Systems Engineering Analysis

SEA-14

Tackling the M-IED Problem

NAVAL
POSTGRADUATE
SCHOOL

Capstone Project Presentation
Systems Engineering Analysis (SEA)
SEA 14

December 11, 2008

Opening Comments

- On behalf of President Dan Oliver, the faculty and students, welcome to NPS
- The SEA curriculum is a response to an initiative by Admiral William J. Fallon, then the Vice Chief of Naval Operations
  - Intended to give Unrestricted Line Officers (URLs) an education in both Analysis and Systems Engineering
  - A foundation for effective requirements officers and staff officers at many levels of the Navy.
  - The Navy sponsor for SEA is OPNAV N8F (Warfare Integration and Assessments)
- Because of the dual emphases in analysis and systems engineering, the degree is granted and the curriculum overseen jointly by the chairpersons of the Operations Research and the Systems Engineering Departments
  - An MS degree in Systems Engineering Analysis is jointly awarded

Opening Comments

- I oversee the program on a day-to-day basis with the indispensable support of
  - Prof. Mark Stevens, Academic Associate and
  - CDR Doug Burton, Program Officer
- SEA Core Educational Threads
  - SEA Preparation (Basics)
  - Analysis
  - Systems Technology
  - Systems Engineering
  - Capstone Project
  - Joint Professional Military Education (JPME)

SEA Projects (Background)

- Interdisciplinary project; problem of significant importance to Navy
- Students:
  - Plan Project
  - Analyze need
  - Determine operational concept
  - Develop functional requirements
  - Allocate req'ts among sub-systems
  - Produce system Architecture
  - Explore sub-system design
  - Assess trade-offs
  - Integrate final design
  - Present results
- Students are introduced to the analytical, political, strategic, tactical, and technical issues surrounding an important Navy problem, and more importantly, an understanding of a repeatable process that can be utilized for many problems
- Students from across campus often contribute
- TDSI students (Singapore) are integrated into every other project team.

SEA Projects (Background)

The Faculty Advisors for this project were:

Prof. Gene Paulo

Industry Prof. Bill Solitario

And RDML Rick Williams, USN (Ret) – NPS' Chair of Mine Warfare

LT Bobby Rowden is the Team Leader of the SEA 14 Capstone Project and will introduce you to their work.

SEA-14

Capstone Presentation –
11 Dec 08

A systems response to the Maritime IED threat

Faculty Advisors
Professor Gene Paulo – Systems Engineering
RDML Rick Williams III, USN (Ret) – Expeditionary and Mine Warfare
Professor Bill Solitario, Northrop Grumman - Industry

Tasking

"Design a system of systems to counter maritime improvised explosive devices in US ports."

Presentation Objectives

- To present the Systems Engineering Analysis Cohort 14 (SEA 14) Capstone Project, including:
  - Project overview
  - Alternatives and Analysis
  - Findings and Recommendations

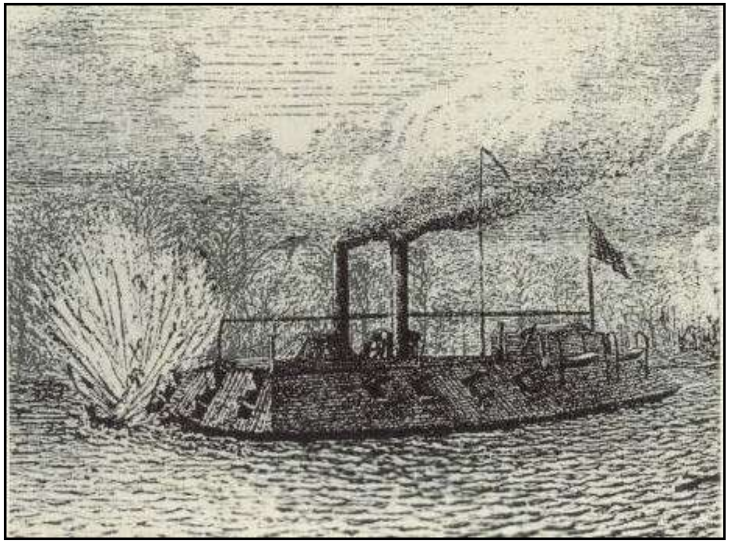
Presentation Agenda

- History and Background
- Systems Engineering Design Process
- Functional Analysis
- Physical Architecture Alternatives
- Wargame, Modeling, and Simulation
- Decision Analysis Results
- Additional Insights
- Findings and Recommendations

Background

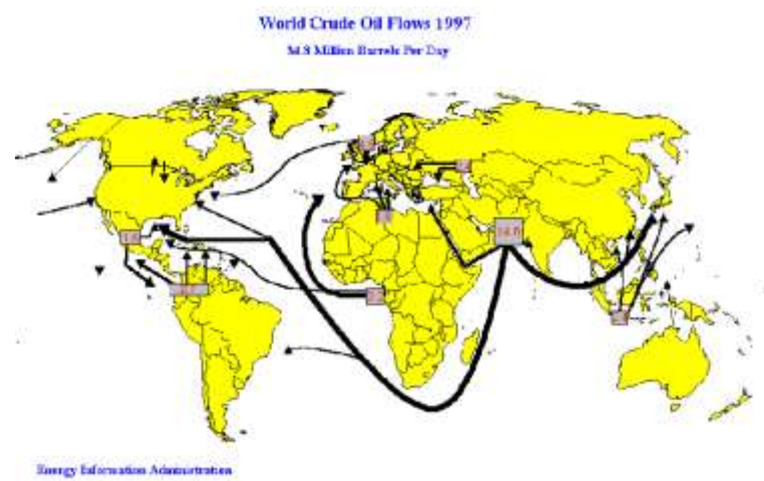
Historical Background

- Bushnell Keg
- USS CAIRO
- Vietnam



Terrorist Mining

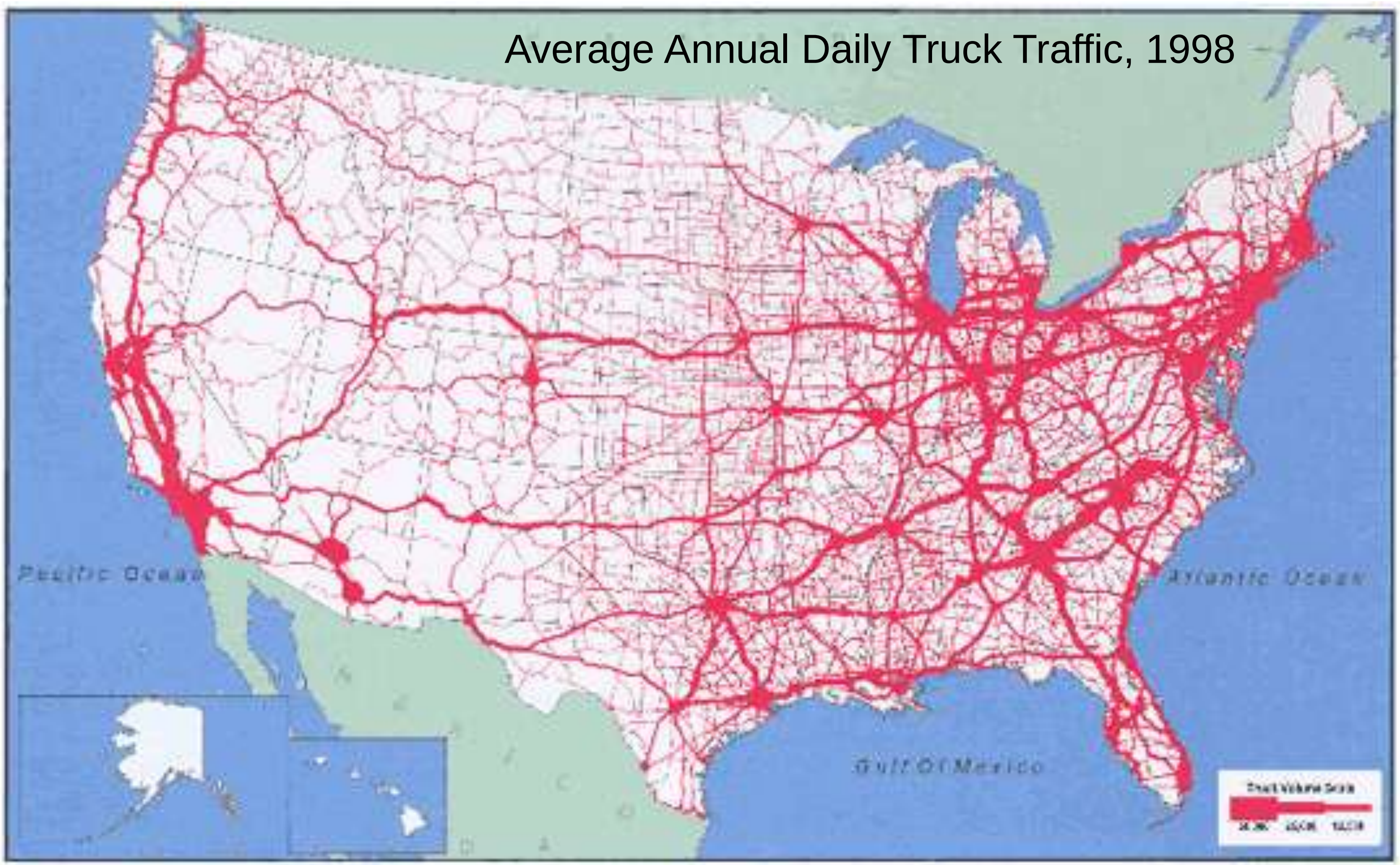
- Patriotic SCUBA Diver, 1980
- “Mines of August” 1984
- Floating IED on Lake Pontchartrain, 2004
- Al Qaeda calls for “Chokepoint Terrorism” April, 2008
- Mumbai Attack of Nov, 2008



Potential for Disaster

- Economic/Political Effects
  - 90%+ US trade transits US ports
- LA/LB Longshoreman Strike, 2002
  - $1.9B per day, and was expected!
- Lack of salvage assets
- Lack of backup options
- Power projection
- Just-In-Time economy

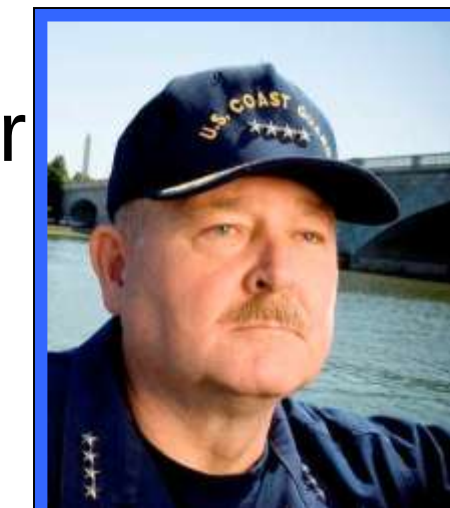
Down-range Effects



Source: Federal Highway Administration Freight Analysis Framework.

The New Focus

- *9-11 Changed the HS/HD World!*
- US MCM focused on expeditionary ops
- An interagency problem
  - USN, USCG, NOAA, FBI, *et al.*
- Tactical/Operational lines unclear



"What keeps me awake at night? The threat of underwater IEDs."

ADM Thad Allen, USCG

Aug 2007

National Strategy

Not Translated to Operational Level!

Systems Engineering Design Process

Our Process – SEDP

Initial Research

Conduct Mission Analysis
Develop Scenarios and Concept of Operations
Determine Customers and stakeholders

Problem Formulation

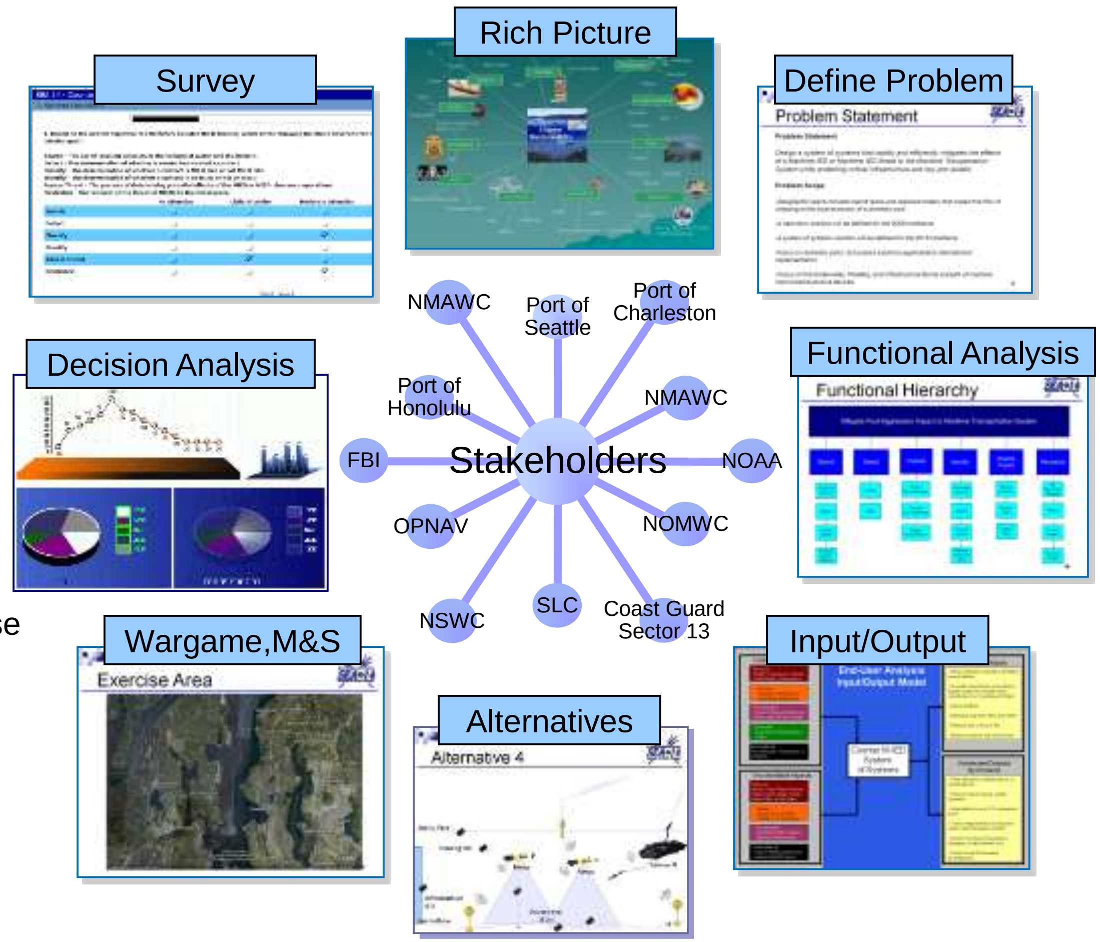
Conduct Stakeholder Analysis
Define and Refine Problem Statement and Scope
Perform Functional Analysis
Develop Functional Architecture

Analysis of Alternatives

Develop Alternative Physical Architectures
Perform Modeling And Simulation Assessing These

Implementation

Conduct And Complete Systems Analysis
Conduct Decision Analysis
Conduct Cost and Risk Analysis
Recommend Preferred Alternative



Problem Statement

Problem Statement

Design a system of systems that rapidly and efficiently mitigates the effects of a Maritime IED or Maritime IED threat to the Maritime Transportation System while protecting critical infrastructure and key port assets.

Problem Scope

-Geographic space includes transit lanes and adjacent waters that impact the flow of shipping or the local economy of a domestic port.

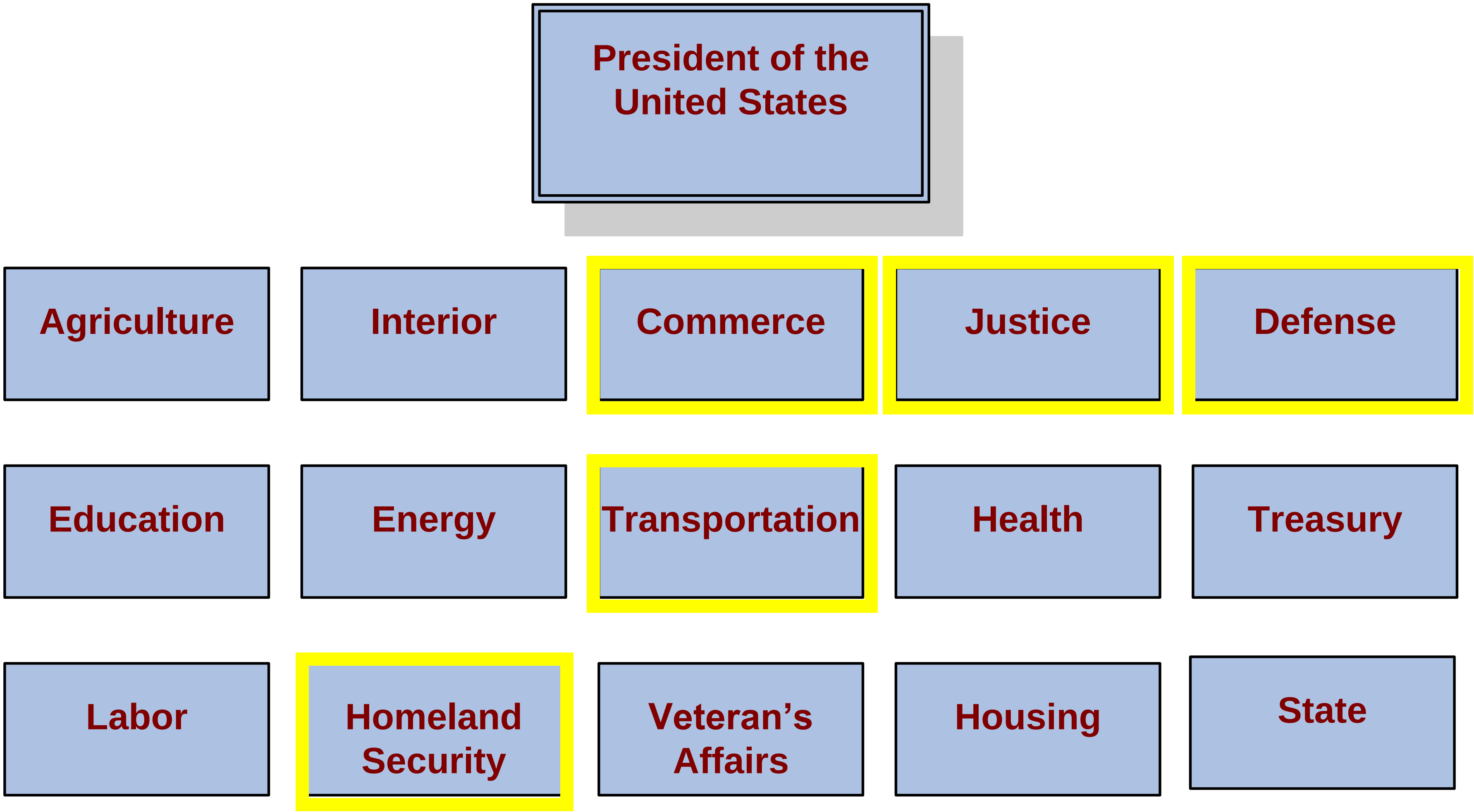
-A near term solution will be defined for the 2009 timeframe.

-A mid term solution will be defined for the 2009-2015 timeframe.

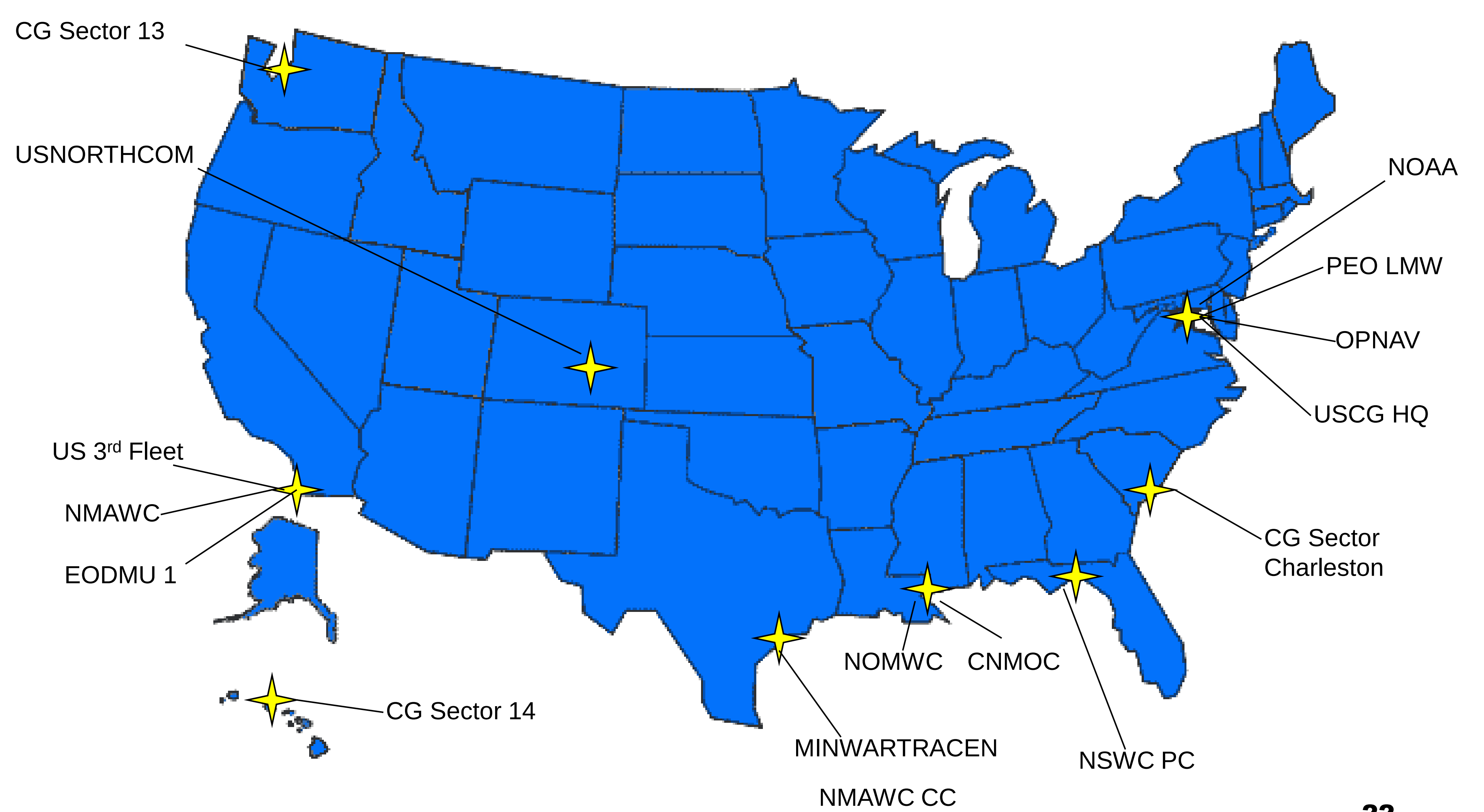
-A long range solution will be defined for 2015 and beyond.

-Focus on the Underwater, Floating, and Infrastructure Borne subsets of maritime improvised explosive devices.

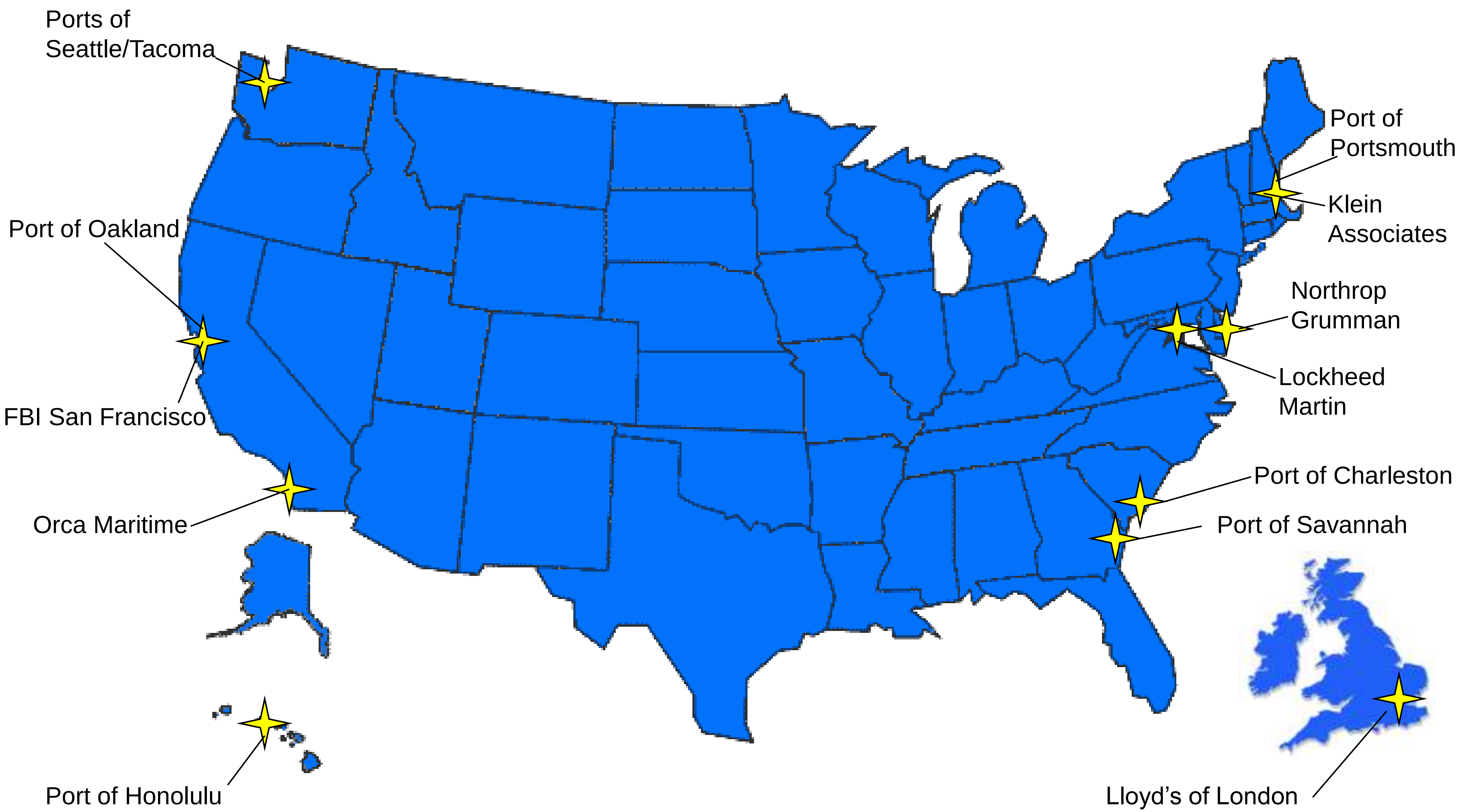
Stakeholders



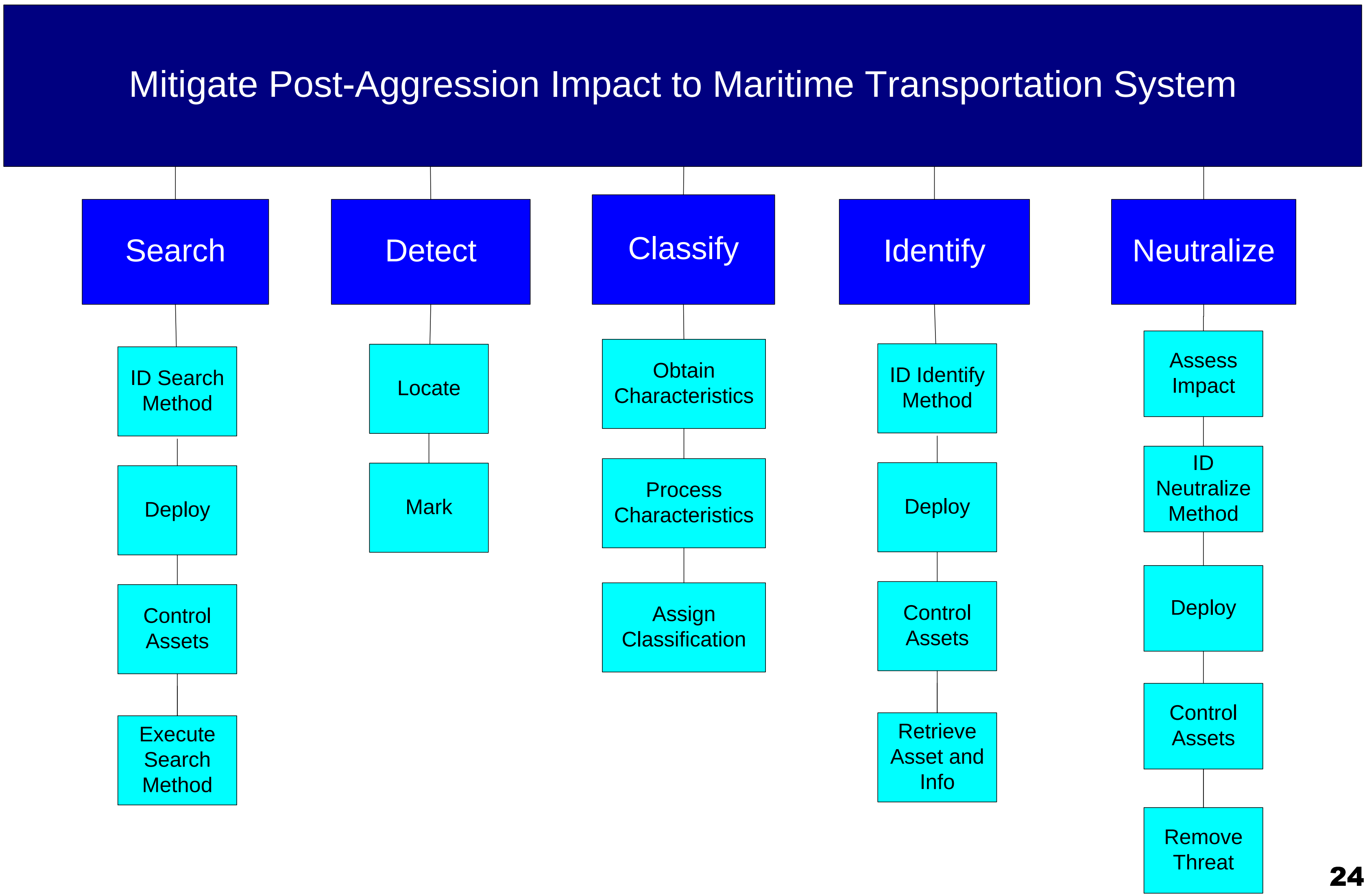
Uniformed Stakeholders

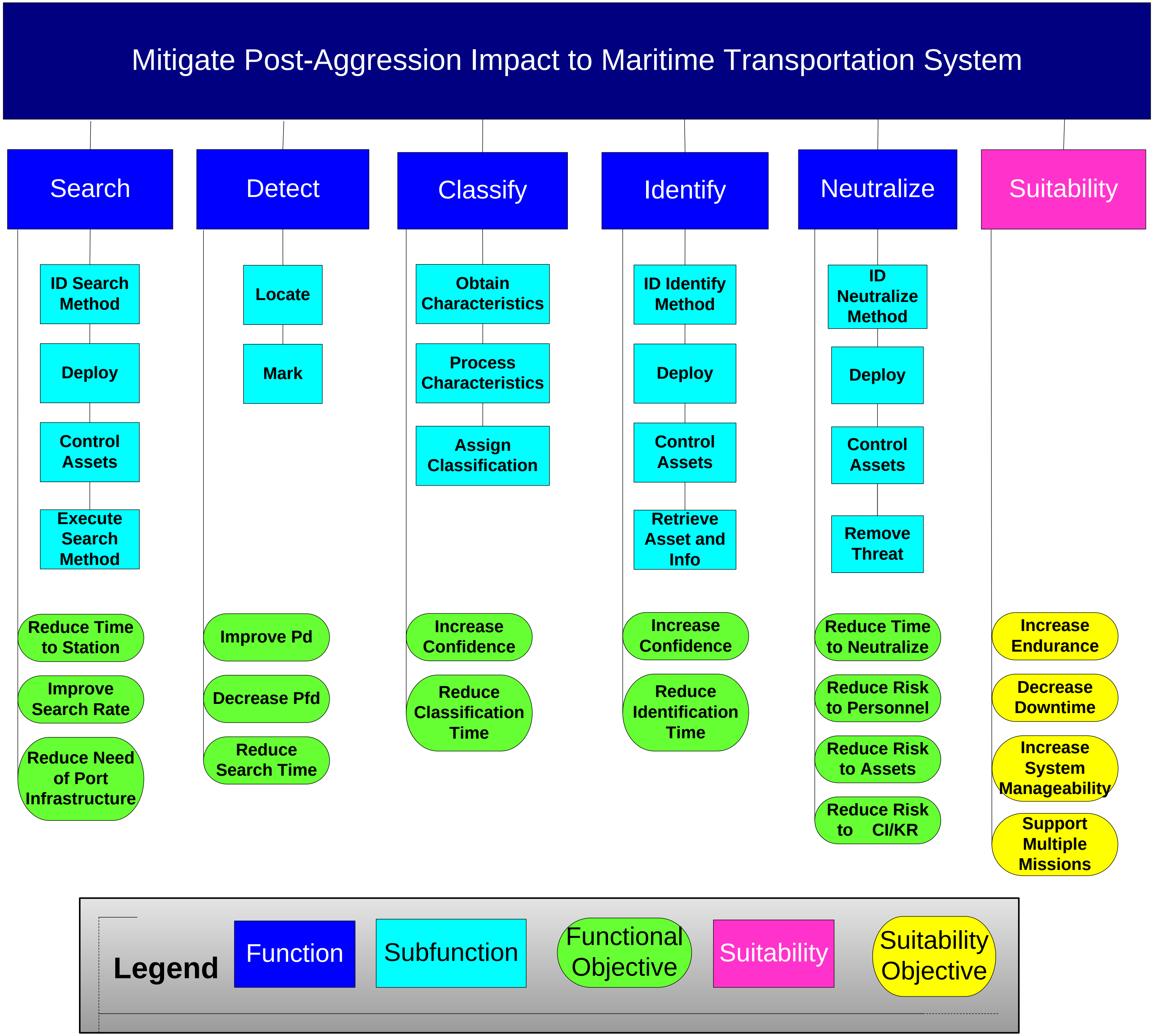


Civilian Stakeholders

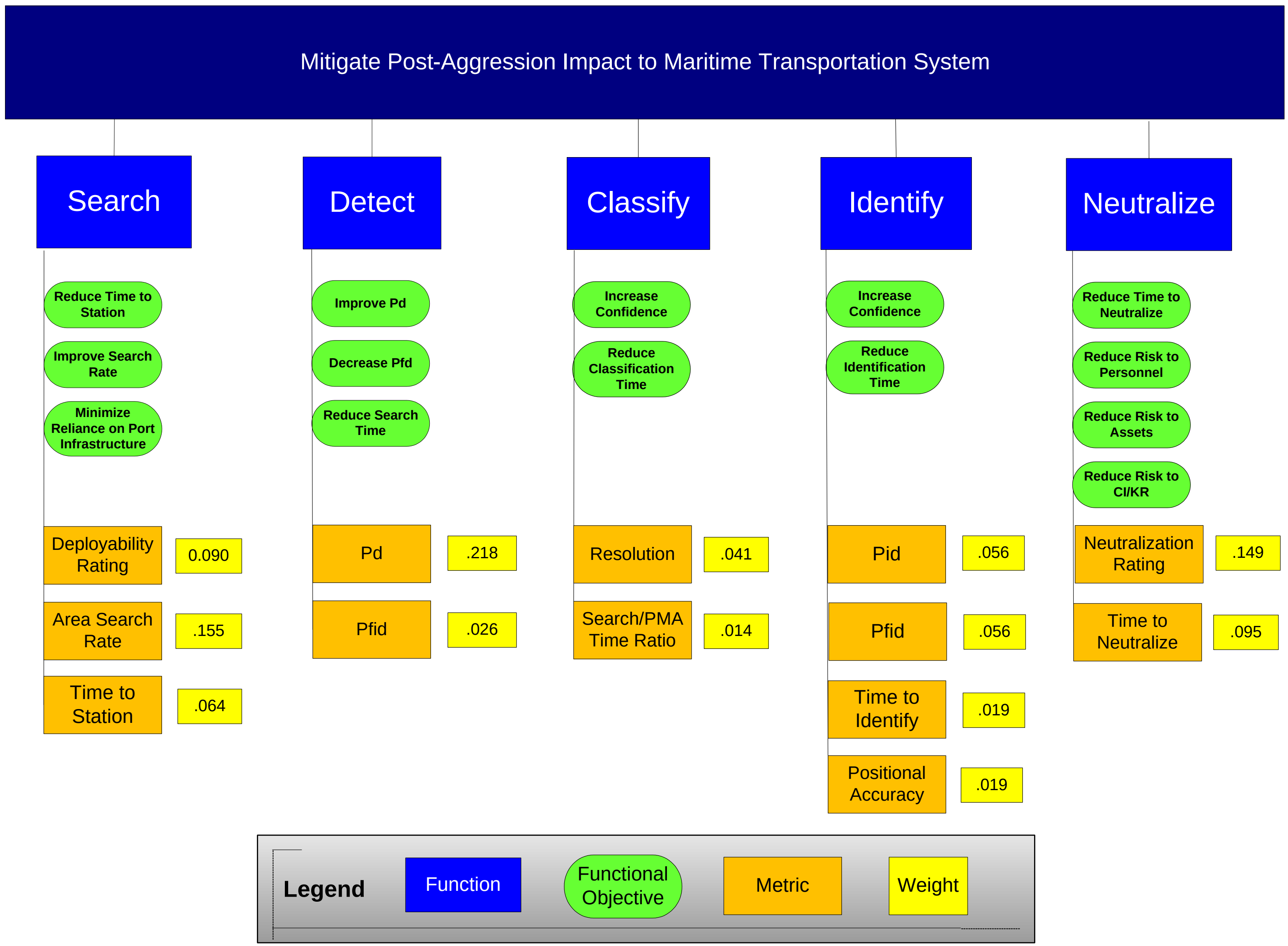


Functional Hierarchy



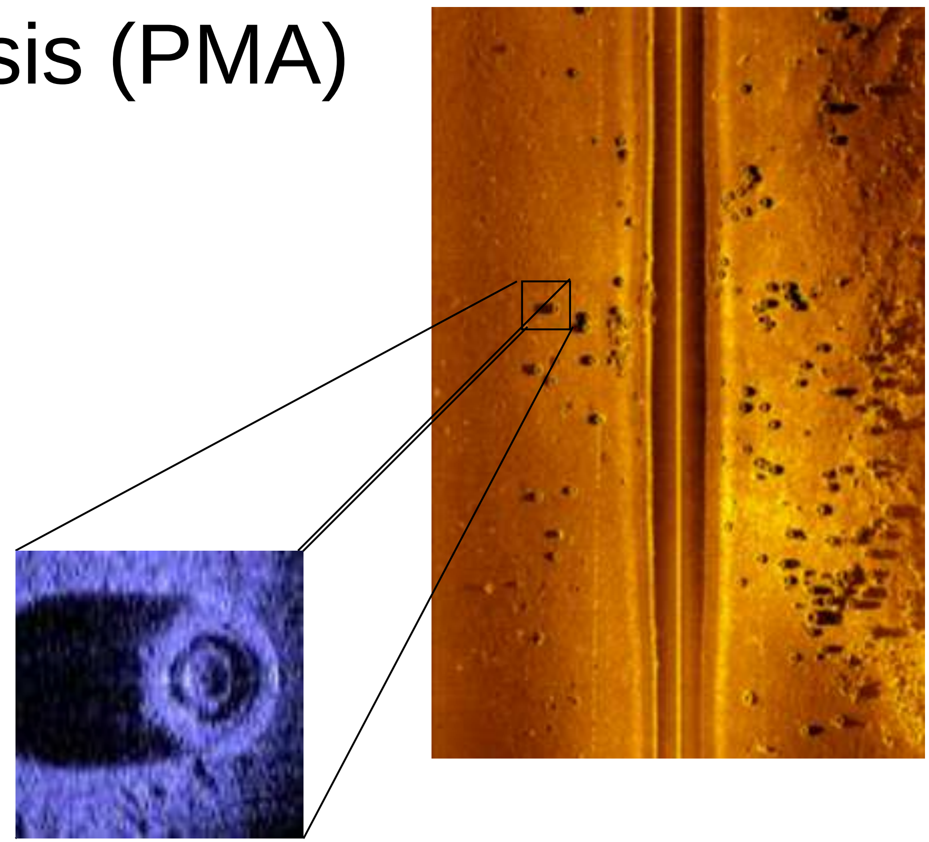

Mitigate Post-Aggression Impact to Maritime Transportation System
Search
ID Search Method
Deploy
Control Assets
Execute Search Method
Reduce Time to Station
Improve Search Rate
Reduce Need of Port Infrastructure
Detect
Locate
Mark
Improve Pd
Decrease Pfd
Reduce Search Time
Classify
Obtain Characteristics
Process Characteristics
Assign Classification
Increase Confidence
Reduce Classification Time
Identify
ID Identify Method
Deploy
Control Assets
Retrieve Asset and Info
Increase Confidence
Reduce Identification Time
Neutralize
ID Neutralize Method
Deploy
Control Assets
Remove Threat
Reduce Time to Neutralize
Reduce Risk to Personnel
Reduce Risk to Assets
Reduce Risk to CI/KR
Suitability
Increase Endurance
Decrease Downtime
Increase System Manageability
Support Multiple Missions
Legend
Function
Subfunction
Functional Objective
Suitability
Suitability Objective

Design Value Diagram

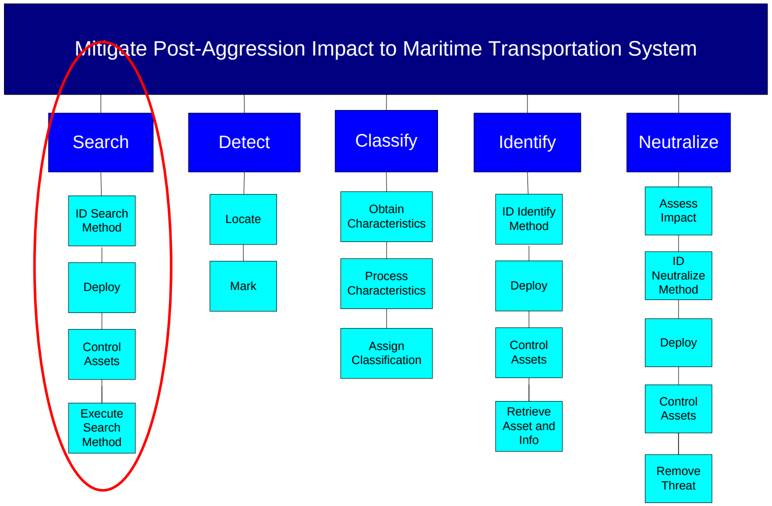


Key Terms

- Post Mission Analysis (PMA)
- CAD/CAC
- Baseline Survey
- Change Detection
- Port Folders

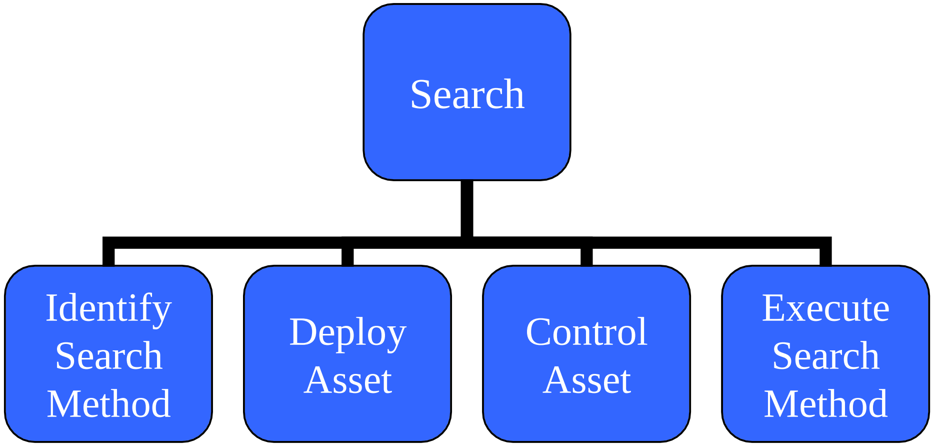


Search

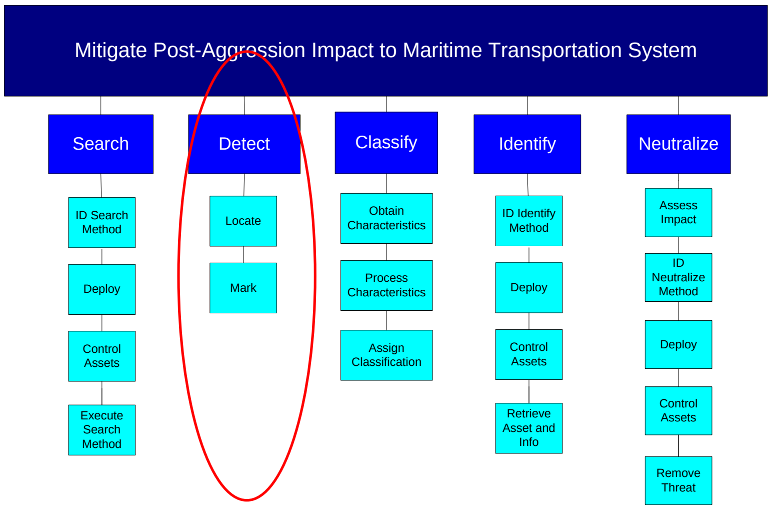


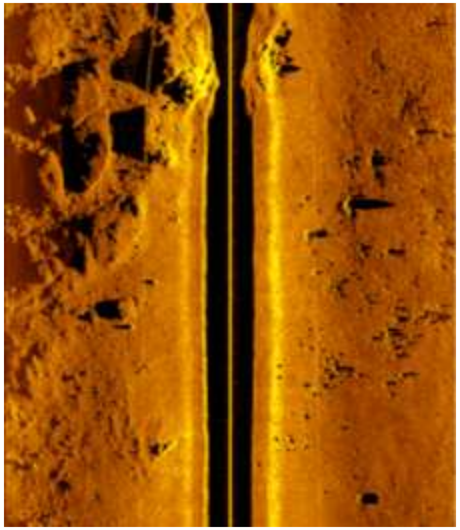
Measures of Performance

- Area Search Rate
- Time to Station (TTS)
- Deployability Rating



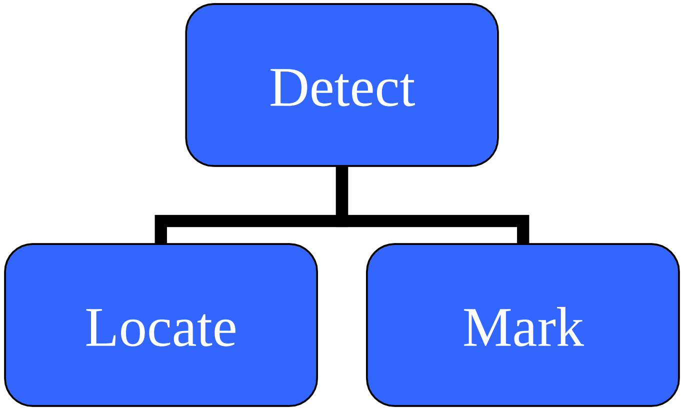
Detect



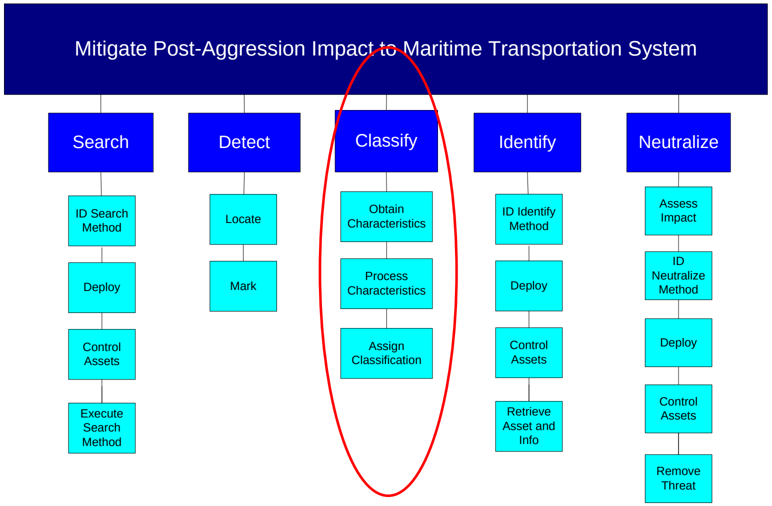


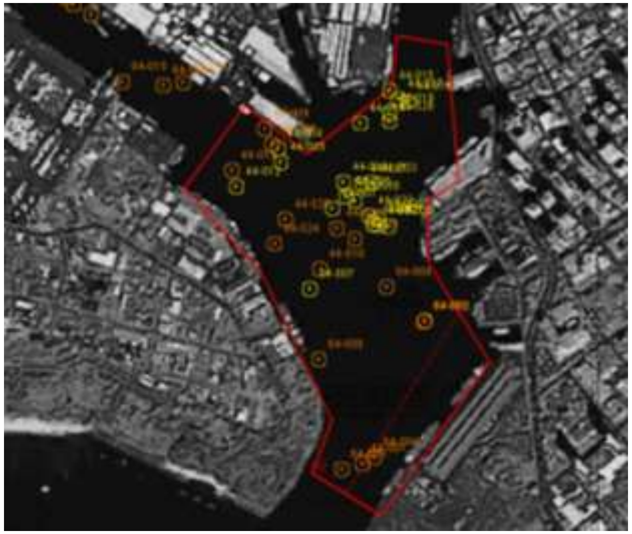
Measures of Performance

- Probability of Detection (P_d)
- Probability of False Detection (P_{fd})
- Detection rate
- Positional accuracy
- Resolution
- Search Time/PMA Time Ratio



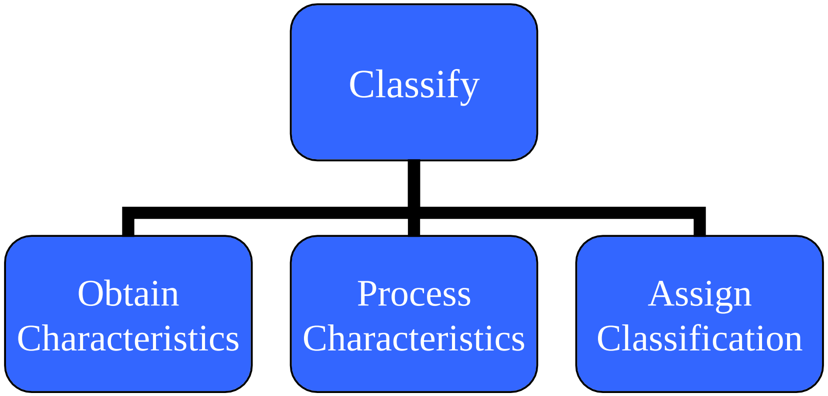
Classify



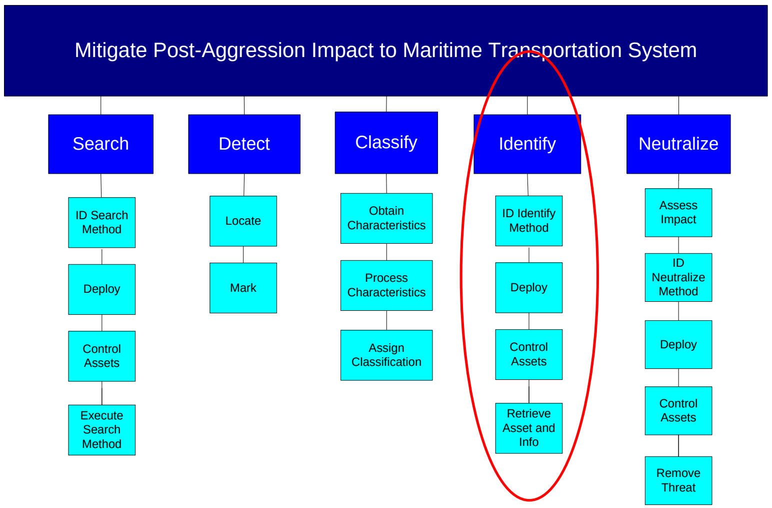


Measures of Performance

- Classification rate
- Probability of Classification (PC)
- Probability of False Classification (Pfc)

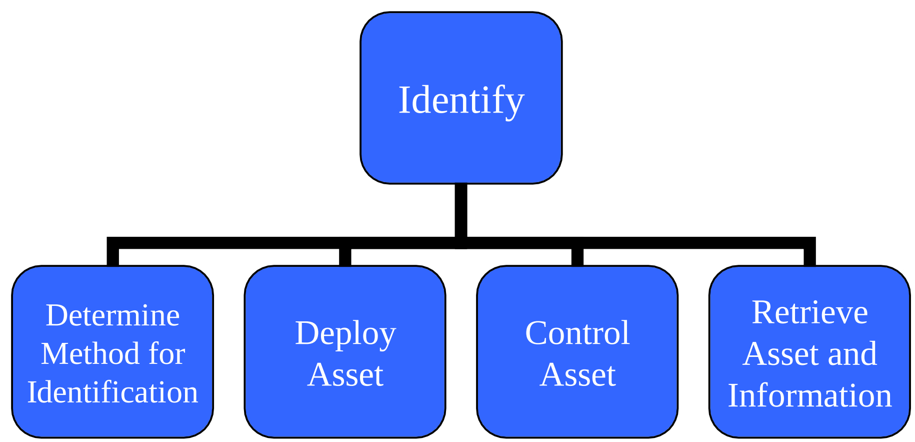


Identify

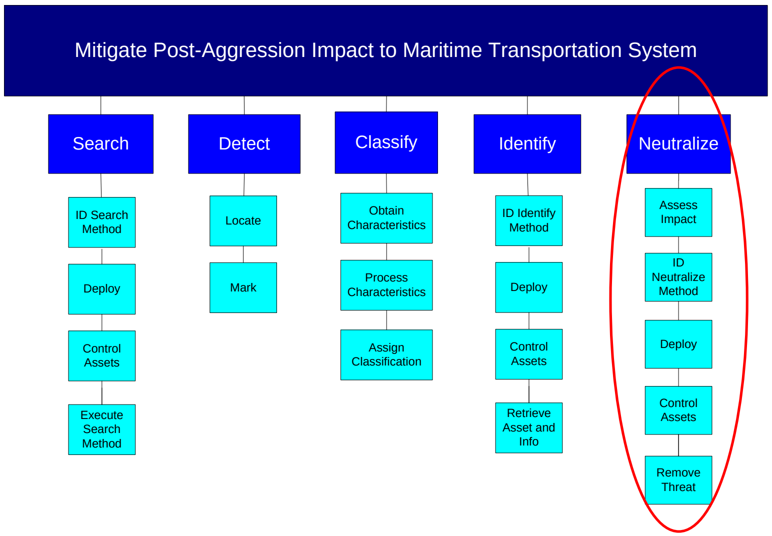


Measures of Performance

- Probability of Identification (P_{ID})
- Probability of False Identification (P_{FID})
- Identification Time per Contact (T_{ID})

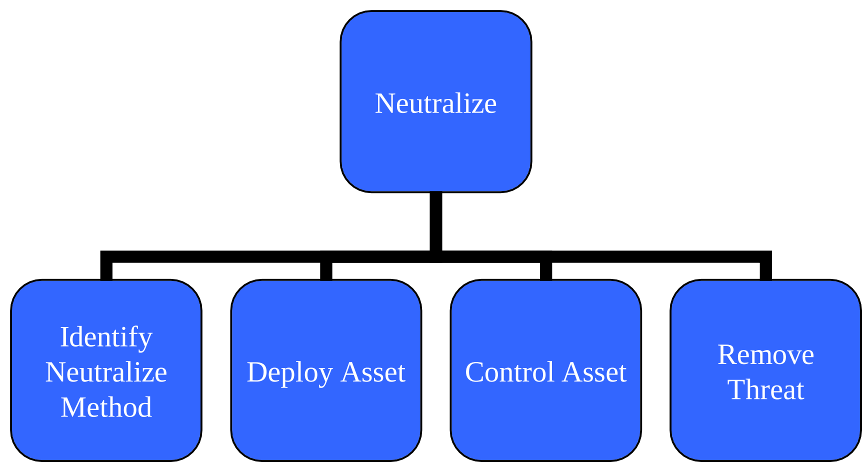


Neutralize



Measures of Performance

- Time required to neutralize/contact
- Neutralization rating
  - Risk
  - Effectiveness



Adaptive Force Package 2009 Baseline

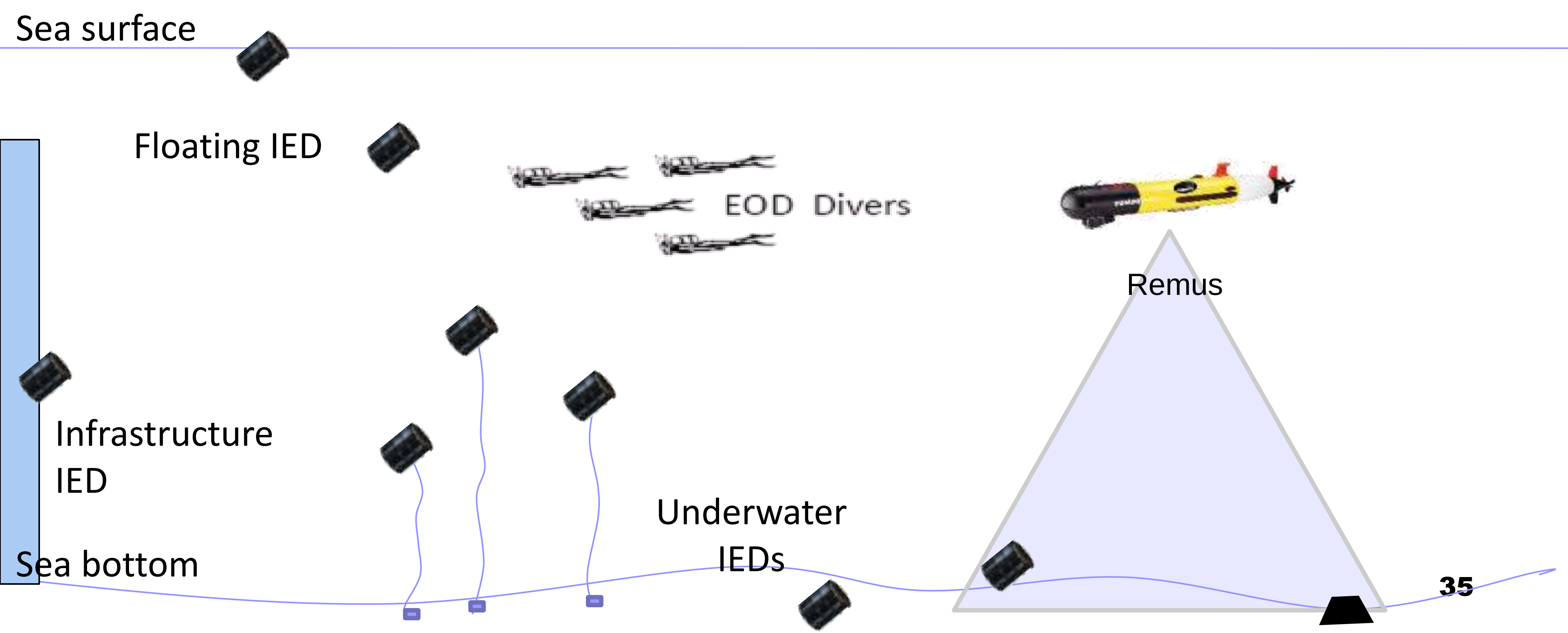
LT Mark Ellis

Baseline

- EOD
  - 5 man teams
  - 72 hour deployability
  - Ability to Identify and Neutralize MIEDs
  - Shortfalls: Places man in the Minefield.

- REMUS
  - NOMWC Platoons, 3 vehicle per platoon
  - Developed: Hydroid, first trials in 2005
  - Speed: 3-5 kts
  - Application: Detection and Classification of MIEDs
  - Shortfalls: Long PMA times, current, SSS

Baseline



Sea surface
Floating IED
EOD Divers
Remus
Infrastructure
IED
Underwater
IEDs
Sea bottom

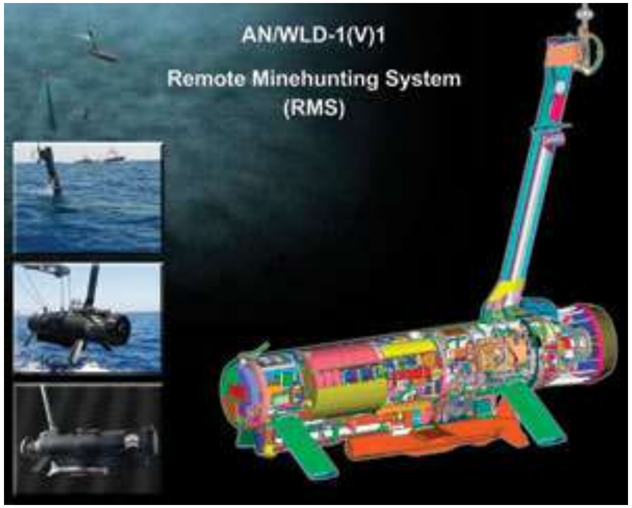
Adaptive Force Packages 2009-2015

AFP 1 – LCS Package

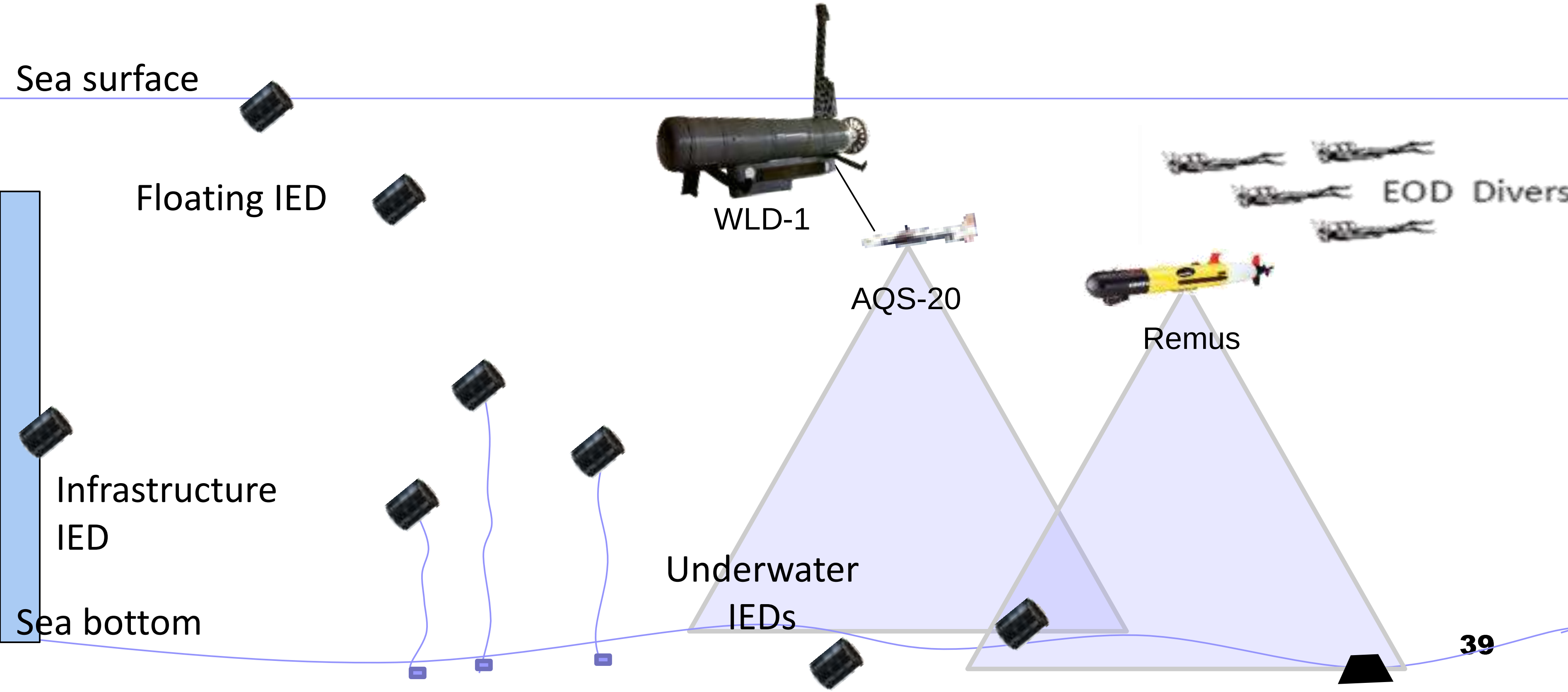
- Baseline Systems
- LCS MIW Mission Module
  - AN/WLD-1 RMS
  - AN/AQS-20

AFP 1 Components

- AN/WLD-1
  - Remote Multi Mission Vehicle
  - Tow/control body for AQS-20
- AQS-20
  - Multi-sensor search body
  - Towed by air, surface, UUV



AFP 1

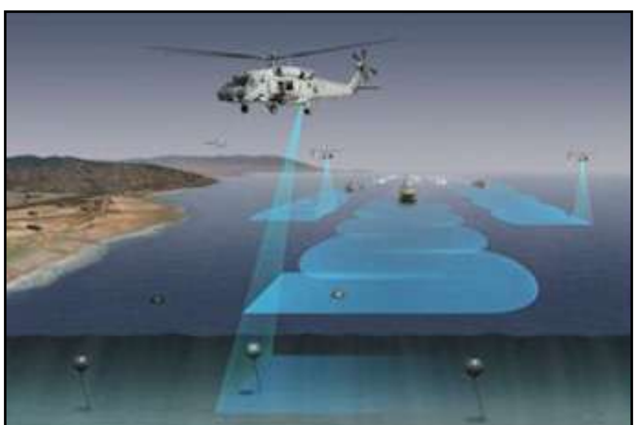

Sea surface
Floating IED
WLD-1
EOD Divers
AQS-20
Remus
Infrastructure IED
Underwater IEDs
Sea bottom

AFP 2 – Airborne Package

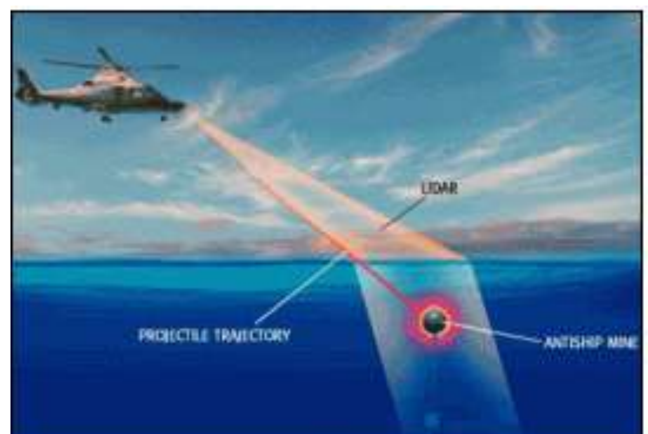
- Baseline Systems
- Airborne Laser Mine Detection System (ALMDS)
- Rapid Airborne Mine Countermeasure System (RAMICS)
- Airborne Mine Neutralization System (AMNS)
- AN/AQS-20

AFP 2 Components

- ALMDS
  - LIDAR sensor
  - Shallow water



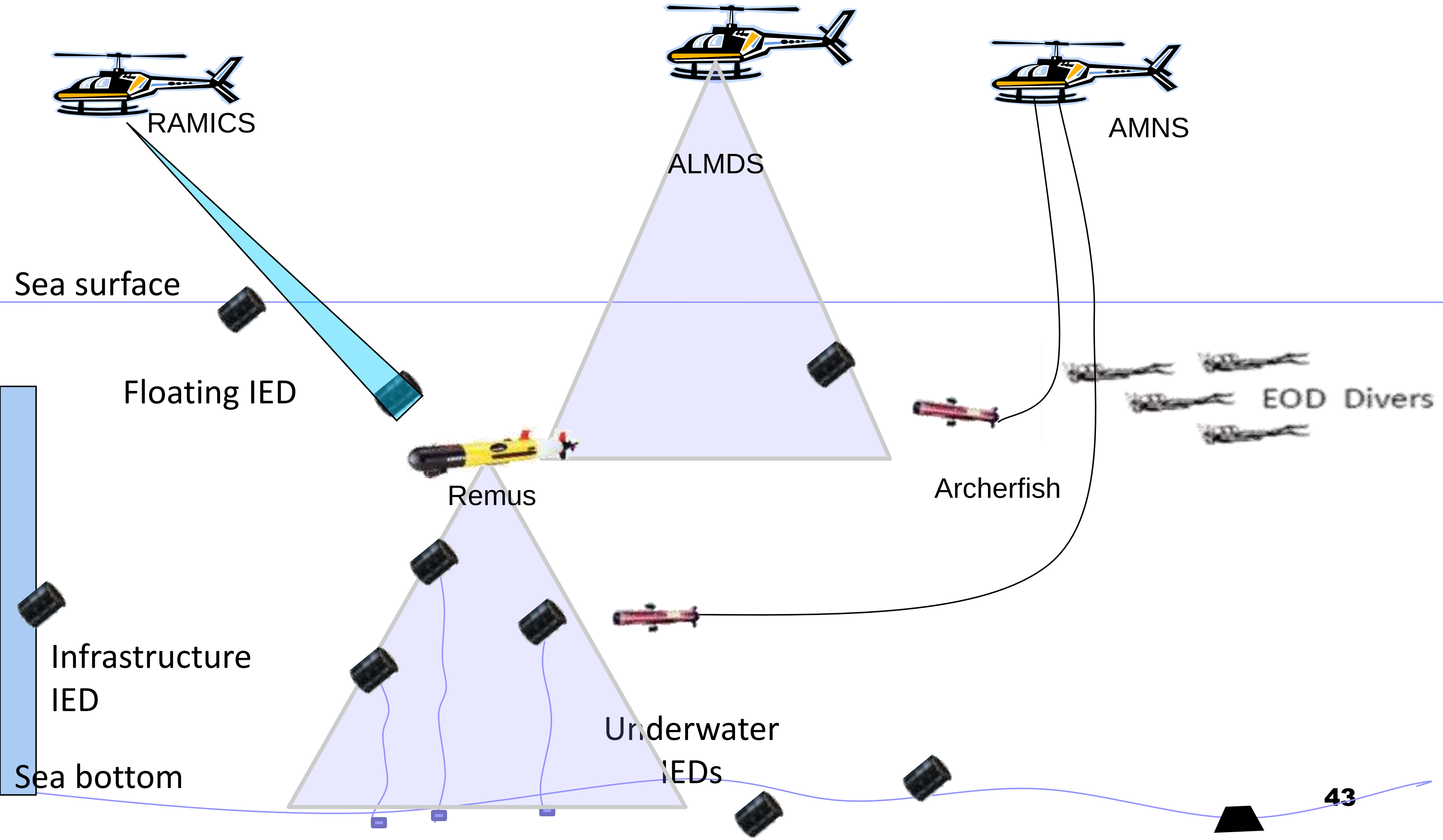
- RAMICS
  - Rapid Airborne Mine Countermeasure System
  - Laser targeted, supercavitating round



AFP 2 Components

- AMNS
  - Archerfish (x4)
  - Single shot expendable UUV
  - Wire guided

AFP 2



RAMICS
ALMDS
AMNS
Sea surface
Floating IED
EOD Divers
Remus
Archerfish
Infrastructure
IED
Underwater
IEDs
Sea bottom

Adaptive Force Packages 2015 and Beyond

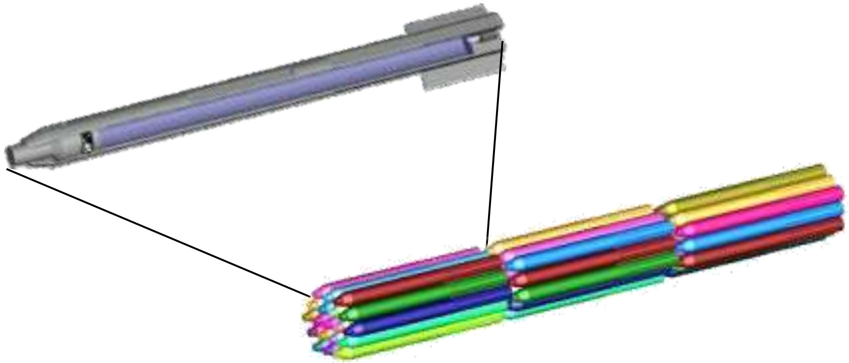
AFP 3 – Silver Bullet

- Talisman M
- Integrated SAS/Laser Line Scan
- 2 Archerfish Expendable Mine Neutralization System
- 2 SeaArcher Chemical Mine Neutralization System

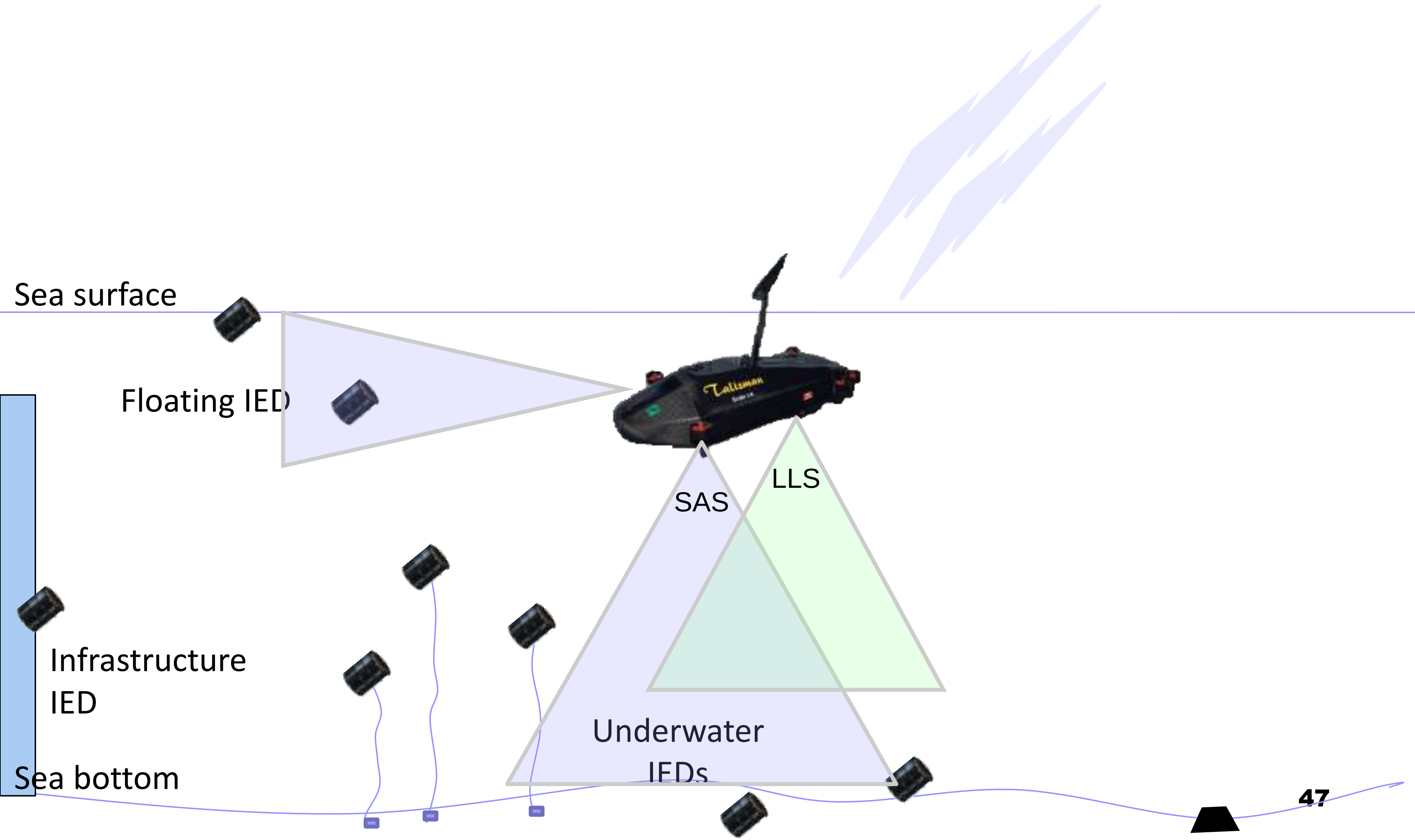
AFP 3 Components

- Talisman M
  - Multirole UUV
  - High payload capacity
  - Multiple sensors
  - Organic neutralization

- SeaArcher CMNS
  - Modified Archerfish EMNS
  - Technology developed for ABS
  - Single-shot application

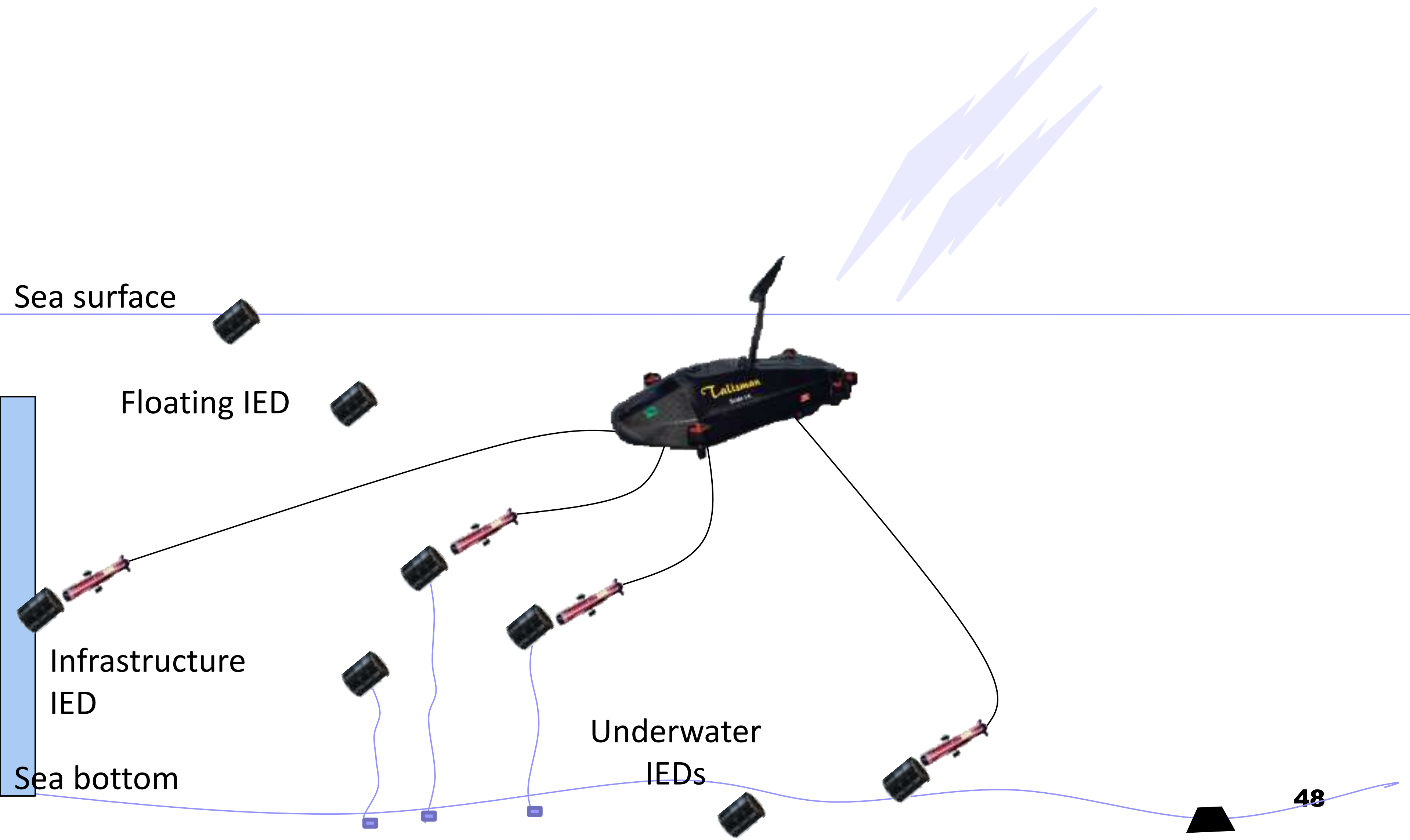


AFP 3 – DTE



Sea surface
Floating IED
Talisman
SAS
LLS
Infrastructure IED
Underwater IEDs
Sea bottom

AFP 3 – Neutralize



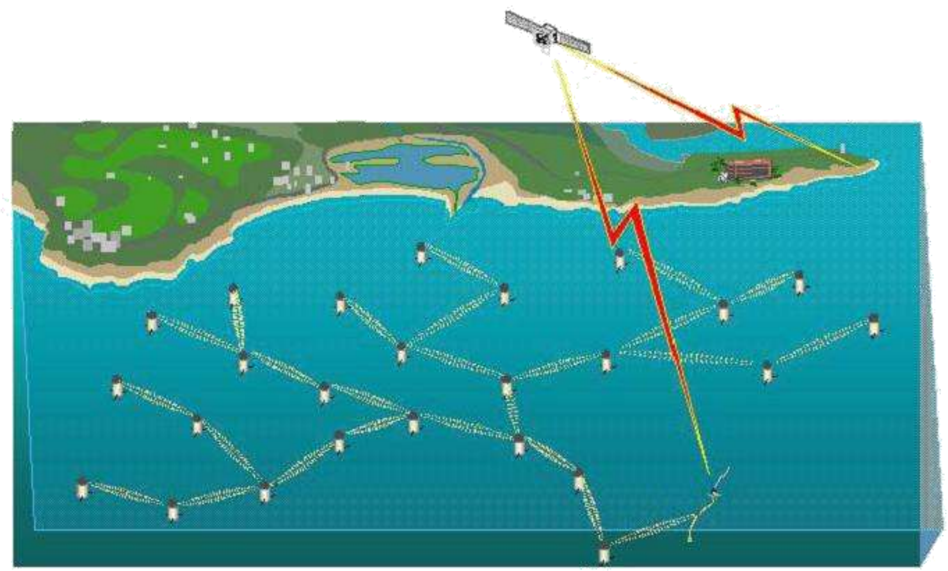
AFP 4 – Vehicle Sentry

Systems Engineering Analysis SEA-14 Tackling the M-IED Problem

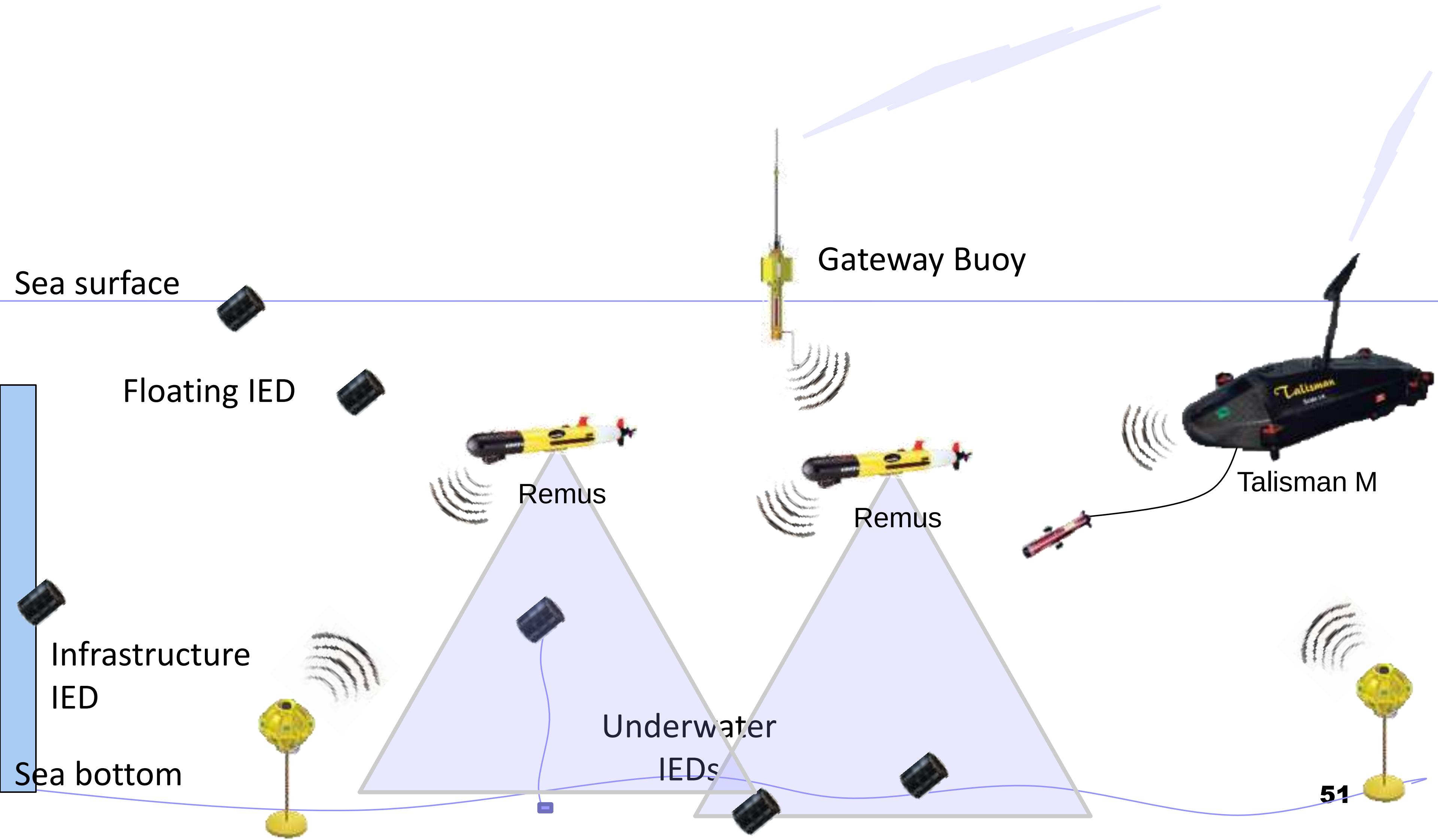
- Improved REMUS
- Talisman M
- SeaWeb Acoustic Network
- 2 Archerfish EMNS
- 2 SeaArcher CMNS

AFP 4 Components

- SeaWeb Acoustic Network
  - Network of acoustic network nodes
  - Sends and Receives data from C2 center and underwater vehicles
  - Underwater nodes, vehicle modems, gateway buoy



AFP 4


Gateway Buoy
Sea surface
Floating IED
Remus
Remus
Talisman M
Infrastructure
IED
Underwater
IEDs
Sea bottom

Wargame, Modeling, and Simulation

LT Julio Nilsson

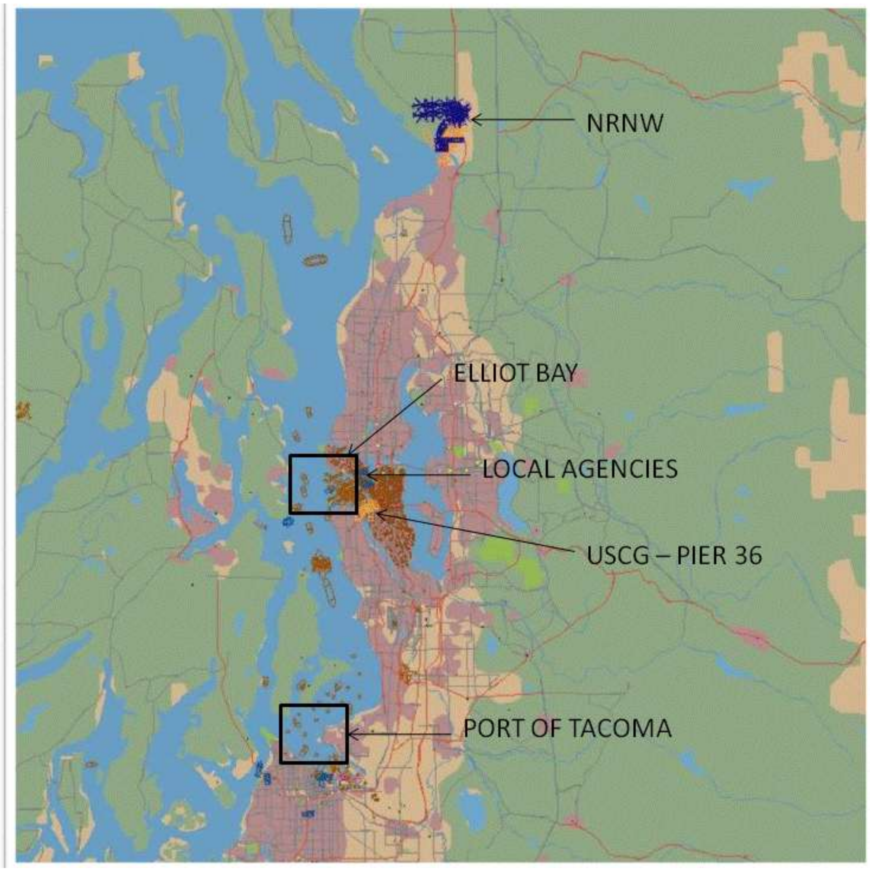
Background

- First SEA cohort to use wargaming
  - Joint Conflict and Tactical Simulation program (JCATS)
  - Used by JFCOM, CAW, DoN, HLS/HLD for contingency planning

Background

- The wargame was designed to support the System's Engineering Design Process
  - Conducted analysis of system of systems
  - Assisted in validating the problem statement, operational concept, and scenario
  - Served as a knowledge generating tool

Game Area



- Port of Seattle provided:
  - A vast area
  - Numerous choke points
  - Large volume of commercial traffic
- Coordinated effort of regional agencies

Scenario

- Event 1 – Time +15 min: Ferry hits MIED in Elliott Bay
- Event 2 – Time +20 min: CG First Responders hit MIED enroute to the ferry
- Event 3 – Time +60 min: Container vessel hits MIED enroute to the Port of Tacoma

Three Phased Approach

- Phase I – Feasibility Wargame
- Phase II – Baseline Wargame
- Phase III – Closed Form Simulation

Three Phased Approach

- Phase I - Feasibility Wargame
  - Supported by JFCOM
  - C2/SOP difficulties
  - Served as proof of concept for our overall approach to the MIED problem

Three Phased Approach

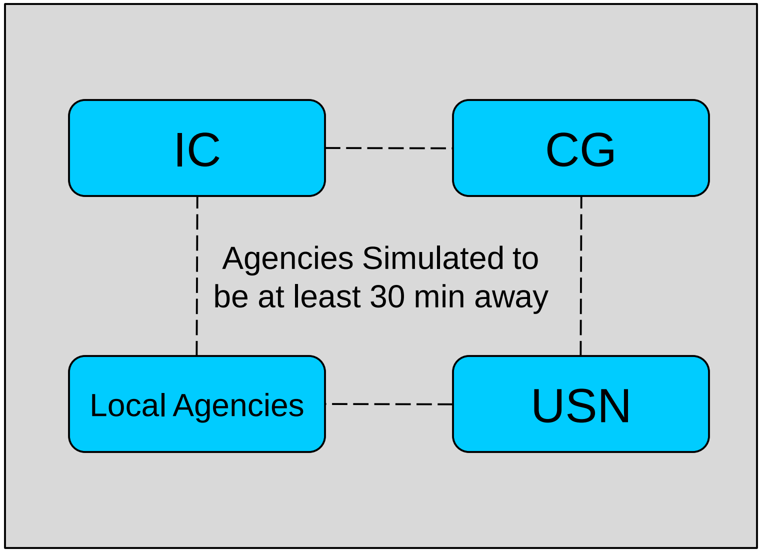
- Phase II – Conduct a Baseline Wargame
  - Prototype Improvements
  - Baseline data collection
    - Based on National Incident Management System (NIMS)

Three Phased Approach

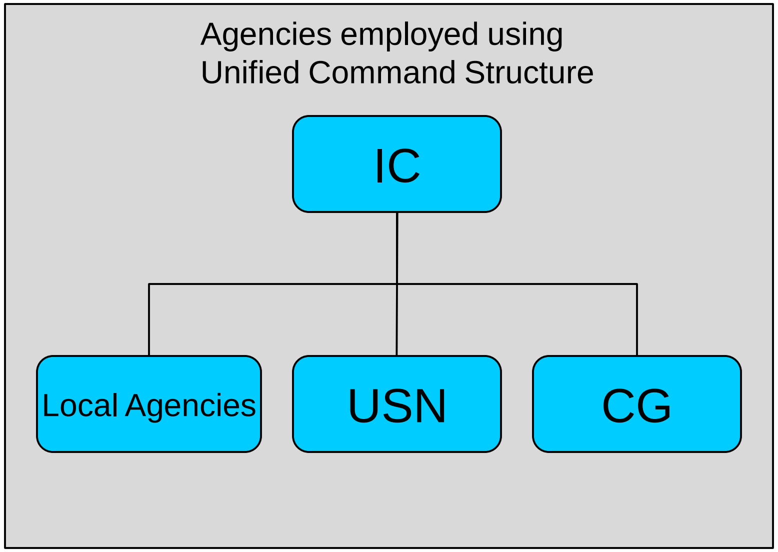
- Phase II – Conduct a Baseline Wargame
  - Expected vs. Actual Results
    - Could only collect area search rate and probability of detection data
    - Asset implementation in JCATS is shorter than Asset Implementation in Reality

Three Phased Approach

- Command Structure Improvements



Feasibility Wargame
- Structure was slow and cumbersome

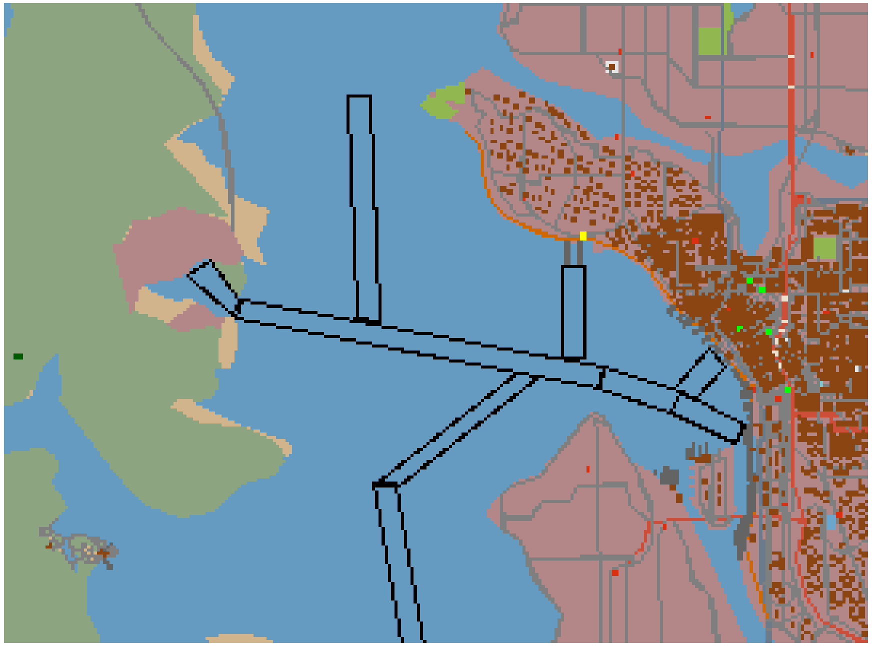


Baseline Wargame
- Structure improved response times

Three Phased Approach

- Phase III - Closed Form Simulation of Alternatives
  - Performance Analysis of the Alternatives
    - Individual System Analysis
    - Grouped System Analysis

Search Areas



- Data collected for analysis
- Used to test all systems

Final Data Collected

- Data verified by theoretical formulas
  - Exhaustive Search Equation: $t = \frac{A}{VW}$
    - t is the time to conduct the search
    - A is the area searched
    - V is the search velocity
    - W is the swath width
  - Probability of Detection: $P_d = \frac{n\pi R^2}{A}$
    - n is the number of contacts
    - R is the sensor radius

Example of Data Collected

- Data used to conduct the decision analysis
  - Area Search Rate

AFP 2 Route: From First Responders to Ferry

#	Distance (Km)	Distance (m)	Area (m^2)	Start Time (Z)	End Time (Z)	Total Time	Actual Time (s)	Velocity (m/s)	Calculated Time (s)
1	1.68931	1689.31	904610.33	0208	0230	22 min	1320	41.155	732.6856411
2	0.509912	509.912							
3	1.80611	1806.11							
4	0.525283	525.283							

Area (m^2)	Actual Time (s)	Calculated Time (s)	Time Difference (min)
904610.3267	1320	733	10

Decision Analysis

- Performance Analysis
- Suitability Analysis
- Cost Analysis
- Risk Analysis

Performance Analysis

Mr. Cheng Hua Lim

Performance Analysis

- Evaluate the system performance and capability based on the MOPs listed for each functions.
- MOPs are weighted accordance feedback and survey using Analytical Hierarchy Process (AHP).
- Adaptive Force Package (AFP) compare to baseline (as reference).

Performance Criteria

Evaluation Criteria		Weight
Search	Area search rate	0.15
	Time to station	0.06
	Deployability rating	0.09
Detect	Probability of Detection	0.21
	Probability of False Detection	0.03
Identification	Probability of Identification	0.07
	Probability of false identification	0.07
	Identification time per contact	0.02
	Positional accuracy	0.02
Classification	Resolution	0.03
	Search time / PMA time ratio	0.01
Neutralization	Time required to neutralize	0.09
	Neutralization rating	0.15
	Total	1.00

		Wt
Deployability Rating	Movement	0.25
	Assembly	0.25
	Operational testing	0.25
	Fueling & Charging	0.25
	TOTAL	1.00

		Wt
Neutralization Rating	Effectiveness in neutr	0.2
	Damage to facilities	0.33
	Damage to personnel	0.14
	Damage to assets	0.33
	TOTAL	1.00

Performance Criteria

SEA 14 - Countering Maritime IEDs

4. Search

33%

1. Search - The act of locating contacts in the volume of water and the bottom

Which objectives are most vital to conducting an effective search?

	No Importance	Little Importance	Moderate Importance	Significant Importance	Most Importance
Reducing Asset Time to Station					✓
Improving the rate of search				✓	
Minimizing reliance on port infrastructure for asset deployment, operation, and recovery			✓		

Prev Next

Performance Criteria

Main functions	Criteria	Search	Detect	Classify	Identify	Neutralize	
Criteria		1	2	3	4	5	Weights
Search	1	1	1	5	3	1	0.28
Detect	2	1	1	5	3	1	0.28
Classify	3	0.2	0.2	1	0.333	0.2	0.05
Identify	4	0.3333	0.3333	3	1	0.333	0.11
Neutralize	5	1	1	5	3	1	0.28

Search Objective	Criteria	Reduce time to station	Improve Area search rate	Minimize reliance on port infra for asset deployment	
Criteria		1	2	3	Weights
Reduce time to station	1	1	0.333	3	0.26
Improve Area search rate	2	3	1	5	0.63
Minimize reliance on port infra for asset deployment	3	0.3333	0.2	1	0.11

- Conducted online survey to determine the relative importance of each functions
- Carry out pairwise comparison of each functions using AHP

Search Objective	Overall weights
Reduce time to station	0.07
Improve Area search rate	0.18
Minimize reliance on port infra for asset deployment	0.03

Performance Criteria

Survey feedback		Wt	Search			Detect		Classify		Identify				Neutralize	
			Area search rate	Time to station	Deployability rating	Probability of Detection	Probability of False Detection	Resolution	Search time / PMA time ratio	Positional accuracy	Probability of Identification	Probability of false identification	Identification time per contact	Time required to neutralize	Neutralization rating
Search	Reducing Asset Time to Station	0.07		1	1										
Search	Improving the rate of search	0.18	1												
Search	Minimizing reliance on port infrastructure for asset deployment, operation, and recovery	0.03			1										
Detect	Improve probability of detection	0.18				1									
Detect	Decrease false alarm rate	0.03					1								
Detect	Reduce the time required to complete detections	0.07				1									
Classify	Increase confidence in object classification	0.04						1							
Classify	Reduce the time it takes to classify an object	0.01							1						
Identify	Reduce the time it takes to identify an object	0.03								1			1		
Identify	Increase the confidence of an objects identification	0.08									1	1			
Neutralise	Reduce time to neutralize	0.11												1	
Neutralize	Reduce risk to personnel	0.04													1
Neutralise	Reduce the risk to assets	0.02													1
Neutralise	Reduce the risk to critical infrastructure/key resources	0.11													1
	Sub-total	1.00	0.18	0.07	0.10	0.25	0.03	0.04	0.01	0.03	0.08	0.08	0.03	0.11	0.17
	Normalize		0.15	0.06	0.09	0.21	0.03	0.03	0.01	0.02	0.07	0.07	0.02	0.09	0.15

Baseline

- Current system (i.e. Baseline) is set as the baseline for comparison of the various alternatives.

AFP 0 - Baseline		Threshold	Goal	Units
Search	Area search rate	460	550	m2/s
	Time to station	1	0.5	hr
	Deployability rating	4	5	-
Detect	Probability of Detection	85	95	%
	Probability of False Detection	5	1	%
Identification	Probability of Identification	95	99	%
	Probability of False Identification	5	1	%
	Identification time per contact	1.5	1	hr
	Positional accuracy	15	3	m
Classification	Resolution	4	3	cm
	Search time / PMA time ratio	3	1	-
Neutralization	Time required to neutralize	3	2	hr
	Neutralization rating	3.26	4	-

Performance Comparison

- Compare Adaptive Force Package with reference to baseline.
- Raw data below threshold would score a value of 0.
- Raw data above goal would score a value of 1.
- Raw data between threshold and goal, the value will be interpolated accordingly.
- Each MOP value are multiple by the MOP weights and summed up to generate the system MOE.

Performance Comparison

Evaluation Criteria		Weight	Baseline			AFP 1		
			Threshold	Goal	units	Data	units	Value
Search	Area search rate	0.15	460	550	m2/s	630	m2/s	1.00
	Time to station	0.06	1	0.5	hr	2	hr	0.00
	Deployability rating	0.09	4	5	-	4.5	-	0.50
Detect	Probability of Detection	0.21	85	90	%	88	%	0.60
	Probability of False Detection	0.03	5	1	%	5	%	0.00

Evaluation Criteria		Weight	Baseline			AFP 1			AFP 2			AFP 3			AFP 4		
			Threshold	Goal	units	Data	units	Value	Data	units	Value	Data	units	Value	Data	units	Value
Search	Area search rate	0.15	460	550	m2/s	630	m2/s	1.00	6650	m2/s	1.00	184	m2/s	0.00	644	m2/s	1.00
	Time to station	0.06	1	0.5	hr	2	hr	0.00	2	hr	0.00	2	hr	0.00	1	hr	0.00
																-	0.00
Detect																%	1.00
																%	1.00
Identification																%	0.00
																%	0.00
																hr	1.00
																m	0.42
Classification																cm	1.00
	Search time / PMA time ratio	0.01	3	1	-	2	-	0.50	2	-	0.50	1	-	1.00	1	-	1.00
Neutralization	Time required to neutralize	0.09	3	2	hr	3	hr	0.00	0.5	hr	1.00	0.5	hr	1.00	0.5	hr	1.00
	Neutralization rating	0.15	3.26	4	-	3.26	-	0.00	3.48	-	0.30	4.47	-	1.00	4.47	-	1.00
	Total	1.00					MOE	0.39		MOE	0.64		MOE	0.64		MOE	0.70

Performance Comparison

Evaluation Criteria		Weight	Baseline			AFP 1			AFP 2			AFP 3			AFP 4		
			Threshold	Goal	units	Data	units	Value	Data	units	Value	Data	units	Value	Data	units	Value
Search	Area search rate	0.15	460	550	m2/s	630	m2/s	1.00	6650	m2/s	1.00	184	m2/s	0.00	644	m2/s	1.00
	Time to station	0.06	1	0.5	hr	2	hr	0.00	2	hr	0.00	2	hr	0.00	1	hr	0.00
	Deployability rating	0.09	4	5	-	4.5	-	0.50	4.5	-	0.50	5	-	1.00	4	-	0.00
Detect	Probability of Detection	0.21	85	90	%	88	%	0.60	95	%	1.00	95	%	1.00	95	%	1.00
	Probability of False Detection	0.03	5	1	%	5	%	0.00	1	%	1.00	1	%	1.00	1	%	1.00
Identification	Probability of Identification	0.07	95	99	%	95	%	0.00	95	%	0.00	95	%	0.00	95	%	0.00
	Probability of false identification	0.07	5	1	%	5	%	0.00	5	%	0.00	5	%	0.00	5	%	0.00
	Identification time per contact	0.02	1.5	1	hr	1	hr	1.00	1	hr	1.00	1	hr	1.00	1	hr	1.00
	Positional accuracy	0.02	15	3	m	10	m	0.42	10	m	0.42	10	m	0.42	10	m	0.42
Classification	Resolution	0.03	4	3	cm	1	cm	1.00	0.01	cm	1.00	0.01	cm	1.00	0.01	cm	1.00
	Search time / PMA time ratio	0.01	3	1	-	2	-	0.50	2	-	0.50	1	-	1.00	1	-	1.00
Neutralization	Time required to neutralize	0.09	3	2	hr	3	hr	0.00	0.5	hr	1.00	0.5	hr	1.00	0.5	hr	1.00
	Neutralization rating	0.15	3.26	4	-	3.26	-	0.00	3.48	-	0.30	4.47	-	1.00	4.47	-	1.00
	Total	1.00					**MOE**	**0.39**		**MOE**	**0.64**		**MOE**	**0.64**		**MOE**	**0.70**

Performance Results

- Overall, Adaptive Force Package 4 had the highest MOE.
- Adaptive Force Package 2 and 3 had the second highest MOE.
- Adaptive Force Package 1 had the lowest MOE.

Suitability Analysis

Suitability Analysis

- Beside the performance and capability of the proposed system, the availability and dependability of the proposed system would also affect the system effectiveness and suitability.
- Thus, the system reliability and maintainability analysis were conducted for the various AFP.

Suitability Analysis

- However, reliability and maintainability for the various AFP were not obtainable as most of the systems are in developmental or design stage.
- Reliability and maintainability prediction conducted to analyze the AFP suitability.

Reliability Prediction

- Reliability prediction conducted based on following factors,
  - Similar equipment
  - Active element group
  - Equipments or parts count
  - Mechanical parts
  - Electrical parts
  - Software complexity

Reliability Comparison

AFP	Components	Reliability prediction based on similar equipment		Reliability prediction based on active element group		Reliability prediction based on equipment parts count		Reliability prediction based on mechanical parts		Reliability prediction based on electrical parts		Reliability prediction based on software complexity		Relative Nett Score
0	REMUS	Proven and reliable	5	Battery, gps system, propulsion system, sonar sensor	5	Few equipment and parts	5	Propulsion system, control system	5	Gps system, sensors	5	Simple and least interface required	5	30
	EOD Divers	Allowable diving time is 2 hrs		Human, diver equipment		Few equipment and parts		N.A		N.A				
1	REMUS	Proven and reliable		Battery, gps system, propulsion system, sonar sensor		Few equipment and parts		Propulsion system, control system		Gps system, sensors			4	25
	EOD													
	AQS-													
	WLD-													
	Supp													
2	REM												3	19
	EOD													
	ALMD													
	AQS-													
	RAMI													
	AMNS													
	MH-60	helicopter		control system, etc		Relatively more parts		system, etc		Navigation system, etc				
3	Talisman M (c/w Archerfish, SeaArcher)	Similar to AQS-20 + AMNS + WLD-1	5	Laser, sonar, firing system, propolusion system, gps system (all in 1 vehicle)	2	More equipment and parts than alternative 1 but less than alternative 2	4	Propulsion system, gear system	5	Firing ssytem, sonar, laser, gps, control system	3	More complex software and interface than alternative 2	2	21
4	Improved REMUS	Similarity to present REMUS	5	Battery, gps system, propulsion system, sonar sensor	2	Few equipment and parts	3	Propulsion system, control system	5	Gps system, sensors	3	Most complex software and interface	1	19
	Talisman M (c/w Archerfish, SeaArcher)	Similar to AQS-20 + AMNS + WLD-1		Laser, sonar, firing system, propolusion system, gps system (all in 1 vehicle)		More equipment and parts than alternative 1 but less than alternative 2		Propulsion system, gear system		Firing ssytem, sonar, laser, gps, control system				
	Benthos Modem Network	REMUS reference Bouy		WIFI		Few equipment and parts		N.A						

AFP	Components	Reliability prediction based on similar equipment		Reliability prediction based on active element group		Reliability prediction based on equipment parts count	
1	REMUS	Proven and reliable	5	Battery, gps system, propulsion system, sonar sensor	4	Few equipment and parts	3
	EOD Divers	Allowable diving time is 2 hrs		Human, diver equipment		Few equipment and parts	
	AQS-20	Similarity to REMUS		Sonar sensor, optical camera		Relatively more parts	
	WLD-1	Similarity to diesel engine		Propulsion system, gps system		Relatively more parts	
	Support Module	Similarity to main frame computer		Software, electronic components		Relatively more parts	

Reliability Results

- From the prediction, among the alternatives:
  - AFP 1 had highest expected reliability
  - AFP 2 and 4 had lowest expected reliability

Maintainability Prediction

- Maintainability prediction conducted based on following factors:
  - Spare parts required
  - Test and support equipment required
  - Maintenance facility required
  - Maintenance organization required
  - System capability to record and process maintenance data / information

Maintainability Comparison

AFP	Components	Maintainability prediction based on spare parts and test & support equipment		Maintainability prediction based on maintenance facility required		Maintainability prediction based on maintenance organization required (personnel, training)		Maintainability prediction based on system capability to record and process maintenace data / information		Relative Nett Score
0	REMUS	Commercially available	5	Unit level	5	Maintenance team	5	Available	5	20
	EOD Diver	N.A		N.A		N.A		N.A		
1	REMUS	Commercially available		Unit level		Maintenance team		Available	5	15
	EOD Div									
	AQS-20									
	WLD-1									
	Support M									
2	REMUS								4	14
	EOD Div									
	ALMDS									
	AQS-20									
	RAMICS									
	AMNS	commercial		Depot level		Manufacturer		Available		
	MH-60	Widely available through Navy and some commercial		Unit level		Crew		Not available		
3	Talisman M (c/w Archerfish, SeaArcher)	Available through Navy	4	Depot level	2	Manufacturer	2	Available	5	13
4	Improved REMUS	Commercially available	4	Unit level	3	Maintenance team	1	Available	5	13
	Talisman M (c/w Archerfish, SeaArcher)	Available through Navy		Depot level		Manufacturer		Available		
	Benthos Modem Network	Commercially available		Intermediate level		Manufacturer		Available		

AFP	Components	Maintainability prediction based on maintenance facility required		Maintainability prediction based on maintenance organization required (personnel, training)	
1	REMUS	Unit level	4	Maintenance team	3
	EOD Diver	N.A		N.A	
	AQS-20	Intermediate level		Maintenace team / manufacturer	
	WLD-1	Intermediate level		Maintenance team / manufacturer	
	Support Module	Intermediate level		Maintenace team / manufacturer	

Maintainability Results

- From the prediction, among the alternatives:
  - AFP 1 had highest expected maintainability
  - AFP 3 and 4 had lowest expected maintainability

Suitability Analysis - Results

- Overall, AFP 1 had highest expected reliability and maintainability.
- AFP 4 had lowest expected reliability and maintainability.

	Reliability	Maintainability
Alternative 1	High	High
Alternative 2	Low	Medium
Alternative 3	Medium	Low
Alternative 4	Low	Low

Cost Analysis

LT Chris Causee

Cost Analysis

- Life Cycle Costs
  - Initial Cost
    - Purchase off the shelf
  - Annual Operation & Support Cost
    - Maintenance
    - Operating personnel cost
  - One-time overhaul / upgrades Cost
    - Mid-point of life cycle
    - 50% of initial cost
  - Scrap Value
    - 2% of initial cost

Cost Analysis Assumptions

- Did not examine cost of successful enemy attack, focused strictly on system life cycle costs
- Did not include RDT&E costs in our initial model, but discussed separately
- Costs based on purchase of single AFP applied to a single port
- Annual operational costs have close dependency on use of manned vs. unmanned systems
- 10 year life cycle for system

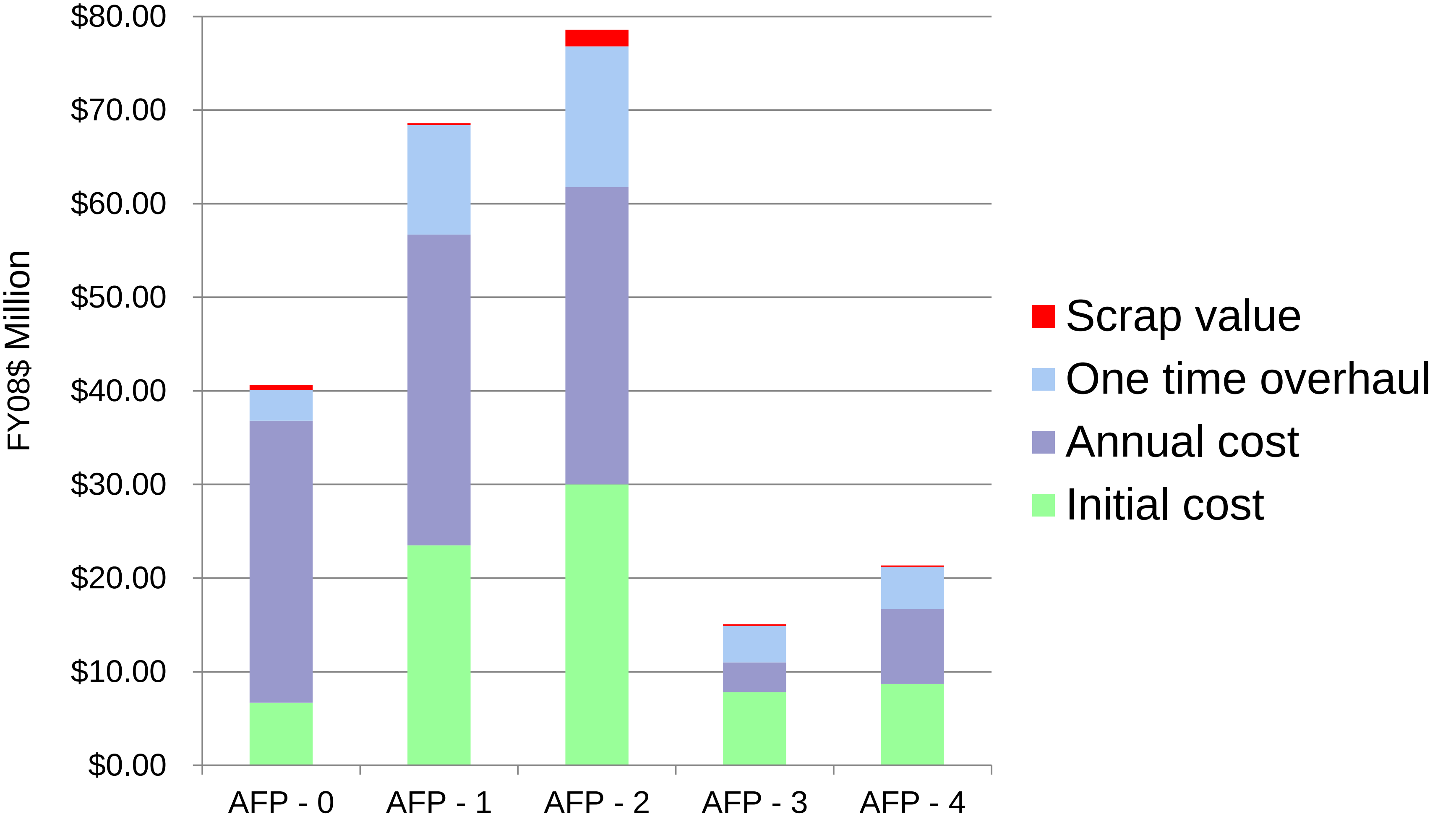
Cost Analysis

10 Year Life Cycle Cost Breakdown – (in FY08$ million)

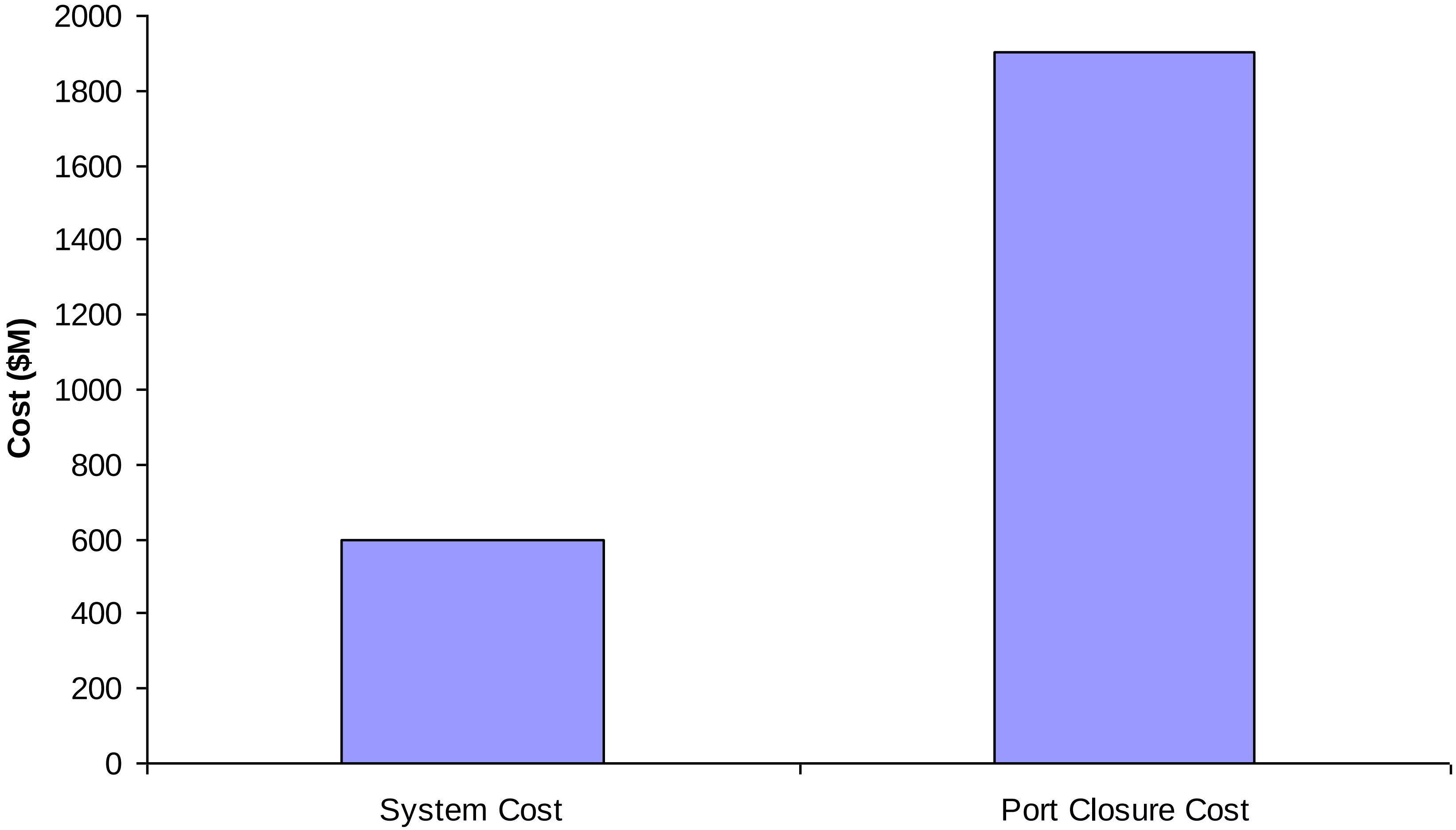
10 Year Life Cycle	Alt - 0	Alt - 1	Alt - 2	Alt - 3	Alt - 4
Initial cost	$6.7	$23.5	$30	$7.8	$8.7
Annual cost	$30.1	$33.2	$31.8	$3.2	$8
One time overhaul	$3.3	$11.7	$15	$3.9	$4.5
Scrap value	$0.54	$0.21	$1.8	$0.16	$0.16
LCC Total (FY08$)	**$43.9**	**$72.8**	**$84.3***	**$15.6**	**$22.2**
RDT&E Cost		**$1100**	**$1600**	**$570**	**$580**

* Does not include cost of MH-60

Cost Analysis



Cost Comparison



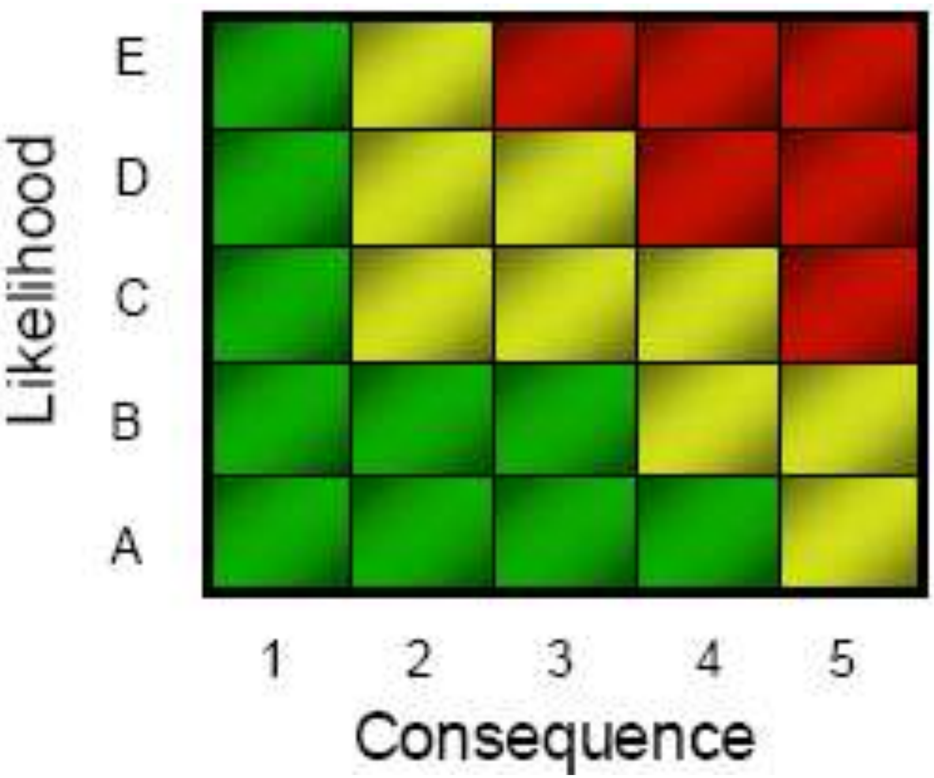
Risk Analysis

LT Eric Winn

Risk Categories

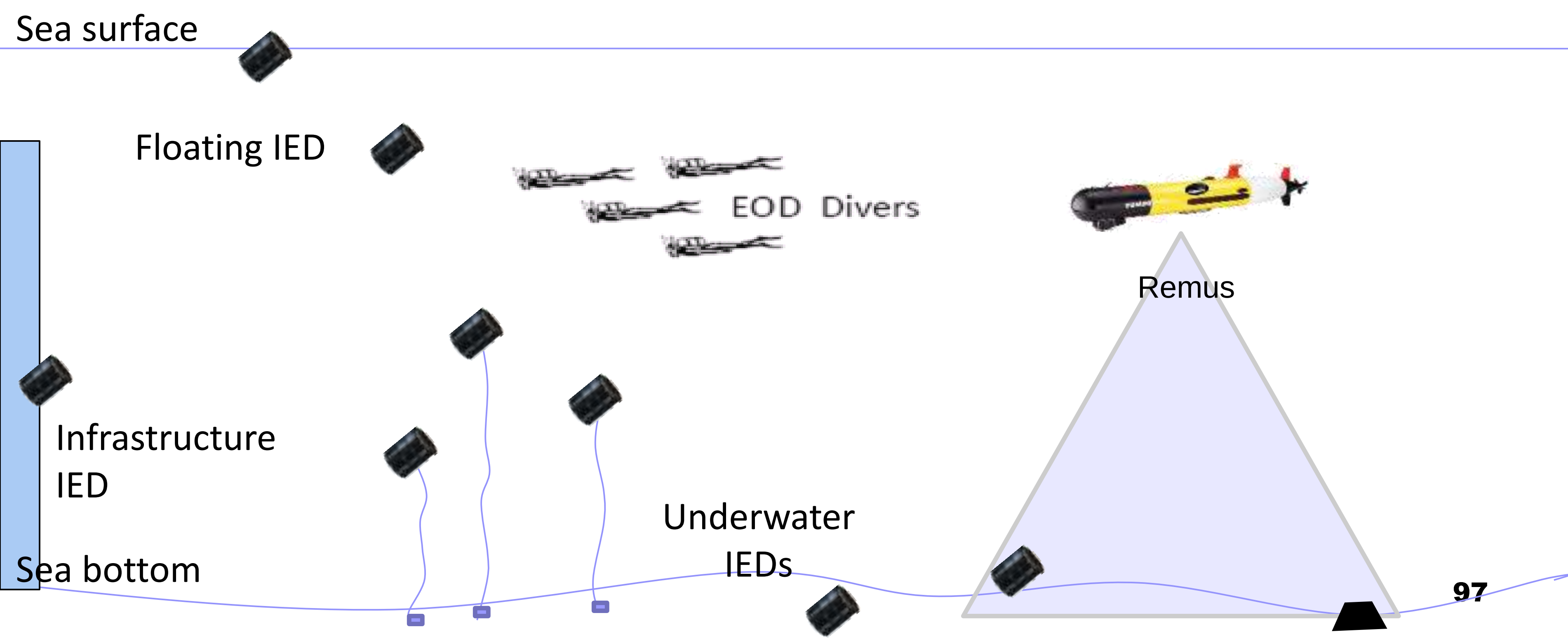
- Developmental risk
- Cost risk
- Schedule risk
- Organizational risk

Risk Matrix



- Green=Low Risk
- Yellow=Medium Risk
- Red=High Risk

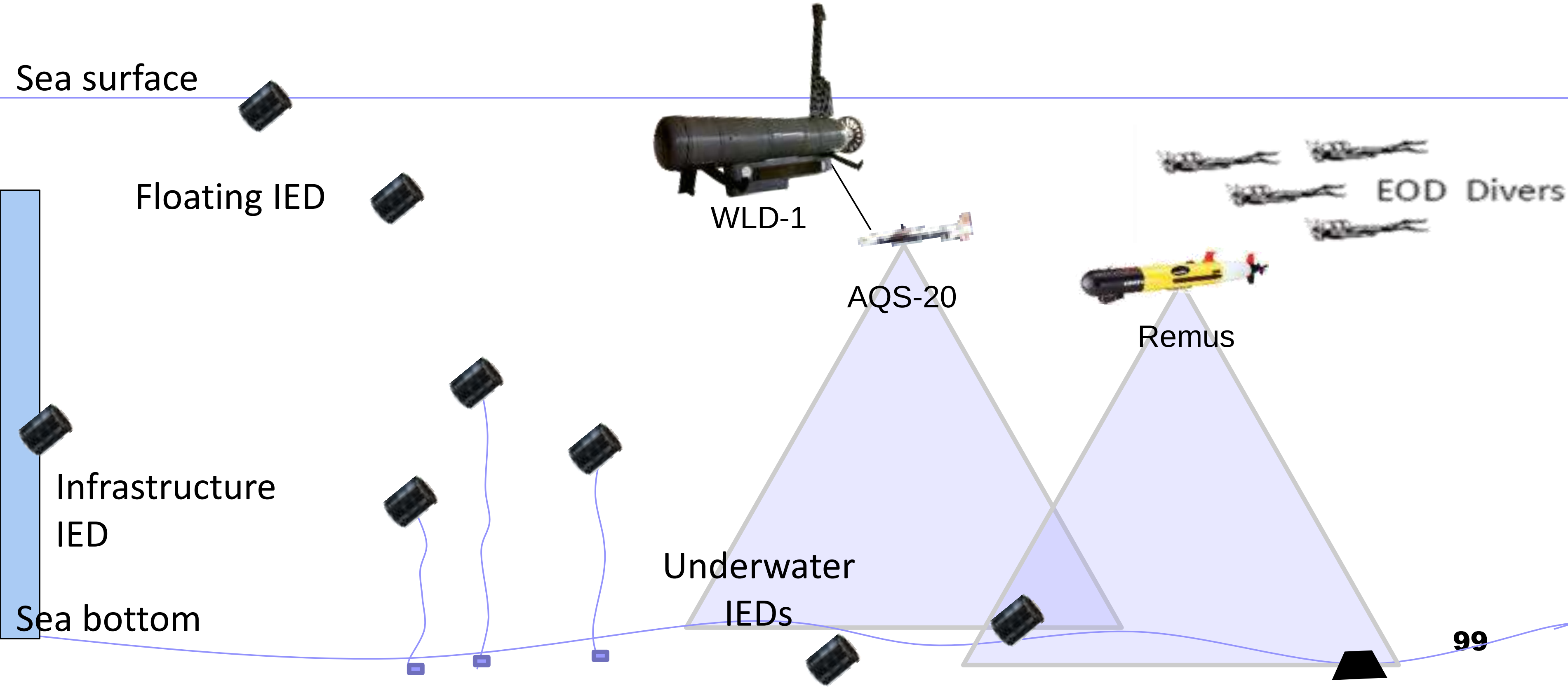
Baseline


Sea surface
Floating IED
EOD Divers
Remus
Infrastructure
IED
Underwater
IEDs
Sea bottom

Baseline

Category	Risk	Mitigation	
Developmental Risk	No risk associated.		
Cost Risk	Lack of continuous funding	Assign roles and responsibilities to the appropriate agencies.	
Schedule Risk	No risk associated		
Organizational Risk	Ineffective Command and Control Structure	Assign roles and responsibilities to the appropriate agencies.	

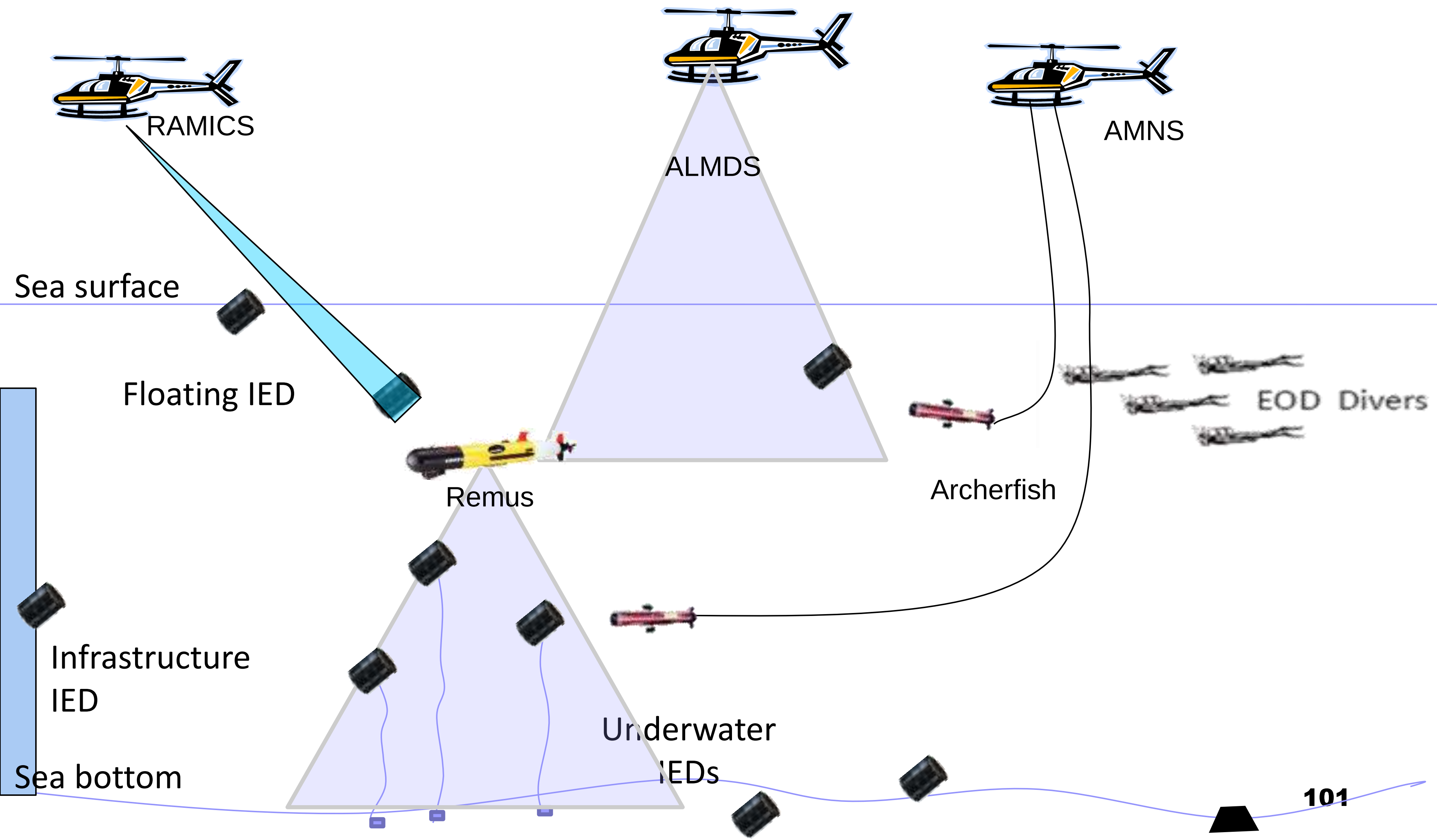
AFP 1


Sea surface
Floating IED
WLD-1
AQS-20
EOD Divers
Remus
Infrastructure IED
Underwater IEDs
Sea bottom

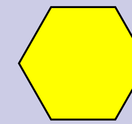
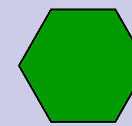
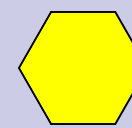
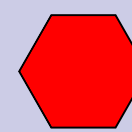
Adaptive Force Package 1

Category	Risk	Mitigation	
Developmental Risk	MPCE production delayed	Allocate more resources to R&D and production; investigate other UUV alternatives	
Cost Risk	Inadequate funding	Assign roles and responsibilities to the appropriate agencies.	
Schedule Risk	MPCE schedule delay	Create system requirement; Manage MPCE development.	
Organizational Risk	Conflicting asset availability	Allocate sufficient assets to the appropriate agencies.	

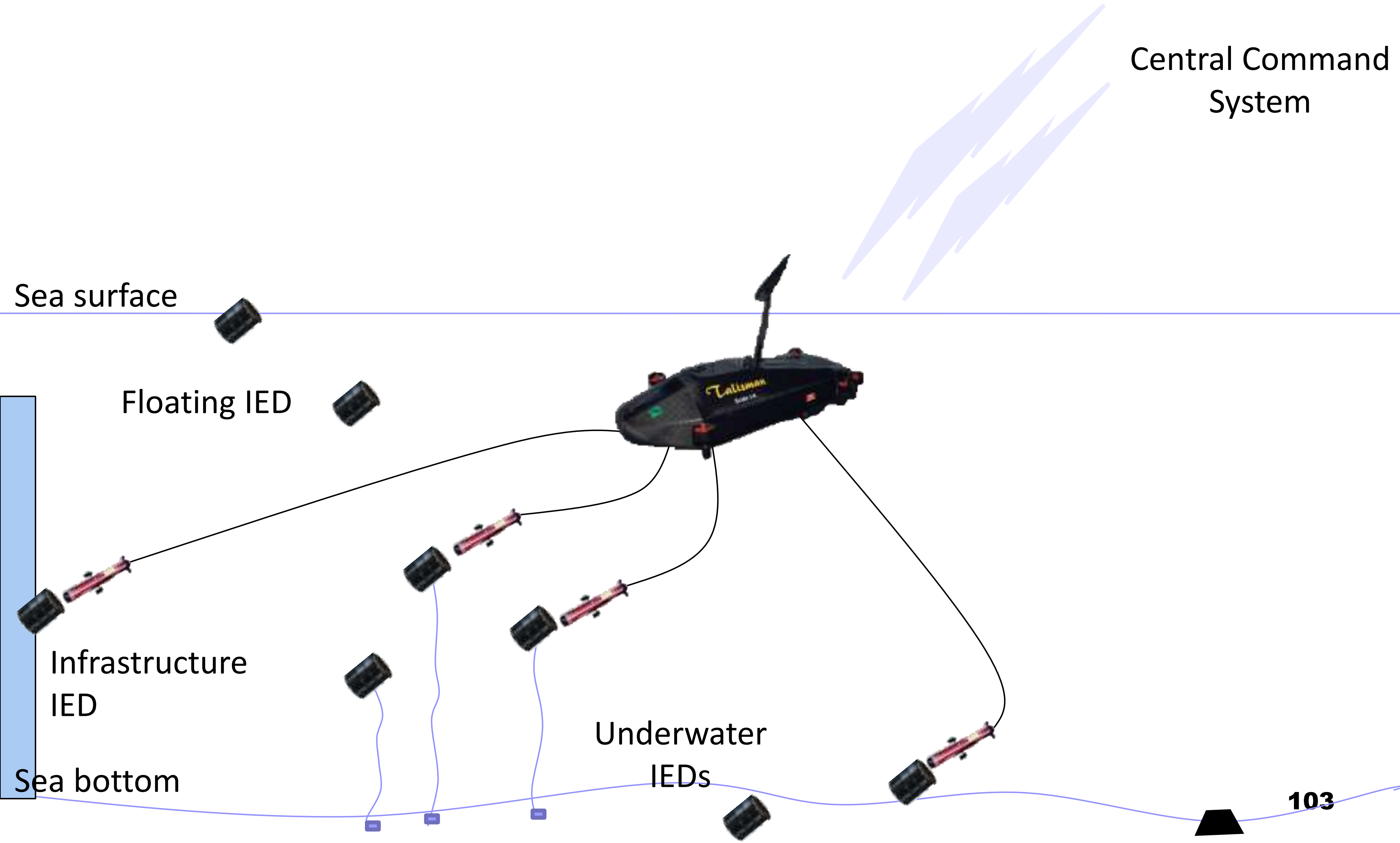
AFP 2


RAMICS
ALMDS
AMNS
Sea surface
Floating IED
EOD Divers
Archerfish
Remus
Infrastructure IED
Underwater IEDs
Sea bottom

Adaptive Force Package 2

Category	Risk	Mitigation	
Developmental Risk	Integration incompatibility between ALMDS and RAMICS	Continue with current OPEVAL; allocate resources to development.	
Cost Risk	Increased H-60 helicopter parts failure	Account for additional maintenance requirements	
Schedule Risk	CSTR schedule delay	Continue with current OPEVAL; allocate resources to development.	
Organizational Risk	Conflicting asset availability	Allocate sufficient assets to the appropriate agencies.	

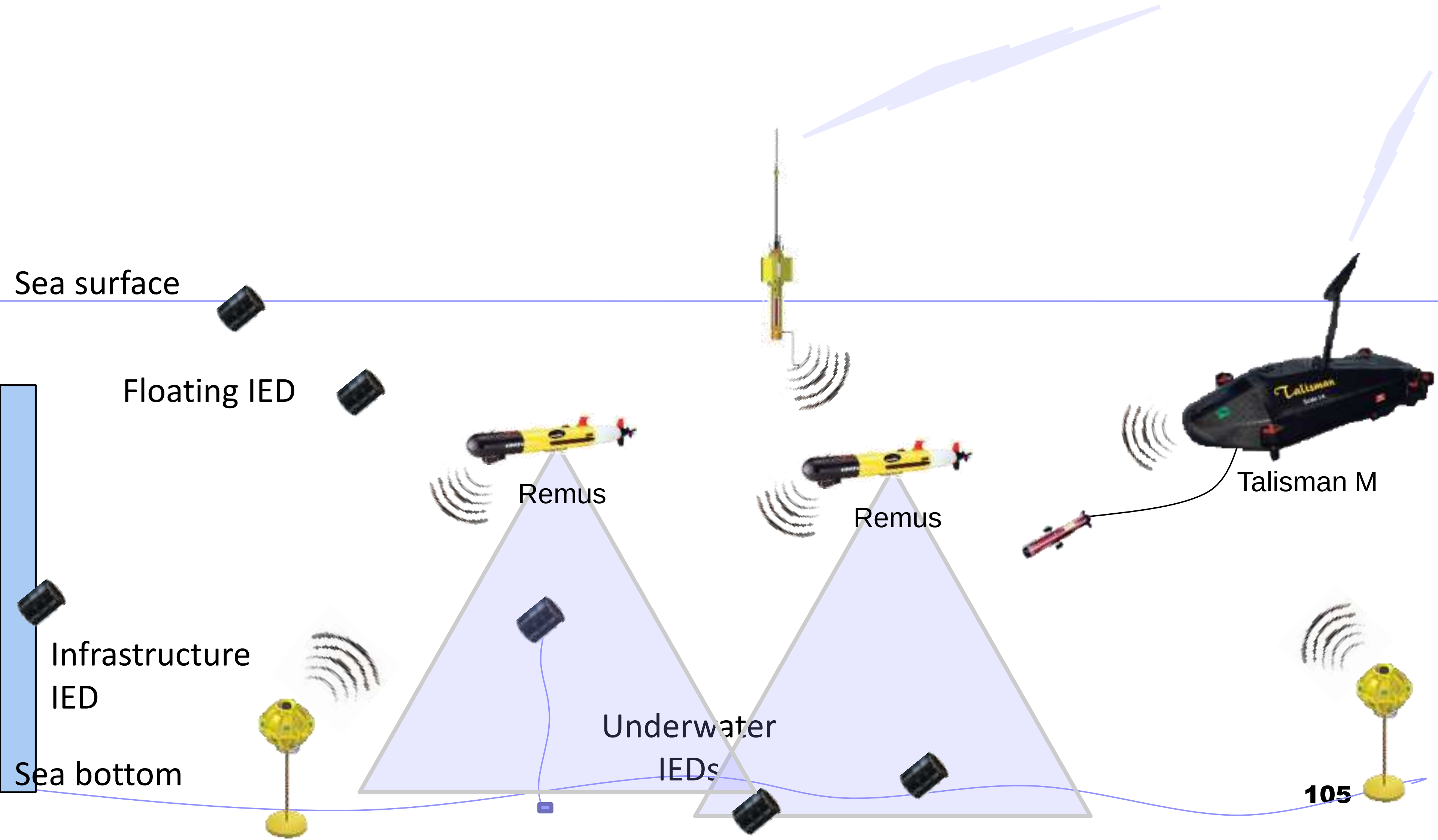
AFP 3 – Neutralize



Adaptive Force Package 3

Category	Risk	Mitigation	
Developmental Risk	System integration and development difficulties	Fallback to baseline systems and transition to partial capabilities	
Cost Risk	Manufacturing/Design issues resulting in delayed timeline	Allocate funds toward research and development.	
Schedule Risk	Manufacturing/Design issues resulting in delayed timeline	Allocate funds toward research and development.	
Organizational Risk	Conflicting asset availability	Allocate sufficient assets to the appropriate agencies.	

AFP 4


Sea surface
Floating IED
Remus
Remus
Talisman M
Infrastructure
IED
Underwater
IEDs
Sea bottom

Adaptive Force Package 4

Category	Risk	Mitigation	
Developmental Risk	Advanced Remus development delay	Create system requirement; use current tech; transition to partial capabilities	
Cost Risk	Manufacturing/Design issues resulting in delayed timeline	Allocate funds toward research and development.	
Schedule Risk	Advanced Remus acquisition delay	Create system requirement; Manage Advanced Remus development.	
Organizational Risk	Conflicting asset availability	Allocate sufficient assets to the appropriate agencies.	

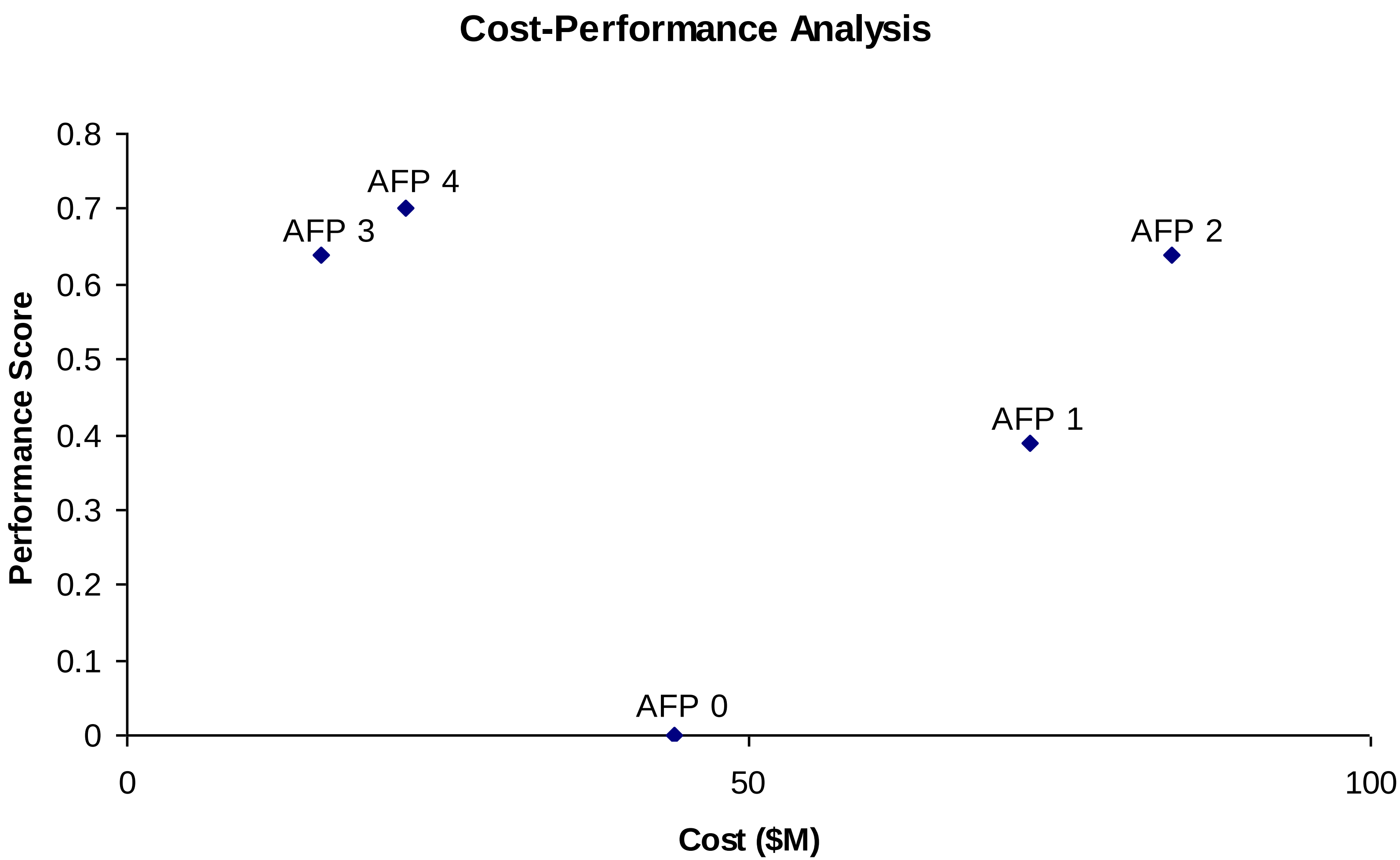
Overall Risk

Baseline	Low
Adaptive Force Package 1	Medium
Adaptive Force Package 2	Medium
Adaptive Force Package 3	High
Adaptive Force Package 4	High

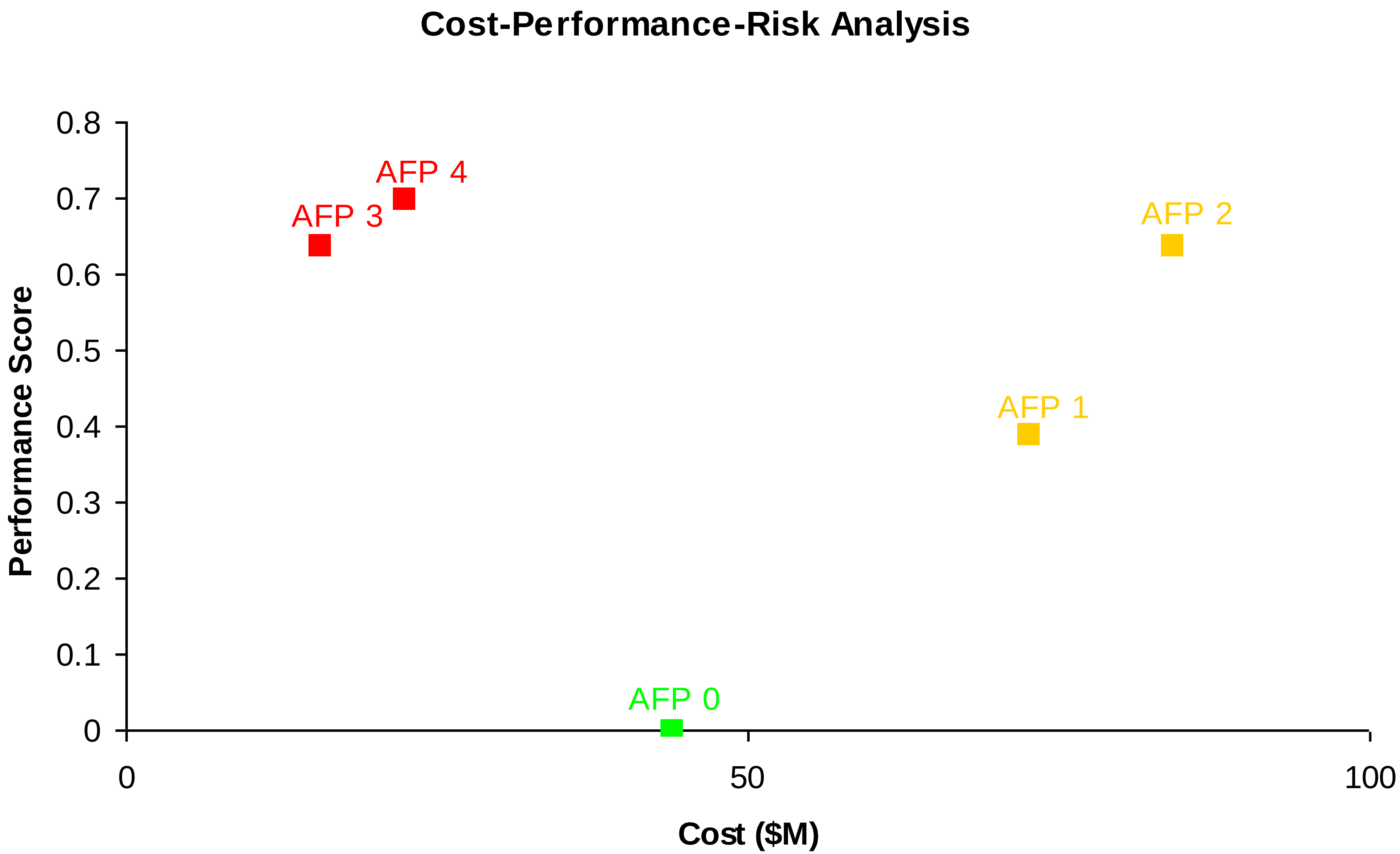
Critical Assessment

LT Bobby Rowden

Cost-Performance Analysis

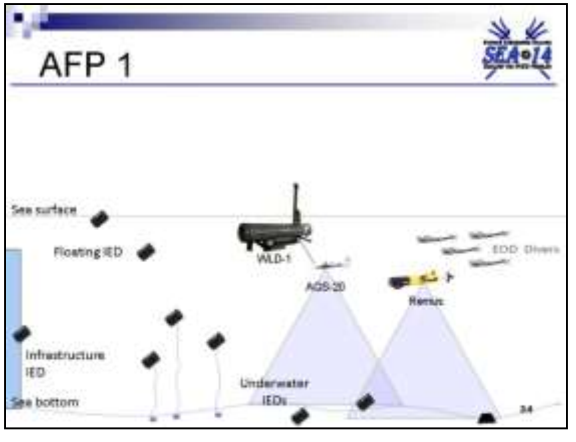


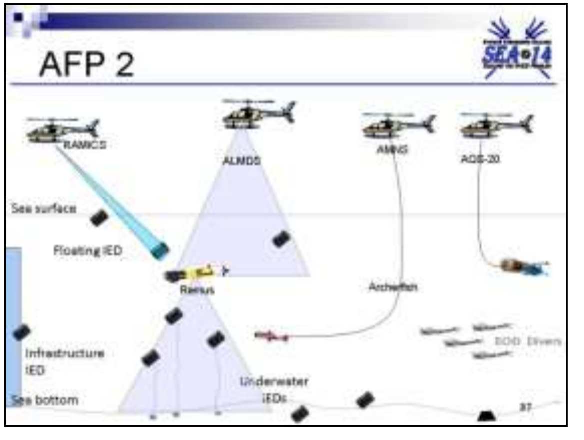
Cost-Performance-Risk



Findings – AFP 1 & 2

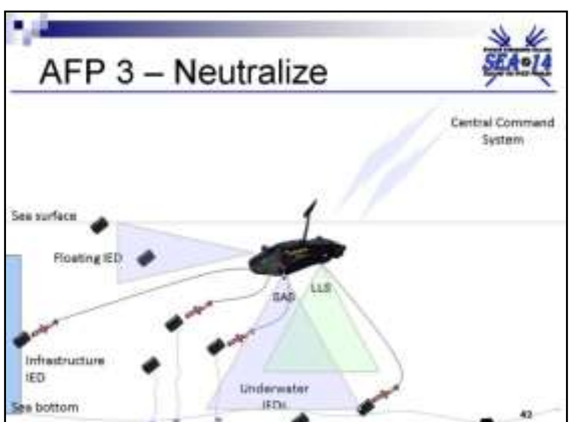
- All alternatives out-perform baseline
- AFPs 1 and 2 enable an interim improvement on performance
- Not well suited as long-term system solutions

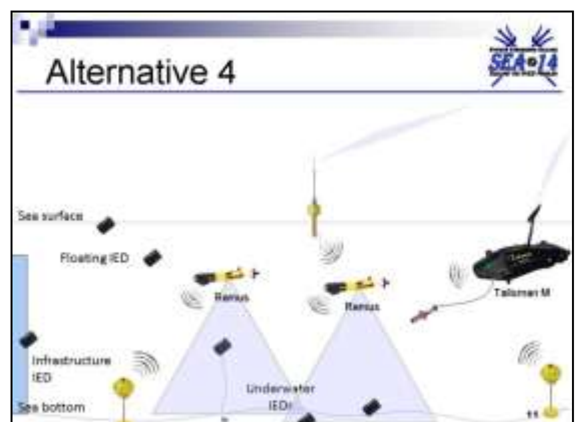




Findings – AFP 3 & 4

- AFPs 3 and 4 offer high performance, too similar to distinguish
- AFPs 3 and 4 offer cost savings, but with higher risk
- Better long-term solutions





Recommendations

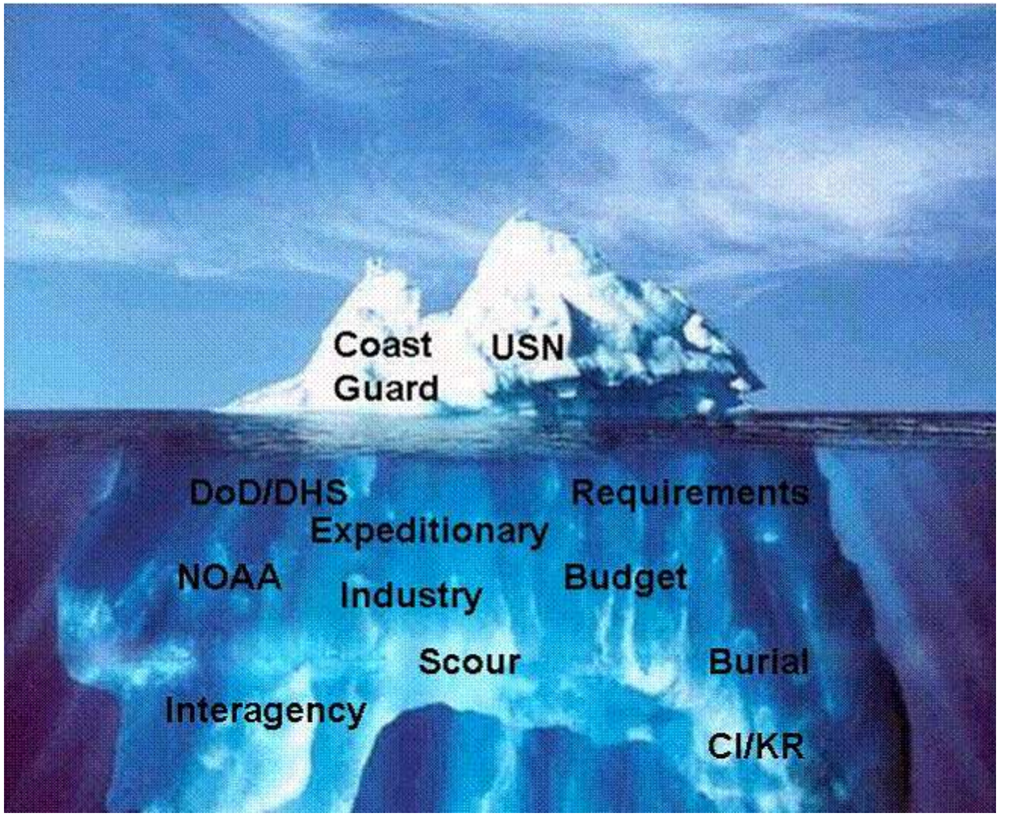
- Invest in development of underwater communication networks
- Further development of CAD/CAC algorithms
- Research and development of non-explosive neutralization techniques

Additional Insights

LT Mike Hellard

The Rest of the Story

- **<u>Articulated Requirements drive solutions</u>**
  - Equipment
  - Personnel
  - Training
  - Preparation
  - Justify Budgets



National Objectives Needed

- Specifically…
  - Prioritized listing of ports
  - National response / recovery timelines

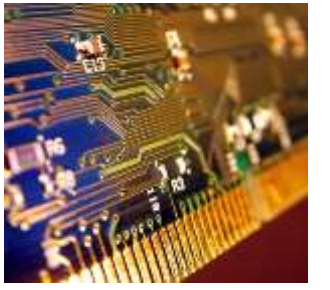
Local Objectives Needed

- Local ports set priority areas
  - Establish “Port Folders”
- Supply chain impacts known
  - Locally
  - Regionally
  - Nationally

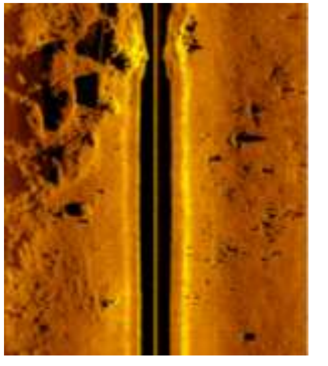
The Key

- ***BASELINE SURVEYS***
  - Lead to Change Detection
  - “Cheap Insurance”

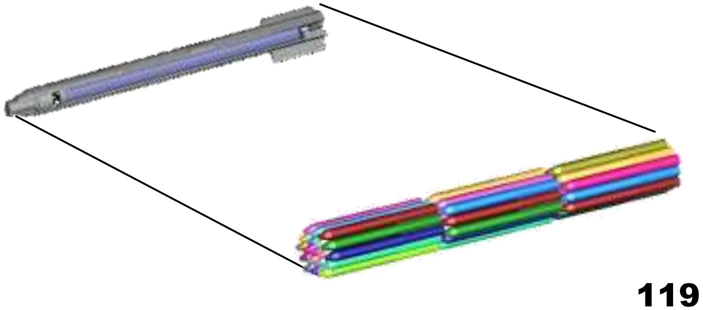
Science & Technology



- Change Detection
  - Requires a baseline
- Post Mission Analysis (PMA)
  - Rapid and accurate
  - Consistent and standardized



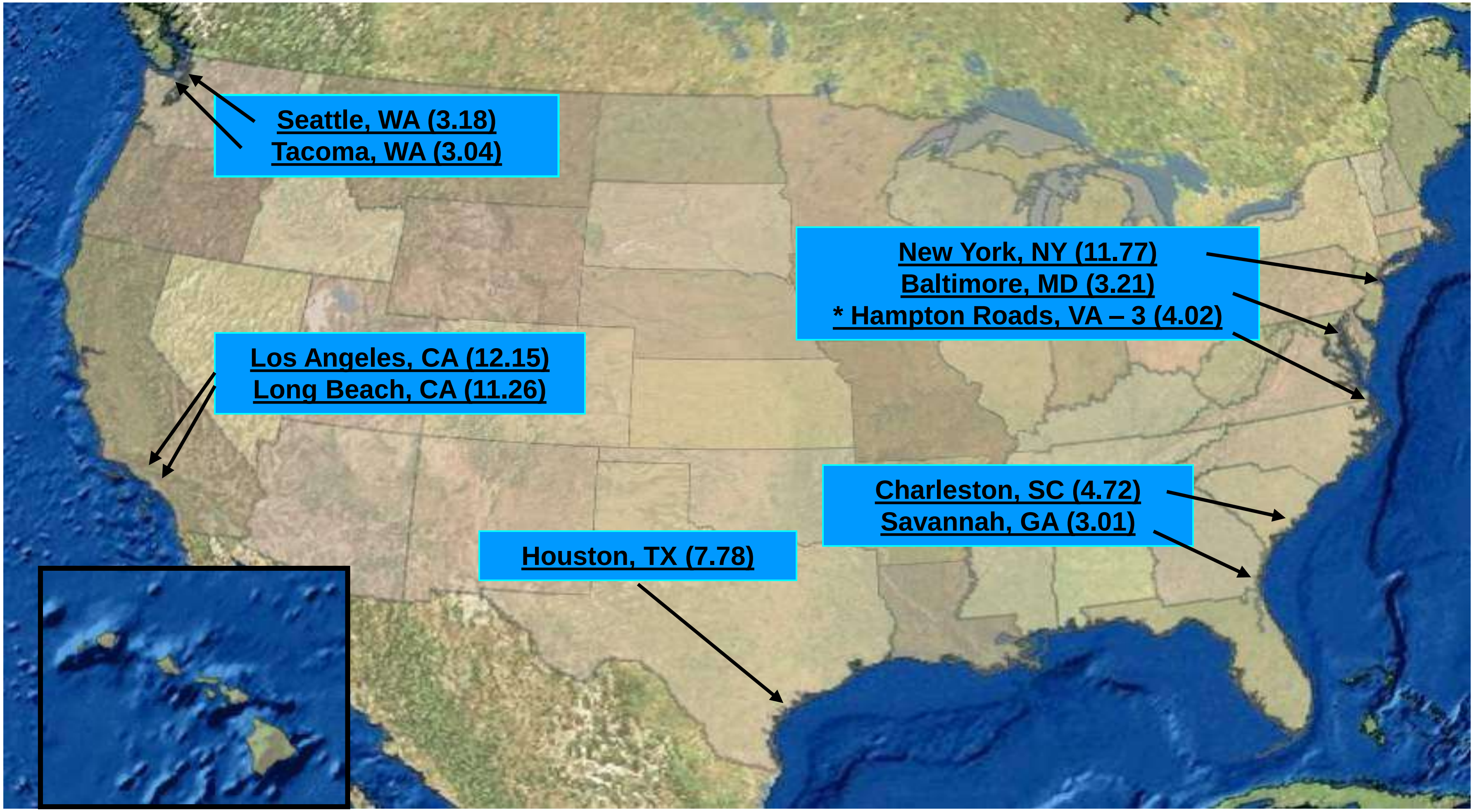
- Non-explosive Neutralization
- Unmanned systems



Priority Ports - TFT

UNITED STATES WATERBORNE FOREIGN COMMERCE 2005 PORT RANKINGS BY VALUE OF CARGO (Millions of Current U.S. Dollars)						
TOTAL FOREIGN TRADE						
RANK	PORT	VALUE		Total Foreign Trade (TFT)	Ports % of TFT	Cumulative % of TFT
1	Los Angeles, CA	$135,079		$1,111,370	12.15%	12.15%
2	New York, NY	$130,838		$1,111,370	11.77%	23.93%
3	Long Beach, CA	$125,171		$1,111,370	11.26%	35.19%
4	Houston, TX	$86,444		$1,111,370	7.78%	42.97%
5	Charleston, SC	$52,483		$1,111,370	4.72%	47.69%
6	Hampton Roads	$44,658		$1,111,370	4.02%	51.71%
7	Baltimore, MD	$35,637		$1,111,370	3.21%	54.92%
8	Seattle, WA	$35,301		$1,111,370	3.18%	58.09%
9	Tacoma, WA	$33,788		$1,111,370	3.04%	61.13%
10	Savannah, GA	$33,424		$1,111,370	3.01%	64.14%
11	Oakland, CA	$32,885		$1,111,370	2.96%	67.10%
12	Morgan City, LA	$21,039		$1,111,370	1.89%	68.99%
13	New Orleans, LA	$20,944		$1,111,370	1.88%	70.88%
14	Miami, FL	$19,899		$1,111,370	1.79%	72.67%
15	Philadelphia, PA	$19,251		$1,111,370	1.73%	74.40%
16	Beaumont, TX	$17,059		$1,111,370	1.53%	75.93%
17	Jacksonville, FL	$16,494		$1,111,370	1.48%	77.42%
18	South Louisiana	$15,630		$1,111,370	1.41%	78.82%
19	Corpus Christie, TX	$15,532		$1,111,370	1.40%	80.22%
20	Port Everglades, FL	$15,298		$1,111,370	1.38%	81.60%
. . .	. . .	. . .				
186	Warroad, MN	$0				
		$1,111,370				

Priority Ports - TFT



Priority Ports – TFT & Navy

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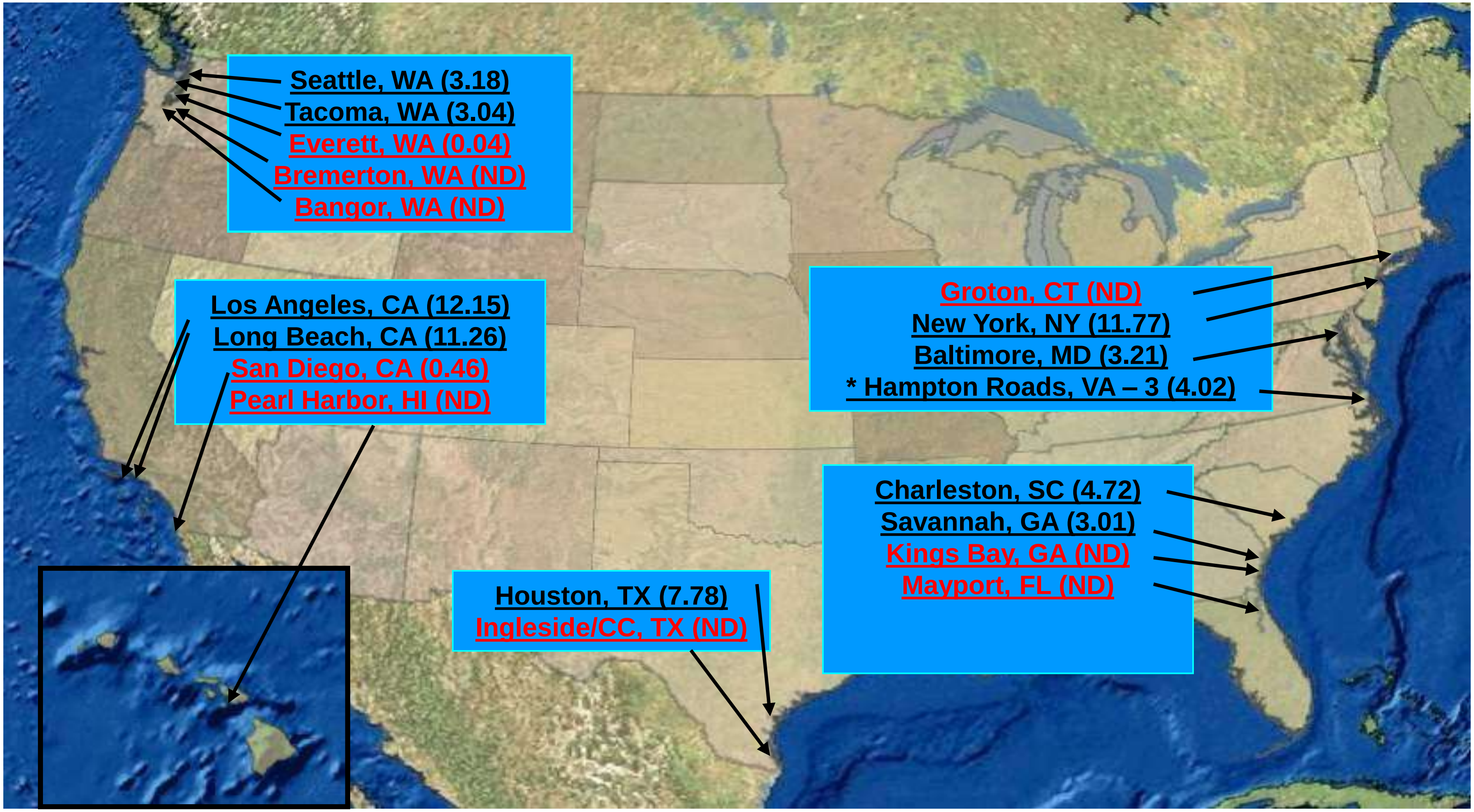
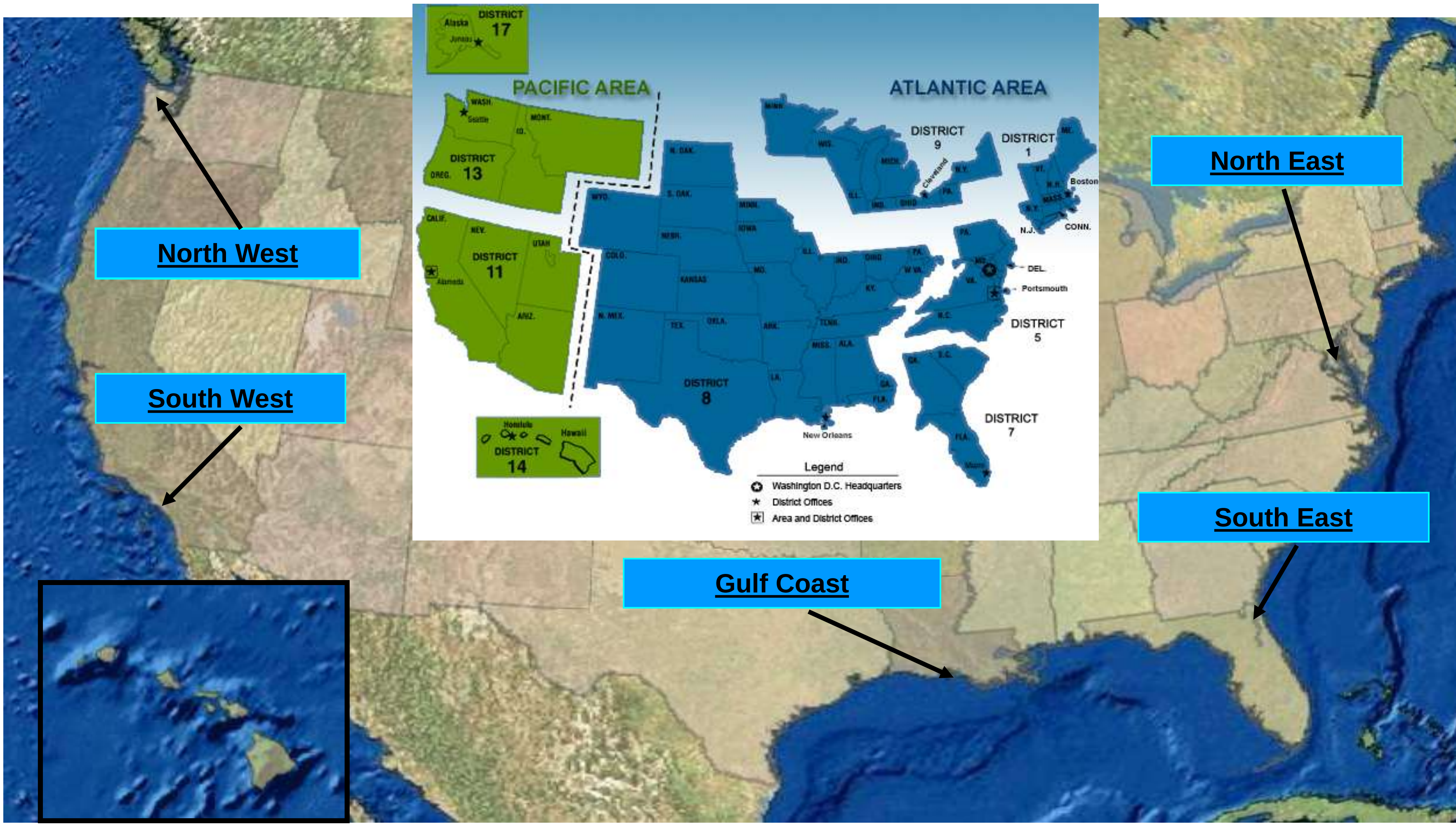
		$1,111,370				

FFC Priorities (12 Ports)
Norfolk
Little Creek
Newport News
Groton
Mayport
Kings Bay
Bangor
Bremerton
Everett
San Diego
Honolulu
Ingleside Corpus Christi

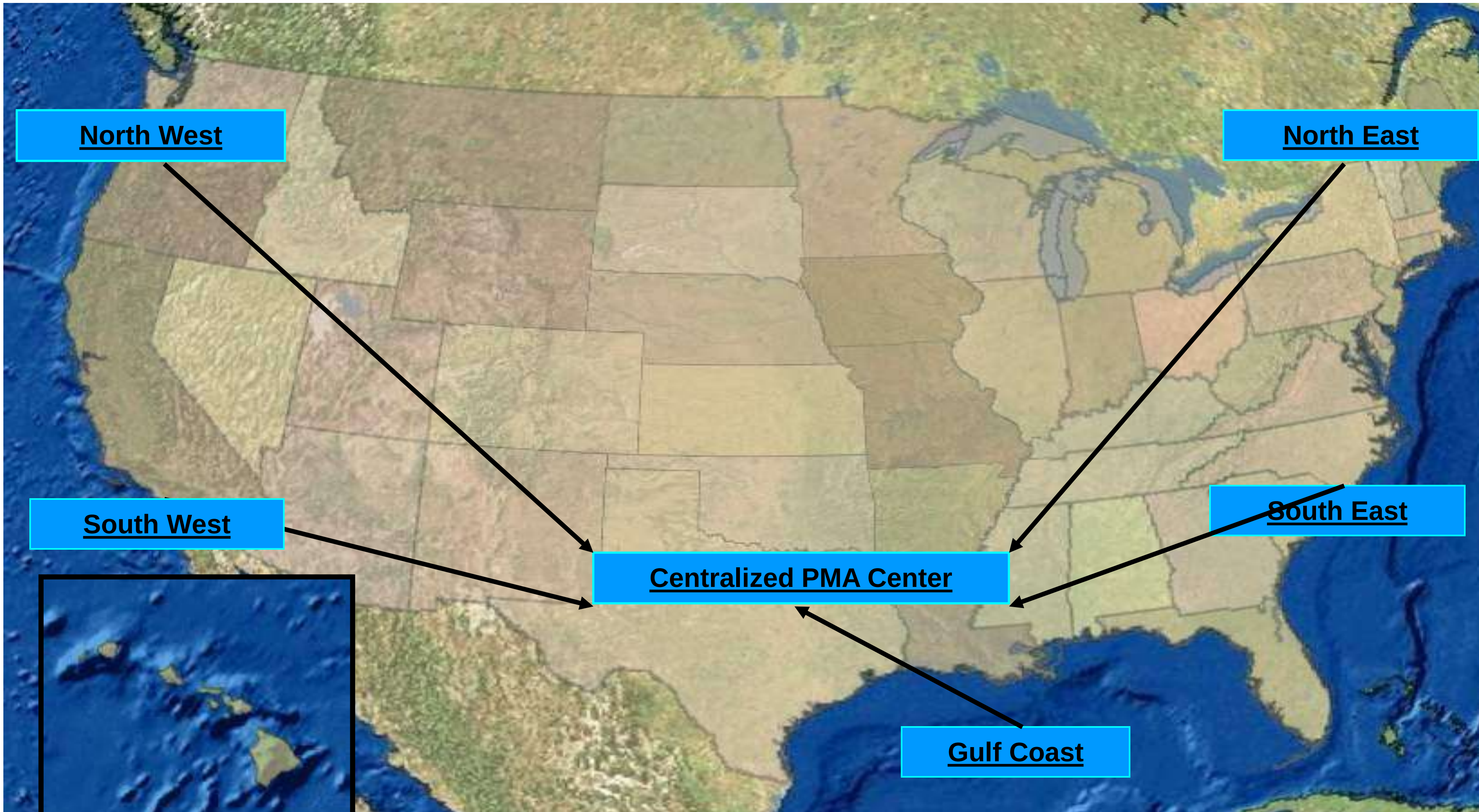
Priority Ports – TFT & Navy



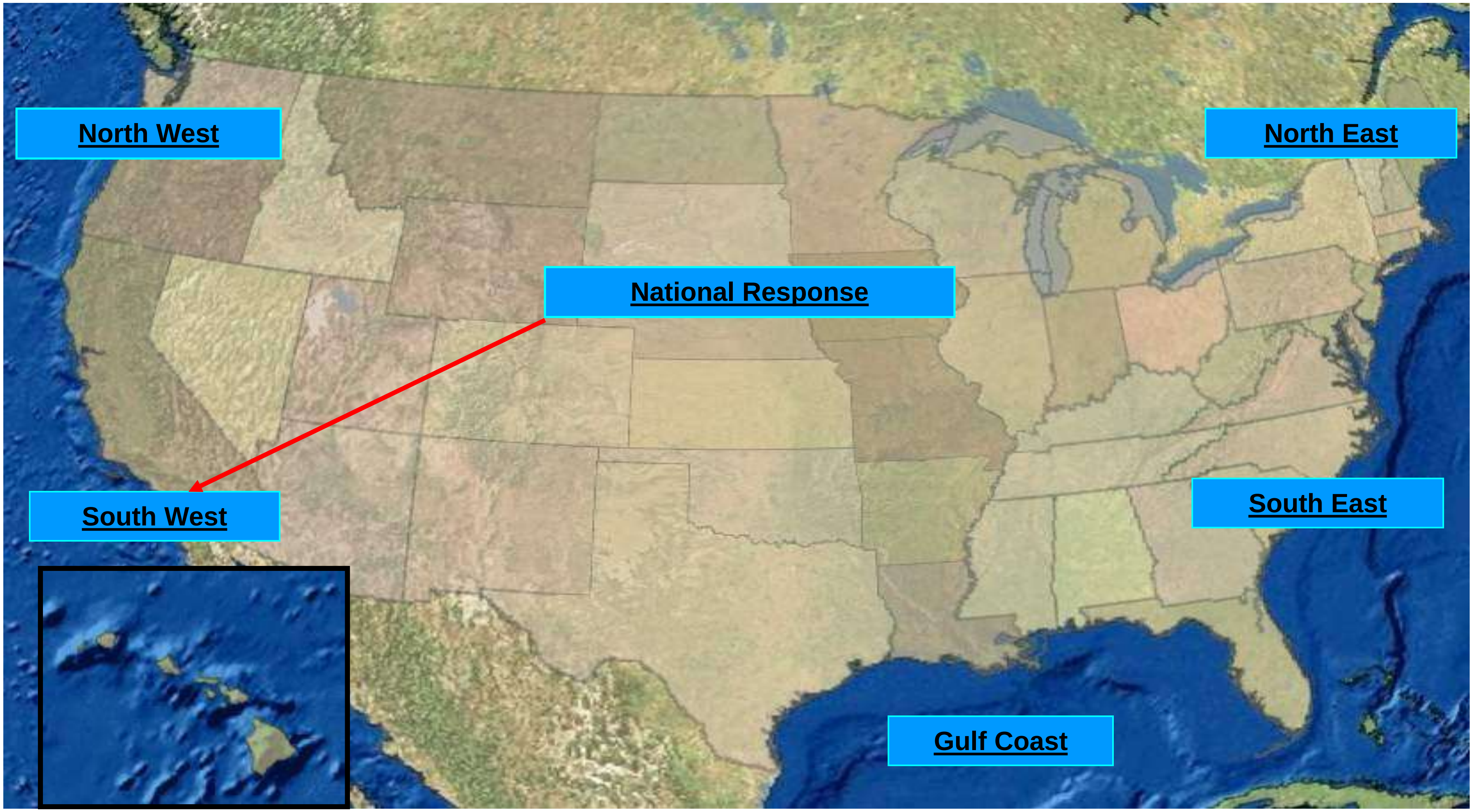
Regional Baseline Approach



Baseline Storage Repository



Neutralization Capability



Caveats - Grants

- Great for short term acquisition
- Need to address long term sustainment
- Provide direction

Caveats - Training

- Exercises need to be realistic
  - People who respond
  - Capabilities they have
  - Quantities they bring
  - “Sensor in the water”
  - Interagency relationships

Caveats - Costs

- Going to cost some money
  - BASELINES ARE MOST IMPORTANT
  - Purchasing equipment to conduct surveys
  - Conducting surveys
  - Building port folders
- Not going to cost money
  - Prioritizing critical areas within ports
  - Establishing key players
  - Building interagency relationships

Caveats - Attitude

- Low Probability – High Impact
  - MIEDs are cheap
  - MIEDs are easy to get
  - Attacks hard to prevent
  - Response and recovery is hard
  - Response and recovery is time consuming
- Sept 10, 2001
- Terrorists can achieve desired impacts

Takeaways

- Time is the key issue
- Baseline Surveys are “A Must Do”
- National Requirements and Guidance
  - Port priorities
  - Response and recovery timelines
  - Priority within the port

Takeaways

- S & T Improvements Needed In…
  - Automated Change Detection
  - Rapid Post Mission Analysis
  - Non-explosive Neutralization
  - Unmanned Systems
- National Structure To Counter MIEDs
- Grants / Training / Costs / Attitude

Project Findings and Recommendations

LT Bobby Rowden

Recommendations

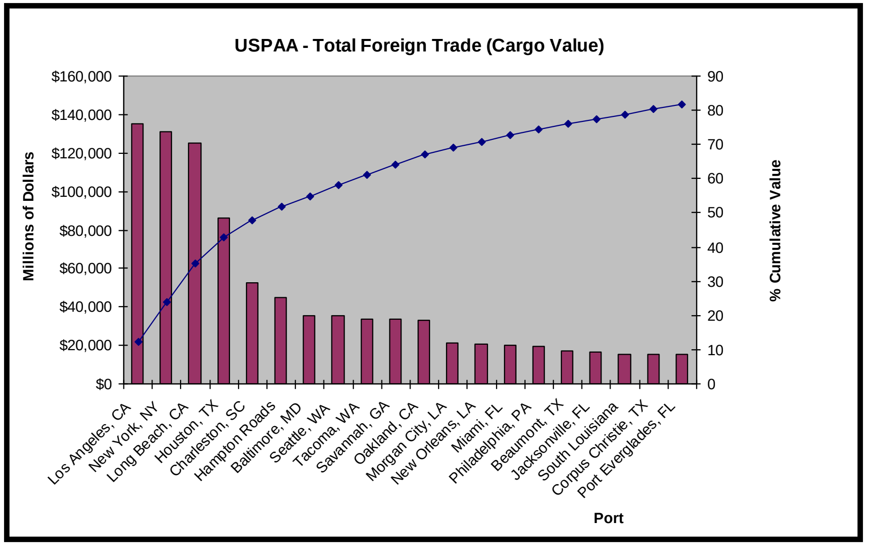
- Set Requirements
  - Timeline Requirements
  - Roles and Responsibilities
  - Lifecycle Funding

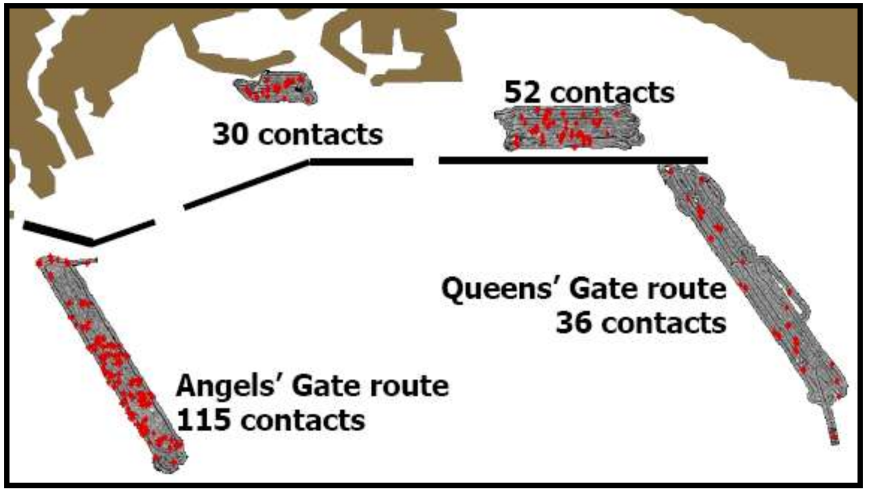
Recommendations

- Make Early Investments
  - Non-explosive Neutralization
  - Underwater Communications
  - CAD/CAC Processes
  - Effect of Port Environments on Sensors
  - Multi-Agency Exercise Development

Recommendations

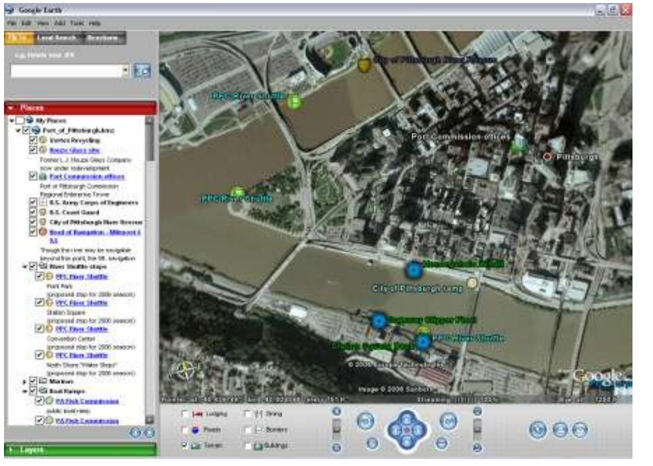
- Set Priorities
  - Counter MIED
  - Port Coverage
  - Port Infrastructure

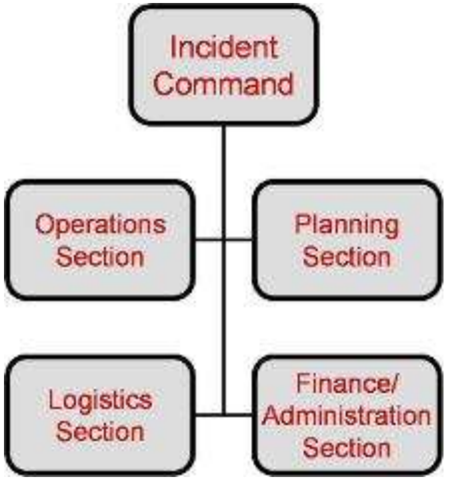




Recommendations

- Develop Force Multipliers
  - Port Folders
  - Change Detection
  - CUP Standards
  - Forensic Study
  - Incident Command System





Future Thesis Possibilities

- Organizational Roles and Responsibilities
- Mine burial modeling
- Command and Control
- MDA fusion/integration
- Port supply-chain shipping impact
- Port environment effects on sensors
- Non-explosive neutralization

Questions?

Backup

Contacts

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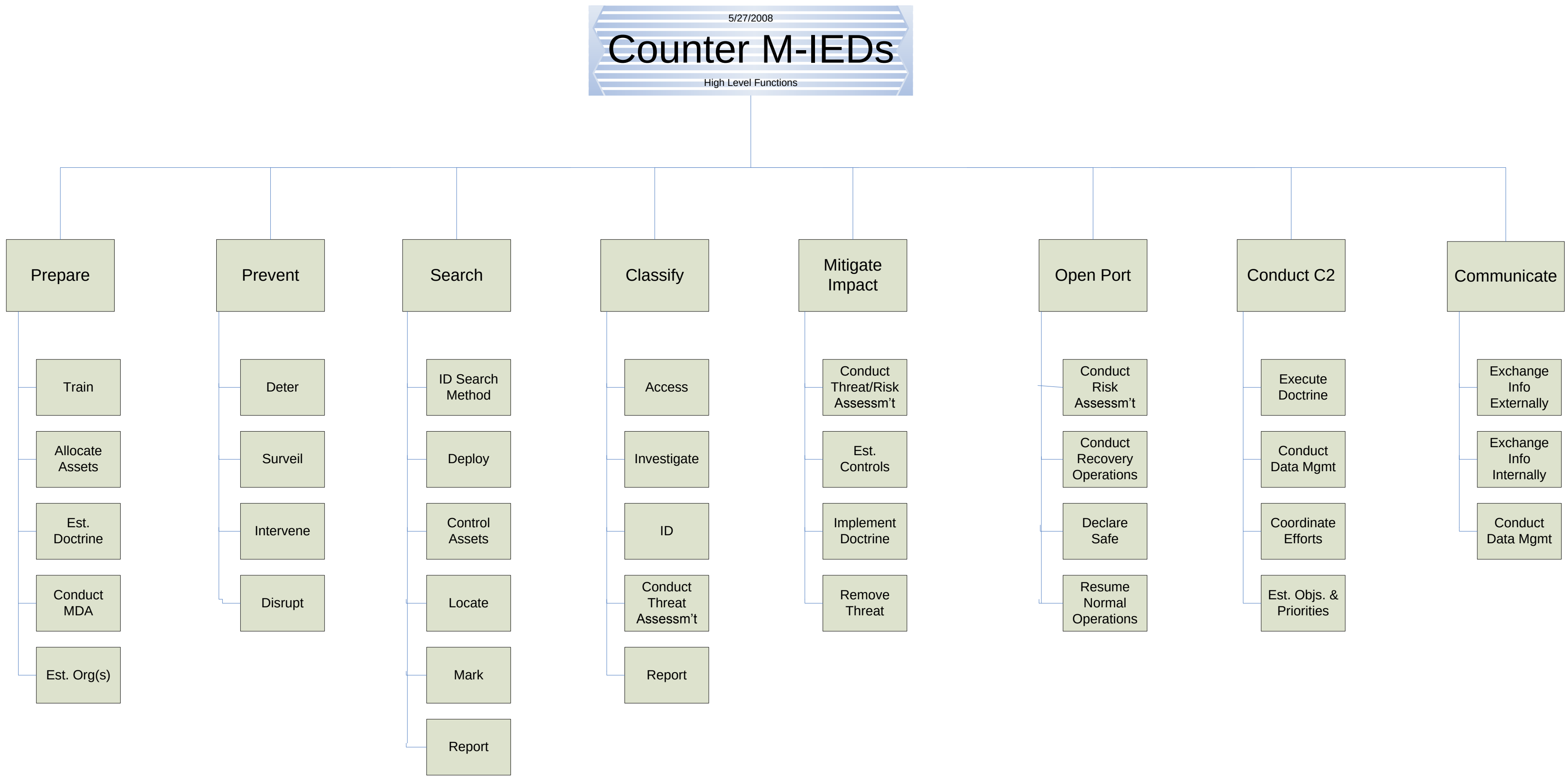
Functional Hierarchy



Initial Problem Statement

Statement of Problem

Develop a system of systems to prepare and defend commercial ports, commercial transit space, and the associated inland waterways from the threat of maritime improvised explosive devices. If defense fails, the system of systems will enable port recovery via the effective and timely search of above-stated waterways, conduct of command and control activities, and the mitigation of commercial impact to the port, regional, and national economies.

Scope of Problem

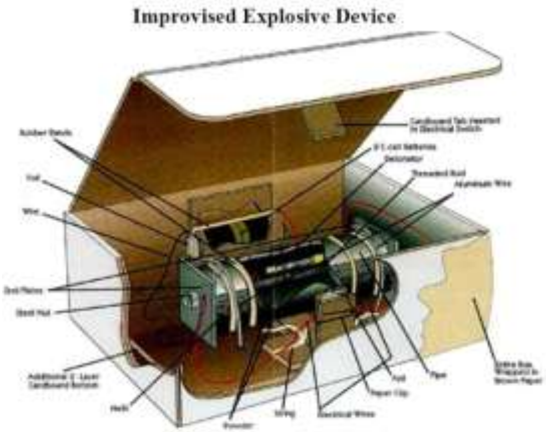
-Geographic space includes transit lanes and adjacent waters that impact the flow of commerce or the local economy of a domestic port.

-Solution shall be available to be implemented in US strategic ports by 2012.

-Focus on domestic ports, but assess solutions applicable to international implementation.

-Focus on the Underwater, Floating, and Infrastructure Borne subsets of maritime improvised explosive devices.

Definitions



IED: A device placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and designed to destroy, incapacitate, harass, or distract. I t may incorporate military stores, but is normally devised from nonmilitary components (JP 3-07.2).

An MIED is an IED placed in the maritime domain, as defined in NSP-41/HSPD-13

Maritime IED's

Floating IED

An explosive device that freely floats on the surface or in the water column, does not have a means of propulsion, and is not directable.

Underwater IED

An explosive device that does not have any projection above the surface or the water, neither from itself or a transporting device. UWIEDs may be bottomed or tethered to the bottom.

Water Craft Borne IED

An explosive device attached to watercraft such as motor driven vessels, sailboats, or submersible/semi-submersibles. Craft may be unmanned, manned, or remotely controlled. Purpose of IED may be against craft itself, or in combination against external target.

Infrastructure Borne IED

An explosive device attached to infrastructure embodiments such as piers, buoys, markers, bridges, etc. Purpose of attack may be against the infrastructure bearing the IED or against targets expected to come in contact/close proximity.