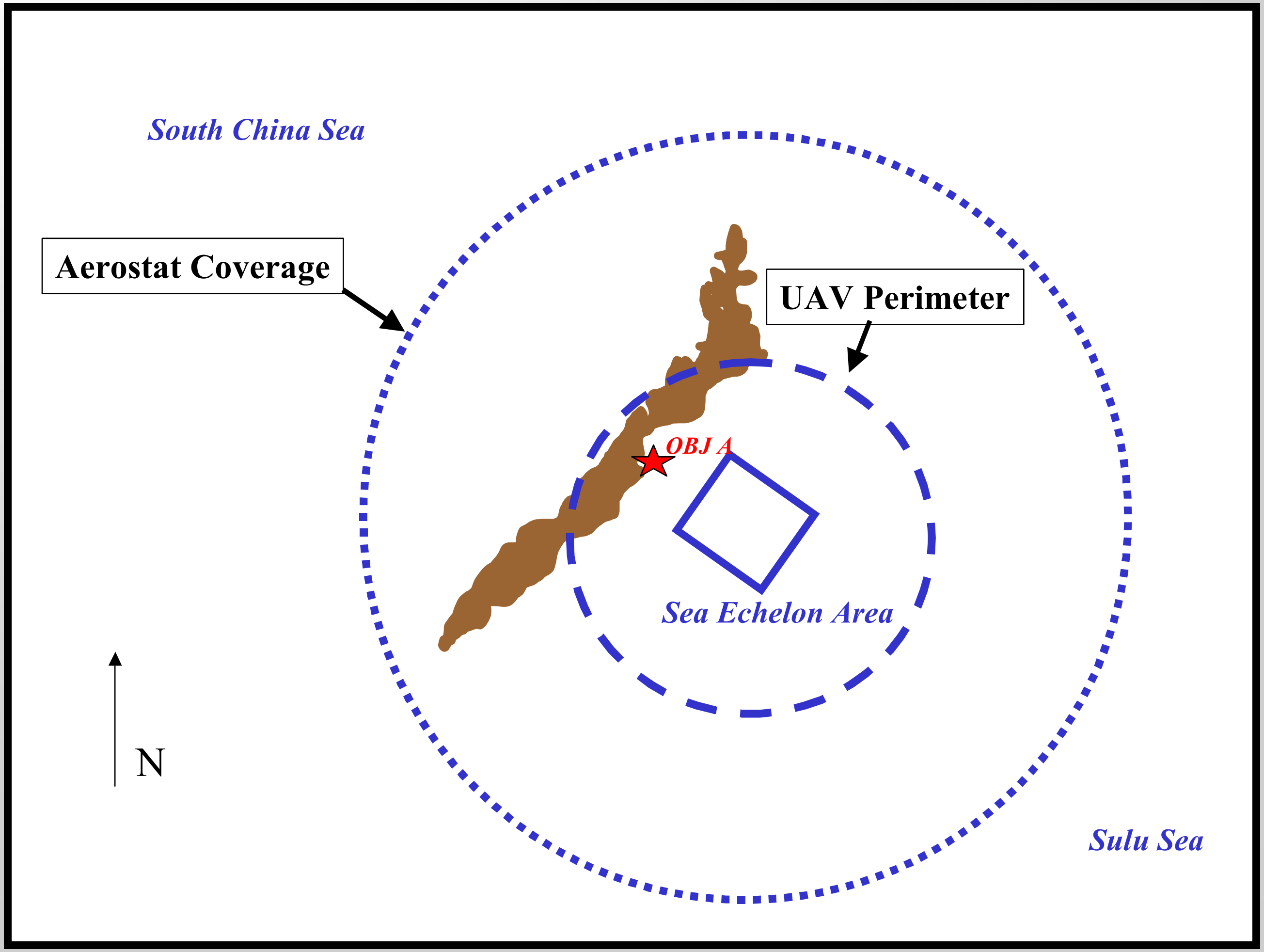
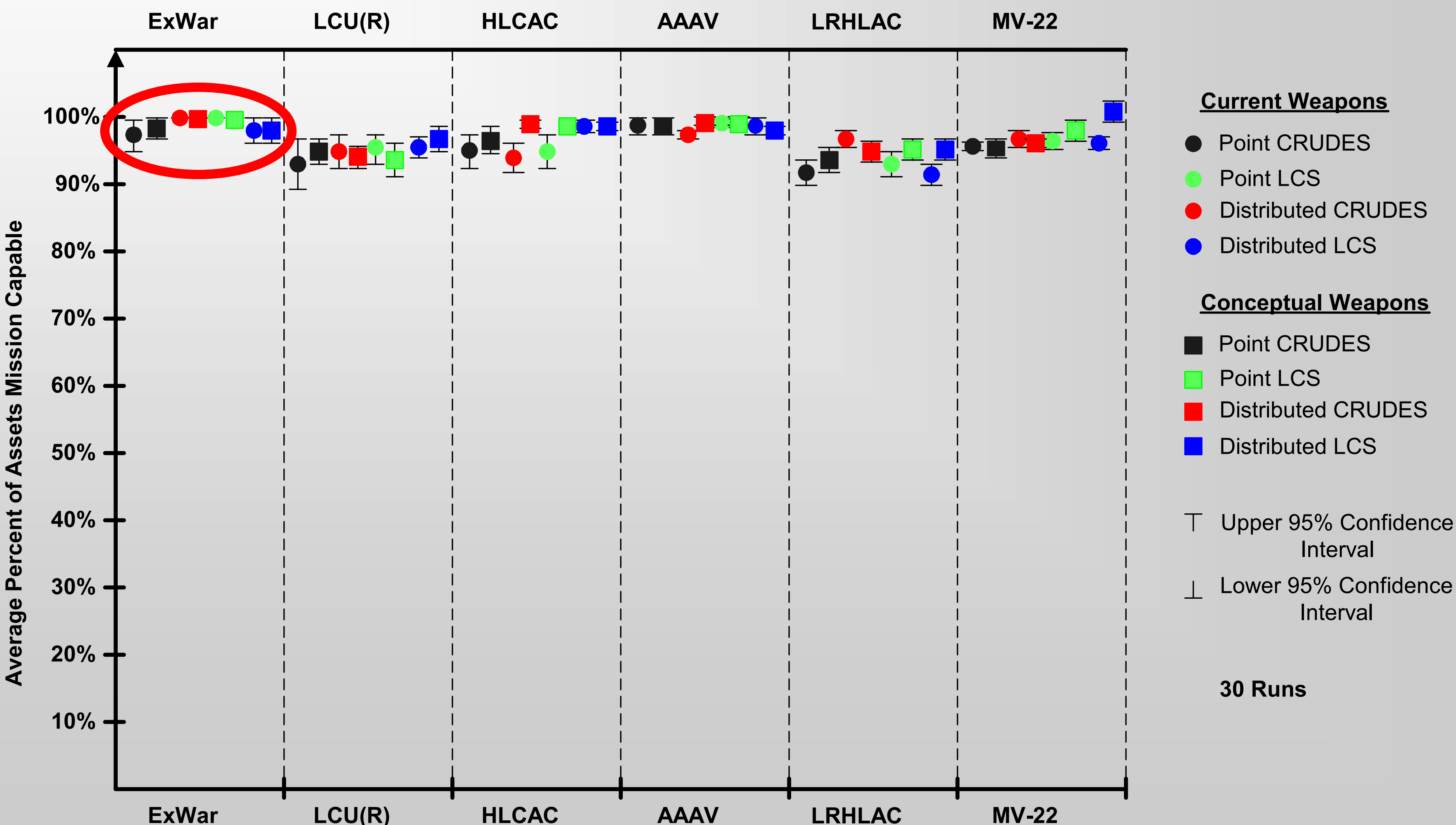


Confounding Results Between Architectures



Distributed Architecture Increases Survivability Along Threat Axis

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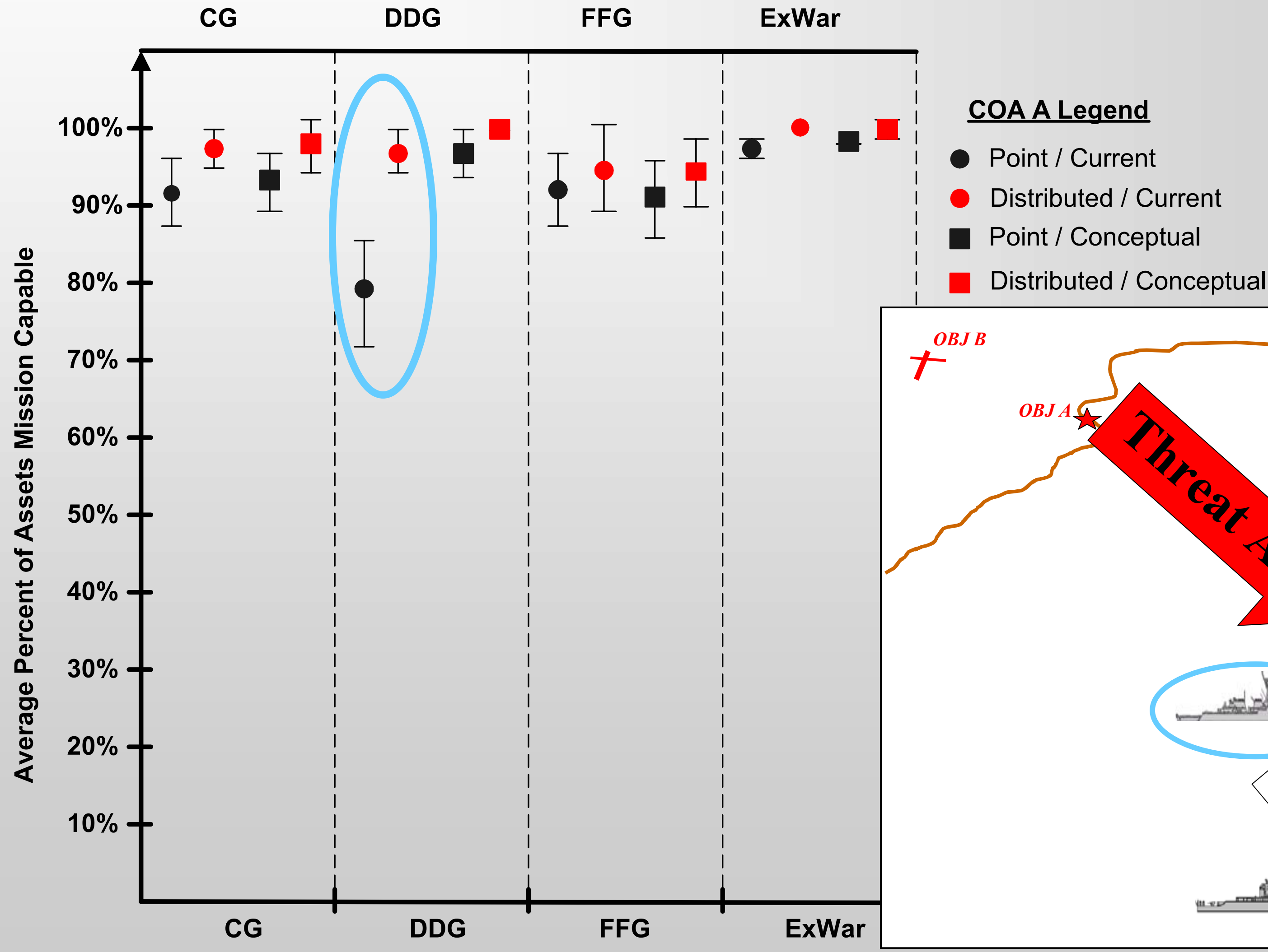
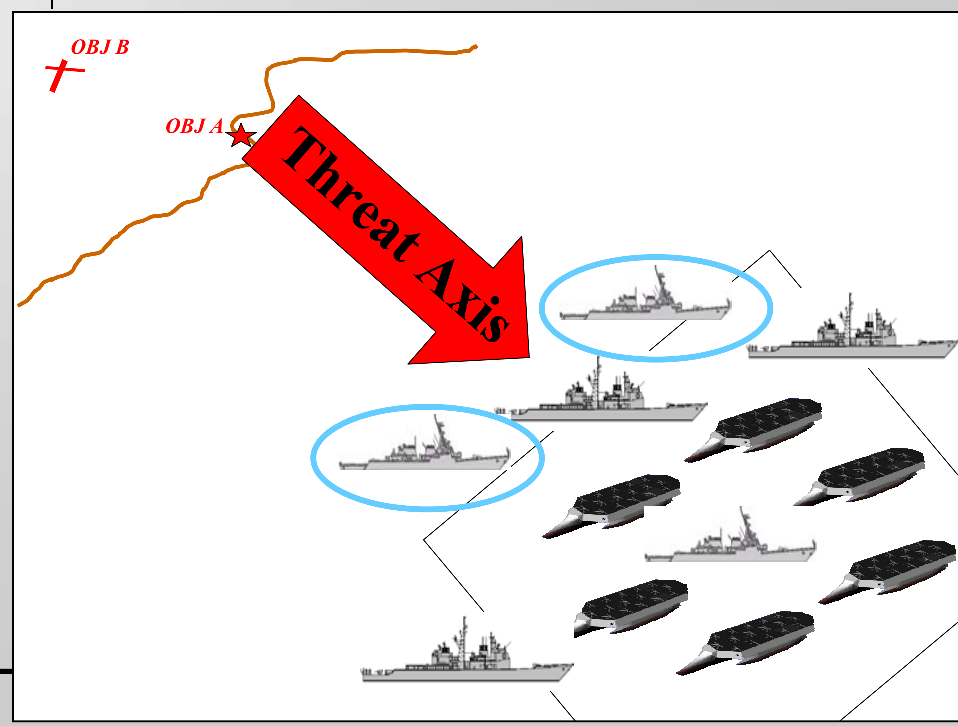
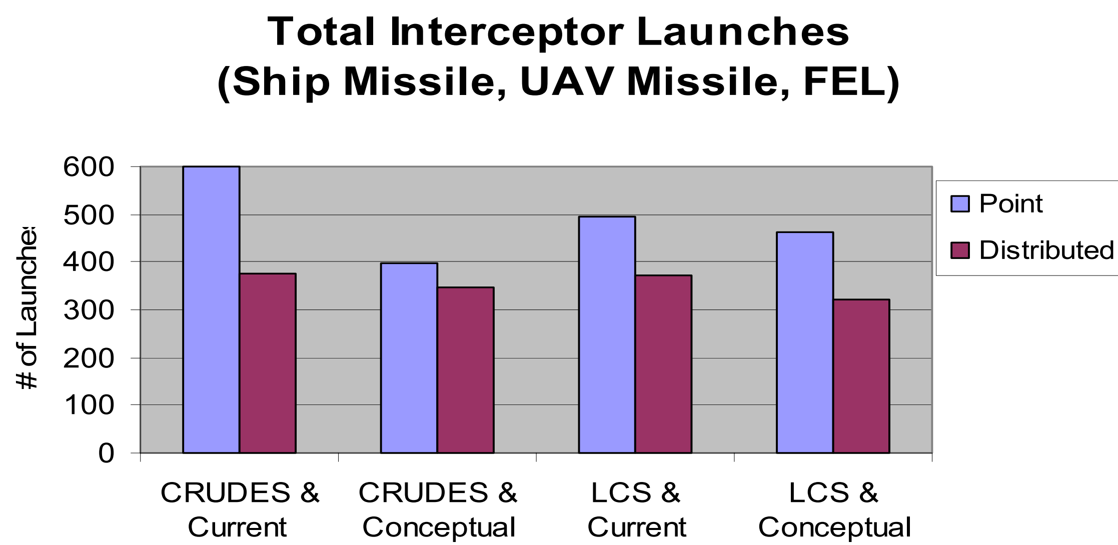
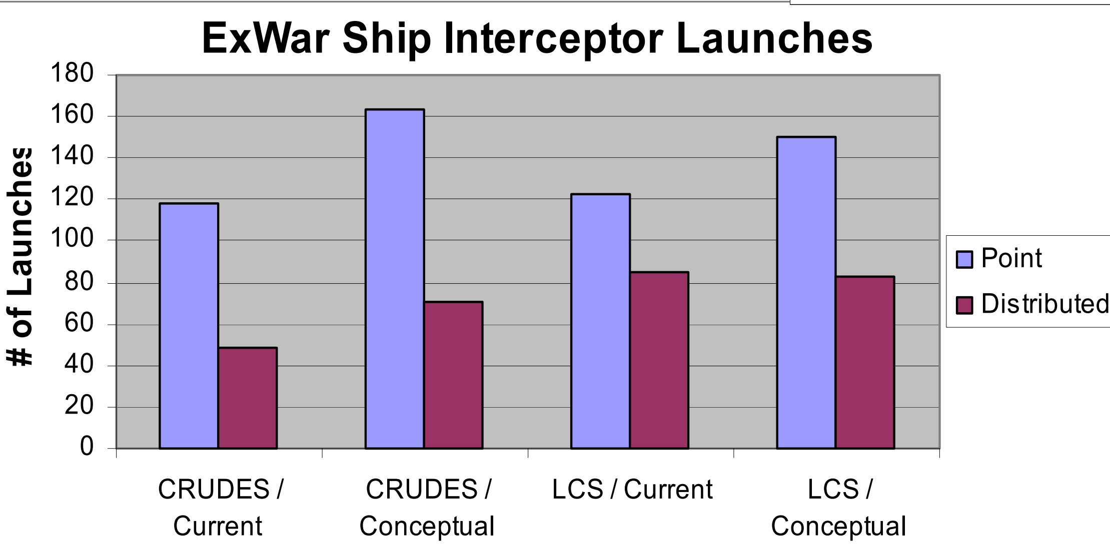




Distributed Architecture Provided The Same Level of Force Survivability While Conserving Weapons





Higher Threat from Longer Range - Distributed is Better

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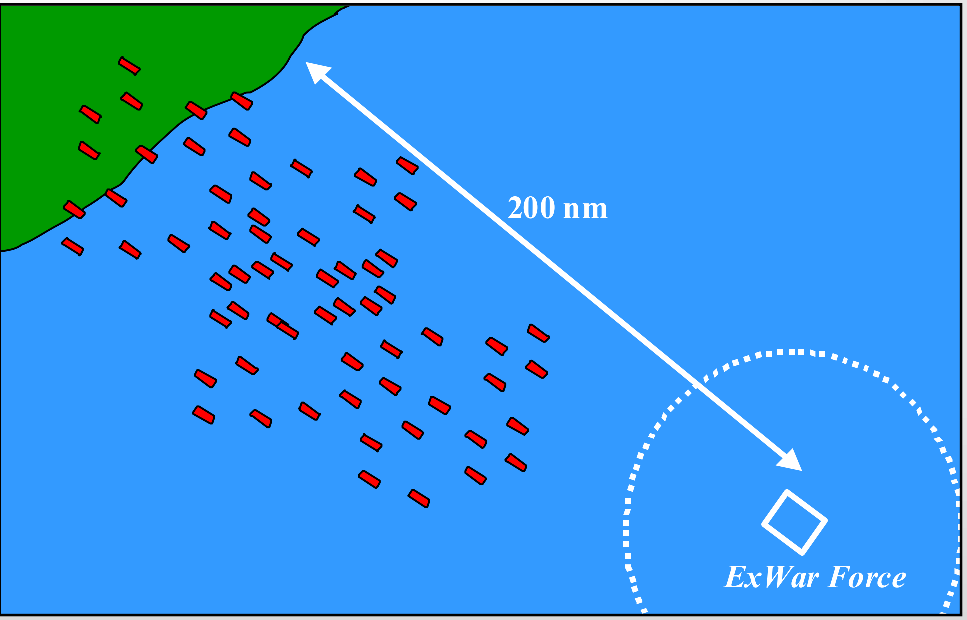

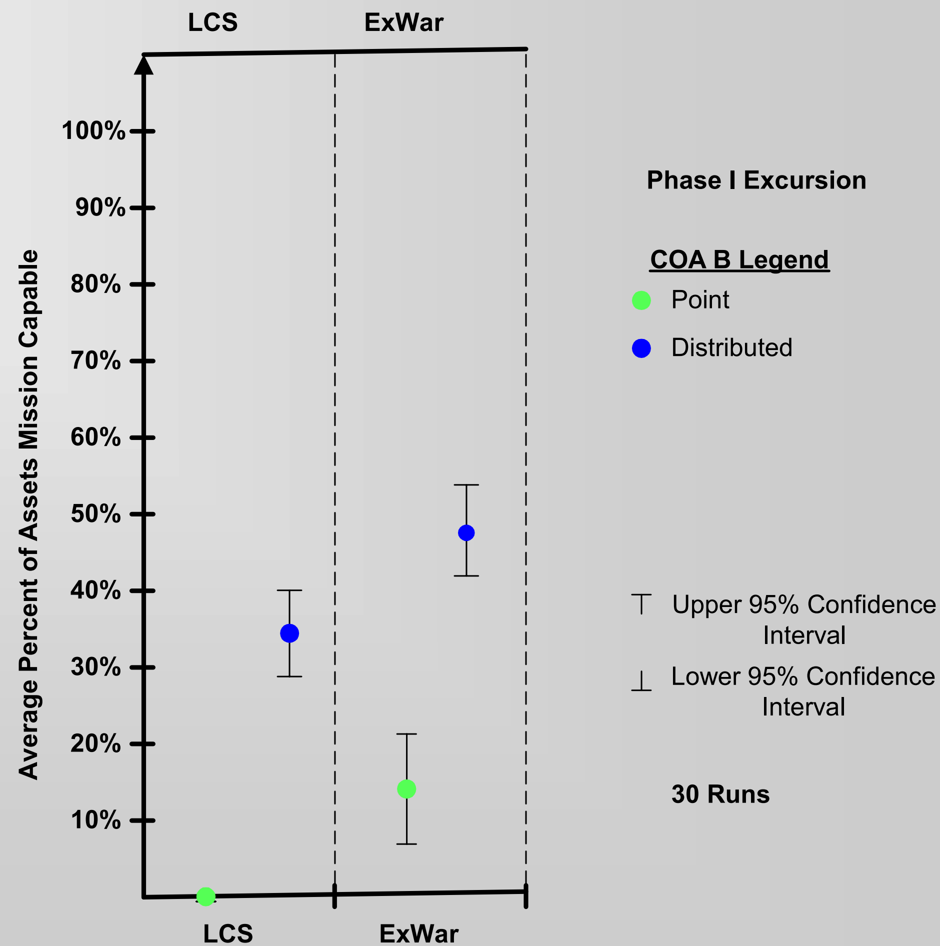

Phase I Excursion: Missile Raid

- 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

EXTEND

- Advantages
  - Easy to learn
  - Easy to model complex processes in detail
  - Visual representations
  - Flexible
  - COTS
- Disadvantages
  - No database
  - Difficult to represent every entity

NSS

- Advantages
  - Detailed, flexible database
  - Hi-res wargame simulation
  - Multiple study replication capability
  - SE management skills learned by working and coordinating with NSS modeler.
- Disadvantages
  - Requires expertise
  - Long processing time
  - Limited land, amphibious operation capability

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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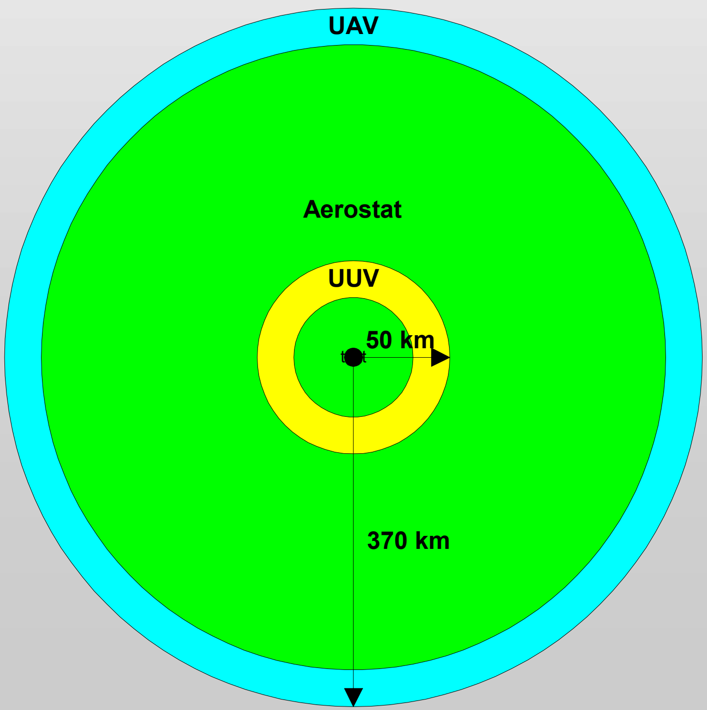
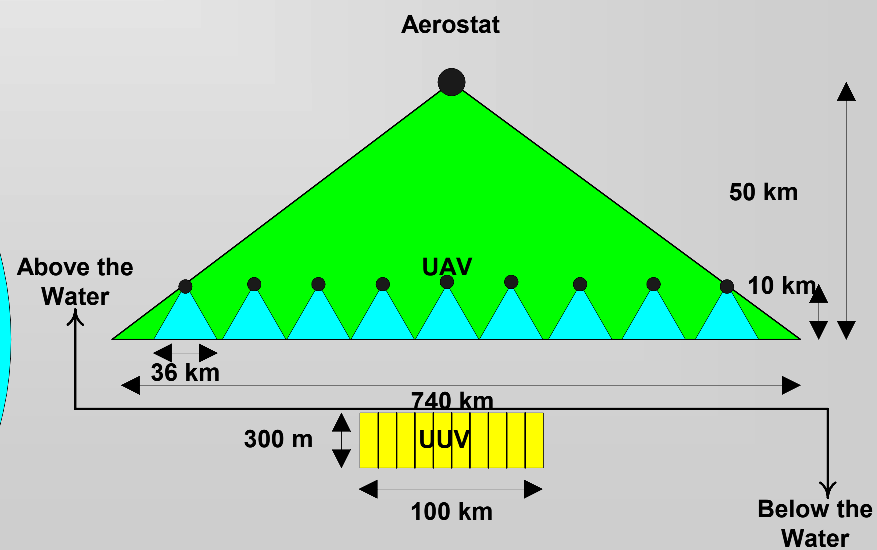
- Distributed Sensors
  - Aerostat
    - High frequency radar (~ 20 GHz)
  - UAVs for 360 degree coverage
    - High frequency radar (~ 20 GHz)
    - 3-5 μm IR
  - UUVs for 360 degree coverage
    - Active Sonar (~1 KHz)
- Conceptual Weapons
  - FEL (3×10^8 m/s, 10 km)
  - INT-2 (1650 m/s, 370 km)
  - 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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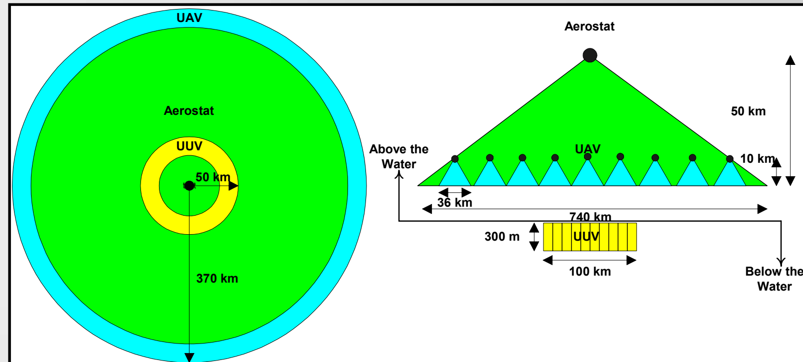
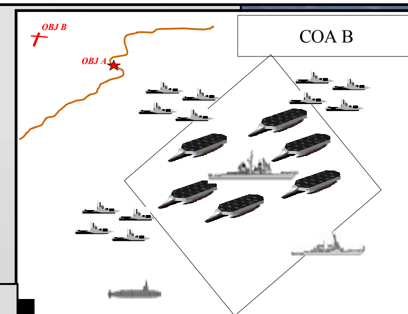
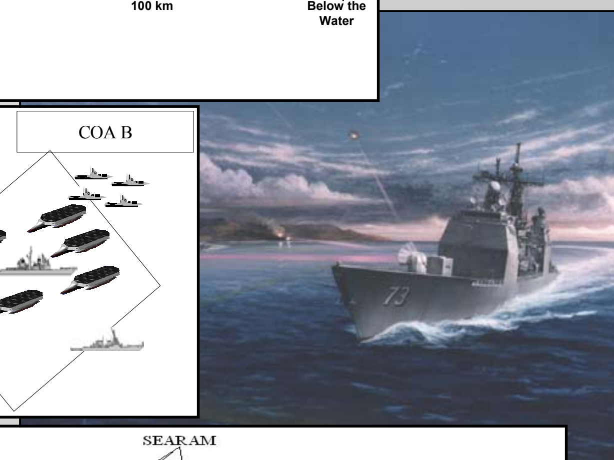


Distributed Sensors
- Greater Reaction Times
- More Engagement Opportunities

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





Force Composition
- 12 LCS + 1 CG + 1 DDG ≅ 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