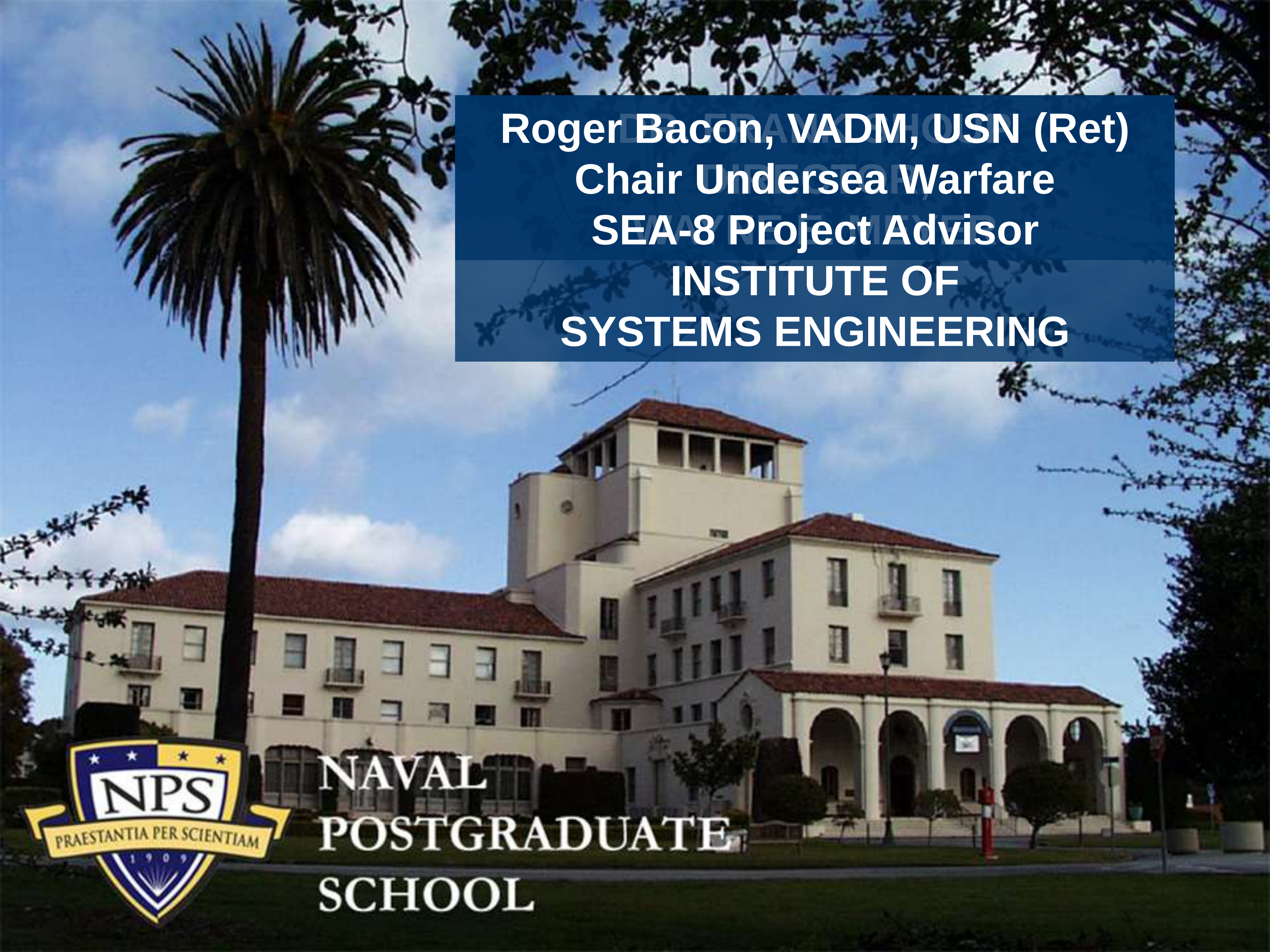
Roger Bacon, VADM, USN (Ret)
Chair Undersea Warfare
SEA-8 Project Advisor
INSTITUTE OF SYSTEMS ENGINEERING



Systems Engineering Analysis
Littoral Undersea Warfare in 2025

Introduction

CDR Vic Bindi, USN

SEA-8 Problem Statement

- **SEA-8**

  .. *design a system that denies enemy undersea forces (submarine and UUV) effective employment against friendly forces within the littorals during the 2025 timeframe.*

Bottom Line Up Front

- Systems engineering principles
- Insights and conclusions:
  - 1) No perfect system
  - 2) Reaction time
  - 3) Persistent systems
  - 4) Kill-Chain Timeline (KCT) tradeoffs
  - 5) Undersea Joint Engagement Zones (UJEZ)
- Results qualified and quantified during brief

Bottom Line Up Front

NO PERFECT SYSTEM

- Theater specific variables
- No generic global solution exists
- Each alternative architecture possessed strengths, weaknesses and performance gaps
- Combination of systems results in significant performance gain

Bottom Line Up Front

REACTION TIME

- Enemy timelines are unpredictable
- SecDef 10/30/30 construct
- ASW 3/10/30/30 construct
- Quick reaction systems hedge uncertainty.

Bottom Line Up Front

PRESENCE

- Pervasive persistence is the goal
- Required in both time and space
  - Traditional methods
  - Non-traditional methods

Bottom Line Up Front

KILL-CHAIN TIMELINE (KCT) TRADEOFFS

- Traditional methods require short KCTs
  - Minimum Trail Range (MTR)
  - Sporadic contact
- Non-traditional methods afford longer KCT
  - Closer trailing distances
  - Decreased probability of lost track
  - Affords the use of stand off weapons systems

Bottom Line Up Front

UNDERSEA JOINT ENGAGEMENT ZONES

- Aviation uses a Joint Engagement Zone (JEZ)
- Future undersea technologies require more than waterspace management
- Future ASW will require Undersea JEZ
- Advances will be required in
  - coordination
  - identification
  - networking

Morning Agenda

- Problem Definition
  - Needs Analysis
  - Objective Analysis
- Design and Analysis
  - Alternative Generation

BREAK

- Design and Analysis II
  - Modeling
- Decision Making
  - Analysis
  - Conclusions

BREAK

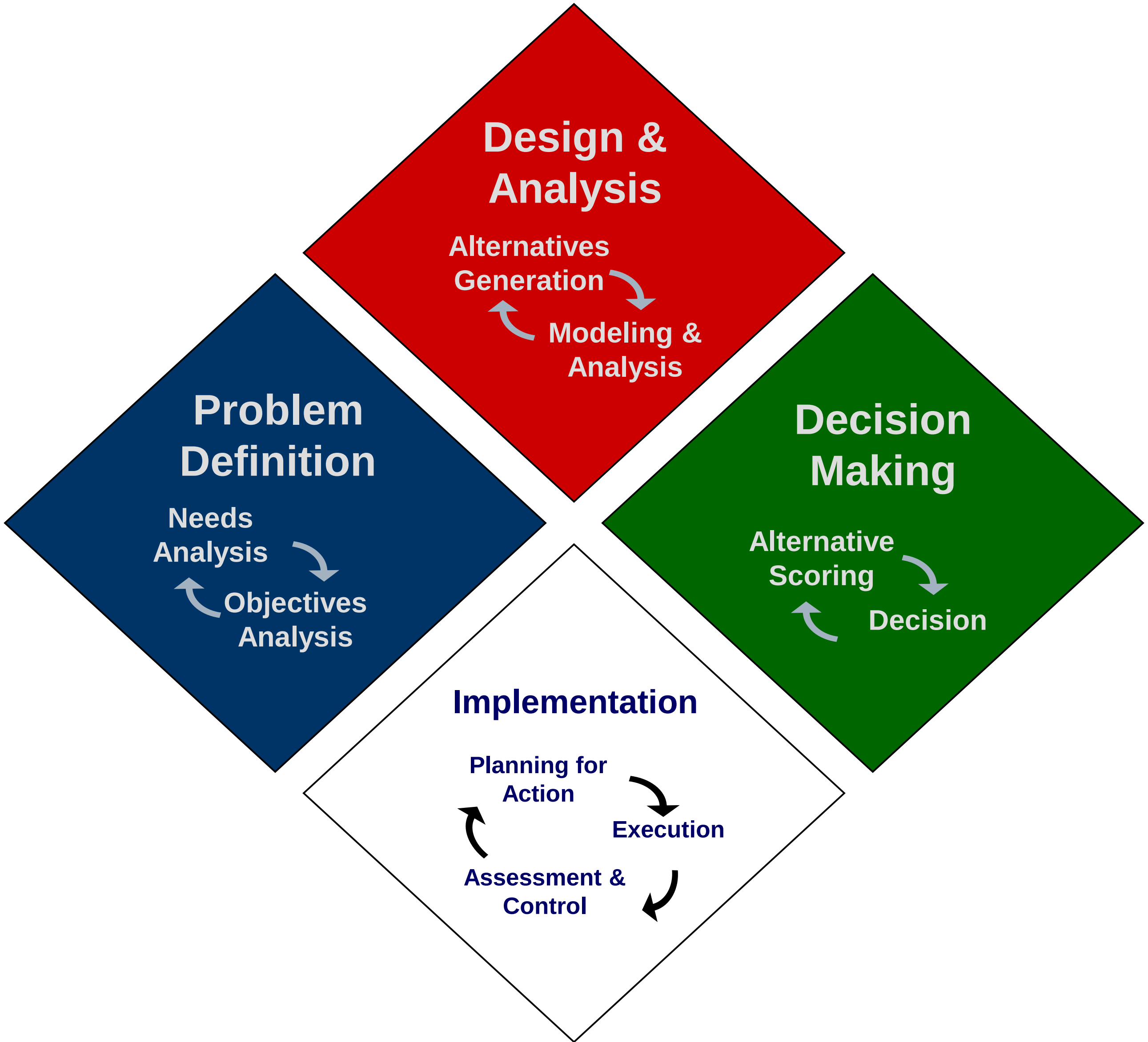
- Total Ships System Engineering (TSSE)
  - Payload and Operational Concepts
  - Combat Systems
  - Hull, Mechanical and Electrical (HM&E)

Afternoon Agenda

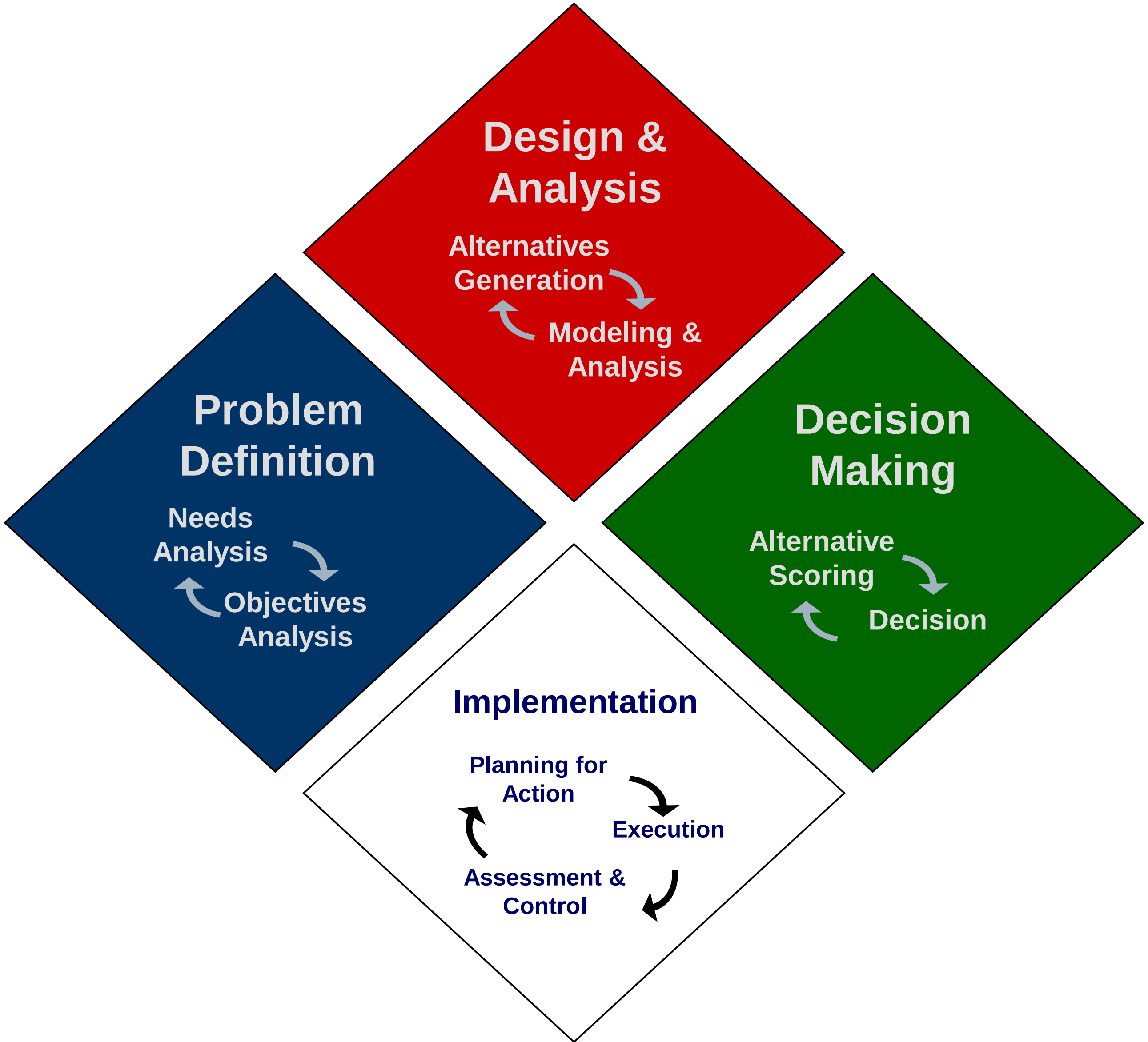
- 1200-1330 Lunch
- 1330-1400 SEA-8 Classified brief (Glasgow STBL)
- 1330-1600 Team Breakout Briefs – Bullard Hall

Modeling	Lab 1
Prosecution	Lab 2
Deployment	Lab 2
Reliability	Lab 2 annex
TSSE	Lab 3
C4ISR	Conference Room

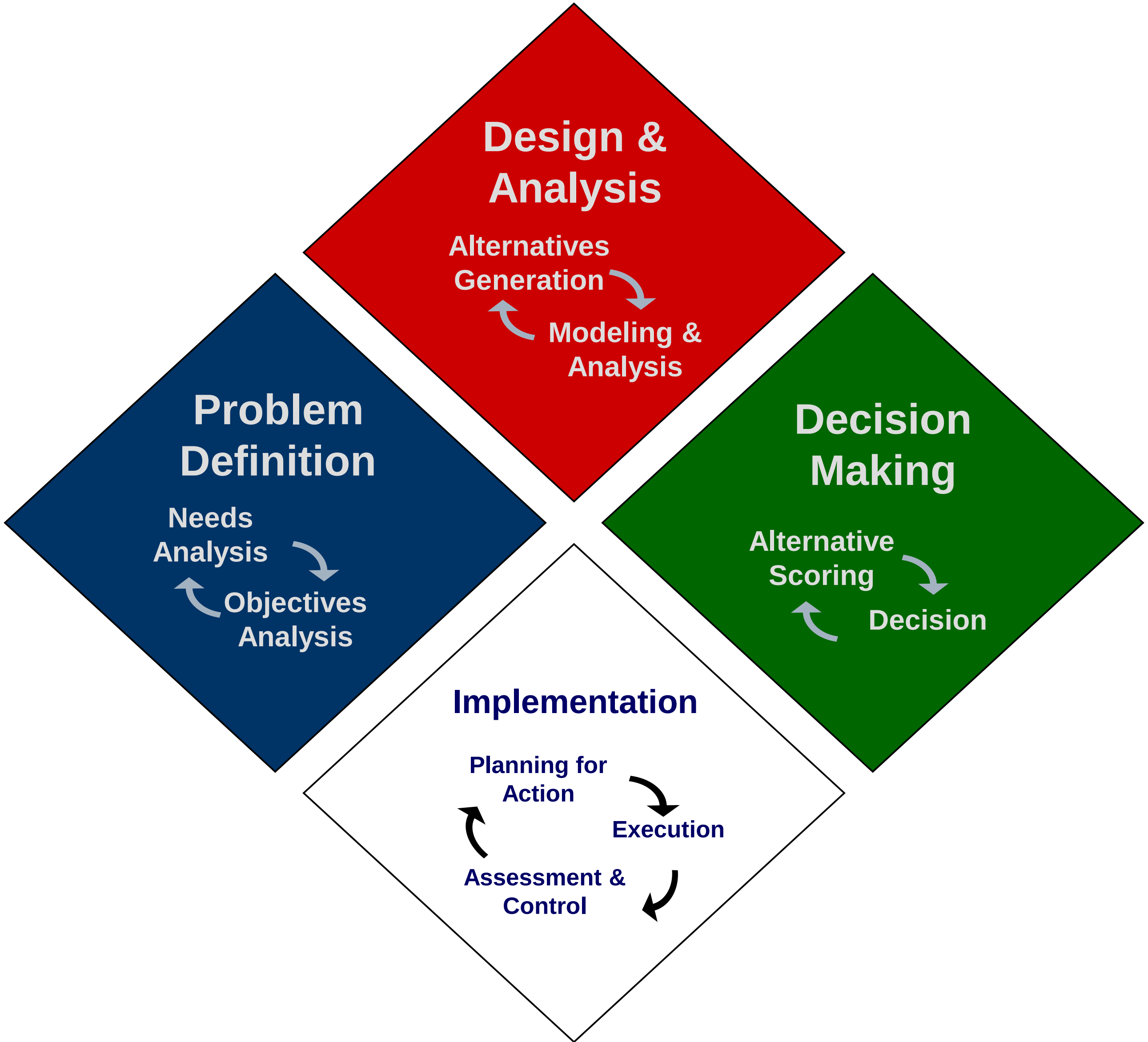
Systems Engineering Design Process



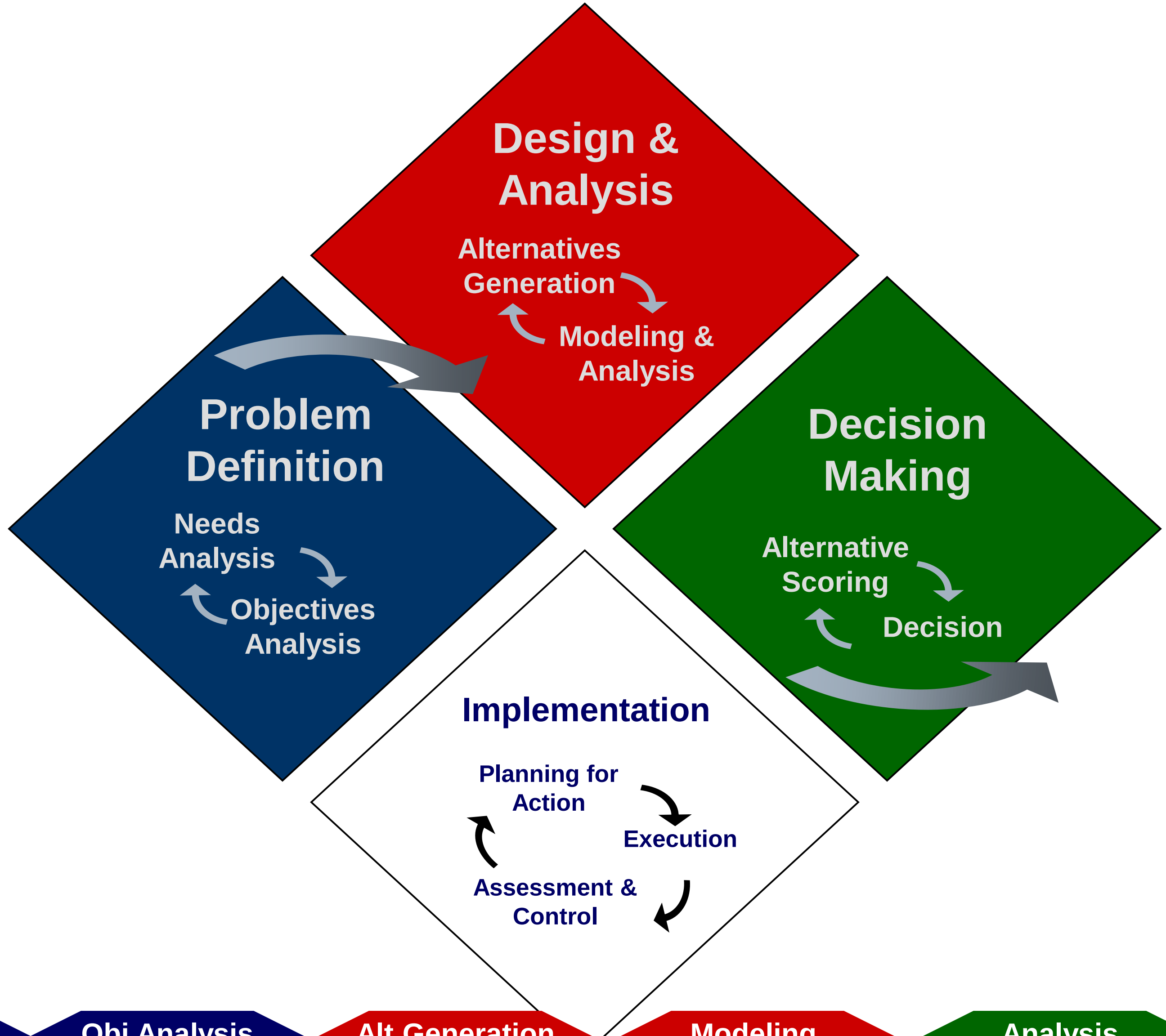
Systems Engineering Design Process



Systems Engineering Design Process



Systems Engineering Design Process



Problem Definition

LT Keith Manning, USN

Problem Definition Phase

- Needs Analysis
  - Primitive Need
  - Stakeholder Acknowledgements
  - System Decomposition
  - Input-Output Modeling
  - Functional Analysis
  - Requirements Generation
  - Futures Analysis
  - Effective Need
- Objectives Analysis
  - Functional Objectives
  - Measures of Performance
  - Measures of Effectiveness
  - Performance Goals

Problem Definition Phase

Understanding Littoral ASW Functions

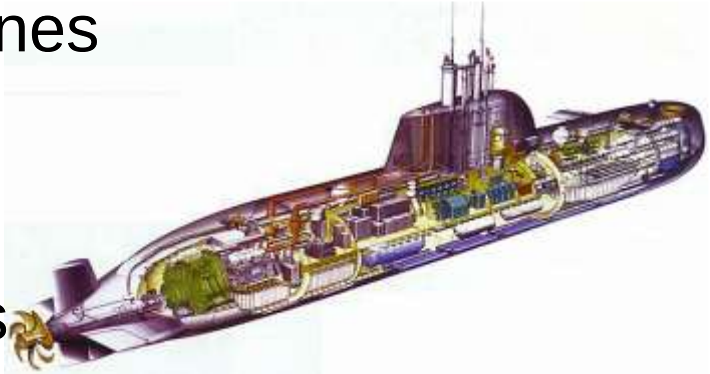
Initial Tasking Need

Primitive Need Statement

Littoral ASW Points

- Anti-Submarine Warfare
  - Denying the effective use of enemy submarines

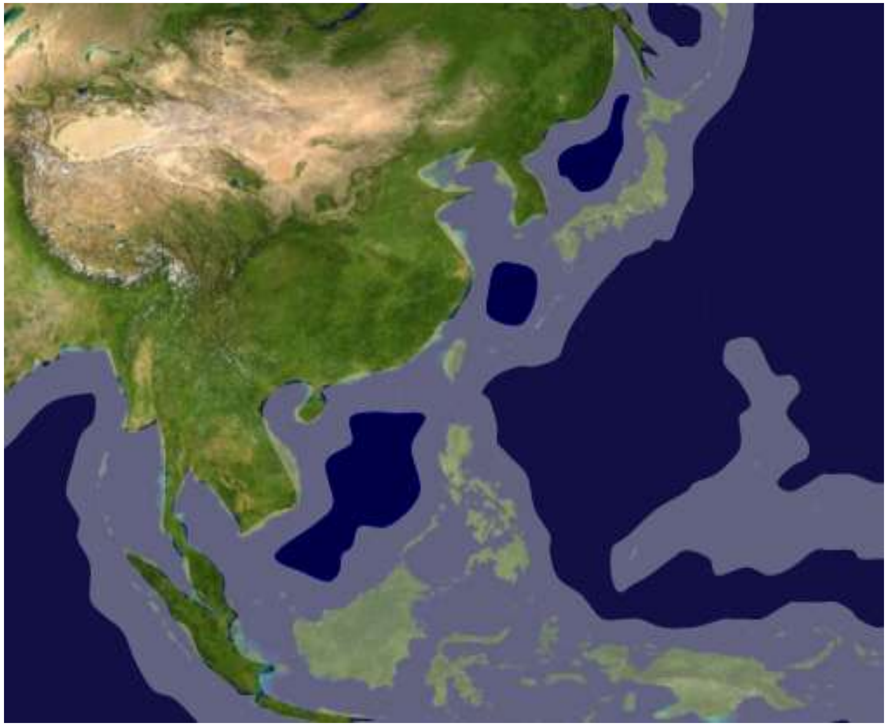
    Avoidance - Deterrence - Destruction
- Littoral ASW Threat
  - Air Independent Propulsion Submarines
  - Fuel Cell Technology Submarines
  - Nuclear Powered Submarines
  - Diesel Powered Submarines
  - Unmanned Undersea Vehicles



Littoral Defined

<u>Littorals</u>:

Defined as waters within 100nm of any oceanic shoreline.



Initial SoS Components

- Alternative mixes of ASW systems
  - Legacy
    - Systems remaining in use in 2025
  - Programs of Record (POR)
    - Systems planned to be operational in 2025
  - SEA and TSSE
    - Alternative systems that are technologically feasible but do not exist as part of any official POR

Primitive Need Analysis

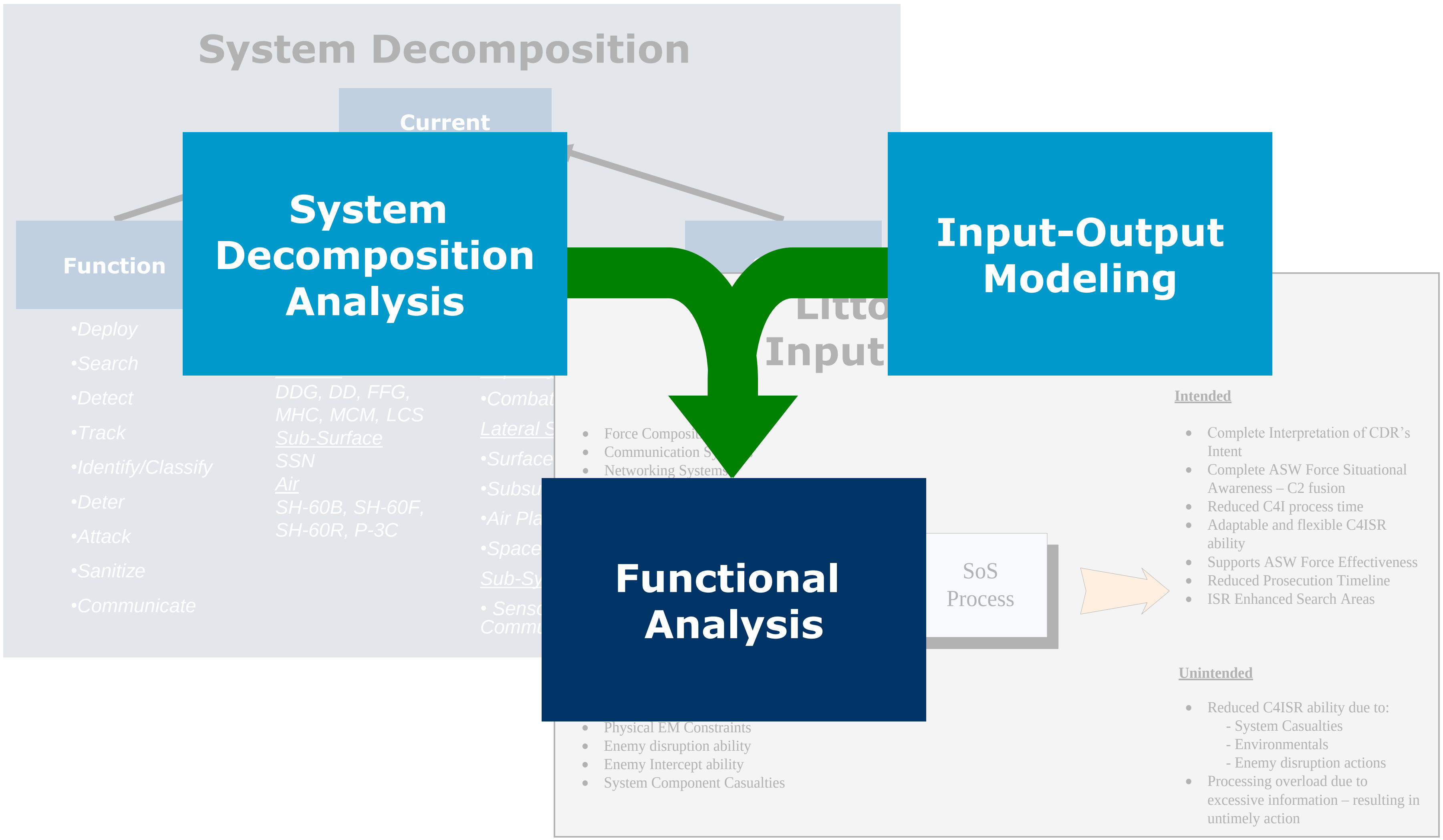
- Primitive Need Statement:

  To develop a System of Systems architecture for the conduct of Undersea Warfare in the littorals in the 2025 time-frame…

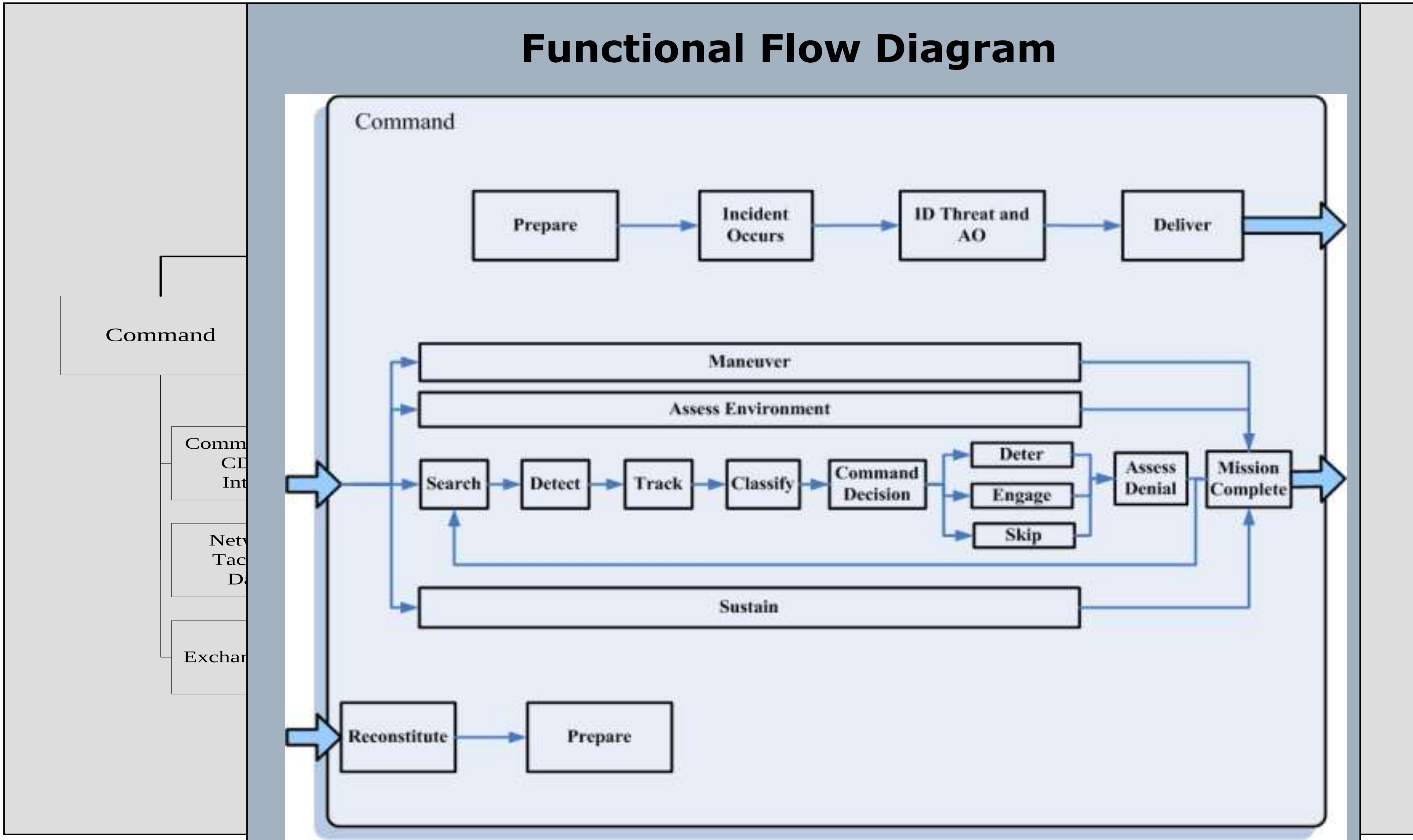
  - Battlespace preparation and monitoring.
  - Persistent detection and cueing.
  - Combined arms prosecution.
  - High volume search and kill rates.
  - Non-traditional methods.
  - Defense in-depth.

Stakeholder Acknowledgements

Functional Analysis Products



Functional Analysis Products



SoS Requirements

Initial Tasking Requirements

Functional Analysis

Refined Stakeholder Needs

Final SoS Requirements

SoS Metrics

Futures Analysis

- Noted Trends
  - The US will maintain its technological advantage
  - However, technology will spread and capability gaps will shrink
  - These gaps will be exploited faster than can be countered
  - The playing field will not be level
  - Center of gravity mismatch and the importance of littoral ASW
  - The Lucky Strike vs. Risk Aversion
    - Standoff
    - Distributed
    - Unmanned
      - Leveraging high-tech to achieve lower human risk

Forming an Effective Need

Primitive Need Statement

Functional Analysis

Stakeholder Analysis

Futures Analysis

Effective Need Statement

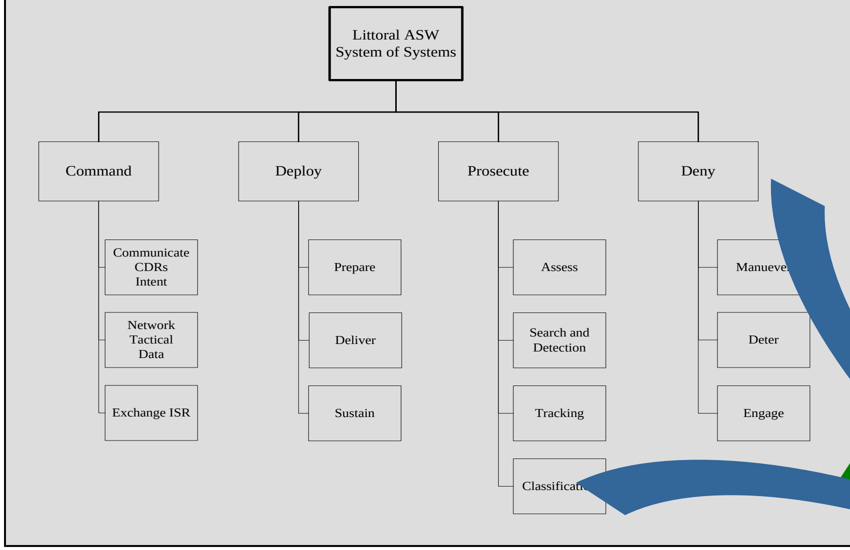
Design a future littoral undersea warfare system of systems that denies enemy undersea forces (submarines and UUVs) effective employment against friendly forces within the littorals during the 2025 timeframe.

Objectives Analysis Phase

- Objectives Analysis
  - Functional Objectives
  - Measures of Effectiveness
  - Measures of Performance
  - Performance Goals

Objectives Analysis Process

Functional Hierarchy



Functional Objective Assignments

Objective Hierarchies

Forming Hierarchies

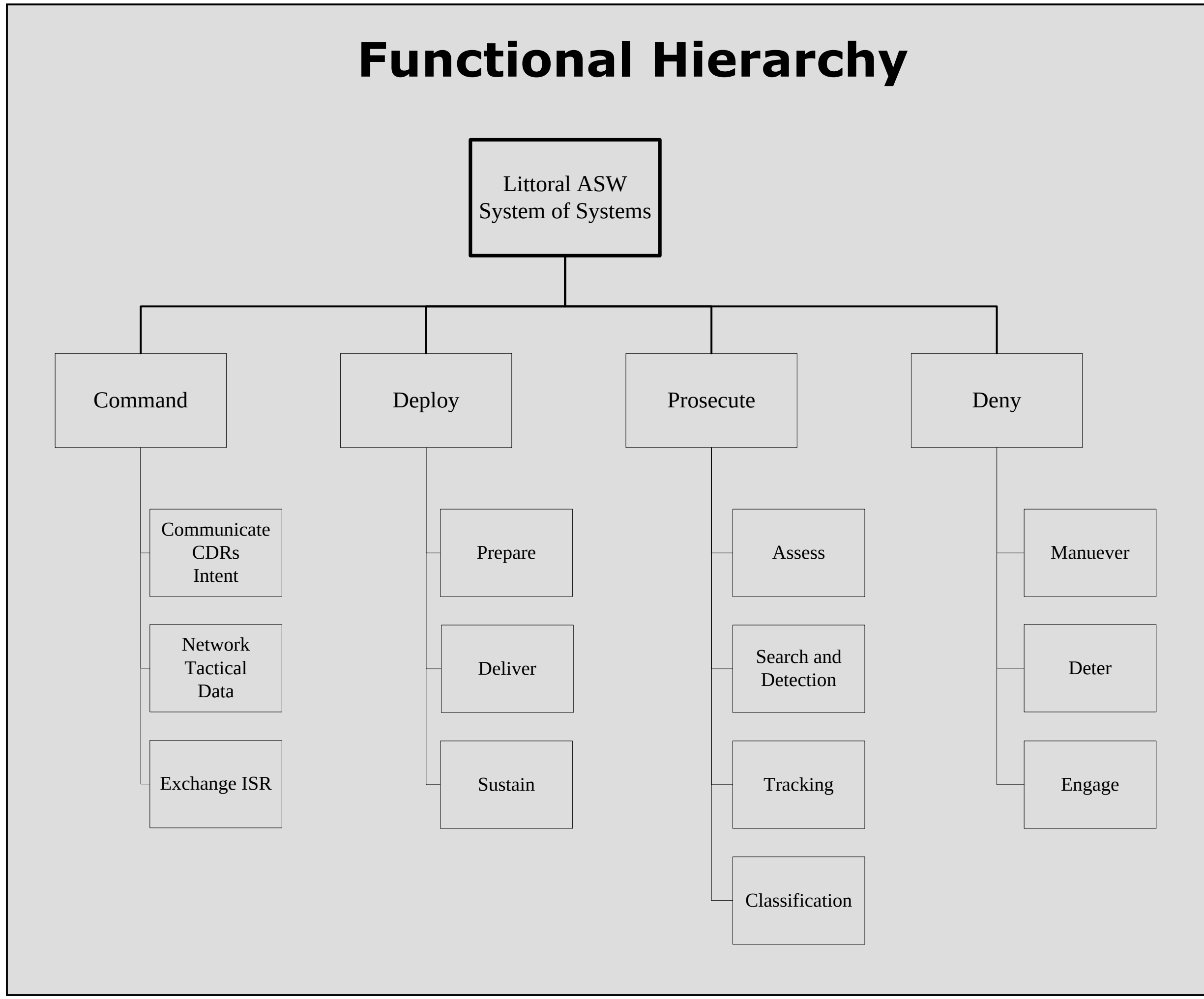
Function

Objective

MOE

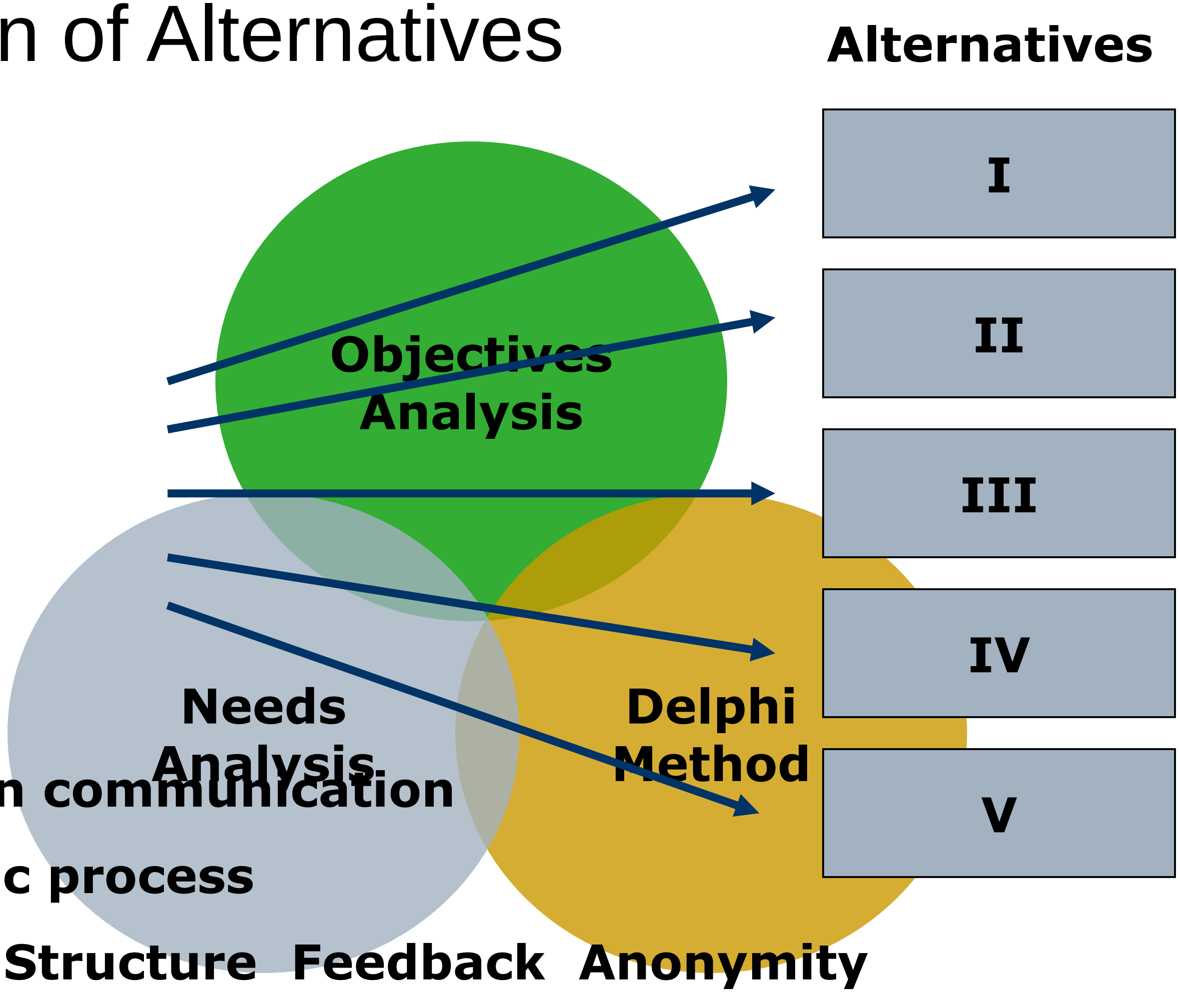
MOP

Goals



Transition to Alternatives

- Generation of Alternatives



- **Exercise in communication**
- **Systematic process**
- **Provides: Structure Feedback Anonymity**

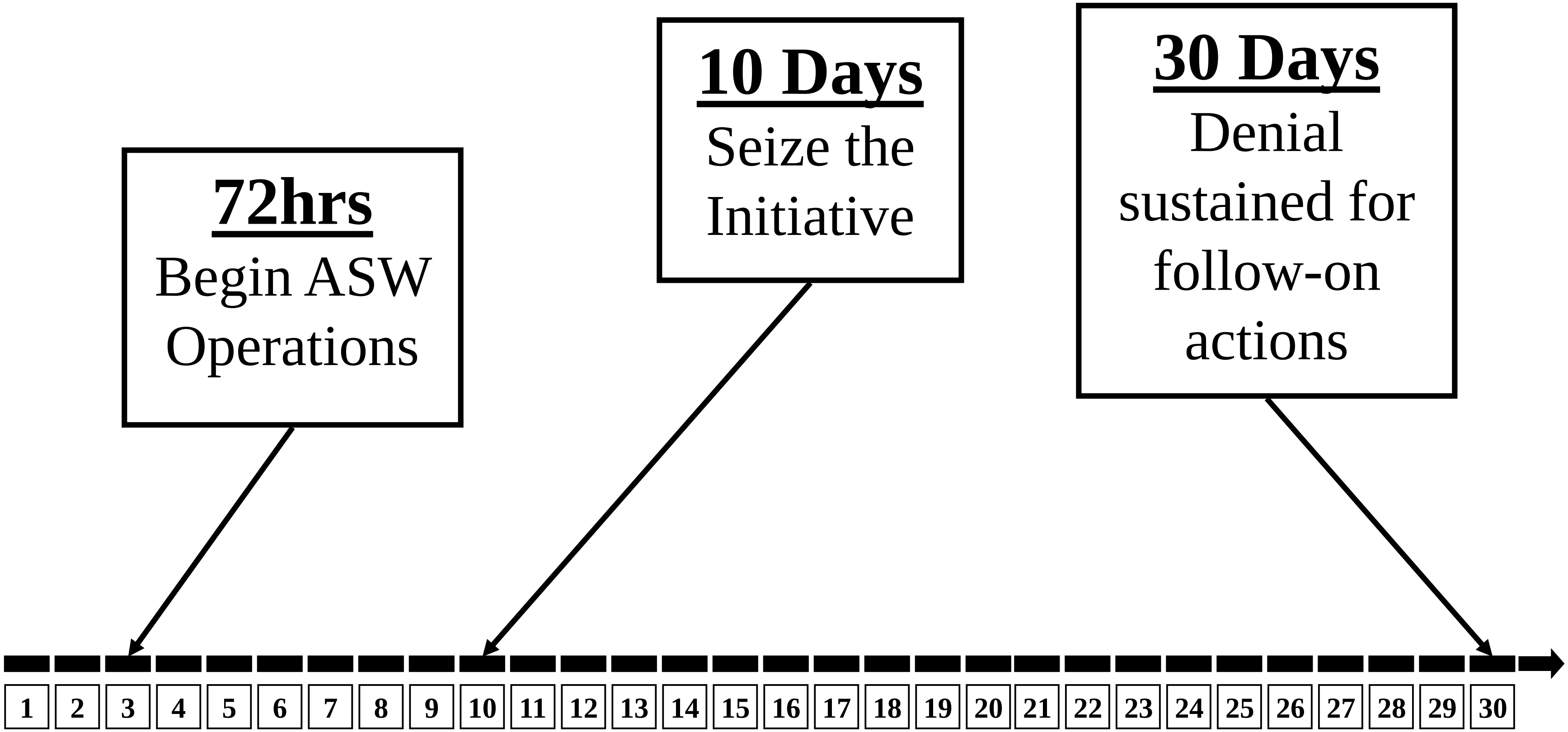
Alternative Generation

LT Artie Mueller, USN

Scenario Building

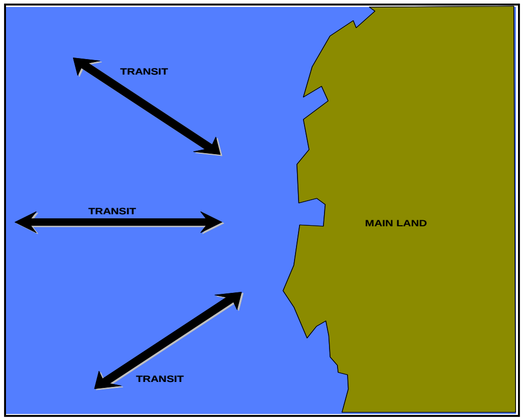
- Scope and bound the project with realistic constraints
  - Timeline
  - Geography
  - Threats
  - Logistics
  - Endurance
  - Capabilities

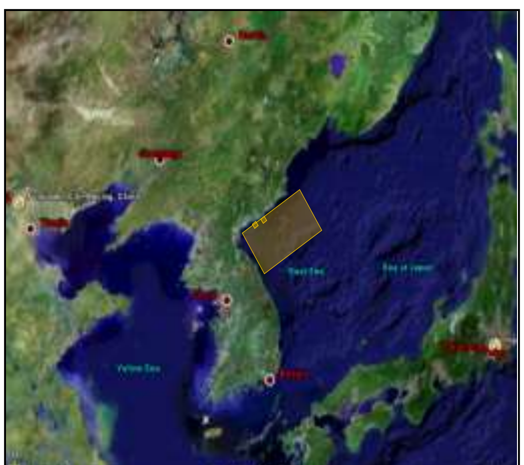
ASW Timeline 3/10/30



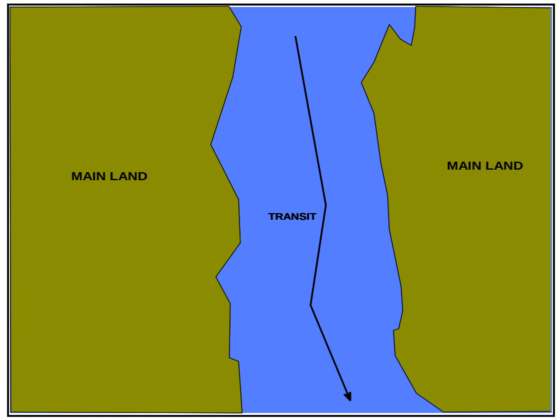
Scenarios

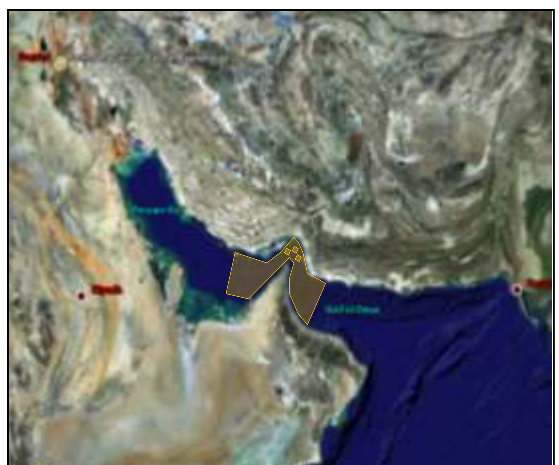
Coastal



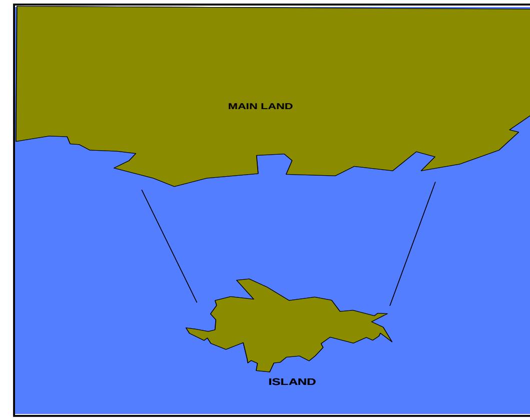


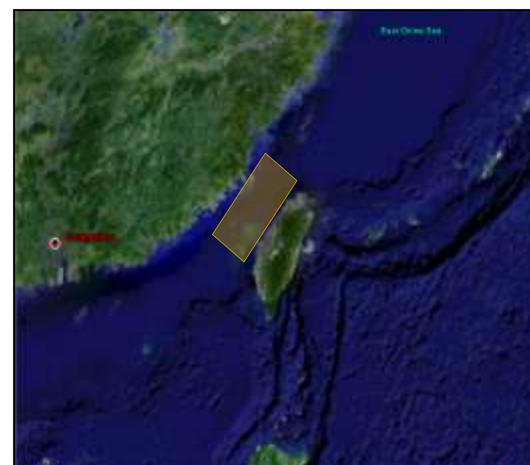
Very Constrained





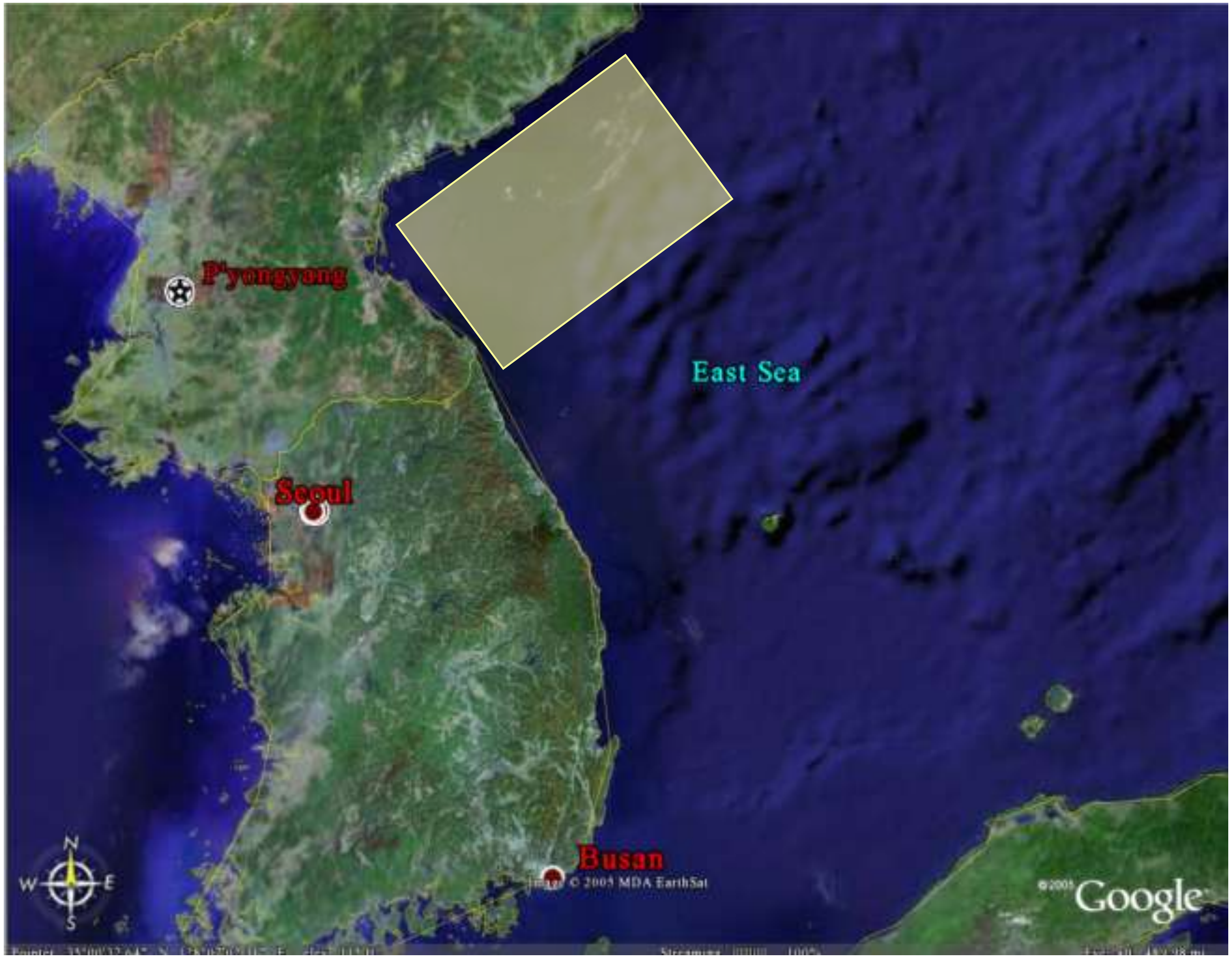
Semi-Constrained





Coastal Scenario

- Defensive, Offensive applications
- All areas open to transit
- Applicable areas:
  - San Diego
  - Norfolk
  - North Korea

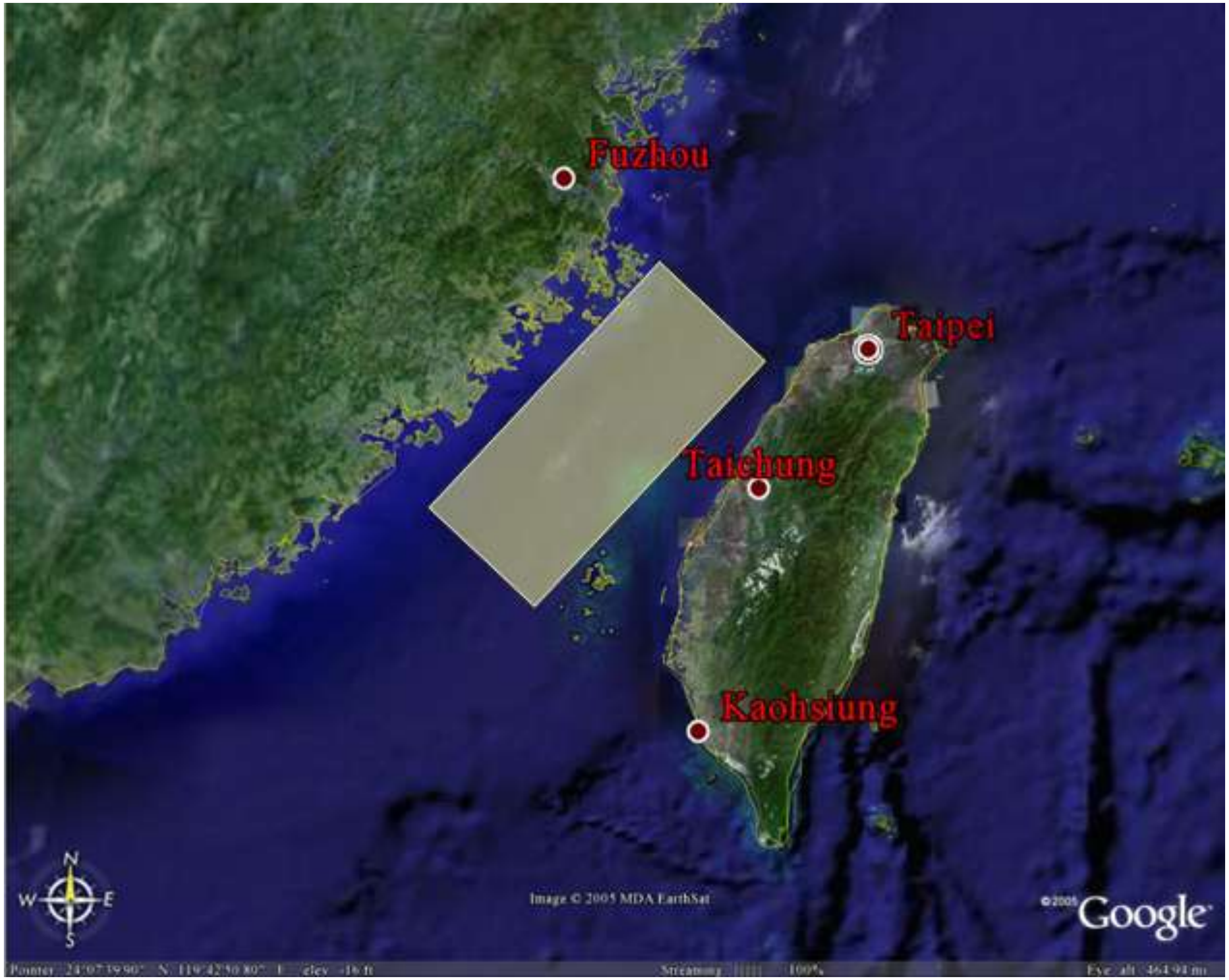


Very Constrained Scenario

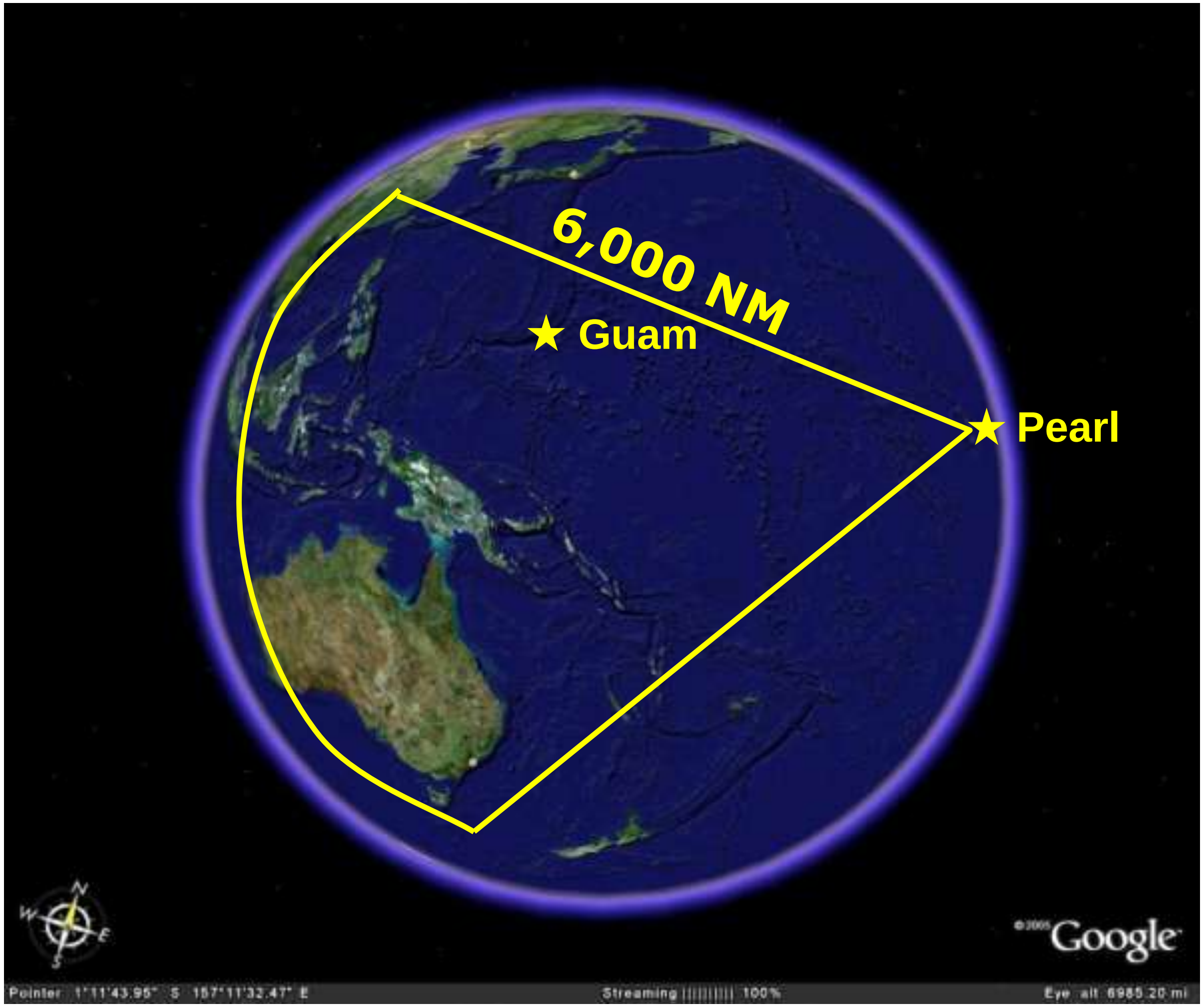
- ❑ **Choke point passage**
- ❑ **Confined waters**
- ❑ **Defined and predictable navigation routes**
- ❑ **Applicable areas:**
  - Strait of Hormuz
  - Strait of Malacca
  - Strait of Gibraltar

Semi-Constrained Scenario

- **Defense of island nation**
- **Applicable areas:**
  - Taiwan Strait
  - Bass Strait



Scenario: Theater Logistics

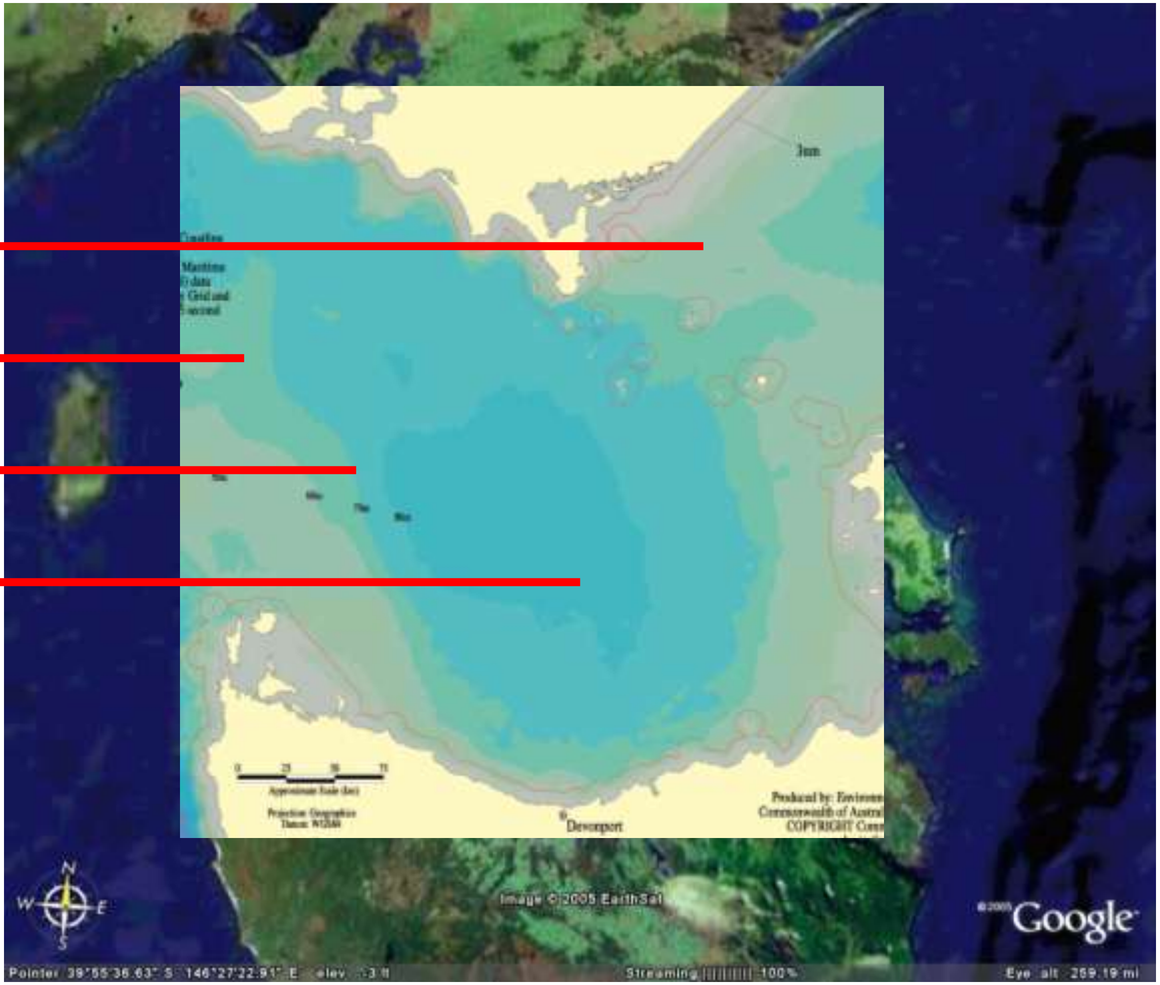


Specific Geographic Littoral ASW Scenario

- Used for geographical scenario planning and simulation
- Bass Strait - water space between Australia and Tasmania

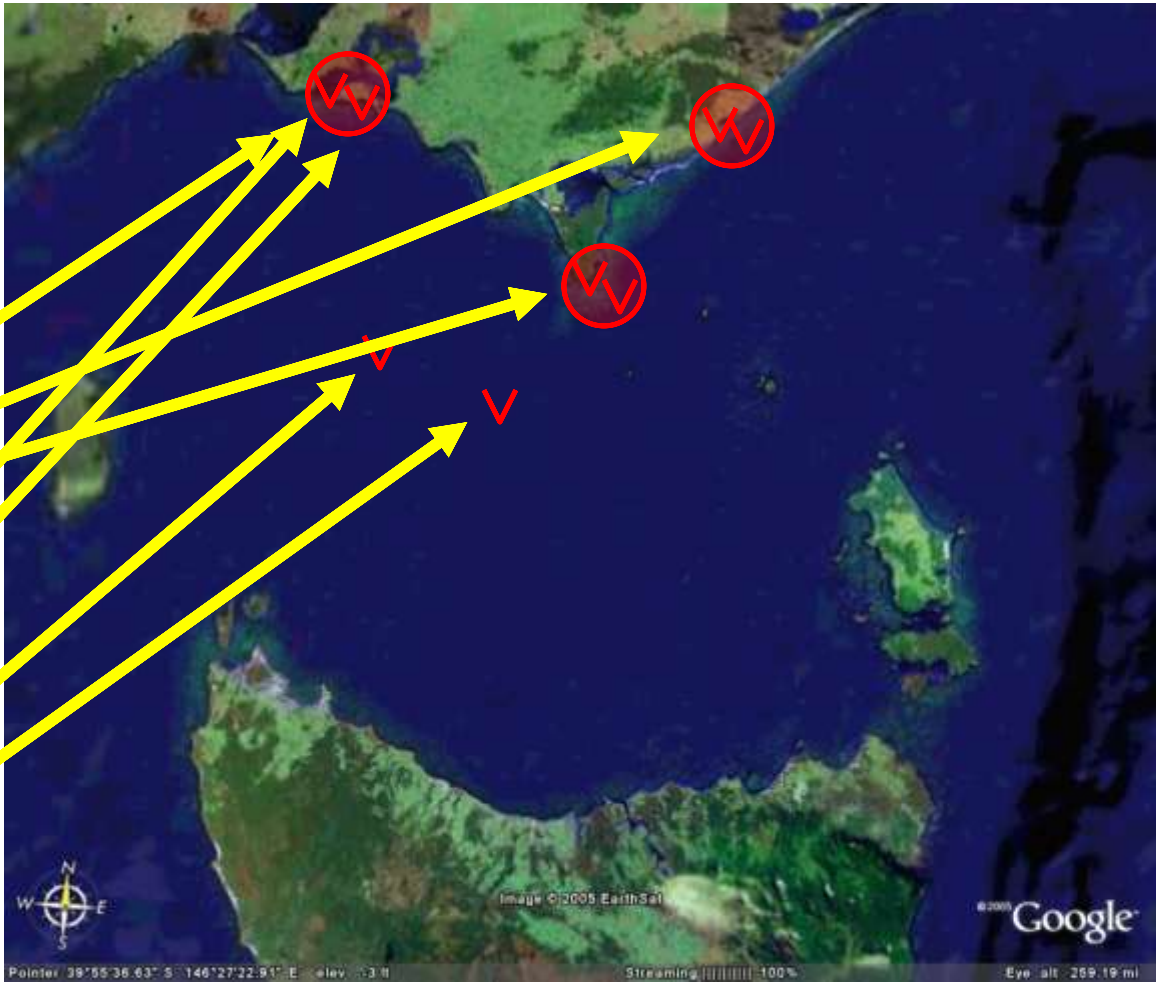
Littoral ASW Scenario: Area of Responsibility (AOR)

- ❑ **Water depth**
- ❑ **50m**
- ❑ **60m**
- ❑ **70m**
- ❑ **80m**



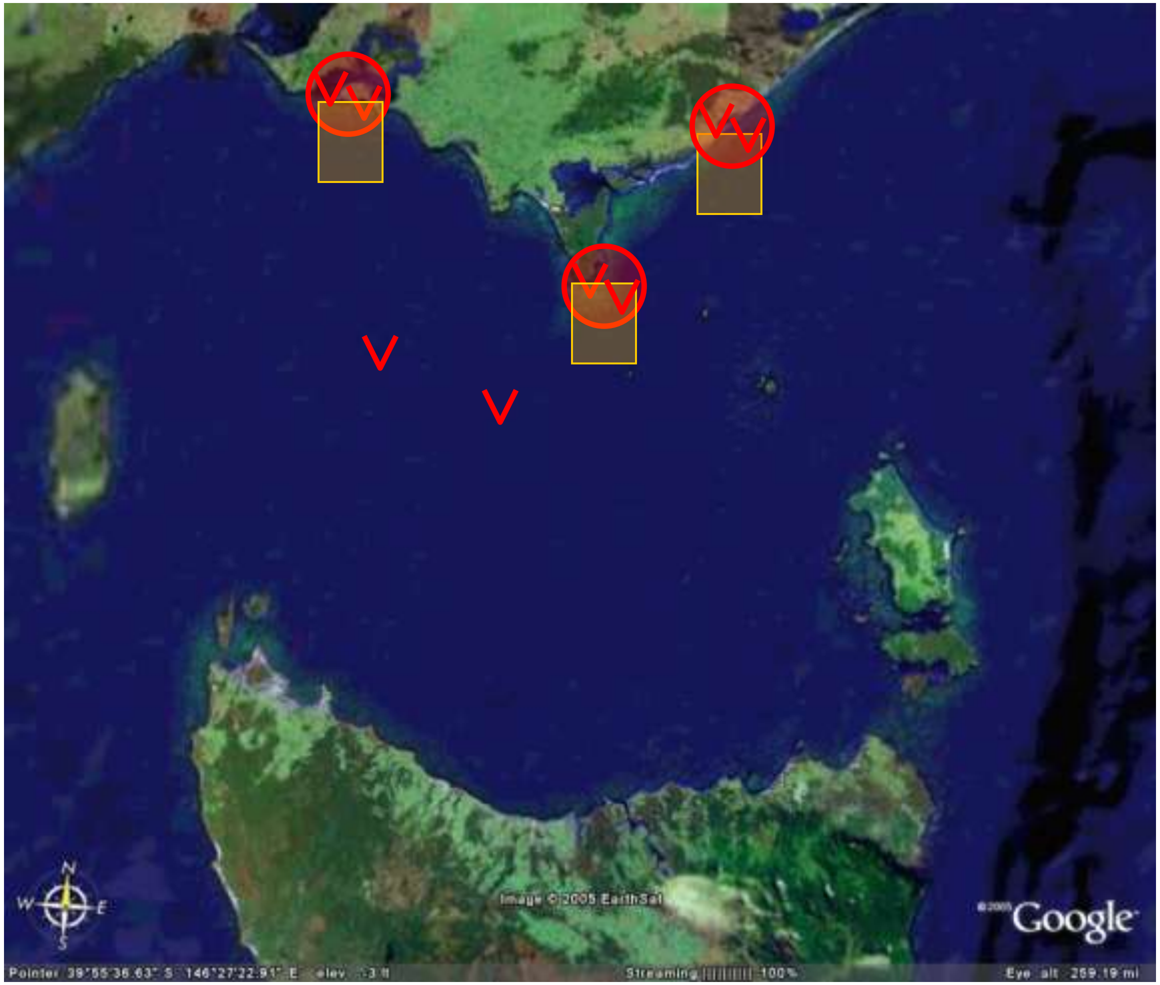
Littoral ASW Scenario:
Area of Responsibility (AOR)

- Defense of island nation
- Air and maritime superiority not established
- 3 enemy port facilities
- 2 enemy AIP submarines in each
- 2 enemy AIP submarines unlocated



Littoral ASW Scenario: AOR operations in 72 hours

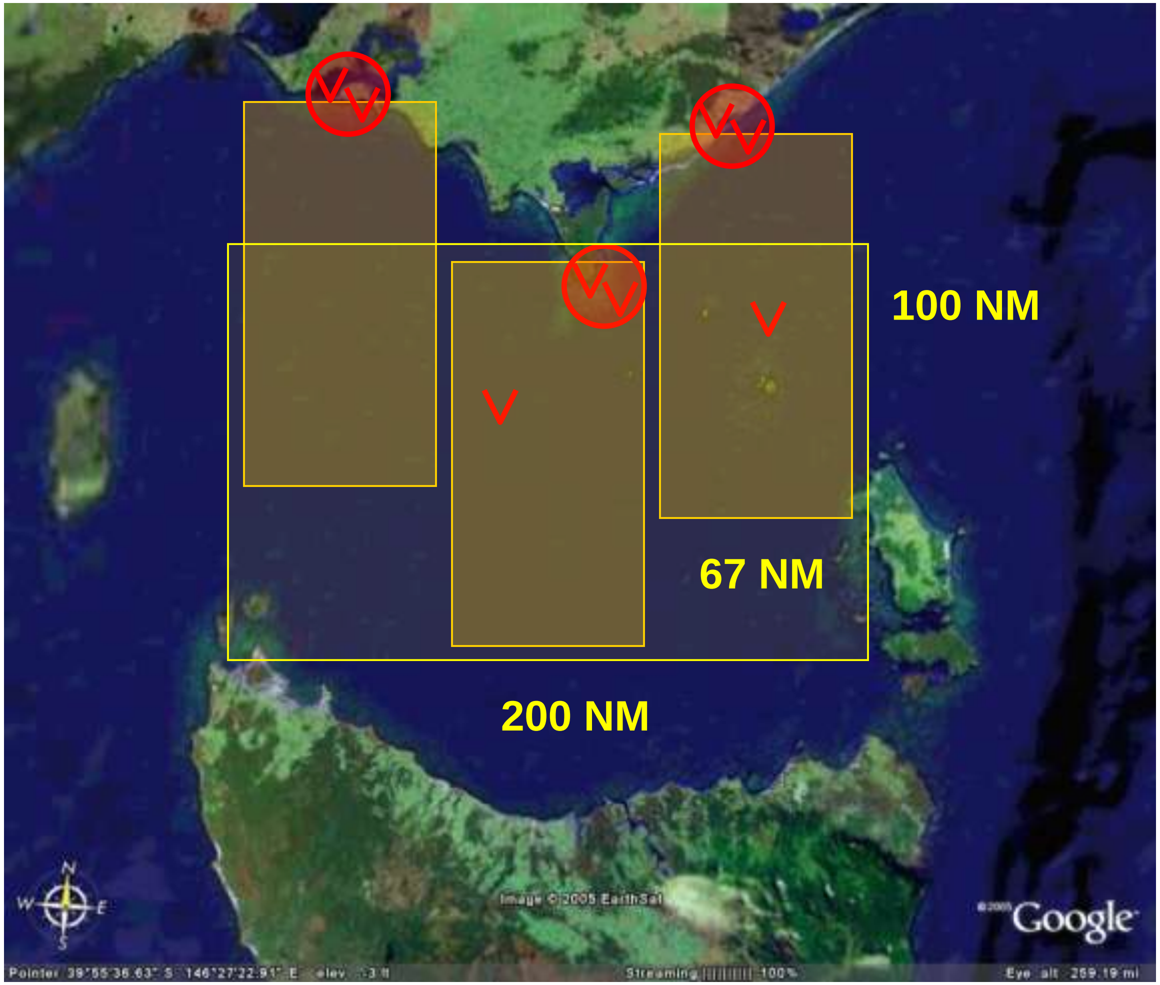
- Operate in the Area of Responsibility within the first 72 hours
- 100 NM^2 (10 x 10 NM blocks) outside enemy port facilities



Littoral ASW Scenario: Sustained Denial in the AOR

- 3 defined Areas of Responsibility
- 100 NM x 67 NM each
- 6,700 NM^2 each
- Total Size of Area of Responsibility

  20,000 NM^2



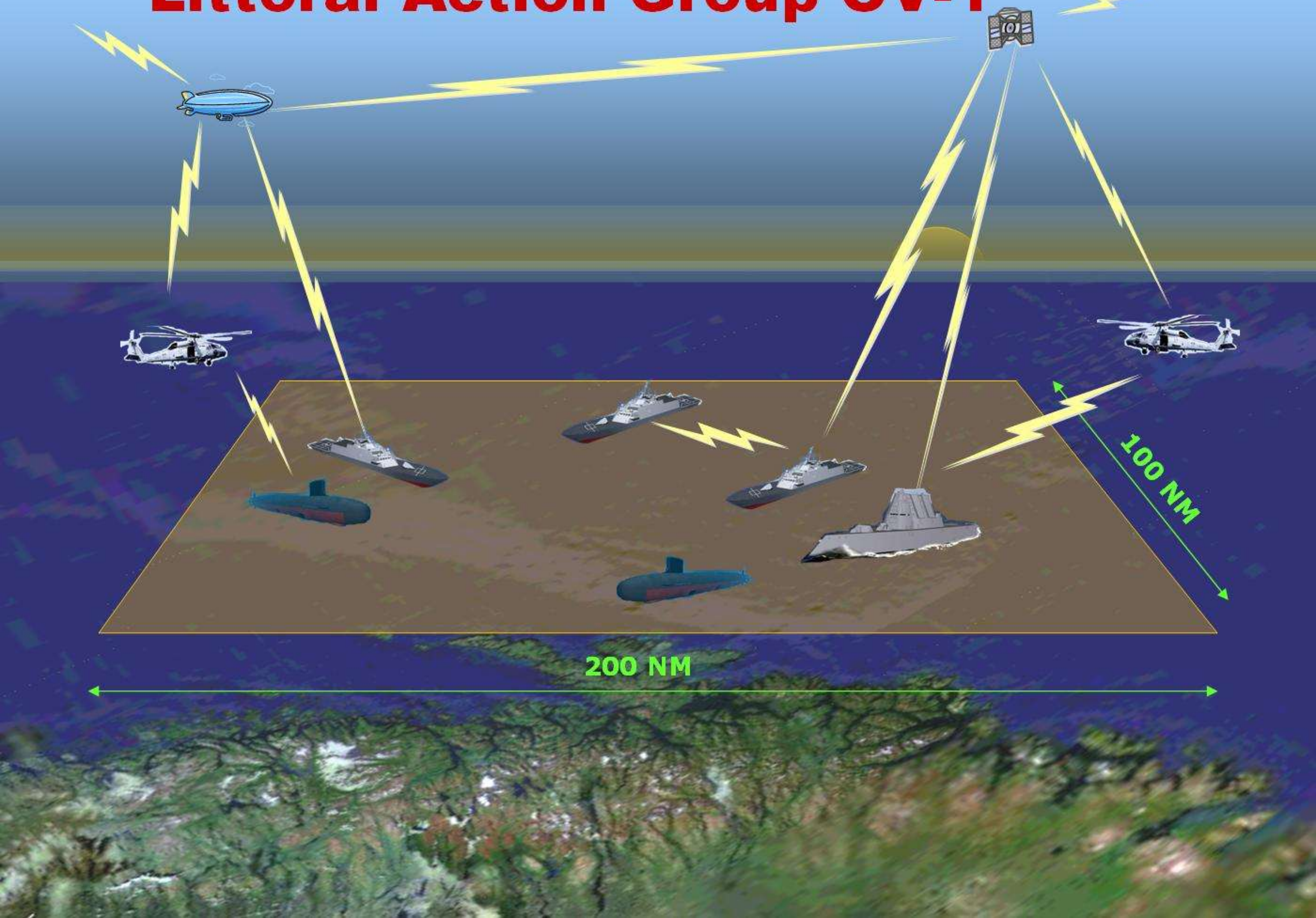
Alternatives Generation

- Created distinct, unique alternatives to address our effective need for our Semi-Constrained Scenario
- Each alternative combines components that are:
  - Existing Systems
  - Programs of Record
  - Technologically feasible
  - System gaps

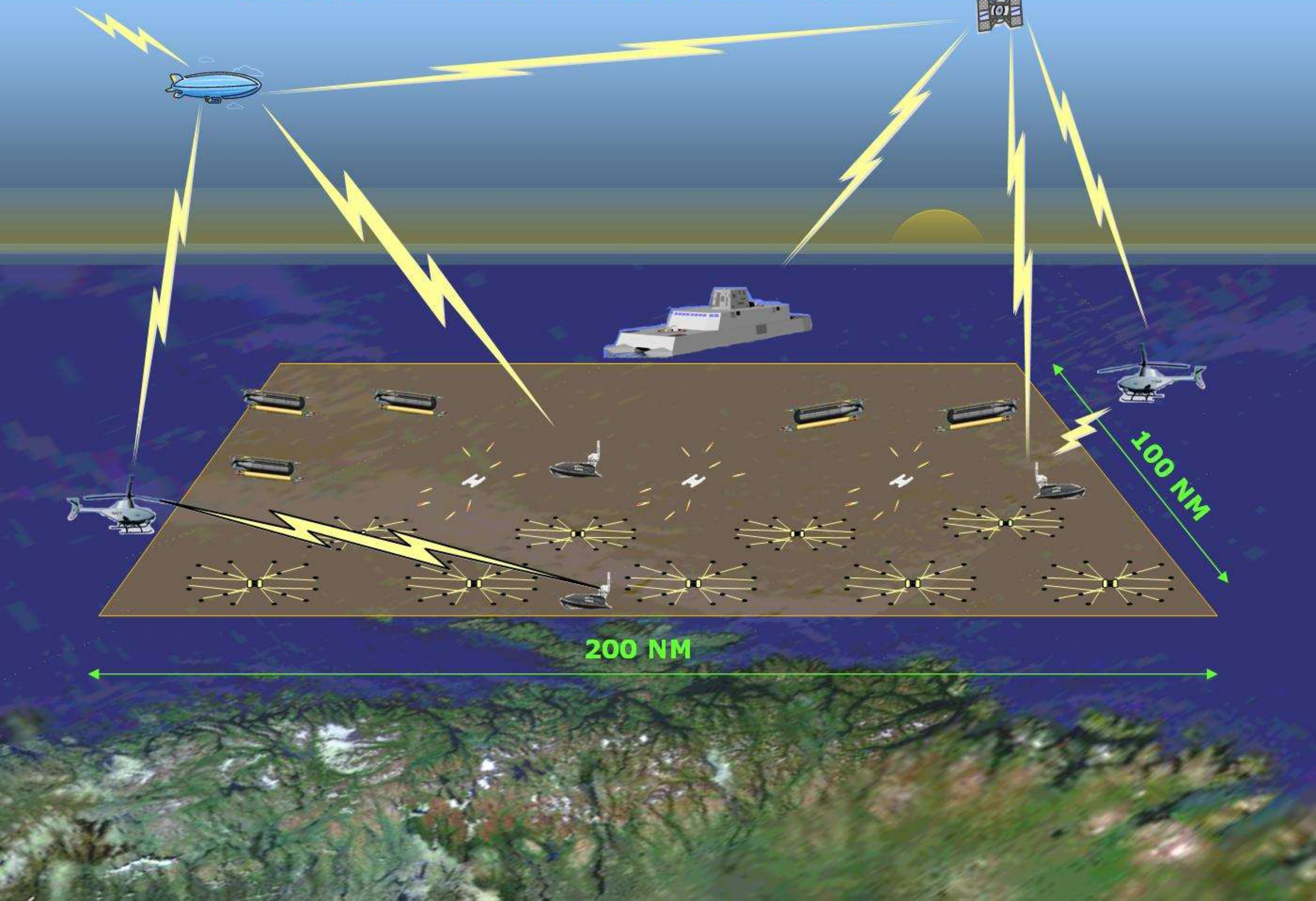
SEA-8 Defined Alternatives

- Littoral Action Group (LAG)
  - DD(X), LCS, SSN, MH-60
- Total Ship Systems Engineering (TSSE) – Sea TENTACLE
  - Host ship, UUV, USV, UAV, Stationary Bottom Sensors
- Tripwire
  - UUV, Rapidly Deployable Stationary Bottom Sensors
- War of Machines
  - UUV, Recharging Stations
- Floating Sensors

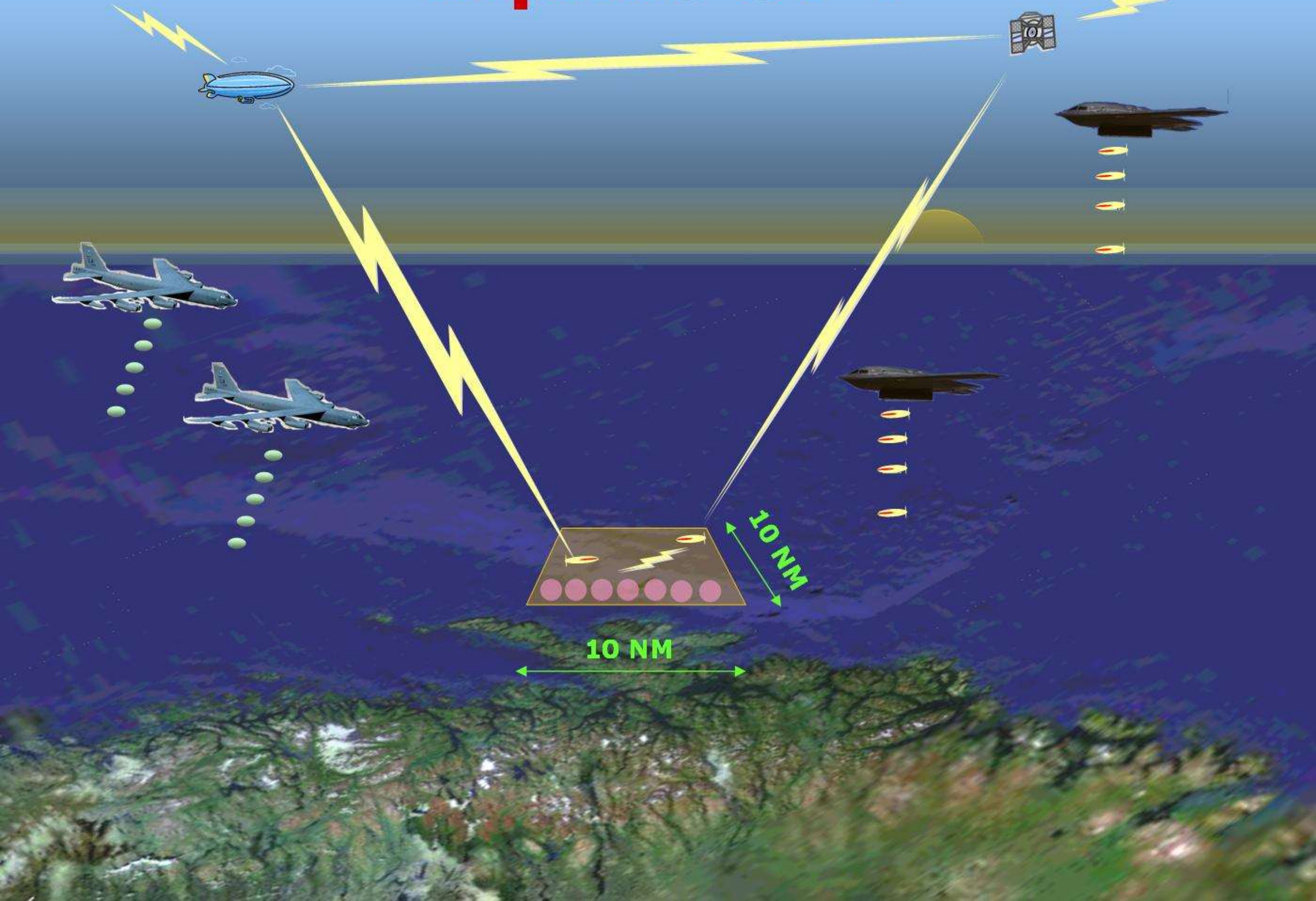
Littoral Action Group OV-1



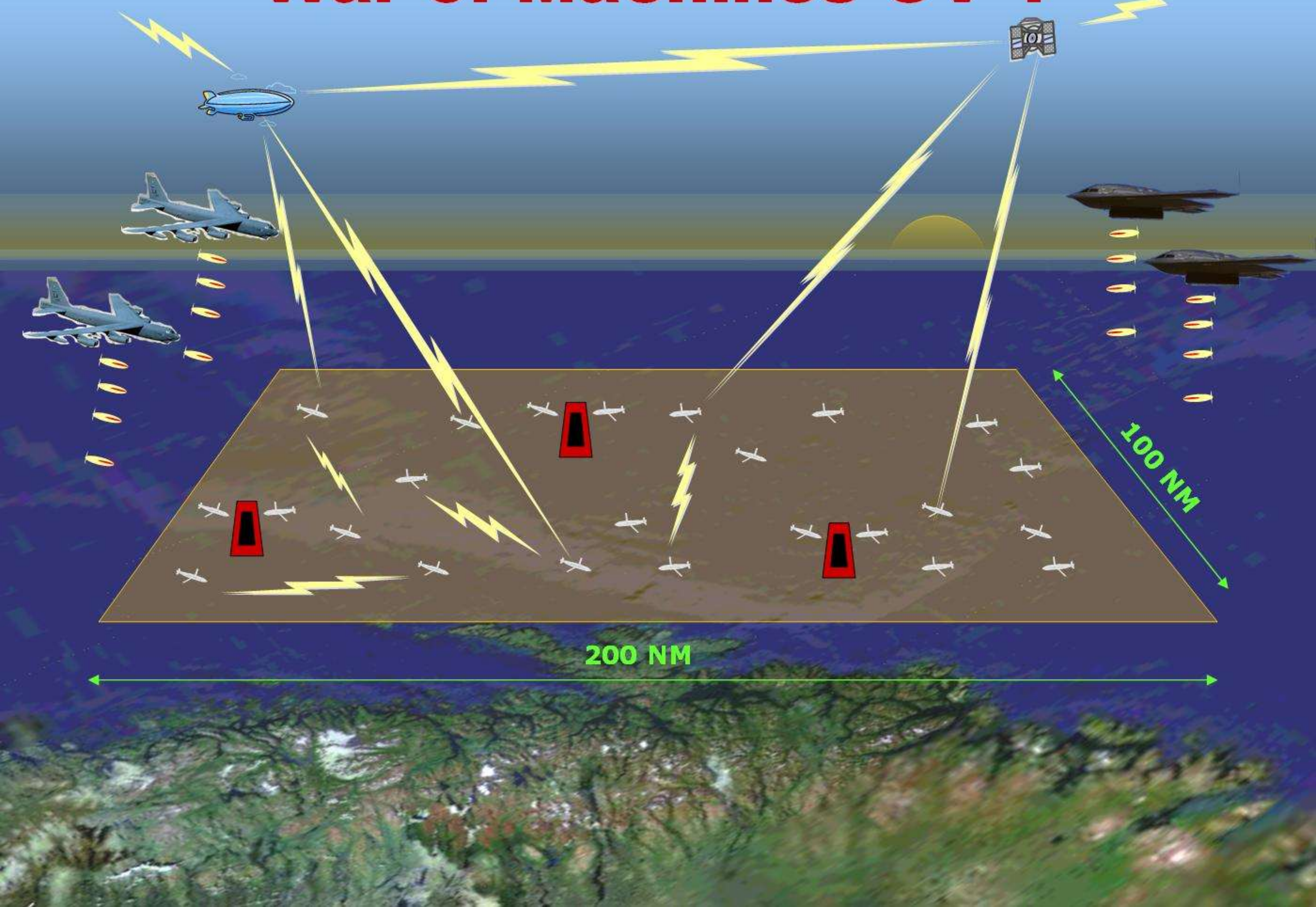
Sea TENTACLE OV-1



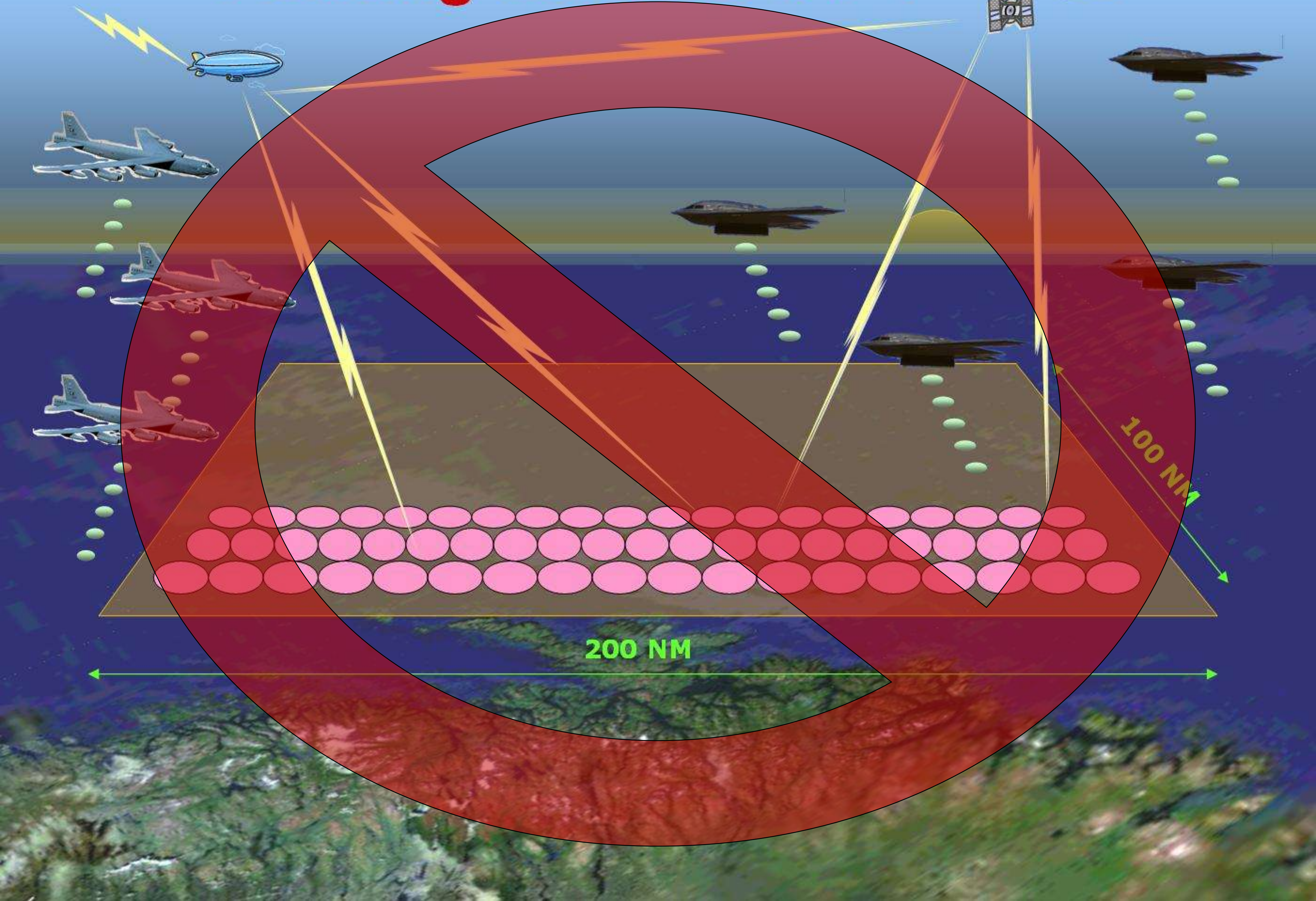
Tripwire OV-1



War of Machines OV-1



Floating Sensors OV-1



Break

Modeling

LT Jeff Baker, USN

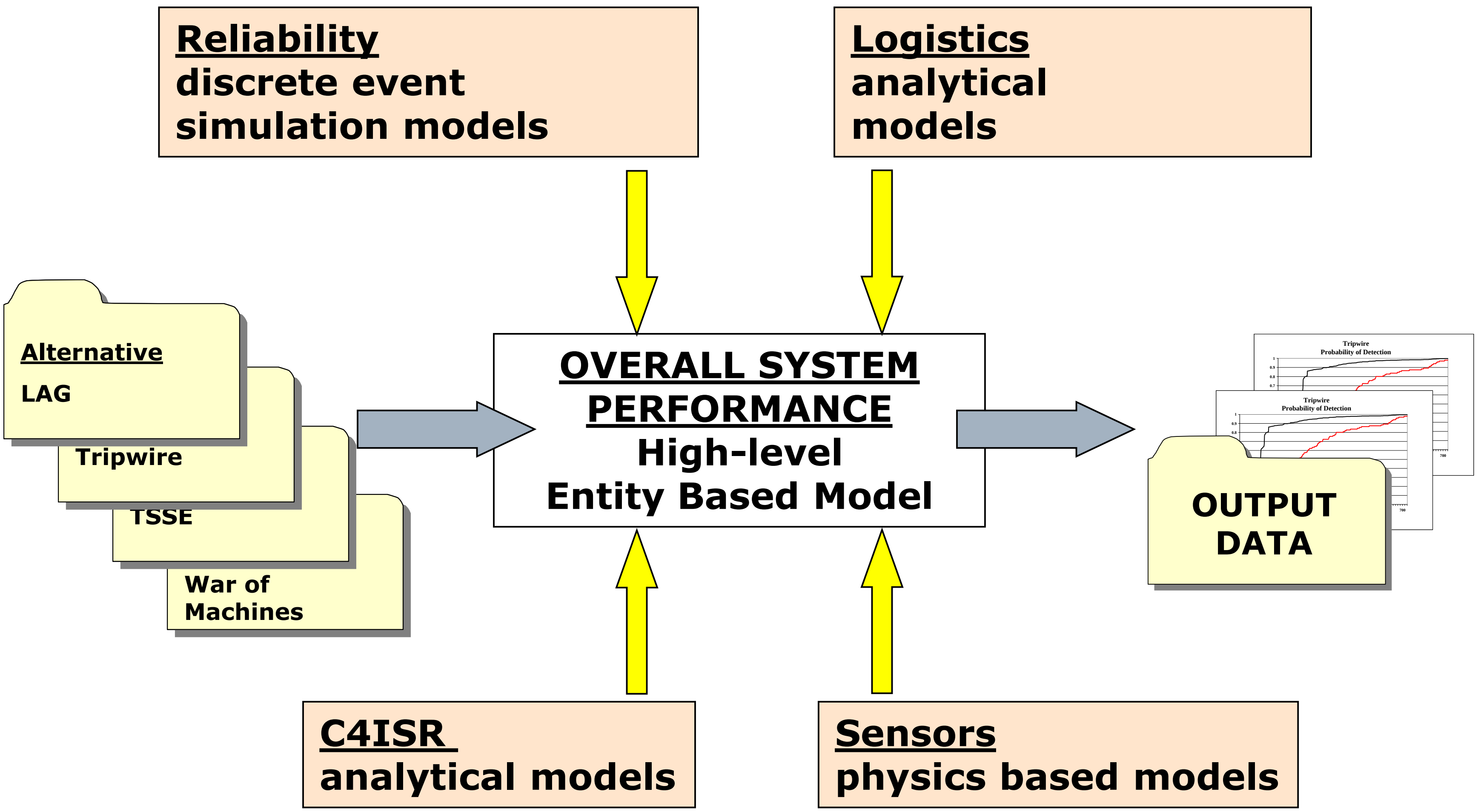
Modeling

- Used to predict or estimate system performance
- Provides insight

Primary Modeling Needs

Sensor Performance	*physics based*
Logistics/Deployment	*analytical*
Reliability	*discrete event*
Command & Control	*analytical*
System Performance	*entity based*

High-level Model Development



Sensor Performance

PCIMAT Physics Based

- Time of Year
- Historical Data
- Bottom Type
- Wind
- Shipping Level
- Figure of Merit
- Red Source Level
- Red Operating Depth
- Frequency of Concern
- Operator’s Ability

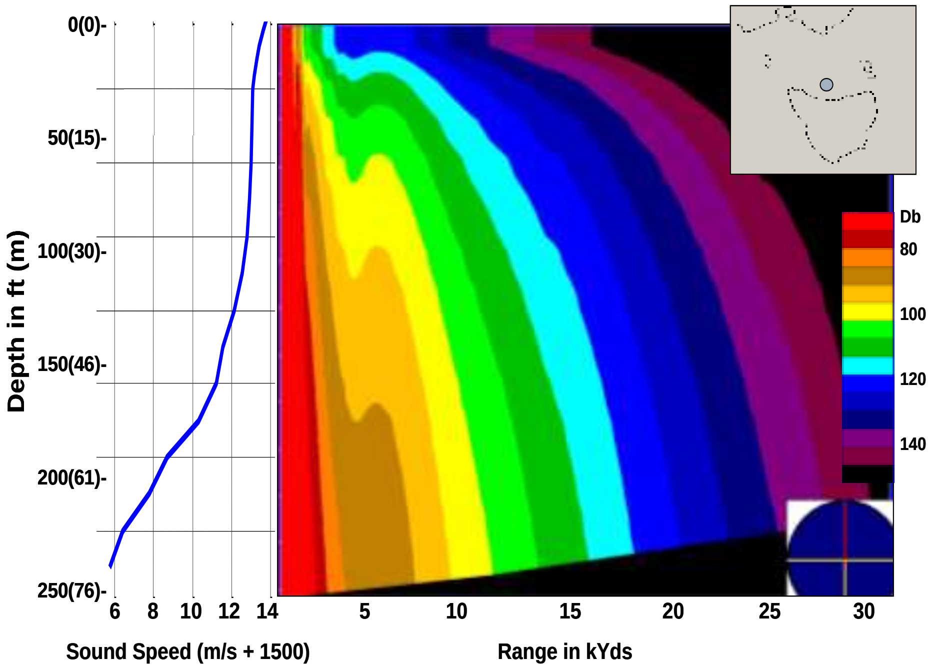
UNCLASSIFIED

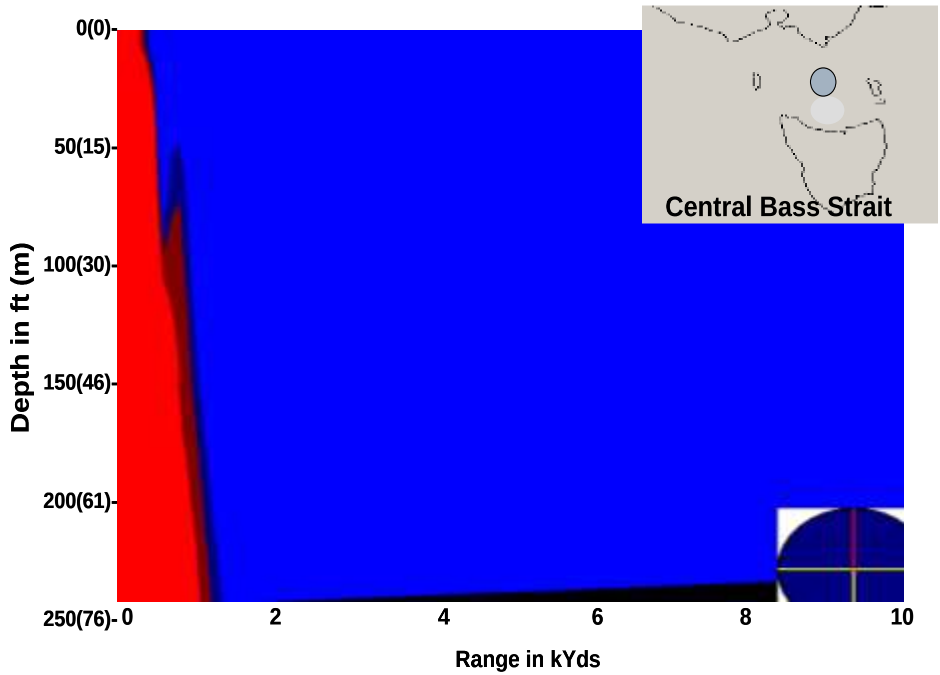
PCIMAT

- Expected Detection Ranges
- Expected Propagation Loss

Sensor Performance

- Examples of propagation loss and detection range outputs from PCIMAT





Logistical Performance

Deployment Analytical Model

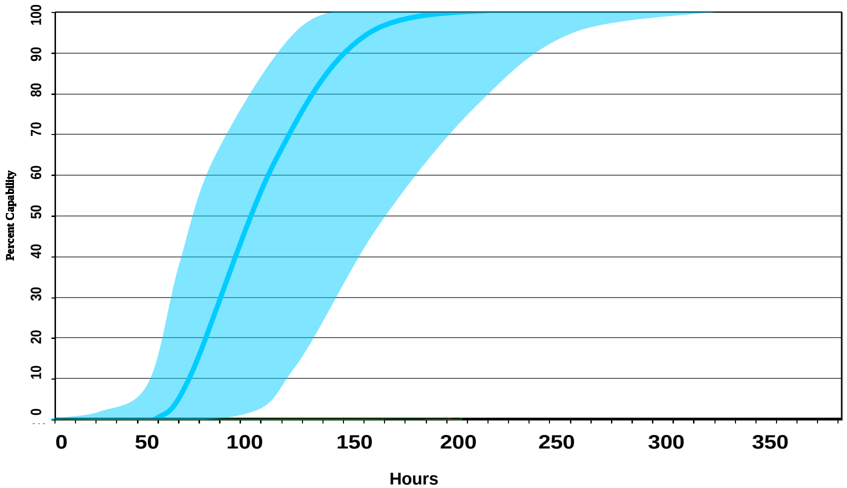
- Transit speed
- Working payload
- Transit distance
- Distance to AOR
- Logistics (refueling)
- Admin (crew rest, maintenance)
- Refueling thresholds
- Sensor components
  - UUVs
  - Sea web sensors
  - Recharging stations

Analytic Based Model

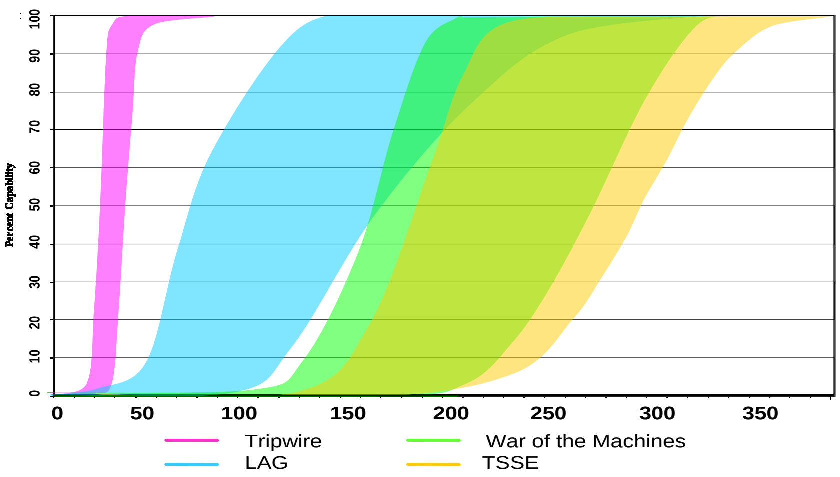
- Force mix to meet
  - Delivery of 50%
  - Delivery of 80%
- Assets required
- Total tonnage of components
- Transit time (hrs)
- Refueling required
- Reseed requirements
- Payload off-load/on-load time
- Asset arrival time
- Percent capability over time

Logistical Performance

Distribution of Logistical Arrival Rate Alternative LAG



Logistical Differences and Limitations Based Upon Alternative Architecture



C4ISR

C4ISR Analytical Modeling

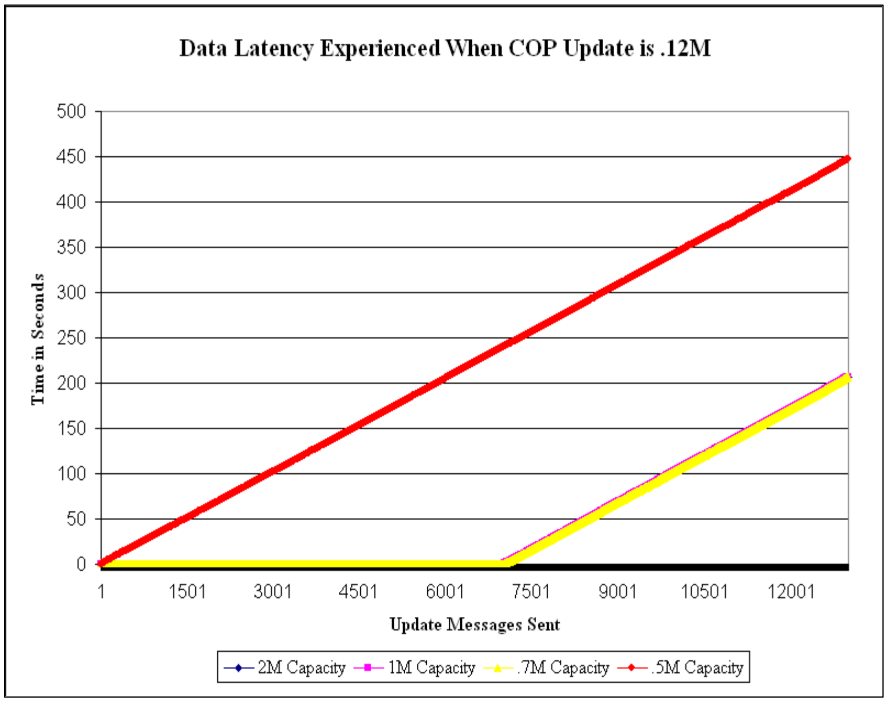
- **Bandwidth available**
- **Bandwidth required**
- **Processing time**
- **Transmission time**
- **Bit Error rate**
- **Frequency**
- **Ambient noise**
- **Power (W)**
- **SNR**

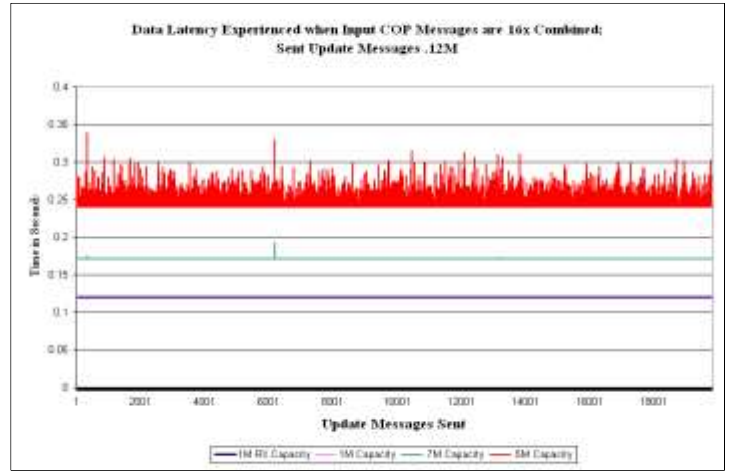
→ **DDS Network Model** →

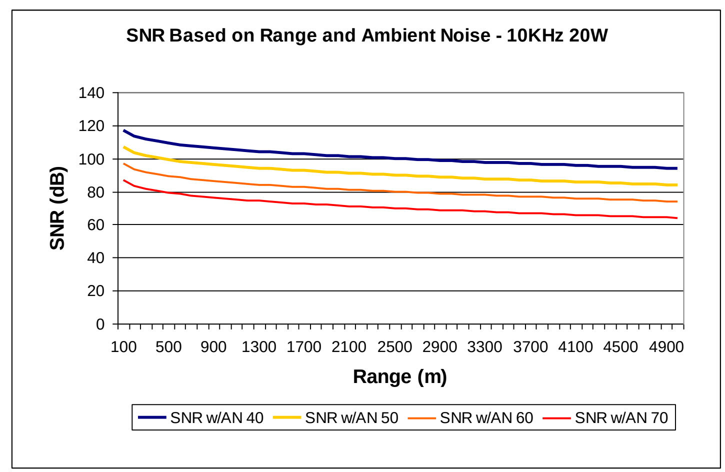
- **Data latency**
- **Capacity**
- **Fusion time**
- **Range**

C4ISR Model Products

C4ISR output examples:







Overall System Performance

- High Level Entity Based Model
- Naval Simulation System

- Environmental
- Communications
- C4ISR
- Susceptibility to detection
- Red/Blue search/transit speed
- Red/Blue search/patrol pattern
- Red/Blue sensor capabilities
- Red/Blue endurance
- Operating Medium

→ **NSS** →

- Surveillance detections
- Tracking sensor events
- Tracking sensor status
- Change time
- Total tracking time

High Level Modeling

NSS Simulation Examples:

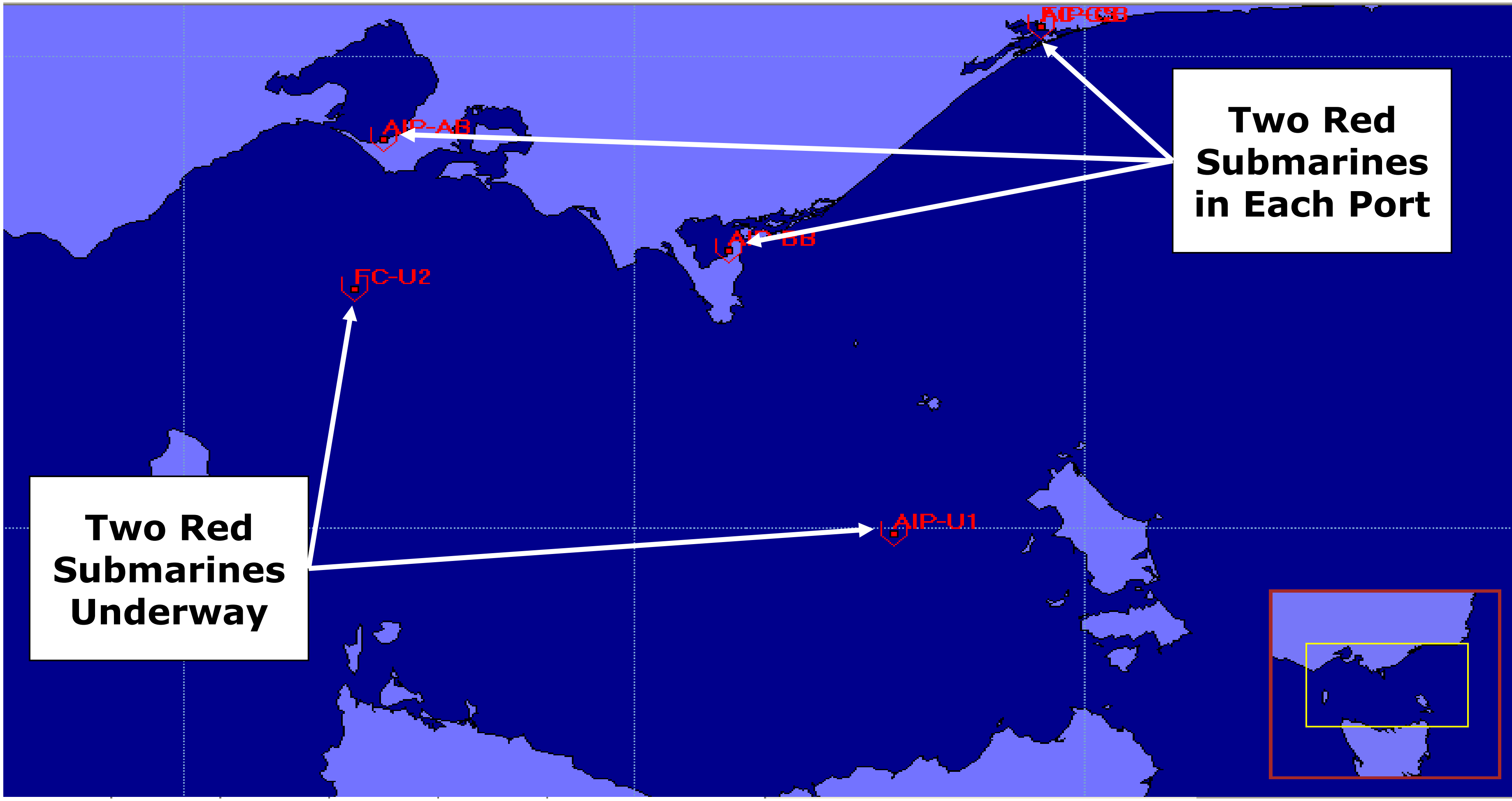
Search & Detection

- Probability of Detection
  - Used NSS to simulate real-world scenario in the Bass Strait over a 30 day period (720 hours)
    - Simulation data shows when Blue assets begin operations in the AOR
  - After analysis, results show:
    - Pd of all Red submarines
    - Pd of any one Red submarine
    - Instantaneous Pd of any Red submarine

Alternative Modeling

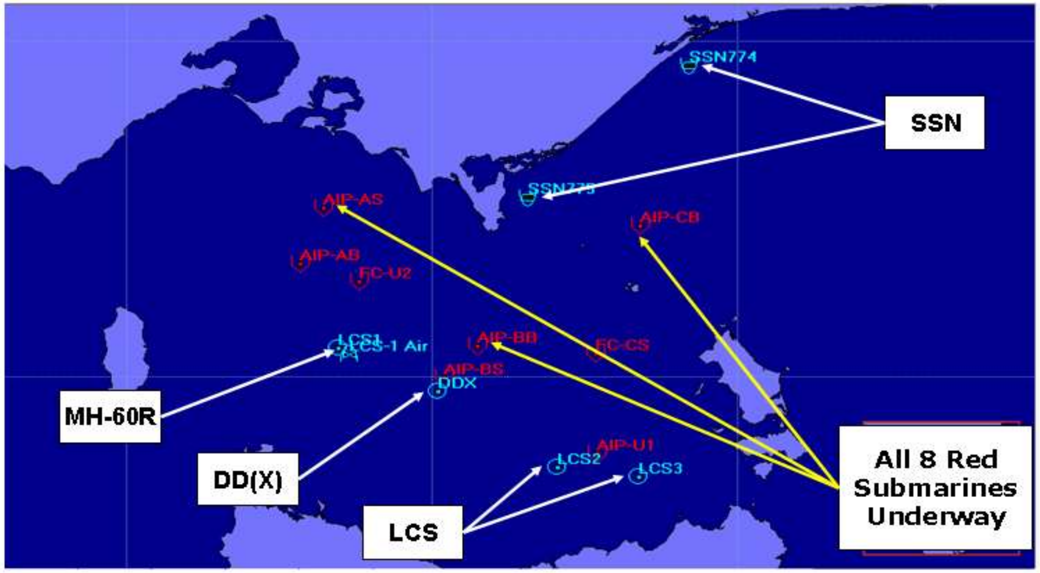
LCDR Michael Kaslik, USN

Location of All 8 Red Submarines at Problem Start



Littoral Action Group Assets and Timeline

- 2 SSNs
- 1 DD(X)
- 3 LCS's
- 5 MH-60Rs
  - 2 on DD(X)
  - 1 per LCS



5th Day

SSNs

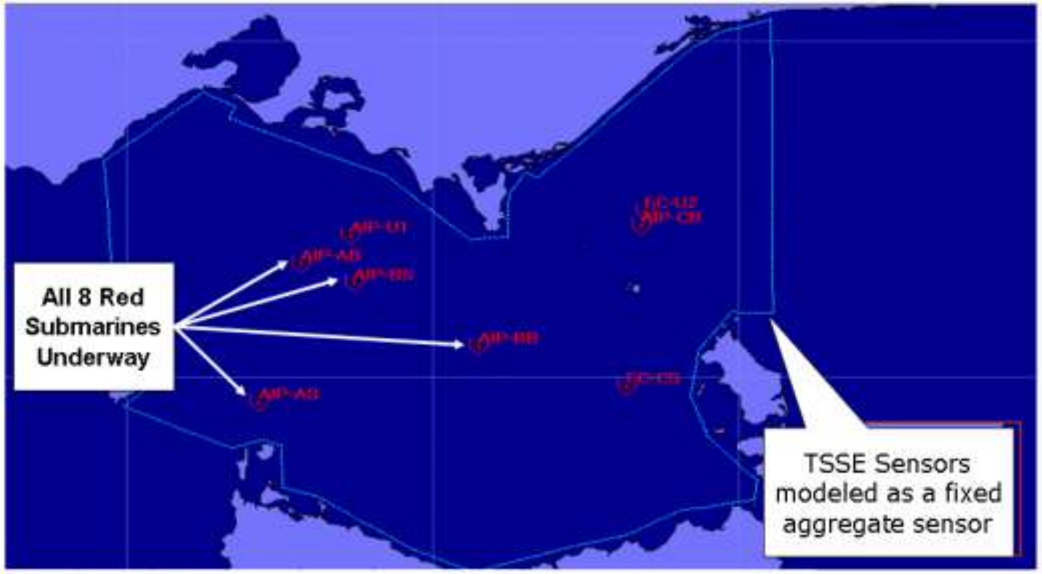
6th Day

DD(X)
LCS's
MH-60Rs

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

TSSE Sea TENTACLE Assets and Timeline

- 3 TSSE Sea TENTACLE Ships
  - 144 Large UUVs
  - 144 UUV Sleds
  - 864 Light Weight UUVs
  - 2304 Man-Portable Deployed Bottom Sensors



6th Day

3 TSSE Ships

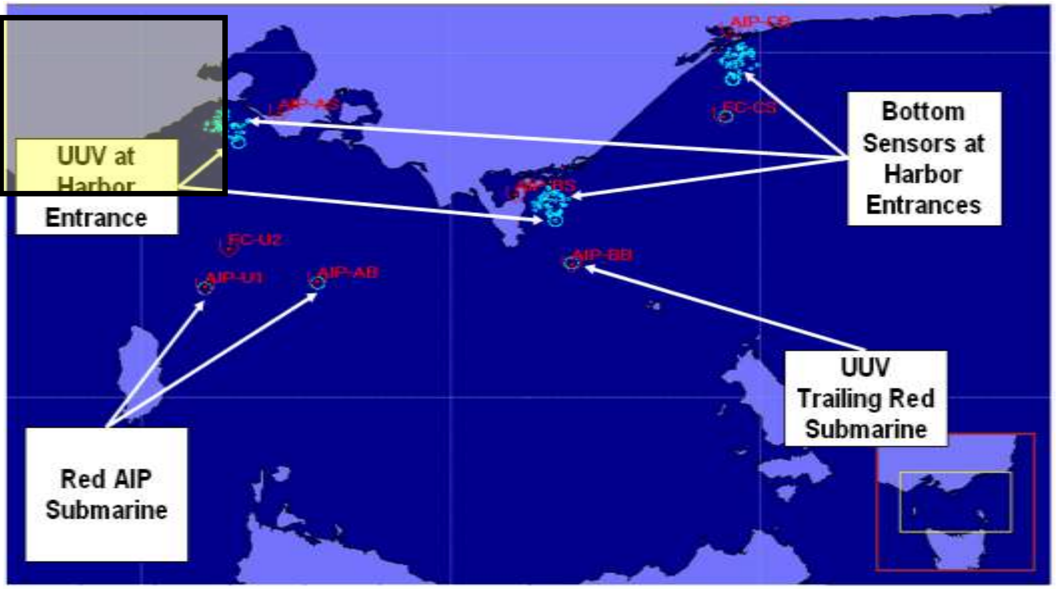
10th Day

Sea TENTACLE Deployment Complete

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Tripwire
Assets and Timeline

- Stationary Bottom Netted Sensors
  - 50 deployed outside each of the 3 harbors
  - Sustainable through 30-day scenario
- UUV
  - 5 deployed outside each of the 3 harbors
  - 80 hr battery duration



24th Hour

150 Bottom Sensors

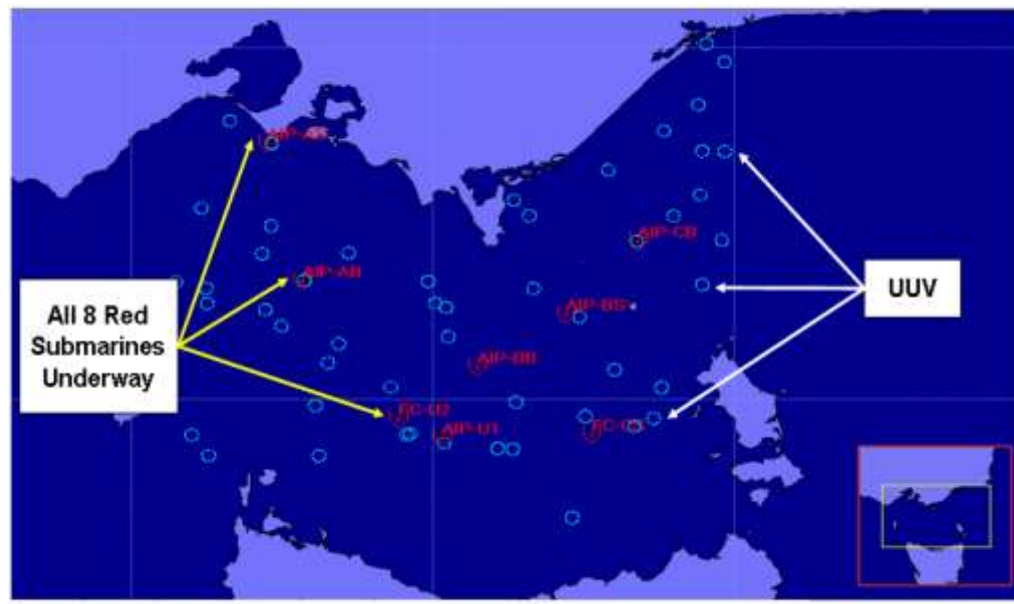
36th Hour

15 UUV's

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

War of Machines
Assets and Timeline

- 51 Heavy Weight Vehicle (HWV) UUVs
  - 45 HWV UUVs air-deployed
  - 2 HWV UUVs outside each Red Harbors
- 9 Recharging stations



8 – 26 Hours

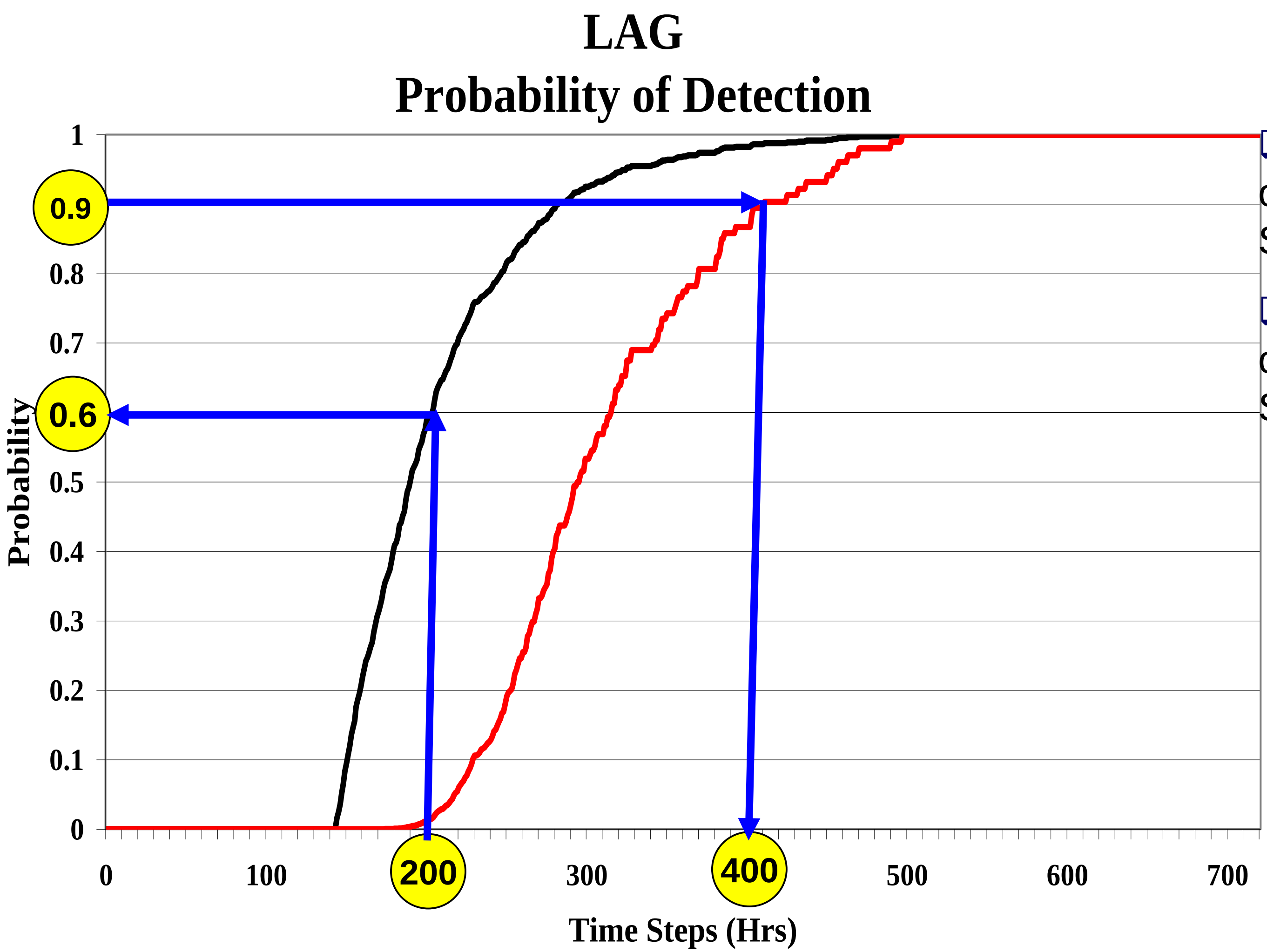
51 UUV's

6th Day

Recharging Stations

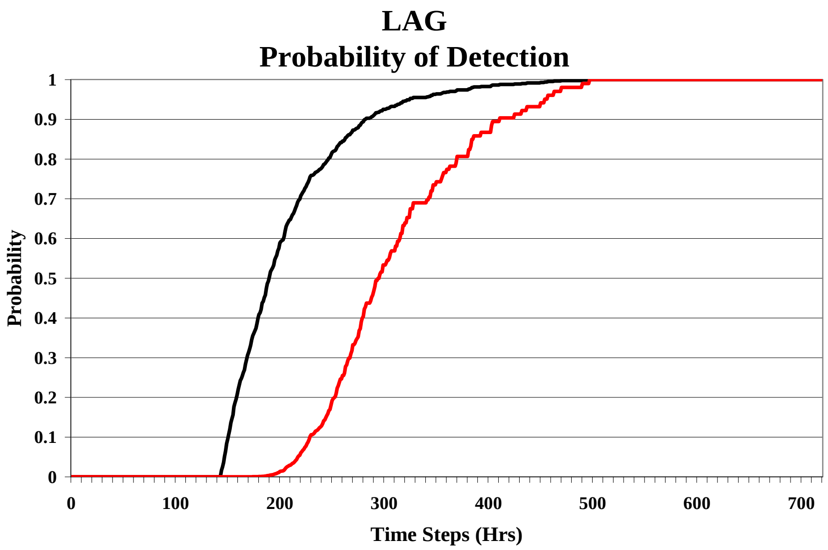
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

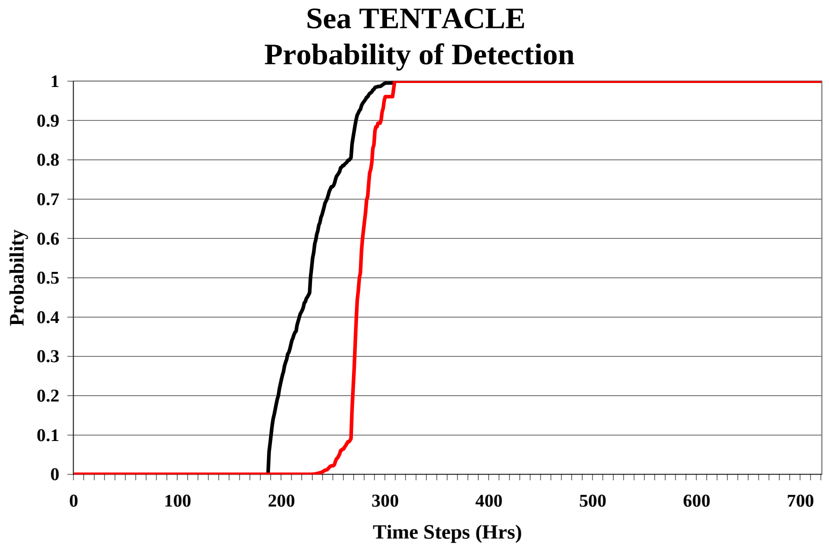
Littoral Action Group Probability of Detection

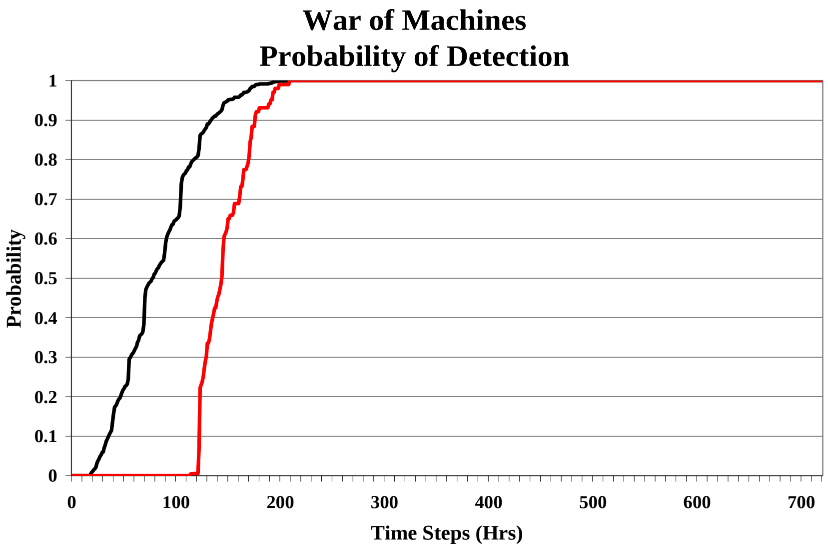


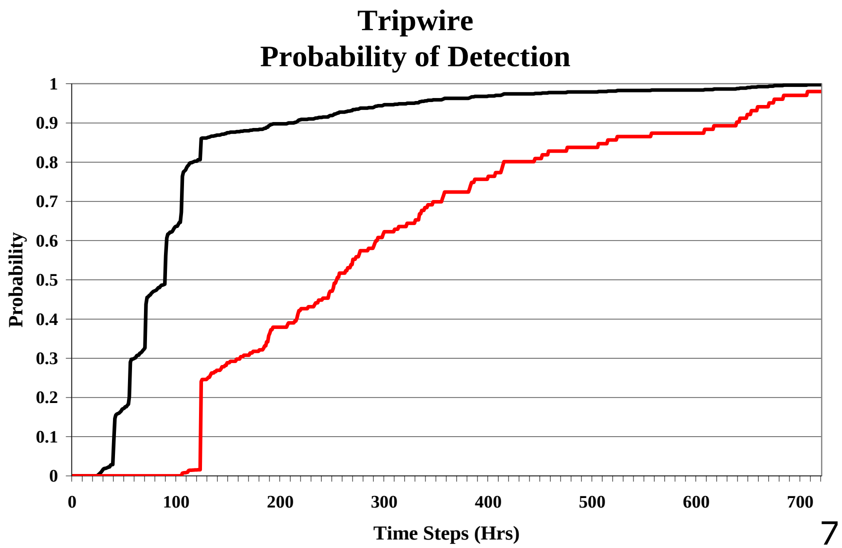
- **Black Line:** Probability of Detecting A single Red Submarine by time step
- **Red Line:** Probability of Detecting all Red Submarines by time step

Alternative Comparison Probability of Detection

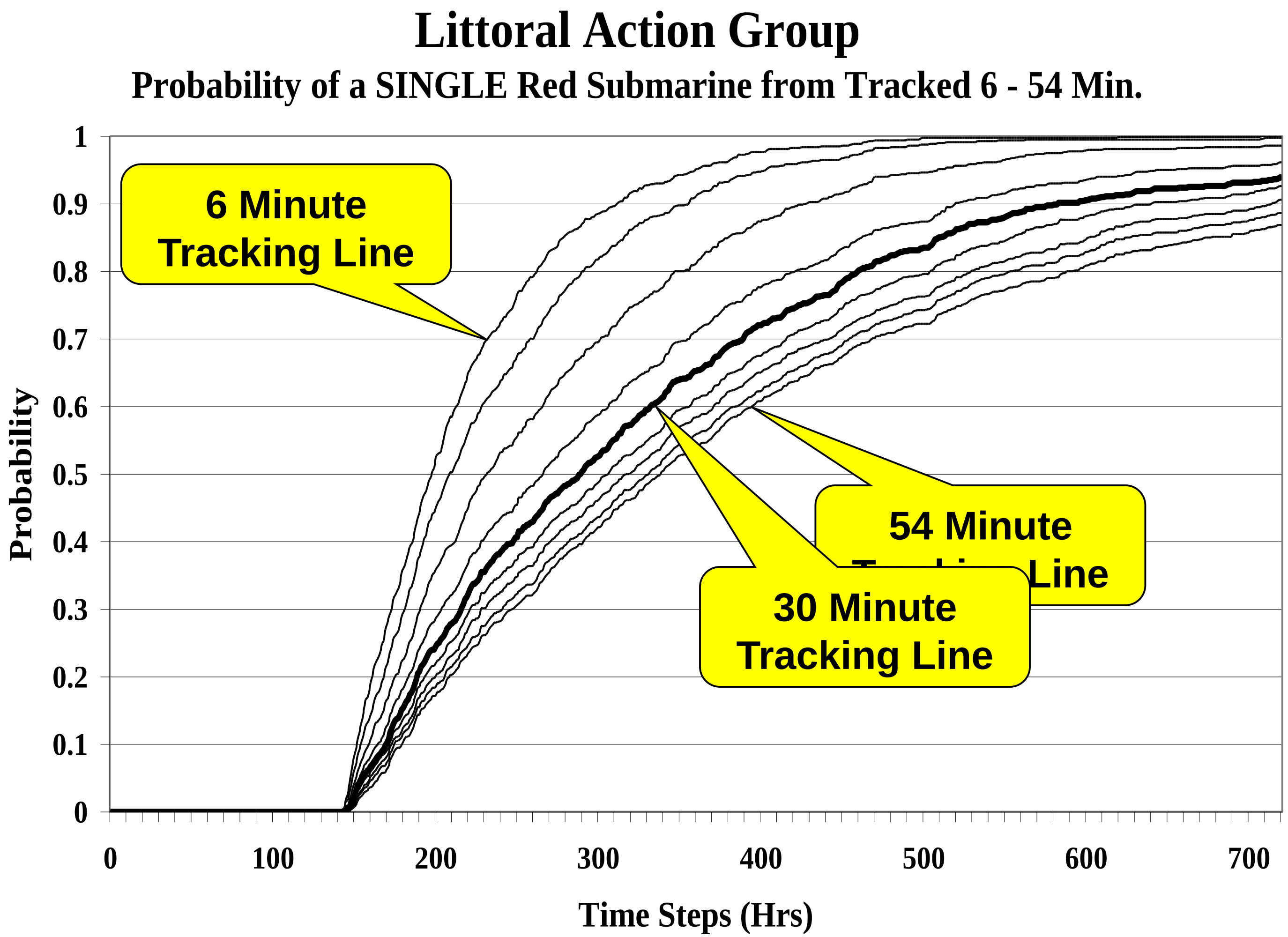






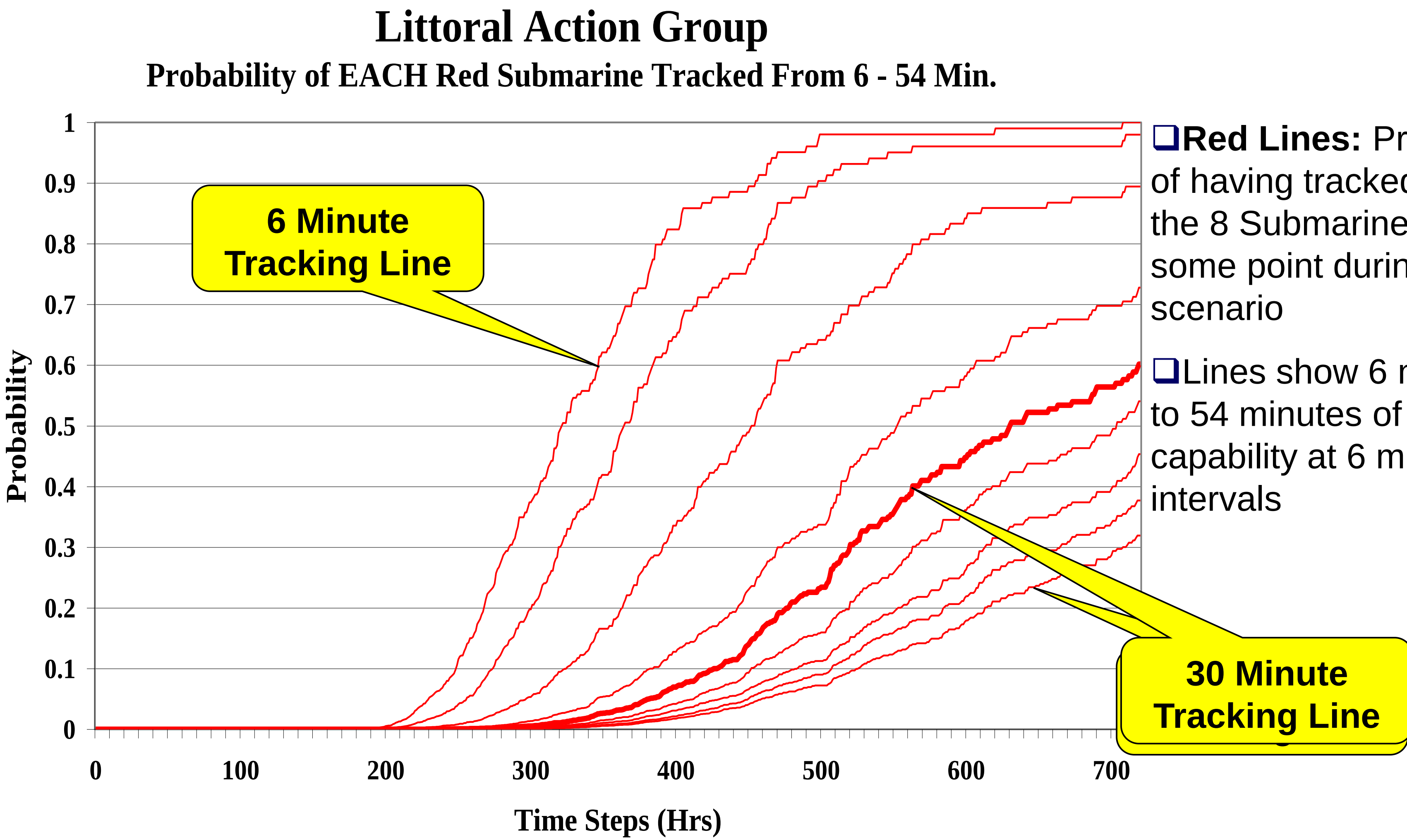


Littoral Action Group Probability of Tracking



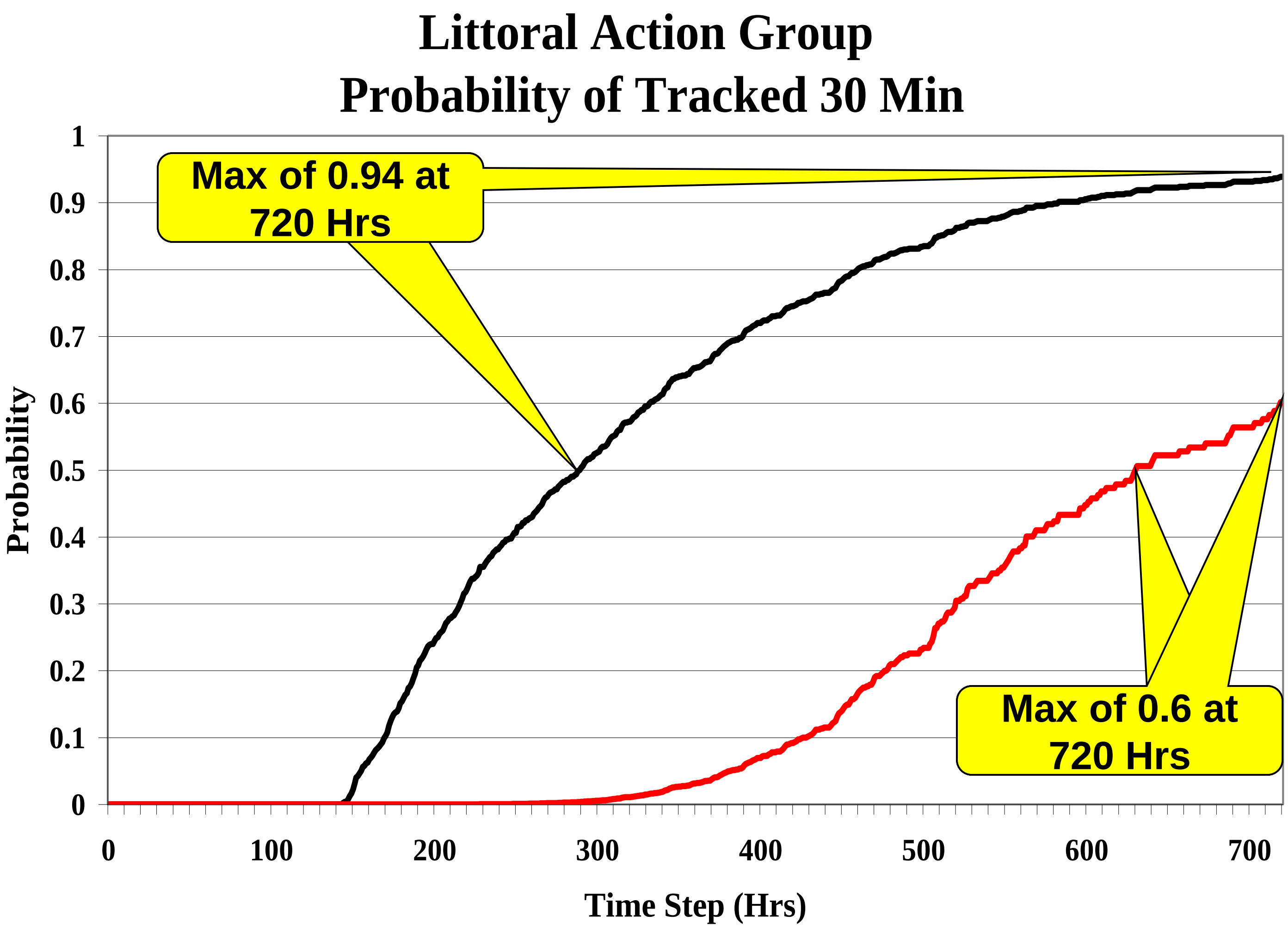
- **Black Lines:** Probability of having tracked a single Red Submarine during the scenario
- Lines show 6 minutes to 54 minutes of tracking capability at 6 minute intervals

Littoral Action Group Probability of Tracking



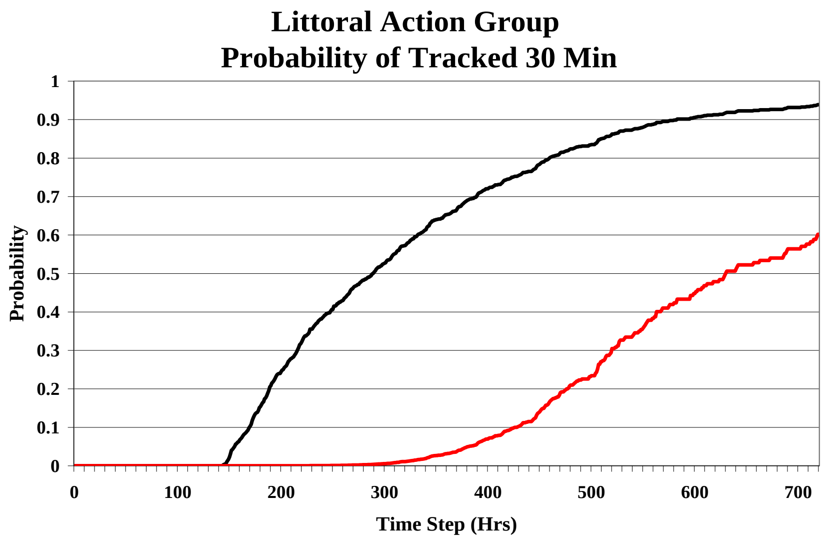
- **Red Lines:** Probability of having tracked each of the 8 Submarines at some point during the scenario
- Lines show 6 minutes to 54 minutes of tracking capability at 6 minute intervals

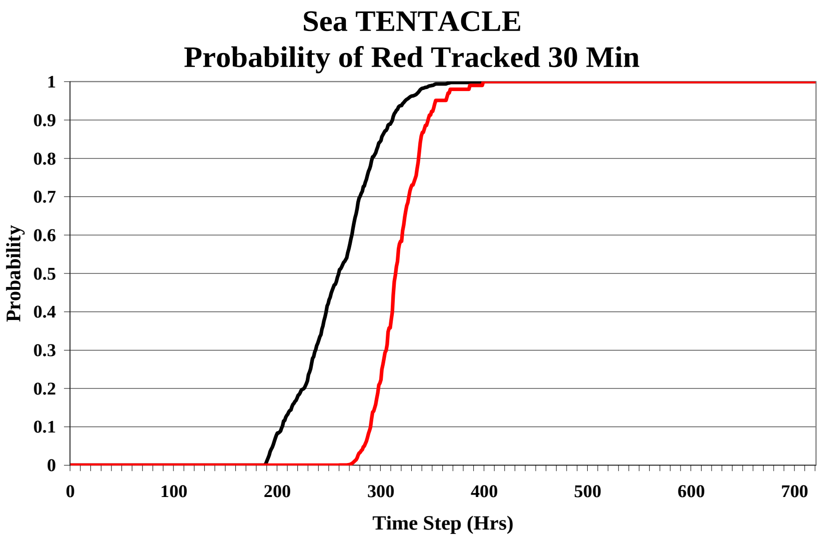
Littoral Action Group Probability of Tracking

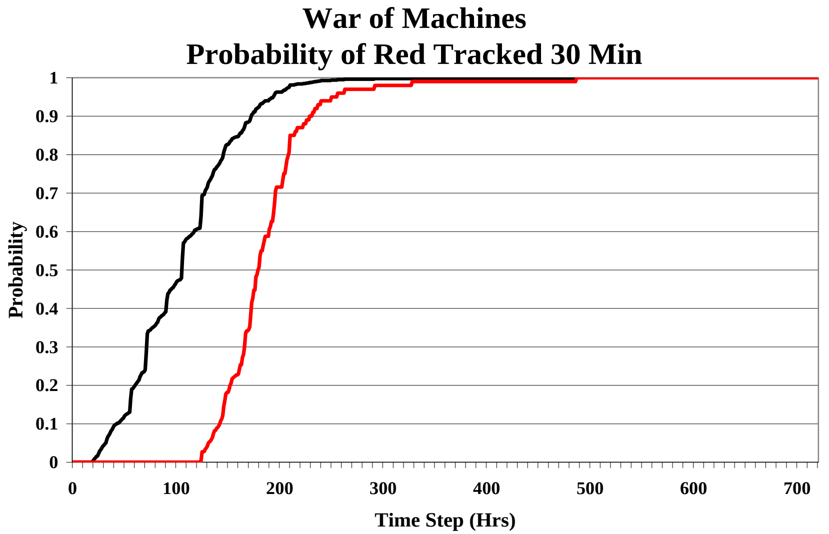


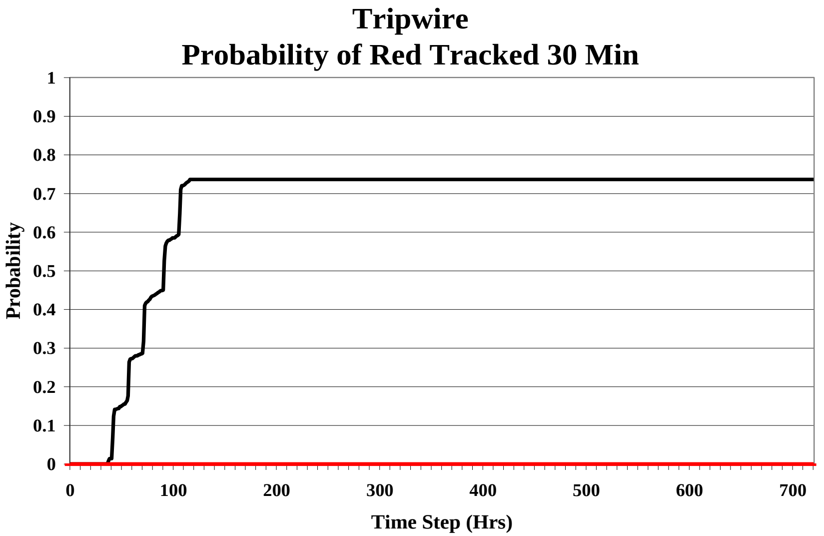
- **Black Line:** Probability of having tracked a Red Submarine for 30 minutes
- **Red Line:** Probability of having tracked each of the 8 Red Submarines at some point during the scenario

Alternative Comparison
Probability of Tracking





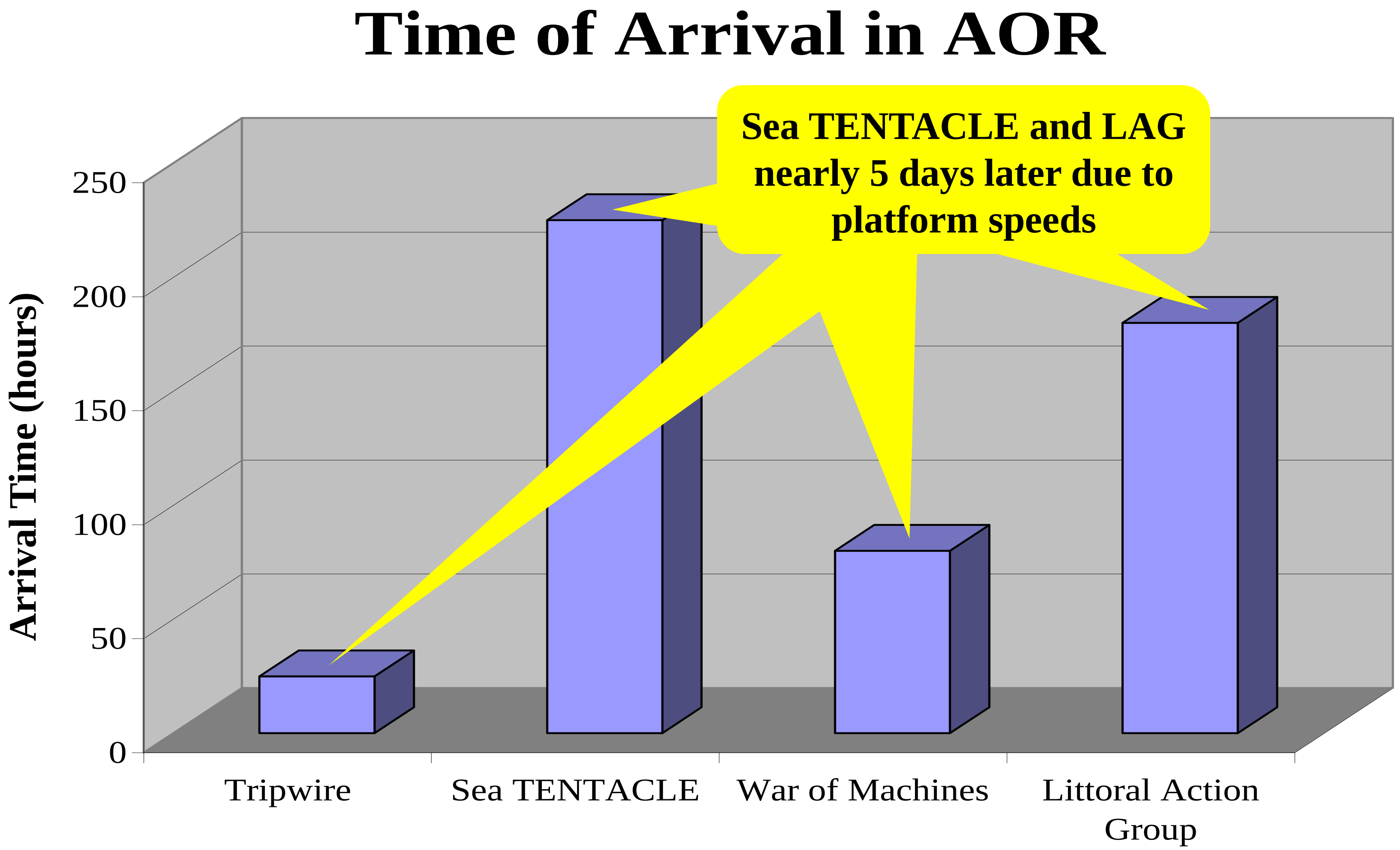




Analysis

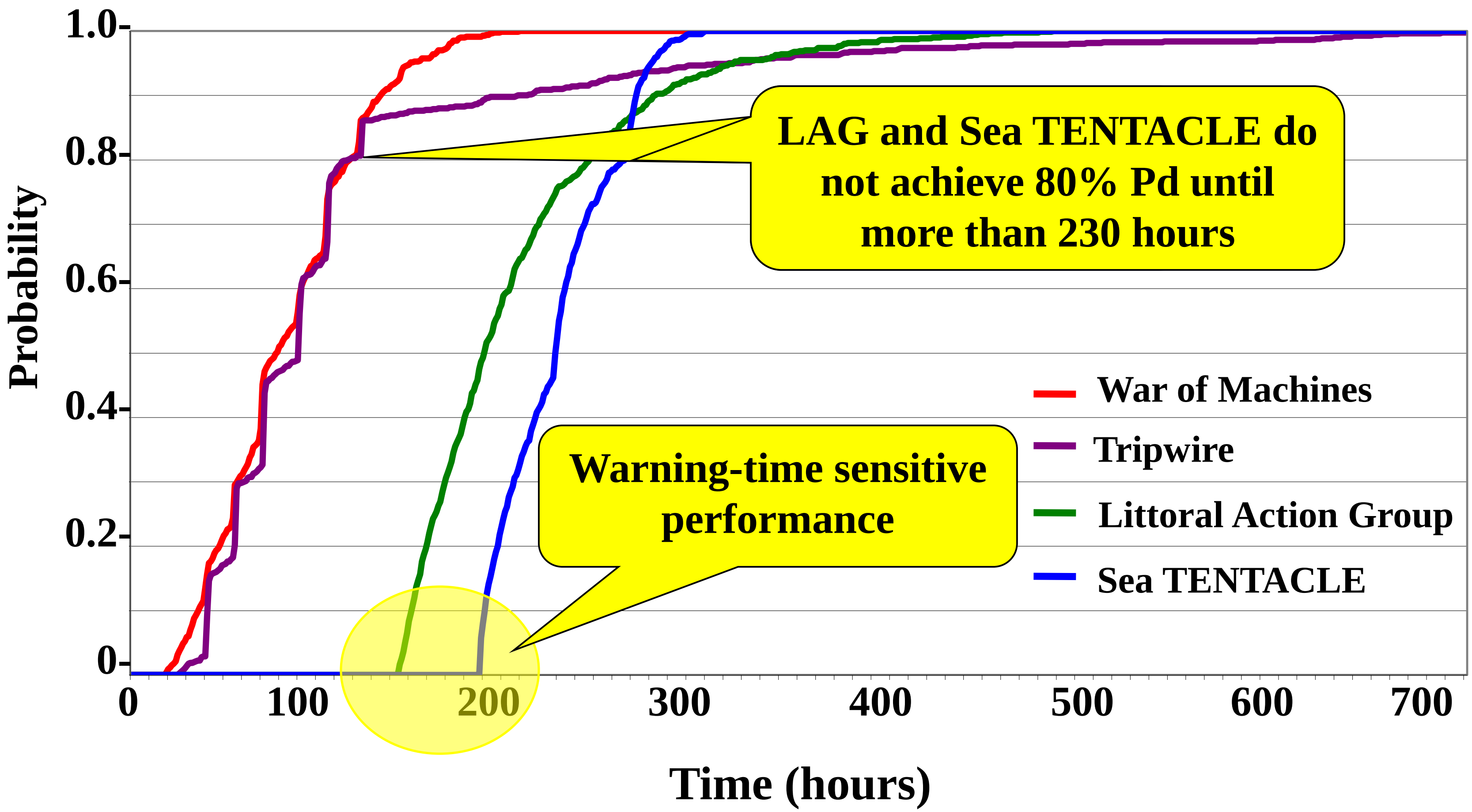
LT John J. Strunk, USN

Arrival Times Vary



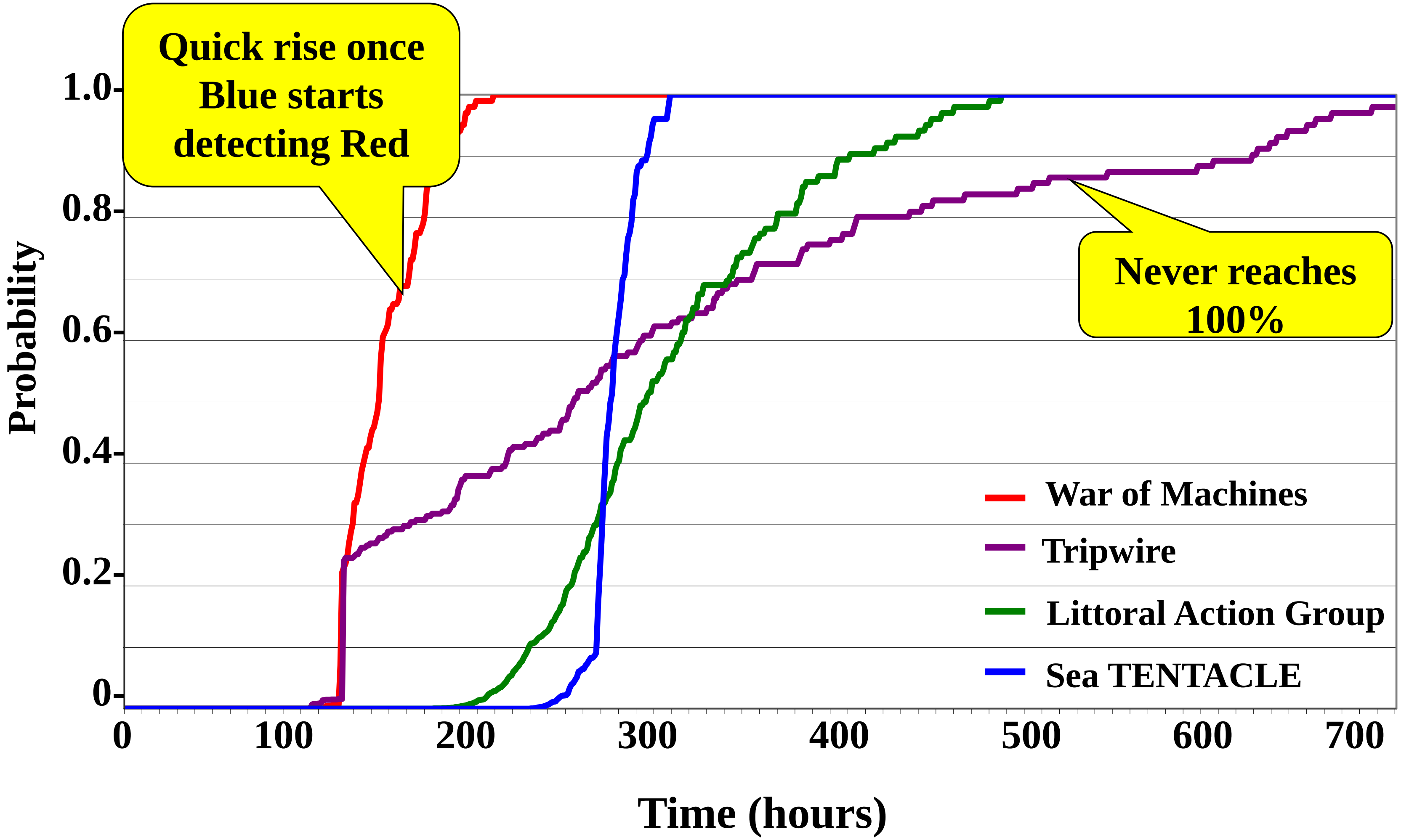
Alternatives' Strengths/Weaknesses

Time to INITIAL Detect of Red Submarines



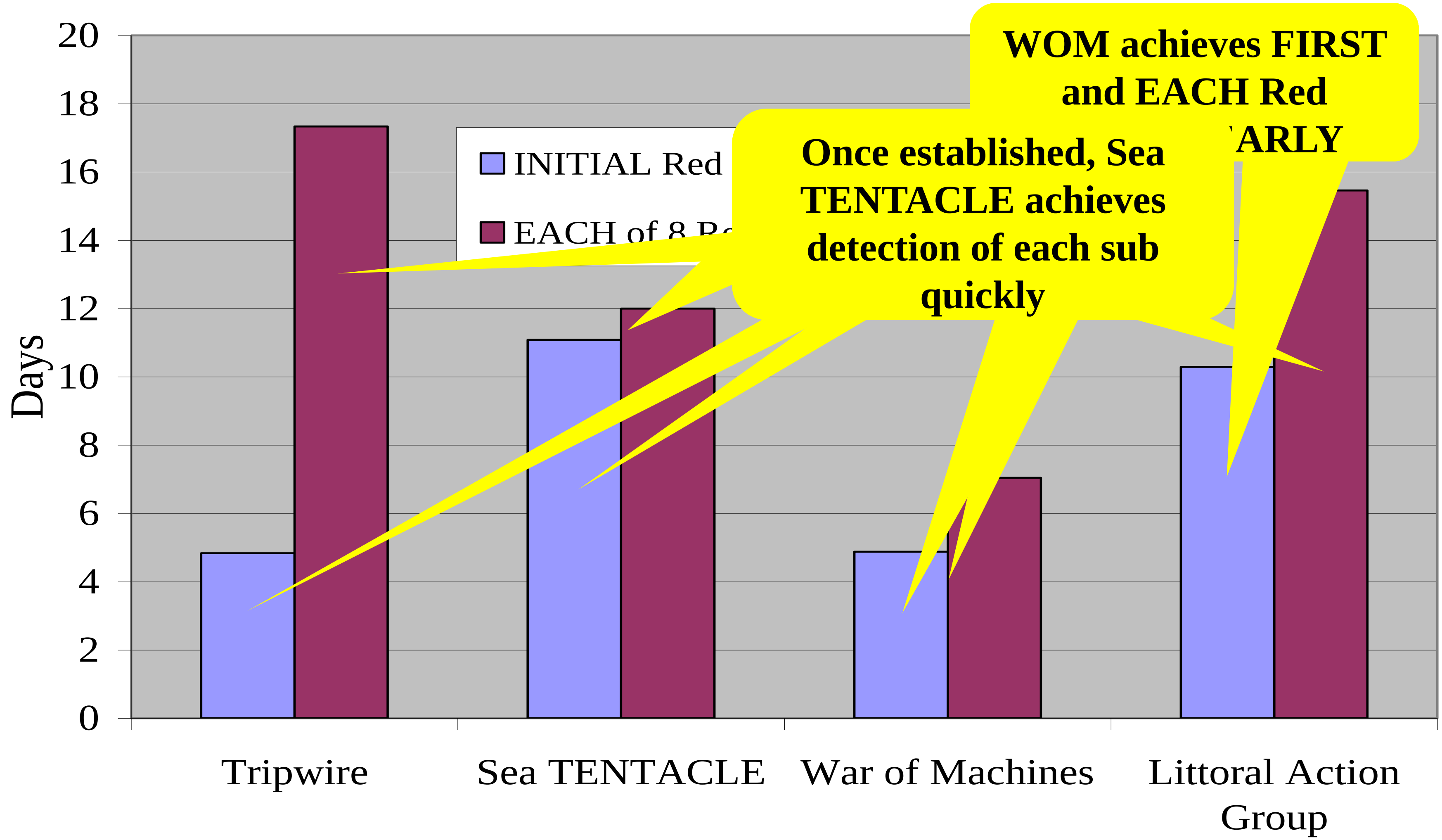
Alternatives' Strengths/Weaknesses

Time to Detect EACH of 8 Red Submarines



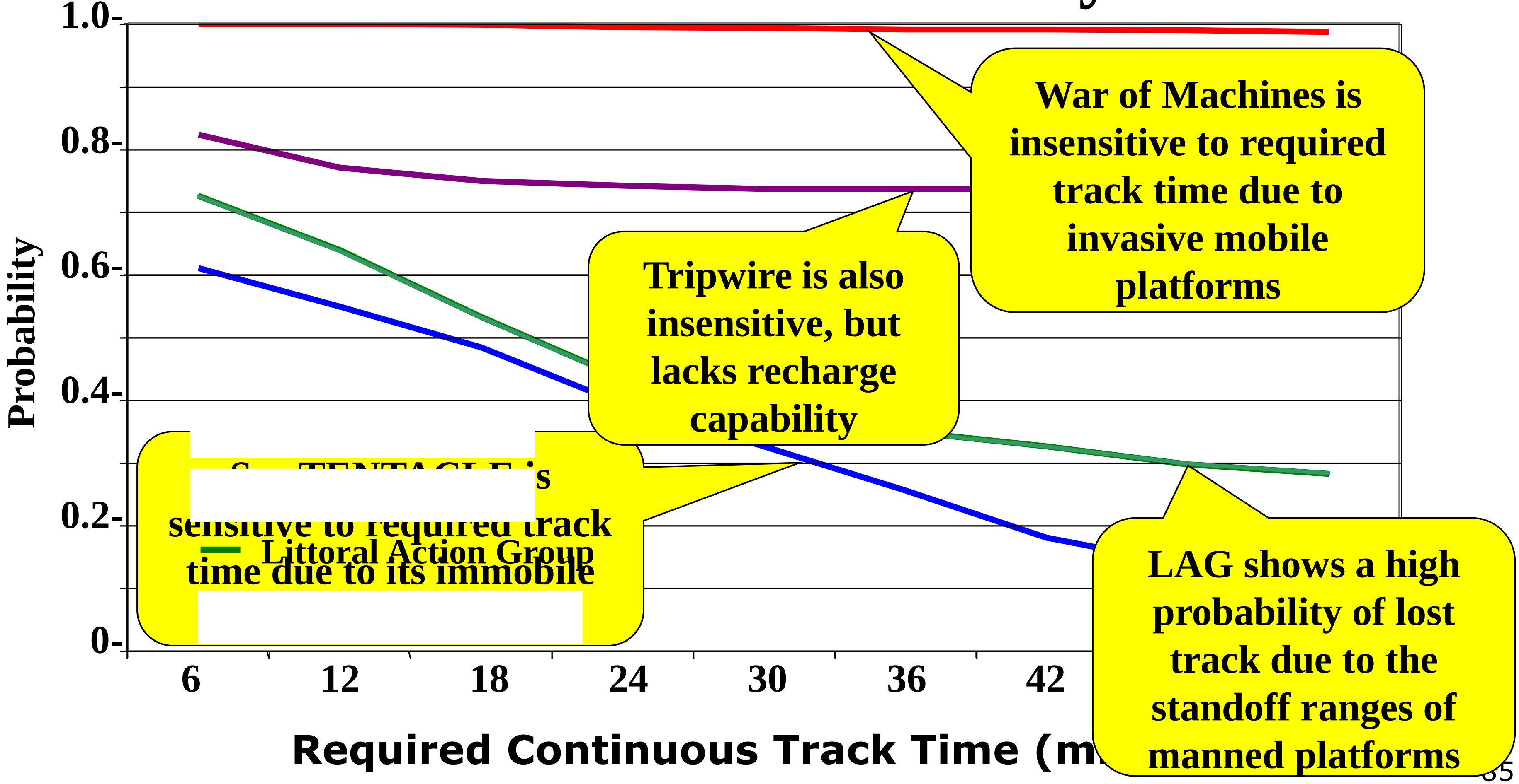
Alternatives' Strengths/Weaknesses

80% Probability of Achieving Two Critical Detection Metrics

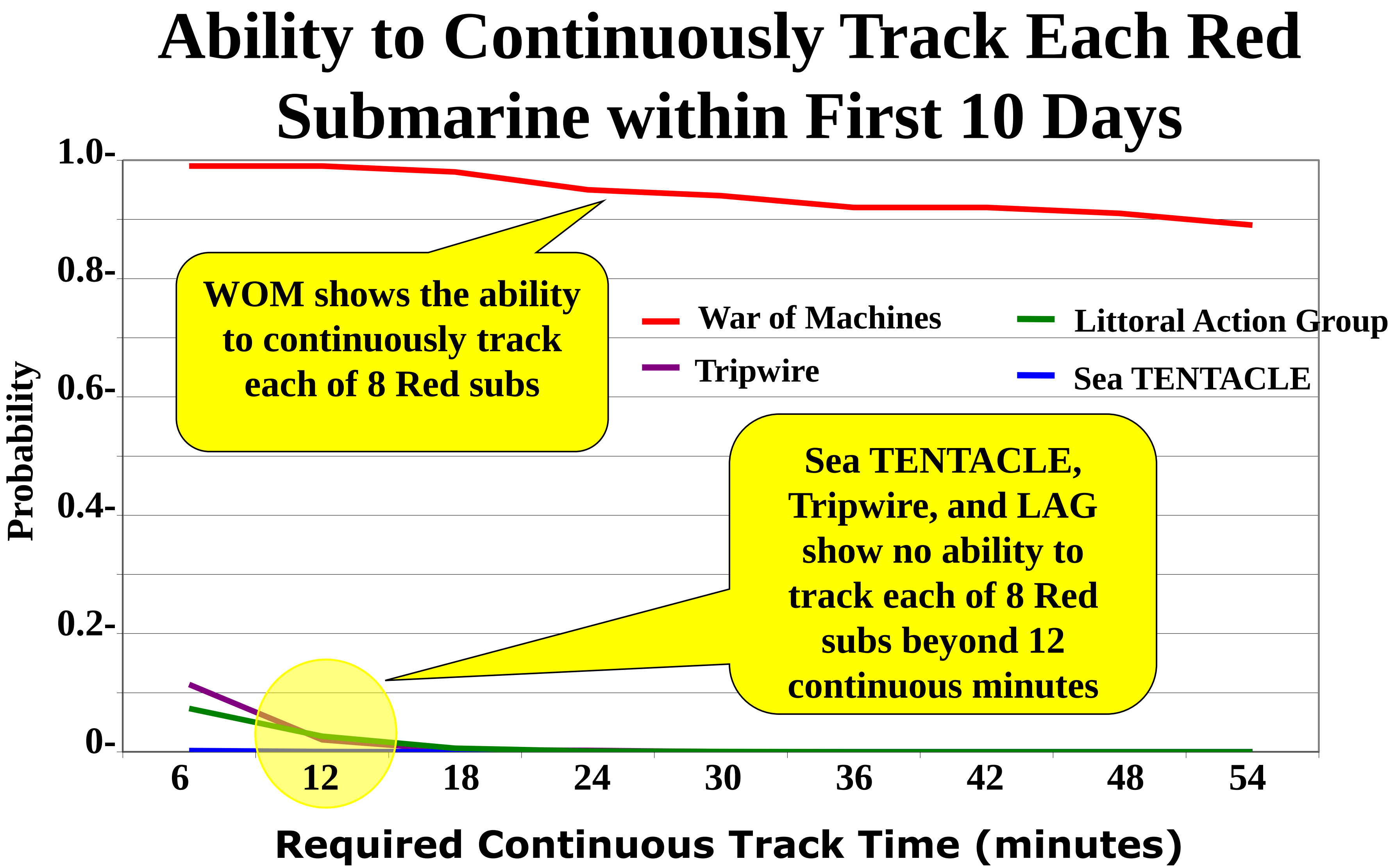


Tracking Ability

Sensitivity to Required Continuous Track Time within First 10 Days



Tracking Ability



SEA-8 Overall Conclusions

CDR Vic Bindi, USN

SEA-8 ASW Results, Insights and Recommendations

- Systems engineering principles
- Results and insights
  - No perfect system
  - Reaction time
  - Persistent systems
  - Kill chain timeline tradeoffs
  - Undersea Joint Engagement Zones (UJEZ)

ASW Results, Insights and Recommendations

NO PERFECT SYSTEM

- Scenario variables were the key factors
- Each alternative studied had weaknesses

RECOMMENDATIONS

- Study mix of developed ASW architectures
- Apply those ASW architectures to theater specific scenarios, via modeling

ASW Results, Insights and Recommendations

REACTION TIME

- Enemy timelines are unpredictable
- Quick reaction systems hedge uncertainty

RECOMMENDATIONS

- Use strategic air to expand the reach of tactical ASW operations
- Develop a JSOW like system to deliver sensors and UUVs close to the enemy shoreline

ASW Results, Insights and Recommendations

PRESENCE

- Pervasive persistence is the goal
- Traditional methods
- Non-traditional methods

RECOMMENDATIONS

- Develop UUV’s with autonomous search and track
- Develop rapidly deployable, netted sensing grids
- Develop systems that recharge, reseed and relief on station capabilities for non-traditional ASW assets

ASW Results, Insights and Recommendations

KILL-CHAIN TIMELINE (KCT) TRADEOFFS

- Traditional methods require short KCTs
- Non-traditional methods afford longer KCTs

RECOMMENDATIONS

- Develop autonomous UUVs that possess the ability to prosecute enemy submarines

ASW Results, Insights and Recommendations

UNDERSEA JOINT ENGAGEMENT ZONE (UJEZ)

- Cooperative mix of assets unlocks future ASW force capabilities
- Future ASW forces will require the establishment of the UJEZ

RECOMMENDATIONS

- Explore the doctrinal shift away from waterspace management and PMI techniques toward UJEZ
- Develop undersea networks required to support UJEZ

Future Studies

- Sensitivity analysis of alternatives in relation to
  - geographic areas
  - threat scenarios (types and compositions)
- Improved UUV energy sources and recharging stations
- Role of the UUV in the engagement sequence
- UUV effects upon the Kill-Chain Timeline
- Application of alternative architectures in MIW
- Integration of strategic air in tactical ASW operations

Systems Engineering Analysis
Littoral Undersea Warfare in 2025