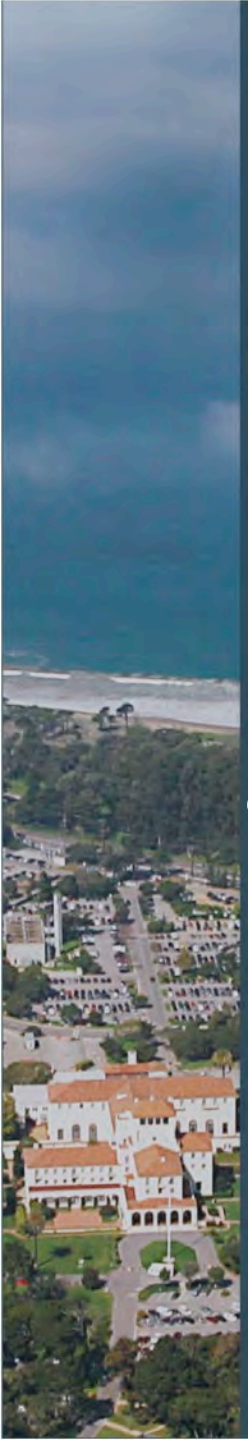


NAVAL
POSTGRADUATE
SCHOOL

# SEA-19A

## "2024: Unmanned Undersea Warfare Concept"

The Nation's Premiere Defense Research University

Monterey, California

WWW.NPS.EDU

# Value of Unmanned Systems

- "In the United States we are in the process of **reimagining naval power** with cyber power and **unmanned systems**." ADM Roughead, Former CNO (2010)

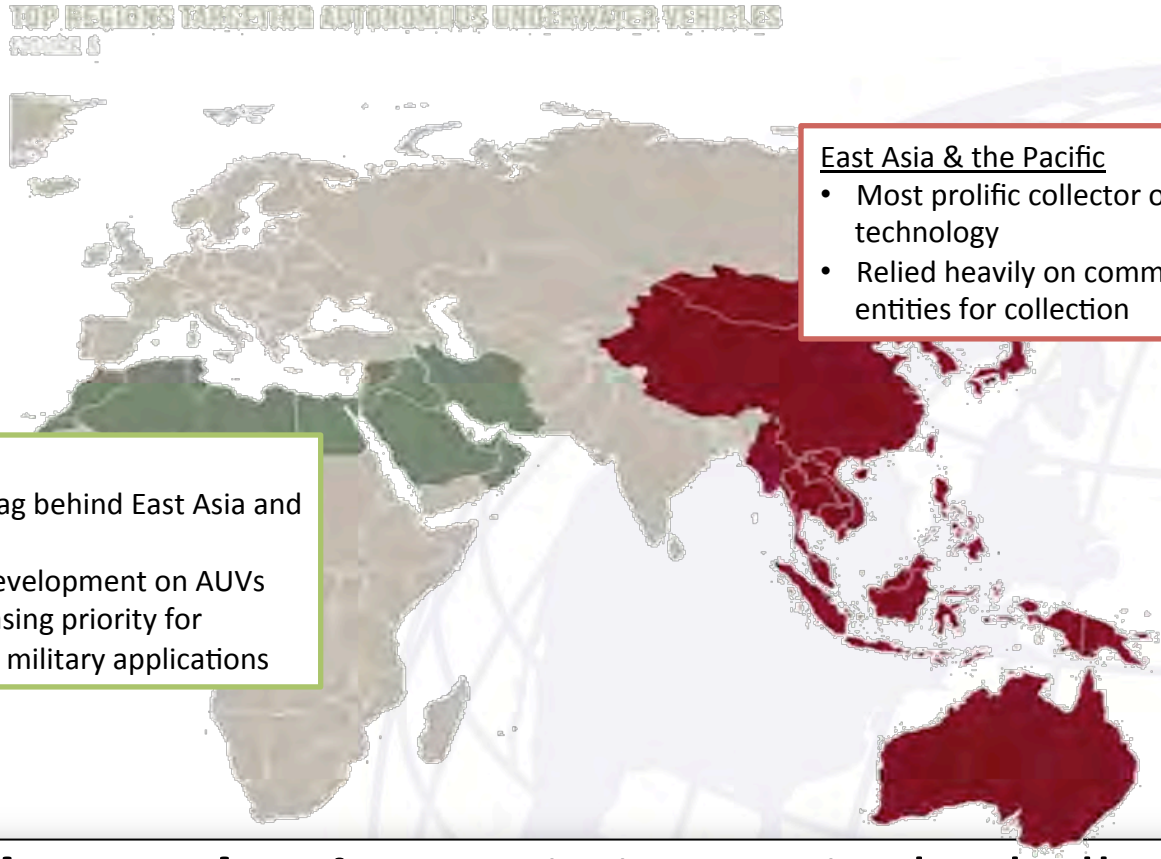
- "Emerging foreign capabilities to hunt and defeat stealthy submarines will force the Navy to find **new ways to maintain dominance** in the undersea warfighting arena." ADM Greenert, CNO (2012)

- "Unmanned undersea combat systems with their **relatively high efficiency and low cost** will become a crucial component of our country's sea power." Li Pengchao, China - Harbin Engineering College (2009)

- "If **deployed in large numbers**, [UUVs] would render the enemy defenseless and unable to resist." Li Jie, China - Modern Navy (2010)

# Global UUV Proliferation

## Other Navies aggressively pursuing unmanned technologies



East Asia & the Pacific
- Most prolific collector of AUV technology
- Relied heavily on commercial entities for collection

Near East
- AUV programs lag behind East Asia and the Pacific
- Research and development on AUVs will be an increasing priority for commercial and military applications

To **maintain undersea dominance** in increasingly challenging A2AD environments, the U.S. must not only ***invest***, but ***accelerate*** the development and deployment of UUVs

# Bottom Line Up Front

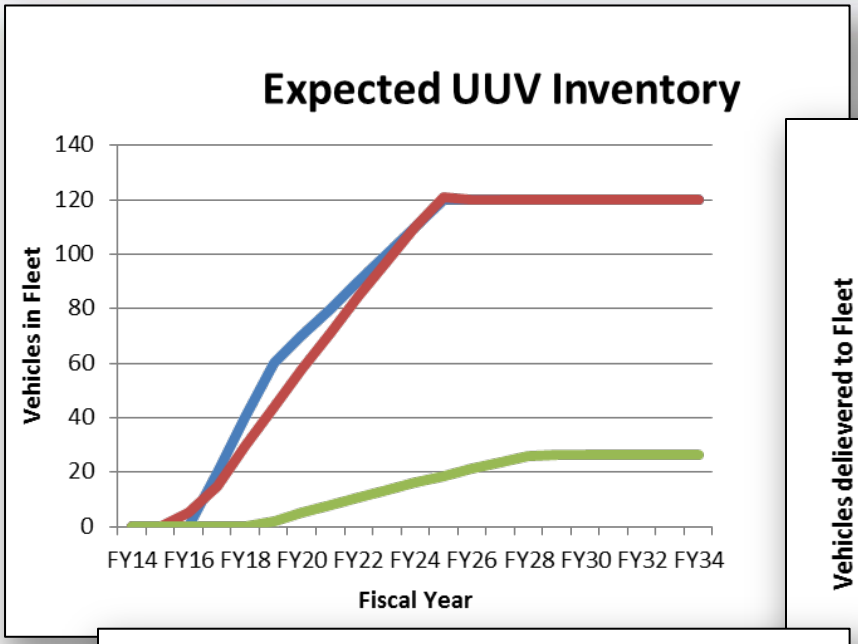
**Project Tasking from OPNAV:**

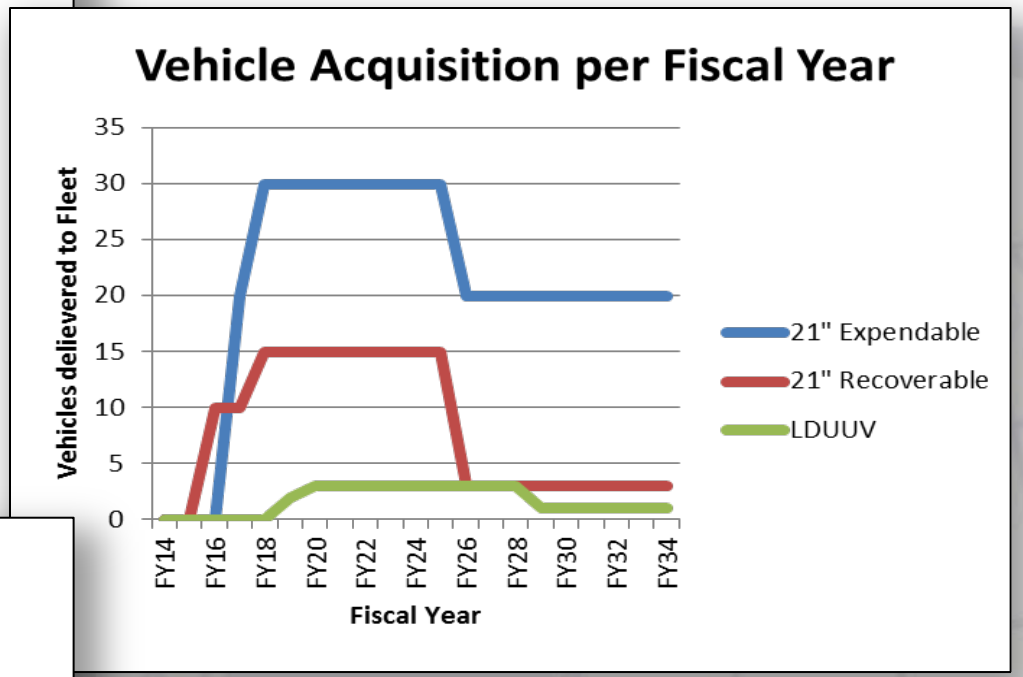
*Design a **family of systems** of UUVs that will provide an **operational undersea force** available for tasking over a **range of missions** by 2024.*

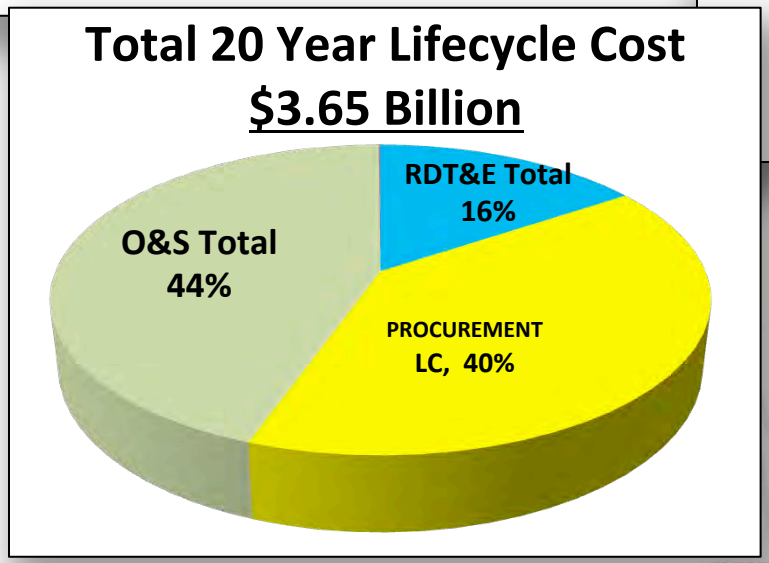
***We recommend a UUV inventory of:***

- ***120** 21" Expendable*
- ***120** 21" Recoverable*
- ***26** LDUUV*

# BLUF: UUV Force Structure




**Acquisition strategy to be combat effective by 2024!**

# Outline of Presentation

1. BLUF
2. Concepts of Operations
3. Decision Drivers
4. Analysis of Alternatives
5. Cost Analysis
6. Force Structure, Revisited
7. Closing Remarks
8. Breakout Sessions

# Diversity of UUV Missions

*Intelligence, Surveillance, and Reconnaissance*

*Mine Warfare*

*Oceanography*

*Payload Delivery*

*Information Operations*

*Anti-Submarine Warfare*
*Anti-Surface Warfare*

*Time Critical Strike*

*Communications/Navigation Network Node*

*Inspection & Identification*

*Homeland Defense & Force Protection*

*Sea Base Support*

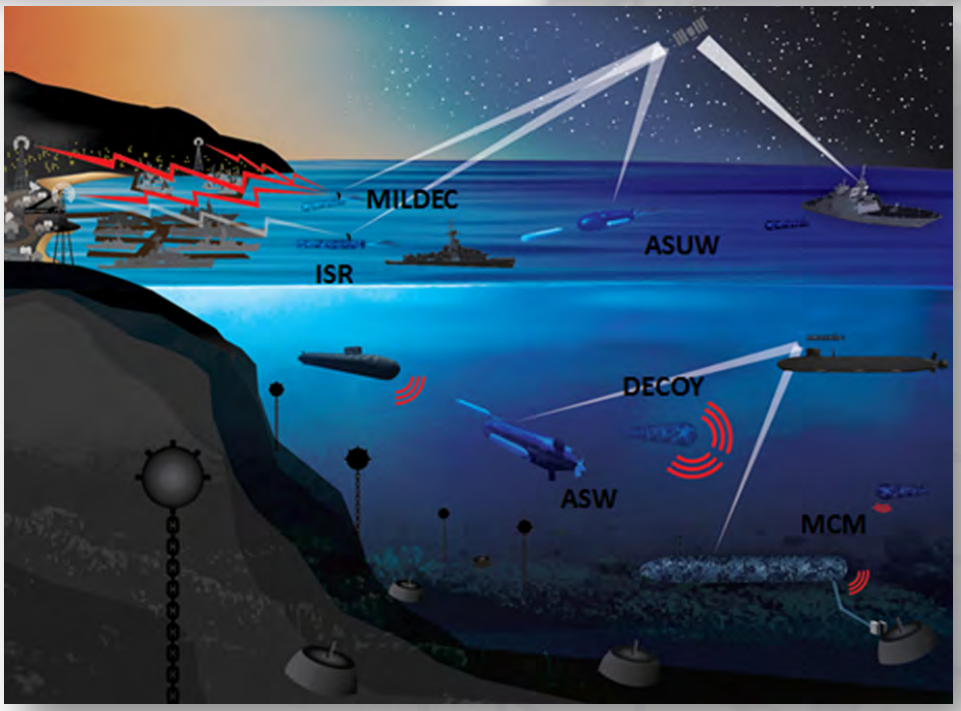
# Concept of Operations

***Intelligence, Surveillance, and Reconnaissance***

***Mine Countermeasures***

***Offensive Operations***

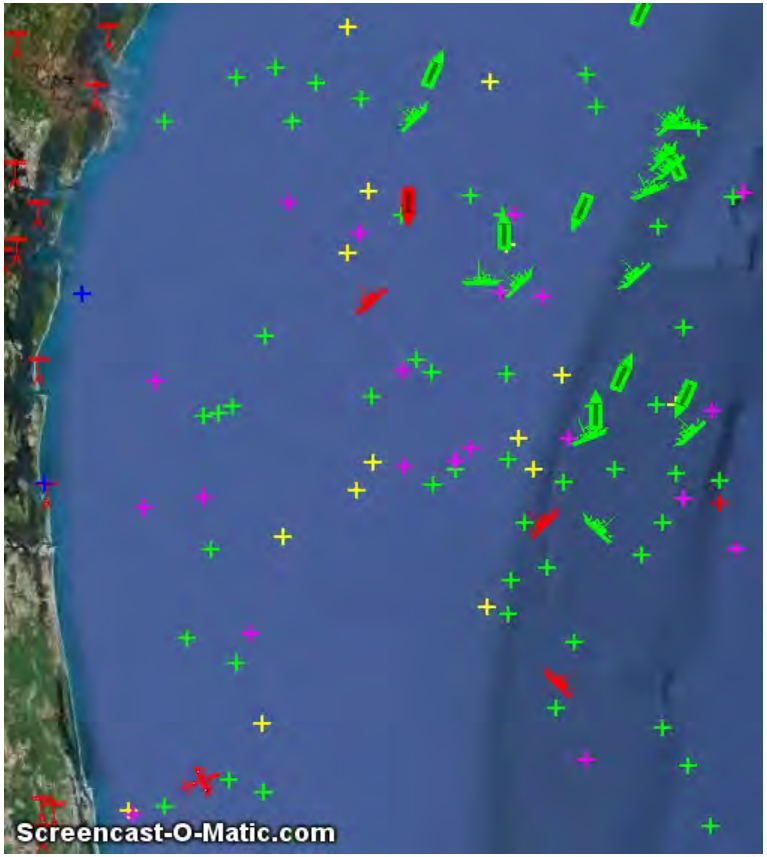
***Information Operations***



# Intelligence, Surveillance and Reconnaissance

**Scenario:**

Persistent coastal surveillance with deployments from varying distances to shore




**Metrics:**

- Probability of successful data collection and transmission

**Key ISR Takeaways**

- Two or **more UUVs** should be utilized to ensure successful data collection and transmission
- **Multiple UUVs** deployed at once yield better successful data collection and transmission
- Use of **expendable UUVs** may result in greater successful data collection and transmission
- **Avoidance programming** results in significantly greater successful data collection and transmission

# Offensive Operations

**Scenario:**
Anti-submarine and anti-surface warfare

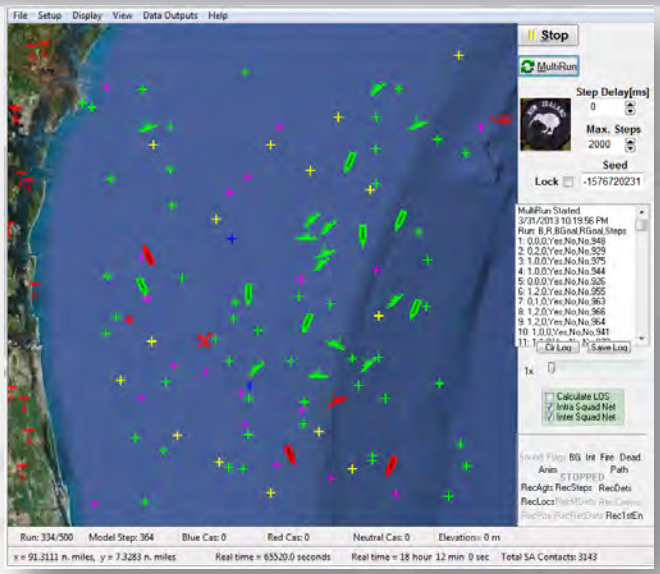
**Scenario:**
Smart mobile mining using UUVs

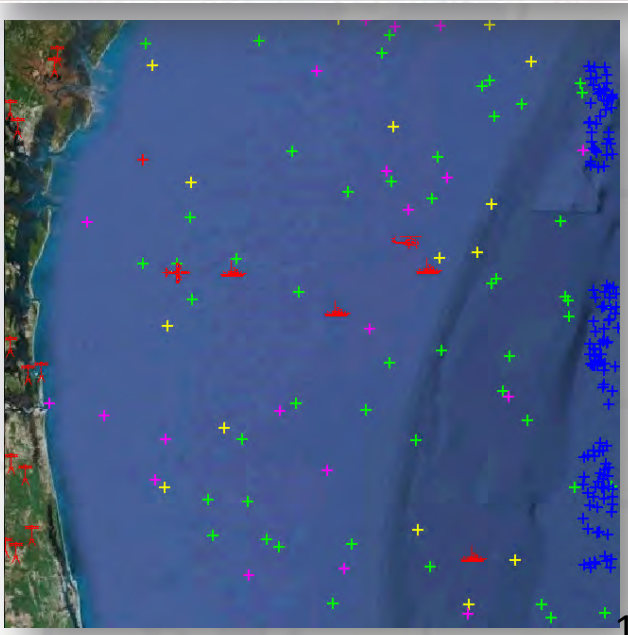
**Metrics**:

- SSN survivability
- # of enemies killed

**Key Offensive Takeaways**

- Best conducted with **large numbers** of **expendable UUVs** or small numbers of highly capable UUVs
- UUV maneuvering **behavior and autonomy** has **significant impact** on the **UUV survivability**
- **UUVs** variants used in an offensive mining role have **significant military capability**



# Information Operations

**Scenario**:
Assessment and observation of adversary's naval exercises

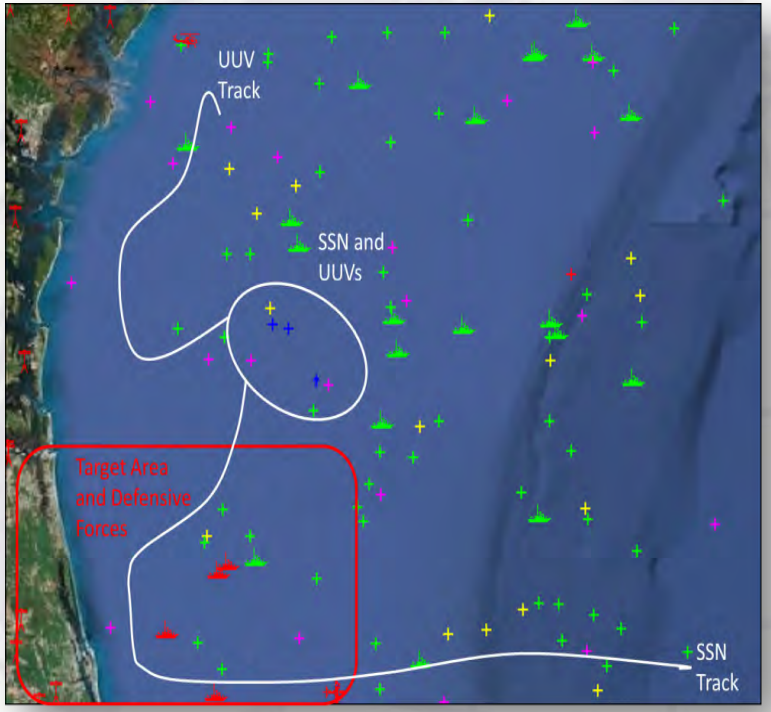
**Scenario**:
Distraction of adversary's coastal security systems

**Metrics:**

- SSN survivability
- Intelligence payoff

**Key IO Takeaways**

- **UUVs force the opposition to expend resources** and time to identify and prosecute the multiple threats
- **UUVs** for decoy and distraction operations **improve SSN survivability**
- Employing **two UUVs** for distraction provides **improved SSN survivability**
- **Avoidance programming** results in improved SSN survivability



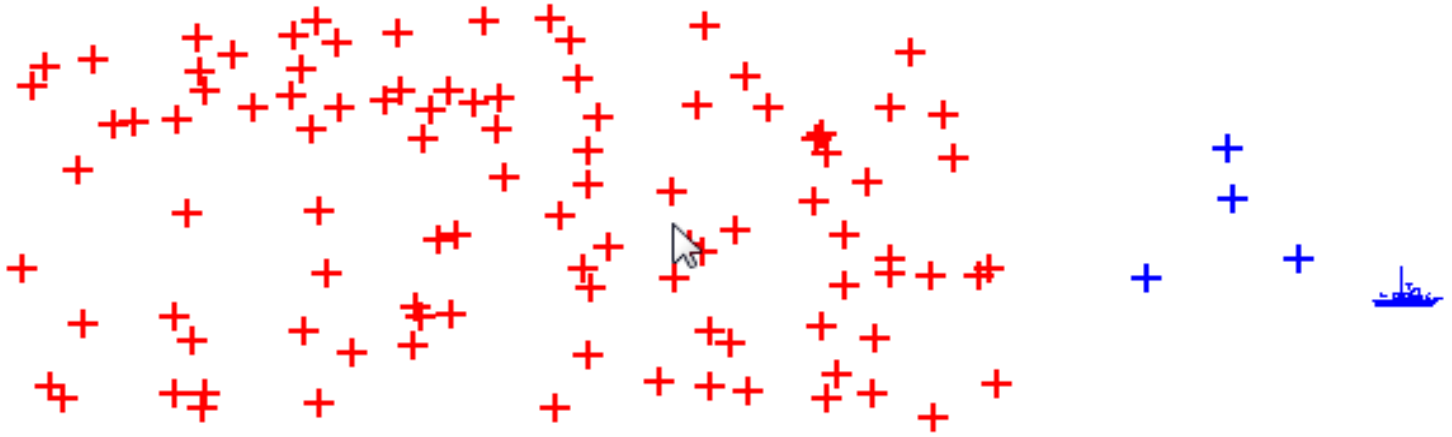
# Mine Counter Measures

**Scenario**:

Covert Q-route discovery and navigation

**Metrics**:

- HVU survival rate
- Q-route success
- Time to navigate
- UUV survival rate



**Key MCM Takeaways**

- **Larger quantities** of UUVs deployed to map Q-routes result in higher HVU survival rates
- UUVs that are equipped with **neutralization capability provide minimal advantage**
- Average time required to map Q-routes not significantly improved with larger quantities of UUVs

# Decision Drivers

**Summary of Key Takeaways:**

1. UUVs will be essential to maintain Undersea Dominance
2. Significant advantages in the employment of multiple (squads) UUVs
3. Benefit in utilizing expendable UUVs
4. Appropriate level of critical capabilities

# Decision Drivers

## Summary of Key Takeaways:

1. UUVs will be essential to maintain Undersea Dominance
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# UUVs will be essential because…

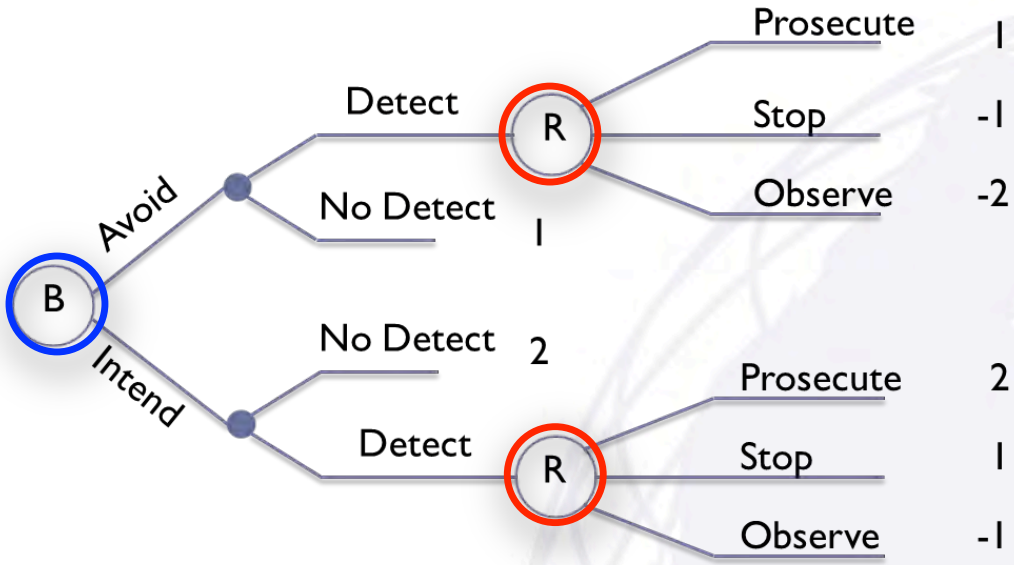
- Increased access capability
- Risk reduction
- Force the adversary to expend resources
- Enhance the SSN's abilities through MILDEC
- Conduct offensive mining

"U.S. undersea forces must include a broad enough mix of platforms and systems such that there is no geographic location or depth of ocean-connected water that is beyond the reach of U.S. undersea forces."

*- Commander Submarine Forces ,2011*

# UUVs will be essential because…

- **Forces the adversary** to decide whether or not to prosecute increased number of contacts




- **Forces the adversary** to develop new capabilities and tactics to address UUV threat

Increased cost to *prosecute* **versus** Increased cost to ignore *contact*

# UUVs will be essential because…

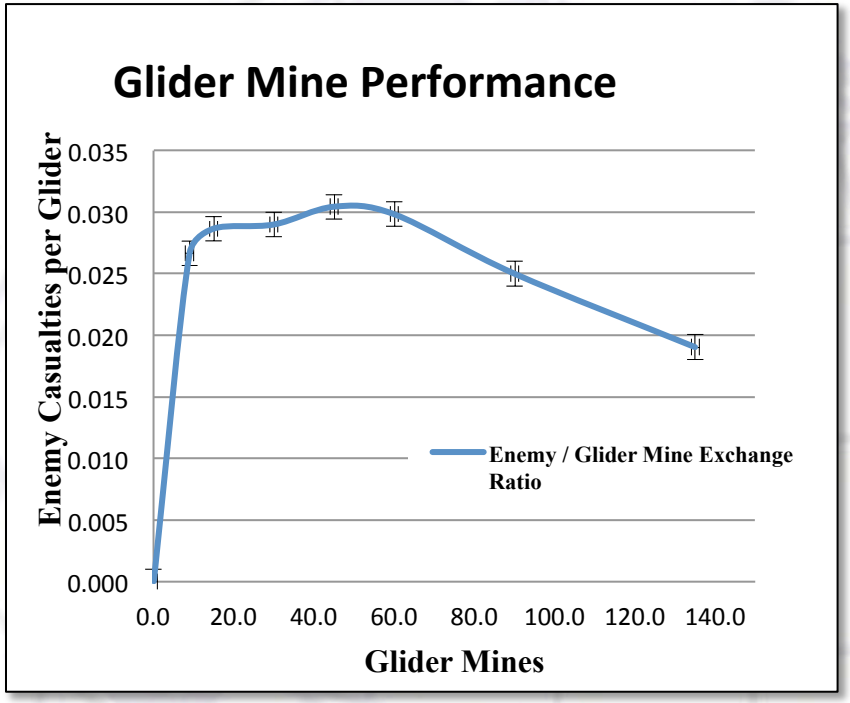
- **Augments SSN** via military deception to enhance intelligence collection through employment of robust decoy capability
  - Game theoretic analysis
    - **Payoff matrix**: Use of UUVs provides **positive** Blue payoff

| Blue / Red | Prosecute | Cease Ops | Observe | | No Detection |
|---|---|---|---|---|---|
| Covert | 1 / 1 | -1 / 1 | -2 / 2 | | 1 / 0 |
| Overt | 2 / -2 | 1 / 0 | -1 / 1 | | 2 / -2 |

# UUVs will be essential because…

- **Addresses** a recognized **capability gap** in the USN for offensive mining
  - Explored one option of glider UUV mines
  - Mobile mines can provide an offensive mining capability through numbers
- Merits dedicated attention:
  - Current ONR Future Naval Capabilities in *Advanced Undersea Weapons Systems*
  - Ongoing LDUUV mine-laying mission development

**Mean Enemy Kills = 1.35 for 45 Weapon Salvo**

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# Decision Drivers

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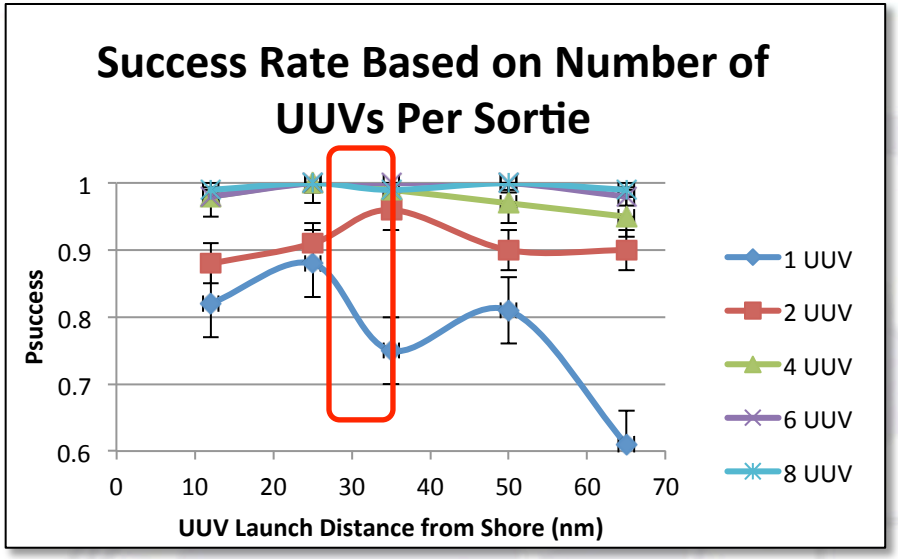
# Advantage of UUV Squads

- For higher mission success in ISR
- Higher HVU survival for MCM and IO
- Higher attack effectiveness with large # of UUVs
- Potential benefit in coordinated operations
- Energy efficiency

# Advantage of UUV Squads

## Improved successful data transmission

- Squads have significantly higher success data collection and transmission rates
- Multiple UUVs deployed at once yield better data collection and transmission rates until onset of diminishing returns

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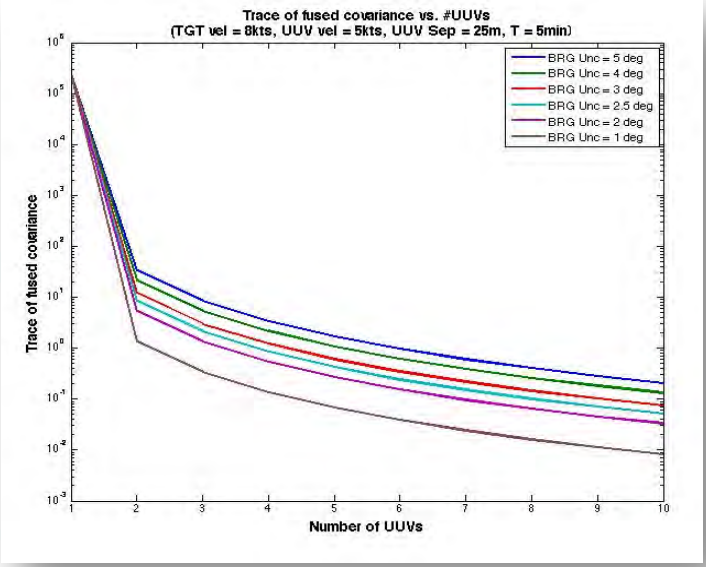
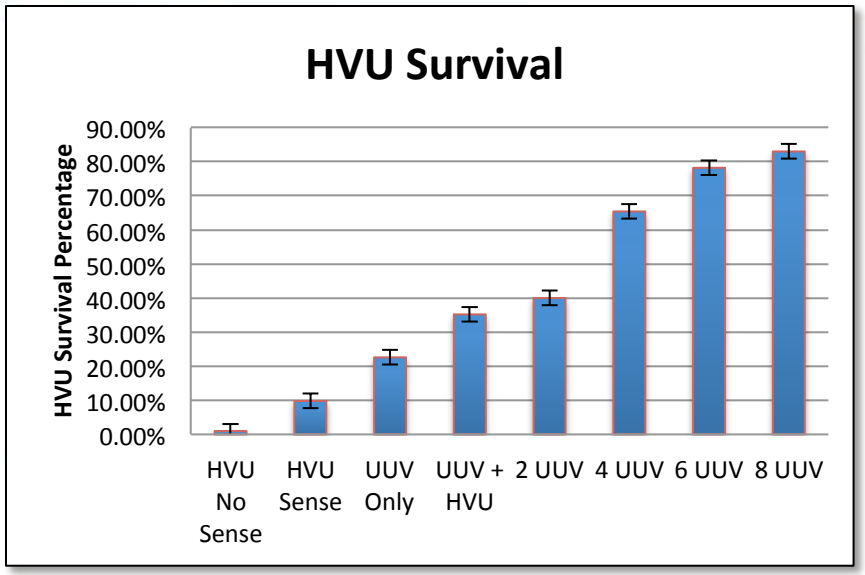



## Coordinated sensing operations

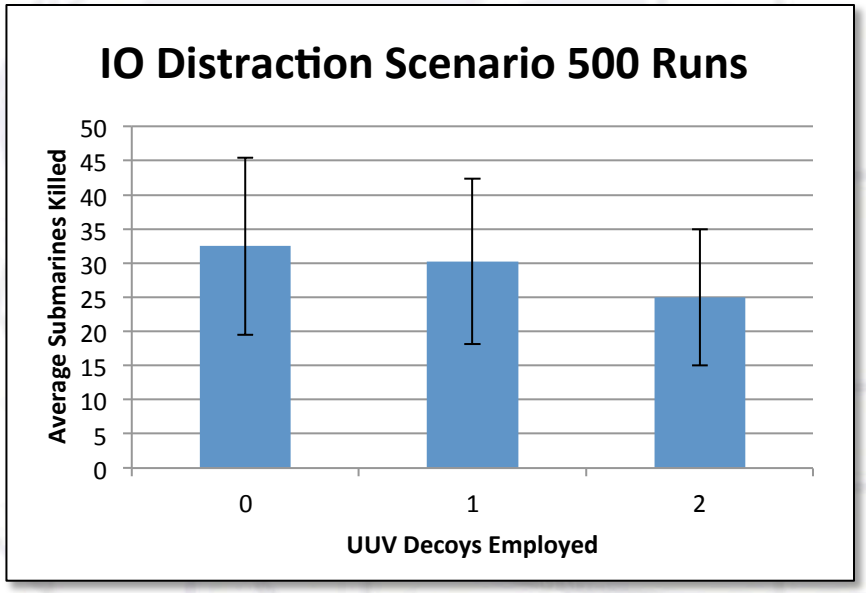
- Quality of data can be enhanced with greater numbers of sensors
- Can be used to explore trade off between number of UUVs and uncertainty in targeting solutions

# Advantage of UUV Squads




- Increased # of UUV pathfinders for MCM Q-routes enhances HVU survival

- Decoys employed for distraction increases survivability in sensitive SSN missions

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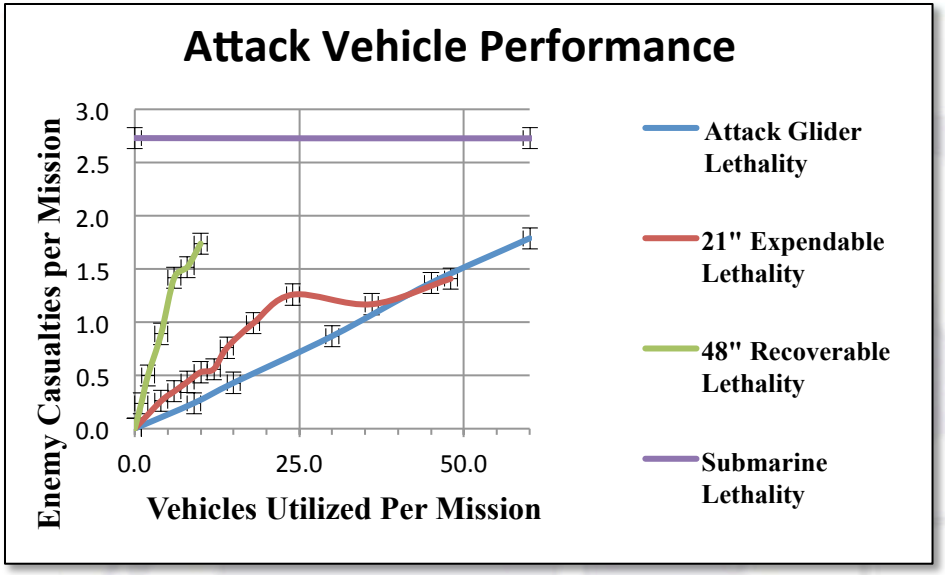
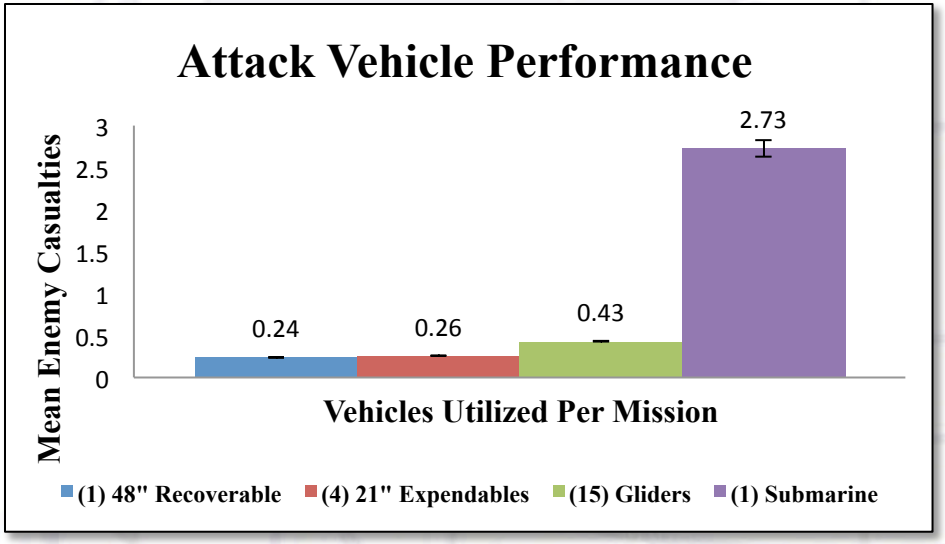
# Advantage of UUV Squads

- **More UUVs** can substantially augment attack mission
  - UUVs cannot replace submarines but can supplement the current force

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# Advantage of UUV Squads

## Energy Efficiency of Multiple Vehicles

**ASSUMPTIONS:**

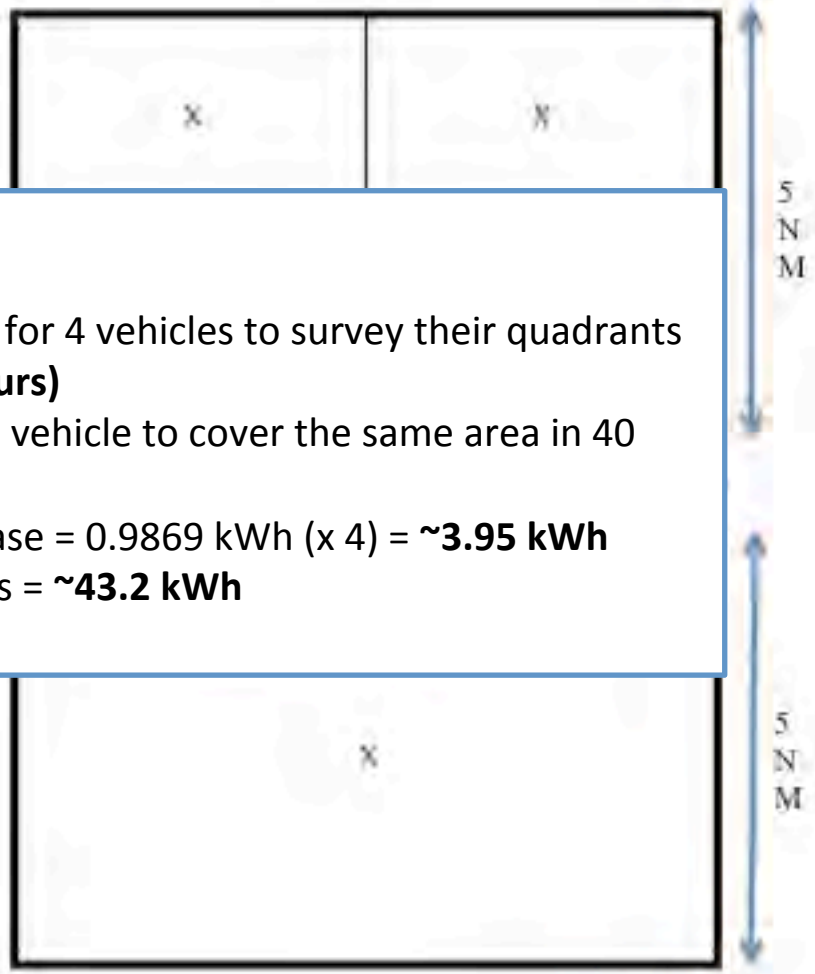
1. Multivehicle mission spd: 3kts
2. Water depth: 250m
3. Vehicle de
4. Scan half-a
5. Vehicle tu
6. Vehicles a

**ENDURANCE**

1. Use SEA-1
   for a 48”
   assumptions
   -1 kWh hotel loads
   -300 Wh/liter battery
   -20% unusable battery capacity

**CALCULATIONS:**

1. Determine how long it will take for 4 vehicles to survey their quadrants simultaneously at 3 kts **(~40 hours)**
2. Determine speed required for 1 vehicle to cover the same area in 40 hours **(~11.5 kts)**
3. Energy consumption for 3 kts case = 0.9869 kWh (x 4) = **~3.95 kWh**
4. Energy consumption for 11.5 kts = **~43.2 kWh**



# Decision Drivers

## Summary of Key Takeaways:

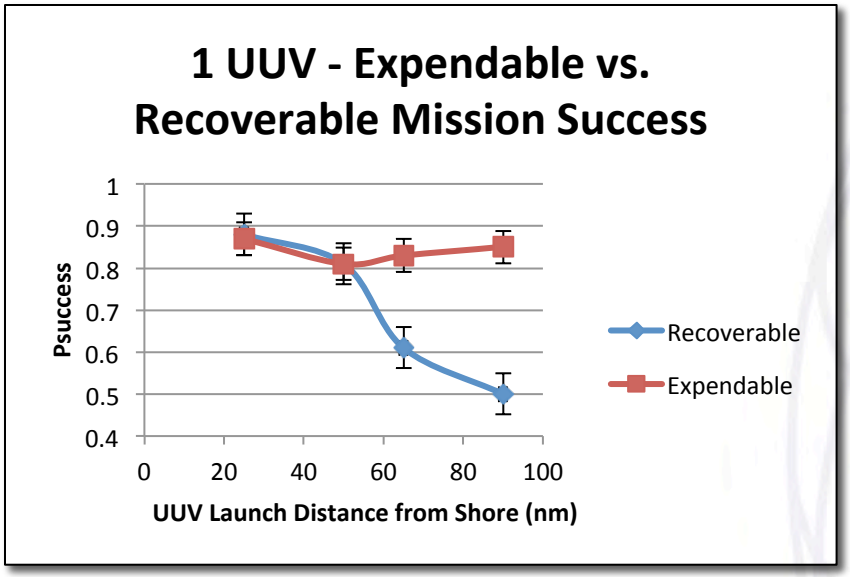
1. UUVs are essential to maintain Undersea Dominance
2. Significant advantages in the employment of multiple (squads) UUVs
3. Benefit in utilizing expendable UUVs
4. Appropriate level of critical capabilities

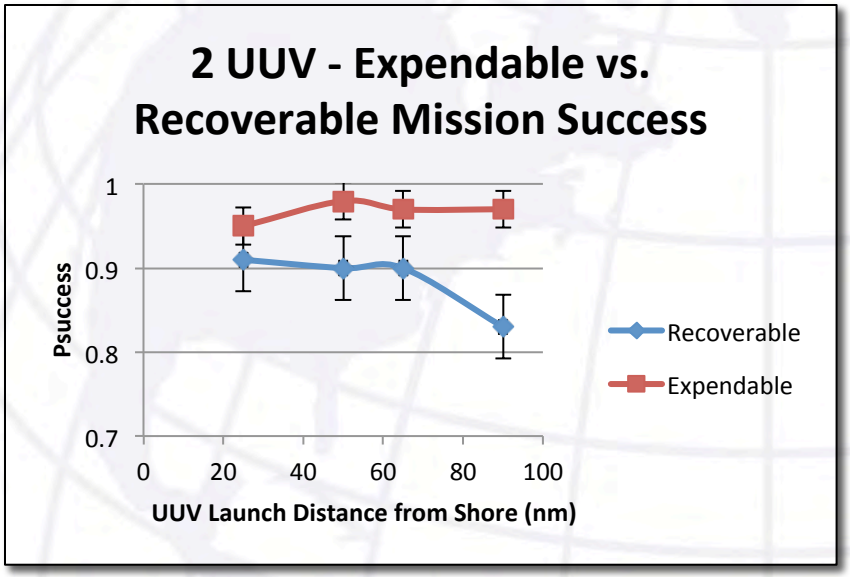
# Expendability because…

- Cost and complexity
- Greater mission success due to extended range
- Operational employment considerations
  - Do not want weapons/decoys to return to host platform

# Expendability because…

- Expendable UUVs provide **higher ISR mission success** over recoverable UUVs
  - assuming equal platform/payload capabilities

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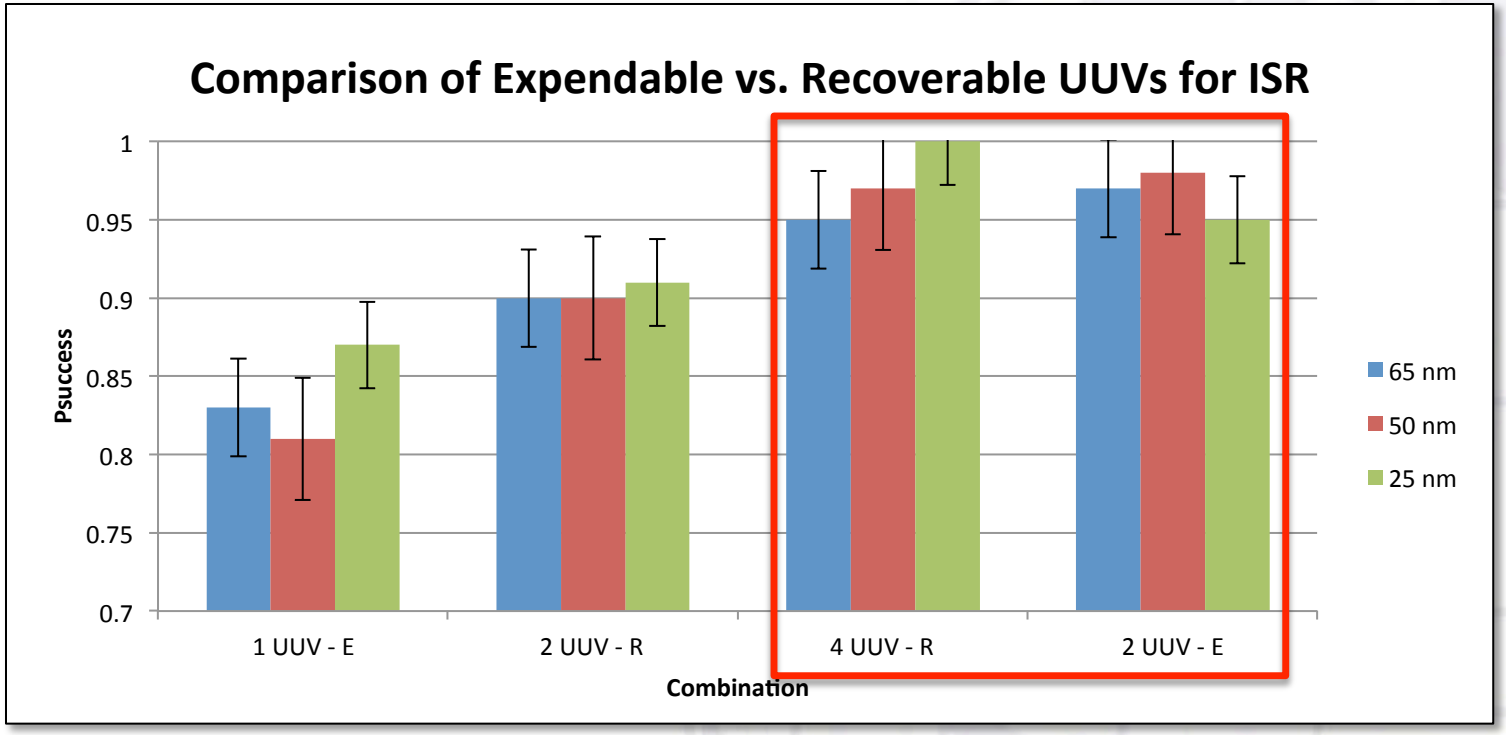
# Expendability because…

- Using expendable UUVs can **lower squad size** for comparable mission performance

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# Expendability because…

- No obligation of host platform to recover (fire and forget)
- Recovery of decoys is problematic
- Recovery systems introduce increased cost and risk to host platform
- Safety and certification concerns with recovering weaponized unmanned platforms

# Decision Drivers

## Summary of Key Takeaways:

1. UUVs are essential to maintain Undersea Dominance
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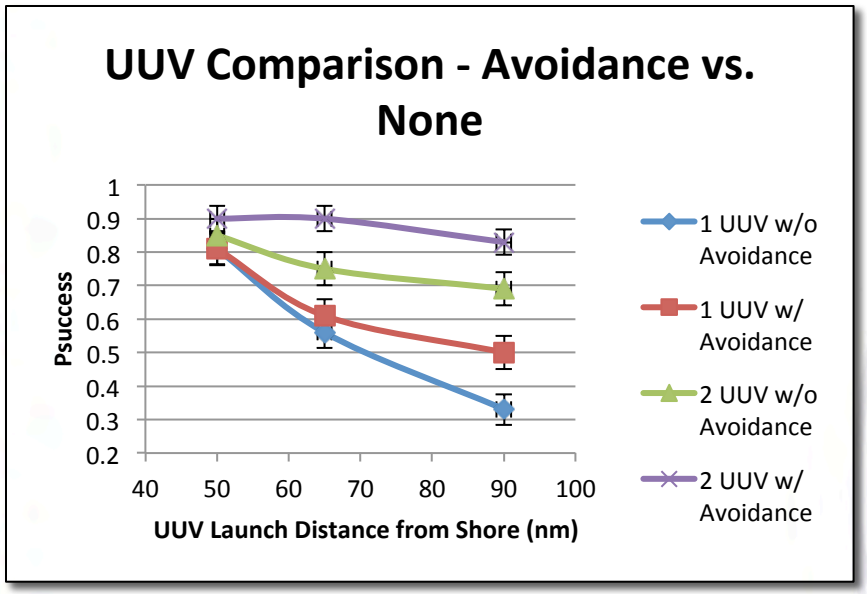
# Appropriate level of critical capabilities

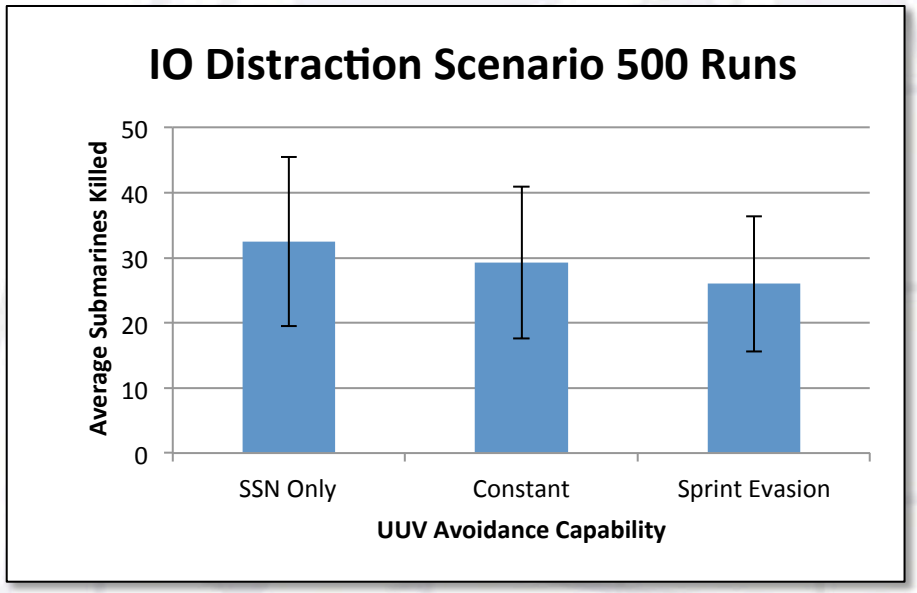
- Robust autonomous collision avoidance is necessary
- Advanced mission functionalities are not necessarily required

# Appropriate level of critical capabilities

**Core Autonomy is required …**

- Avoidance programming produced increased $P_{success}$ in ISR and increased SSN survival in IO

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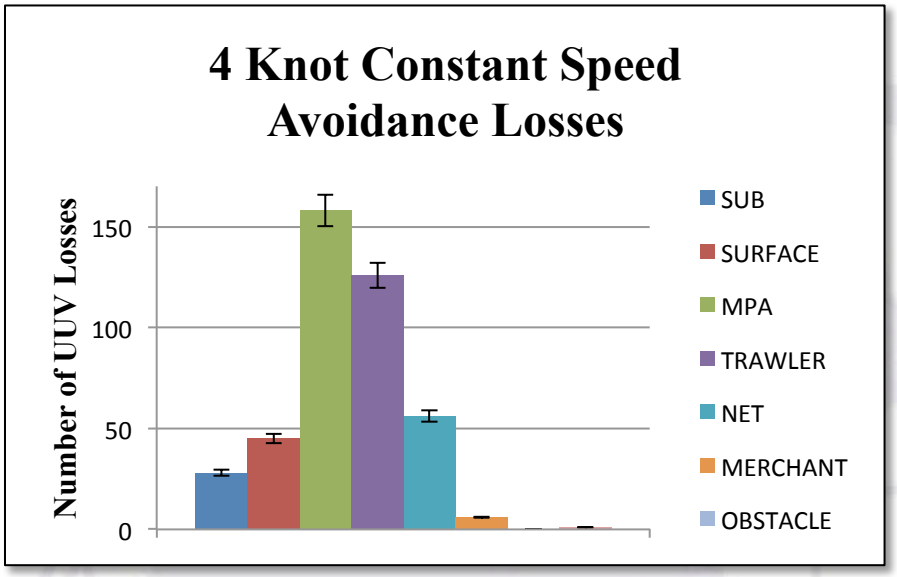
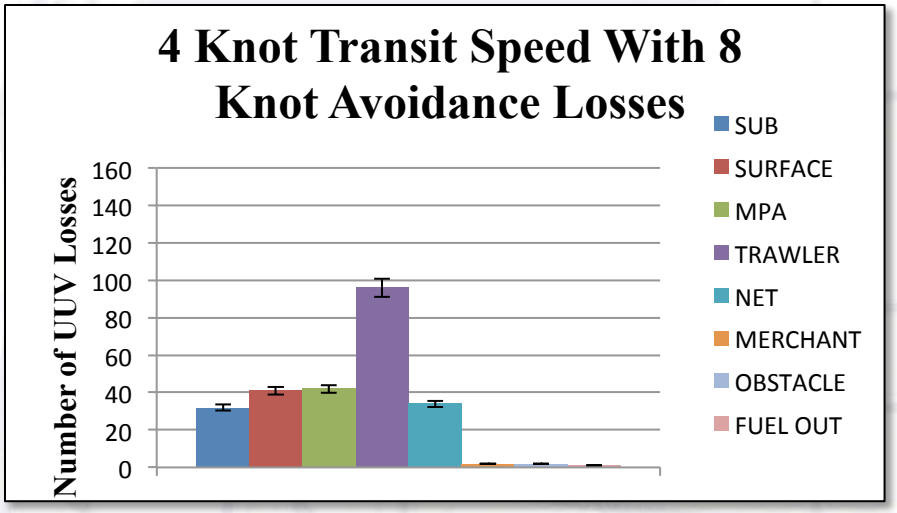
# Appropriate level of critical capabilities

**Core Autonomy is required …**

- Enhanced maneuver speed increases UUV survivability
- Reduces mean loss rate by 41%
  - Due to fishing nets, collisions with merchant vessels and trawlers, and loss due to enemy air, surface and submarine assets

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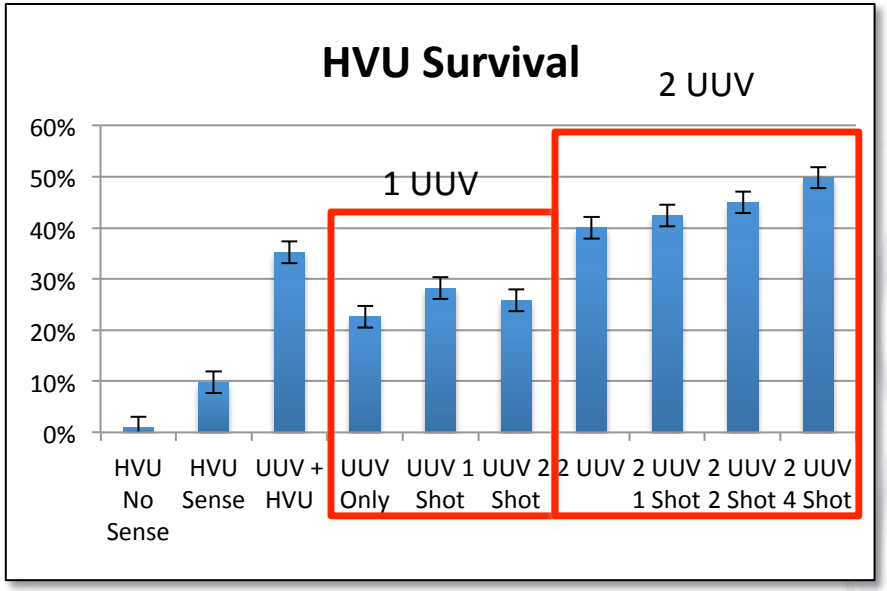
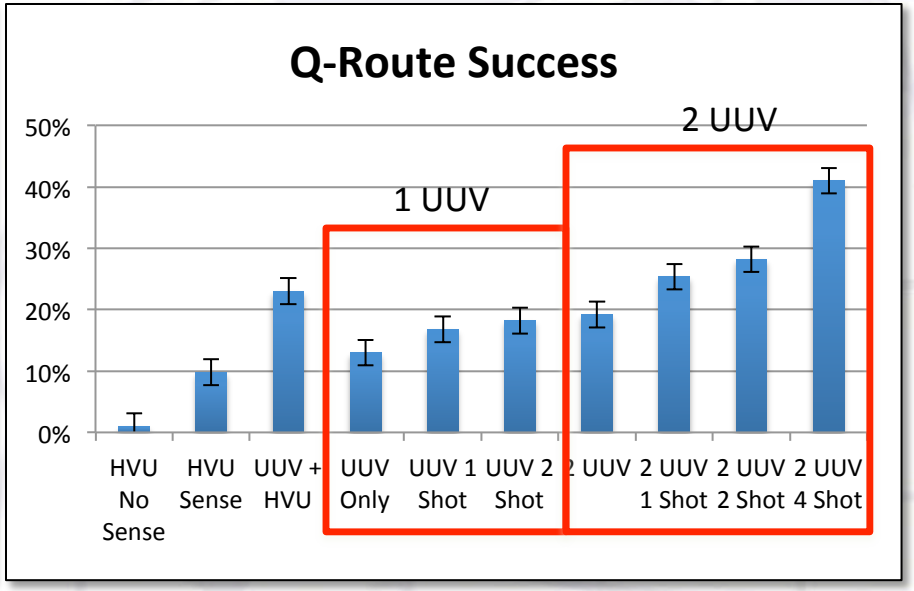
# Appropriate level of critical capabilities

**Advanced mission functionality may not be required…**

- Mine neutralization capability has negligible advantages over mine localization

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# Outline of Presentation

1. BLUF
2. CONOPS
3. Decision Drivers
4. Analysis of Alternatives
5. Cost Analysis
6. Force Structure, Revisited
7. Closing Remarks
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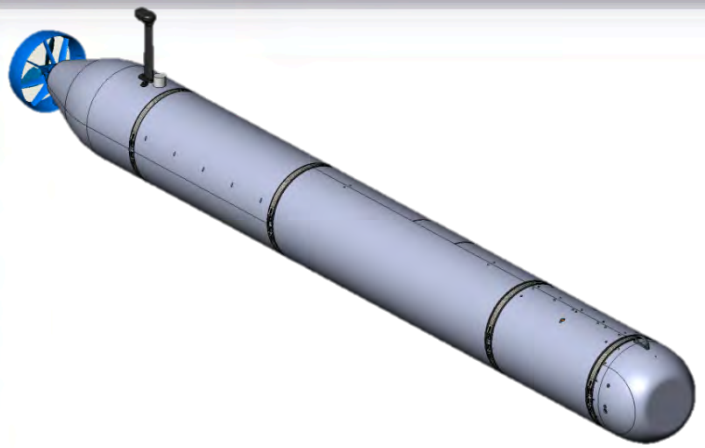
# Analysis of Alternatives



# Analysis of Alternatives

- AoA conducted using
  - Multi-Attribute Decision Analysis (MADA)
  - Cost as an Independent Variable (CAIV)
    - Establish system level requirements/capabilities first
    - Enables trade space between cost and performance

| Analysis of Alternatives Comparison Matrix | | | | |
|---|---|---|---|---|
| **Vehicle** | **MCM** | **ISR** | **IO** | **Attack** |
| (1) 21" Recoverable UUV | X | X | | |
| (1) 21" Expendable UUV | | | X | X |
| (2) 21" Recoverable UUV | | | X | |
| (2) 21" Expendable UUV | | | X | |
| (4) 21" Recoverable UUV | | X | | |
| (4) 21" Expendable UUV | | X | | X |
| (6) 21" Recoverable UUV | X | | | |
| (6) 21" Expendable UUV | X | | | |
| (1) 48" UUV | X | X | X | X |
| (1) 60" UUV | X | X | X | X |
| (1) SSN | X | X | X | X |
| (15) Expendable Gliders | | | | X |

# Ranking Matrix for System Attributes

Importance of each attribute with respect to each mission is ranked. Rankings lead to assignment of weights for each attribute

| | ISR | MCM | IO | Attack |
|---|---|---|---|---|
| **Mission effectiveness**<br>• Enemy Kills<br>• Mission Success<br>• HVU survivability | 1 | 1 | 1 | 1 |
| **Endurance**<br>• Time | 3 | 3 | 3 | 2 |
| **Stealth**<br>• Size/Mast exposure | 2 | 5 | 5 | 4 |
| **Ease of tactical employment**<br>• Launch/recovery time | 5 | 2 | 2 | 5 |
| **Years to field**<br>• TRL | 6 | 6 | 6 | 6 |
| **Mission flexibility**<br>• Volume | 4 | 4 | 4 | 3 |

*1 – Most important* *6 – Least important*

# Overall MOEs

- Attribute weights and scores are used to calculate an overall MOE for each alternative
- SSN scores significantly higher with exception of MCM
- Conducted an iteration with the SSN excluded from the alternatives

| Attack Alternatives | Score (with SSN) | Score (w/o SSN) |
|---|---|---|
| (1) 21" Expendable UUV | 0.18 | 0.28 |
| (1) 48" UUV | 0.10 | 0.56 |
| (1) 60" UUV | 0.09 | 0.60 |
| (4) 21" Expendable UUVs | 0.10 | 0.40 |
| SSN | 0.88 | |
| (15) Expendable Gliders | 0.12 | 0.73 |

| ISR Alternatives | Score (with SSN) | Score (w/o SSN) |
|---|---|---|
| (1) 21" Recoverable UUV | 0.53 | 0.55 |
| (1) 48" UUV | 0.33 | 0.46 |
| (1) 60" UUV | 0.31 | 0.49 |
| (4) 21" Expendable UUVs | 0.58 | 0.61 |
| SSN | 0.76 | |
| (4) 21" Recoverable UUVs | 0.63 | 0.66 |

| IO Alternatives | Score (with SSN) | Score (w/o SSN) |
|---|---|---|
| (1) 21" Expendable UUV | 0.68 | 0.71 |
| (1) 48" UUV | 0.38 | 0.51 |
| (1) 60" UUV | 0.38 | 0.56 |
| (2) 21" Recoverable UUVs | 0.54 | 0.69 |
| SSN | 0.78 | |
| (2) 21" Expendable UUVs | 0.66 | 0.69 |

| MCM Alternatives | Score (with SSN) | Score (w/o SSN) |
|---|---|---|
| (1) 21" Recoverable UUV | 0.17 | 0.20 |
| (1) 48" UUV | 0.15 | 0.28 |
| (1) 60" UUV | 0.15 | 0.33 |
| (6) 21" Recoverable UUVs | 0.42 | 0.46 |
| SSN | 0.26 | |
| (6) 21" Expendable UUVs | 0.46 | 0.74 |

# Conclusions of the AoA

- All mission sets can benefit from **multiple 21" UUVs**
- **Expendables** generally perform better across all mission sets
- LDUUVs offer unique capability
  - Potential for significant contribution in offensive attack and persistent ISR
- Critical trade space is defined by UUV diameter
  - Small diameter: less time to deploy, significant capability
  - Large diameter: more mission flexibility, longer endurance

# Final Presentation Outline

1. BLUF
2. CONOPS
3. Decision Drivers
4. Analysis of Alternatives
5. Cost Analysis
6. Force Structure, Revisited
7. Closing Remarks
8. Breakout Sessions

# Desired Coverage Capability

**Determine the minimum necessary inventory to address the following A2AD environment**

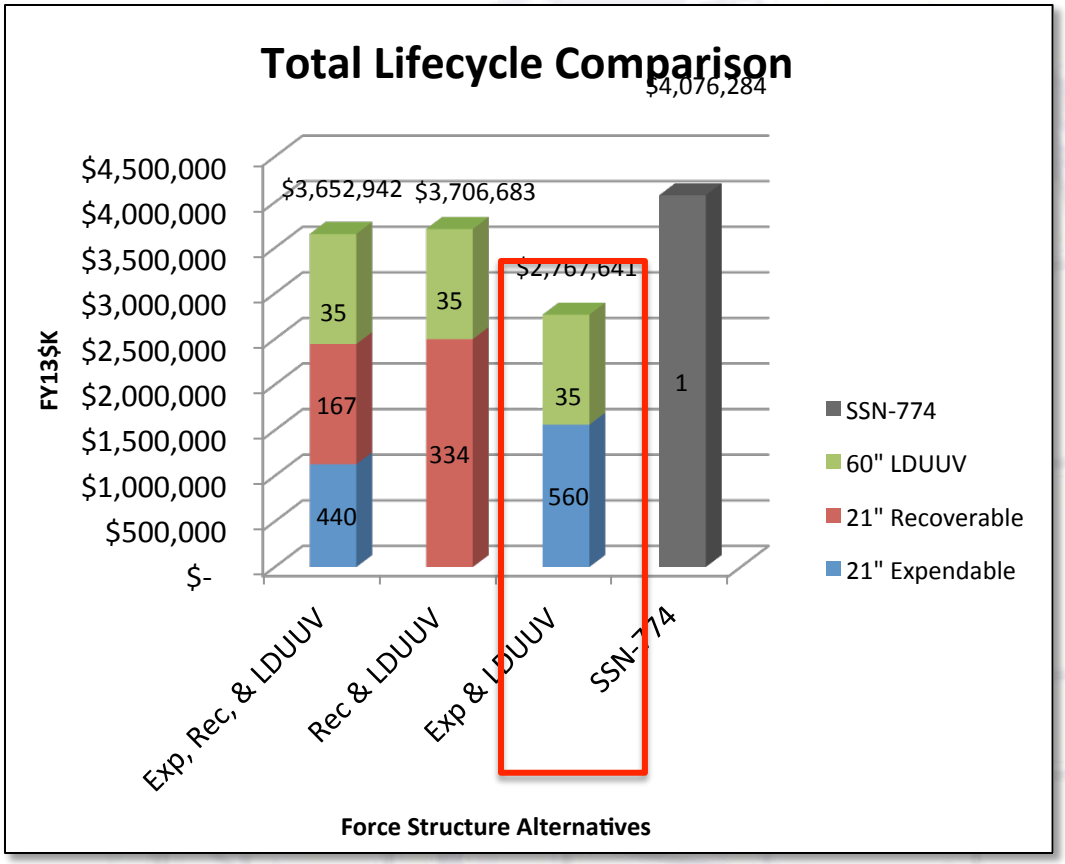
- **MCM**: 10 forced entries and exits into a potentially mined area
- **IO**: 30 submarines at sea with 2 decoys each
- **ISR**: Dual UUV coverage of 4 target areas for 30 days
- **Attack**: 13 Enemy surface ship / submarine kills


**Led to (240) 21”/(26) LDUUV annual inventory**

# First Pass Cost Analysis

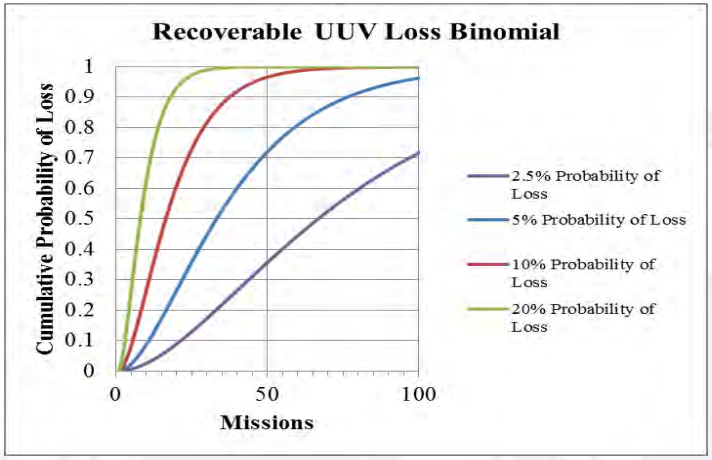
- Total Ownership Cost (through 2034) for expendable alternative:
  - **$2.76B FY13$**

**But…**

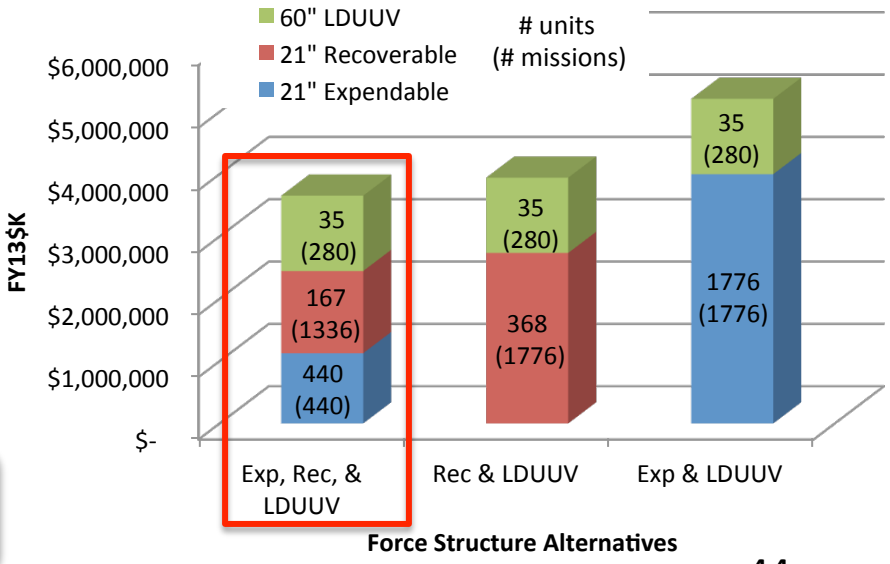


# Per-Mission Cost Analysis

- **Mixed is most cost effective option**
- Normalized the lifecycle cost per mission
- Cost per mission
  - $1.7M per mixed family
  - $2.0M per 21”R + LDUUV
  - $3.3M per 21”E + LDUUV




**Total Lifecycle Mission Comparison**

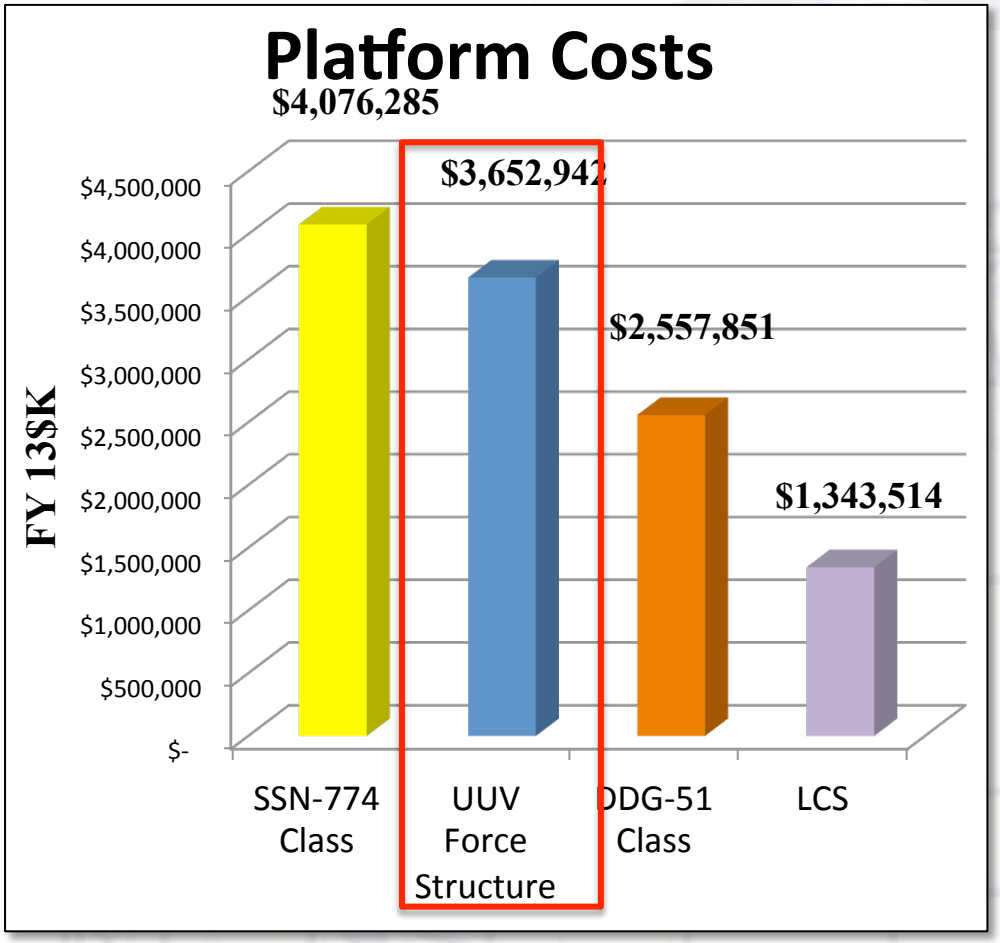



**Recoverable UUVs are cost-effective!**

WW

# Updated Cost Analysis

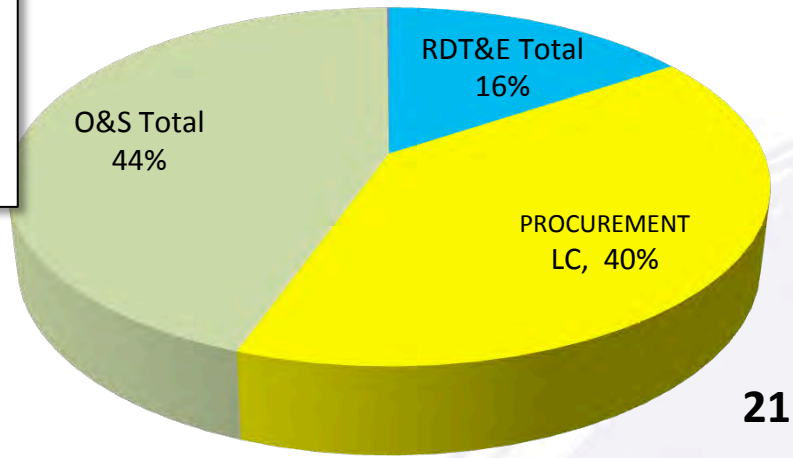
- Total Ownership Cost (through 2034) for recommended alternative:
  - **$3.65B**
- Advantages
  - **Diversity** and **increased #** of capable missions
  - **Balance risk** to host and added capability



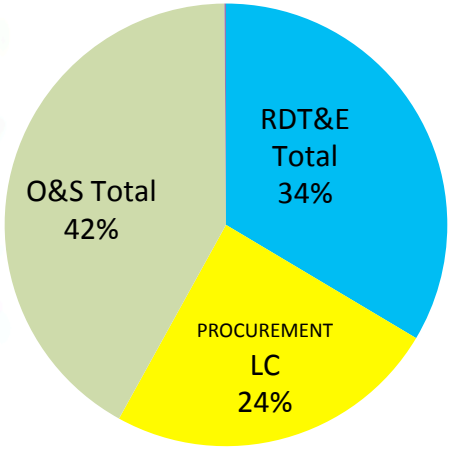
# Program Lifecycle Cost Estimate

**Total Lifecycle Inventory**
**167** 21" Recoverable
**440** 21" Expendable
**35** LDUUV

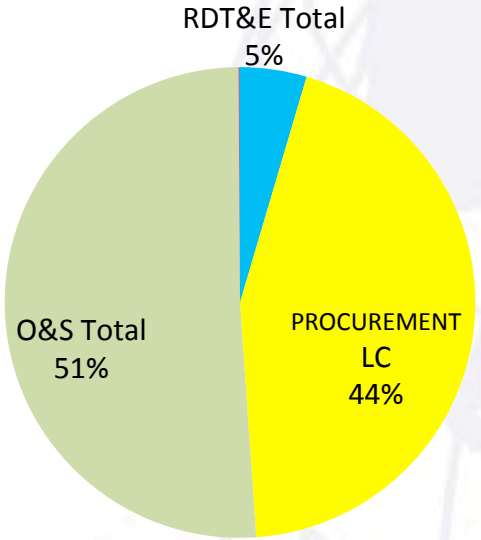
## Total Lifecycle Cost $3.65 Billion



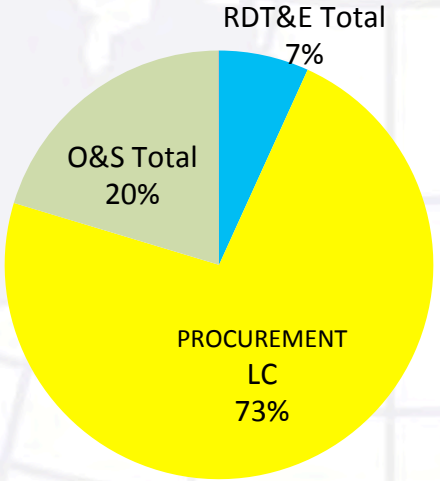

## LDUUV $1.2 Billion




## 21" Recoverable $1.3Billion




## 21" Expendable $1.1Billion



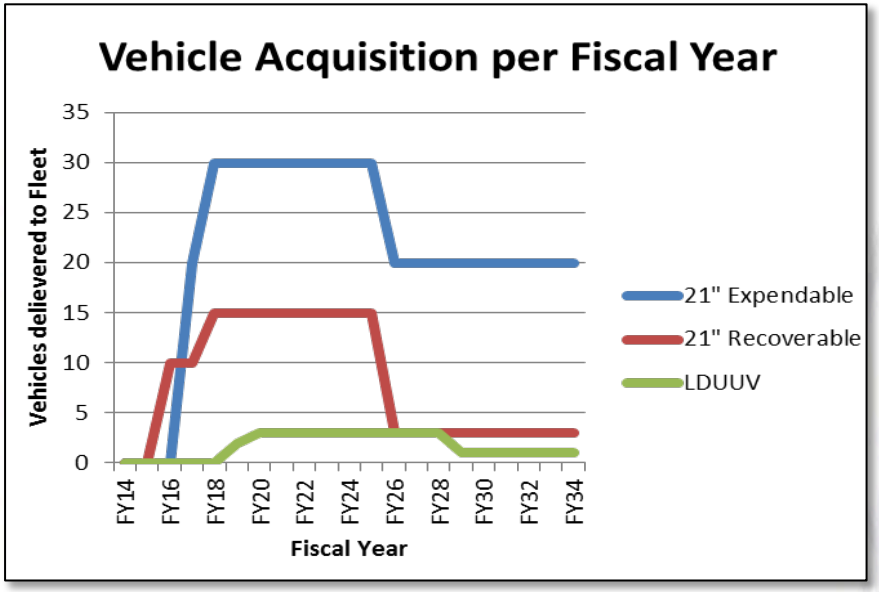
# Sustained Force Structure

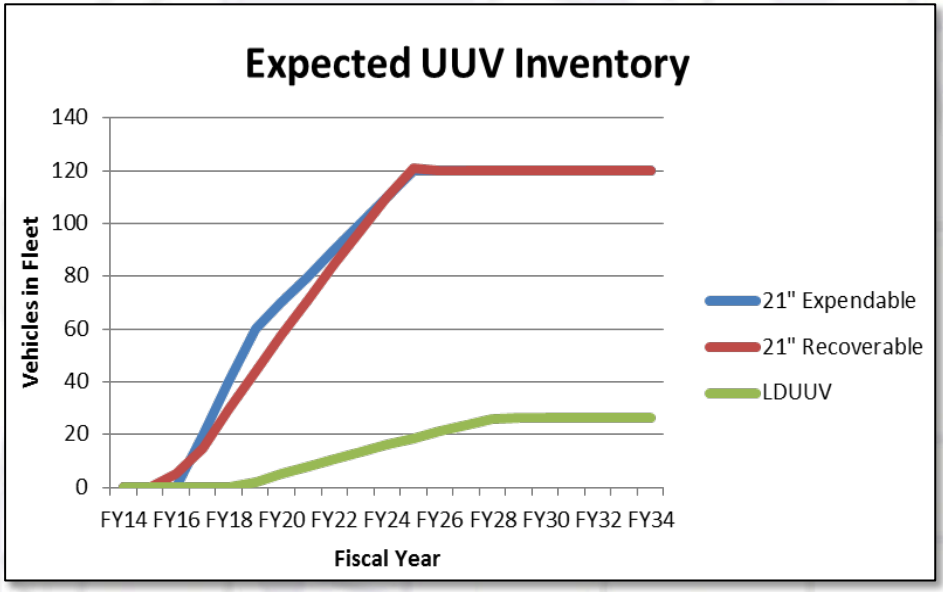
| 2024 Operational UUV Force Structure | | |
|---|---|---|
| **Mission** | **UUV Type** | **Quantity** |
| ISR and Attack | LDUUV | 26 |
| ISR | 21" Recoverable | 25 |
| Attack | 21" Expendable | 48 |
| MCM | 21" Recoverable | 96 |
| IO | 21" Expendable | 72 |

| Total Sustained UUV Force Structure Based on Recommended Size | | |
|---|---|---|
| | **LDUUV** | **26** |
| | **21" Recoverable** | **120** |
| | **21" Expendable** | **120** |

# Force Structure Procurement

- Total 20 year UUV Procurement Plan:
  - **167** 21” Recoverable
  - **440** 21” Expendable
  - **35** LDUUV



# Organization and Manning

Total UUV Squadron strength: **175 Personnel**

- **15** leadership and support personnel (Shore Duty Billets)
- **160** operations and maintenance personnel (Sea Duty Billets)
- **80** personnel deployment-ready
  - LDUUV manning is approximately **40** personnel in **13** detachments (3 per Embarked DET)
  - 21" recoverable manning is approximately **40** personnel in **20** detachments (2 per Embarked DET)
  - 21" expendable manning utilizes current ship's company. Specialized personnel not required.

# Training Recommendations

Consider the creation of a specialized naval enlisted codes (NEC) for operations and maintenance personnel

- Prospective source rates for UUV technicians are:
  - Sonar Technician (STG/STS)
  - Machinist Mates (Submarine Weapons)
  - Electronics Technicians (ET)
  - Gunners Mates (GM)

*AN-BLQ11 LMRS deployment*

# Closing Remarks

- The **primary contributions** of this integrated project include:
  - Recommended **force structure** for the future of unmanned undersea vehicles
  - Recommended **DOTMLPF** considerations
  - Significant UUV **mission & capability assessments**
  - **Concepts of UUV operations** for Year 2024
  - In-depth UUV **costing** and **analysis of alternatives**
  - Substantial **cross-campus engagements**
  - **Modeling and analysis strategies and tools**

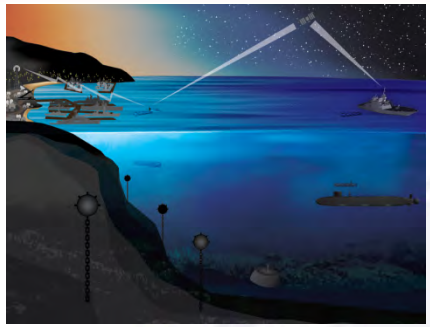
# Mission Statement

SEA-19A's mission is to provide unbiased concept generation and research in the domain of unmanned undersea warfare.

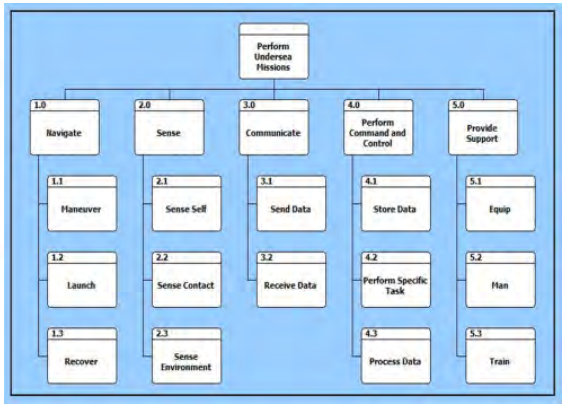
Goal is to make recommendations that provide warfighters with the tools necessary to execute undersea missions.

# Systems Engineering Foundation

- Problem Definition
- Missions
- Functions
- Capabilities
- Requirements
- Analysis of Alternatives
- Systems Architecture
- Recommend Solution



MATLAB
The Language of Technical Computing

# Operational Stakeholders

NAVAL POSTGRADUATE SCHOOL

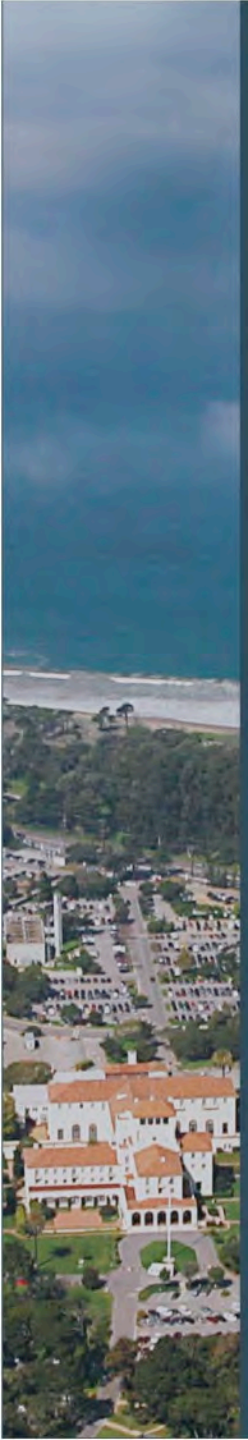
# Naval Enterprise Stakeholders

# NPS Stakeholders


- CRUSER
  - Warfare Innovation Workshop: "Undersea Superiority 2050"
- Chair of Undersea Warfare
- Chair of Expeditionary and Mine Warfare

***Examples***

- Blue-green laser comms
  - Applied Physics
- Acoustic Communications
  - Applied Physics
- Mine warfare modeling
  - Operations Research
- LDUUV scenarios
  - Computer Science
- MK18Mod2 Total Ownership Cost
  - Cost Estimation
- Systems Engineering



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# Thank you!

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