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Tactical Consideration for MCM CONOPS Establishment for Unmanned Surface Vehicles [video]

Song, Kwang Sub

Tactical Considerations for MCM CONOPS Establishment For Unmanned Surface Vehicle

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Introduction

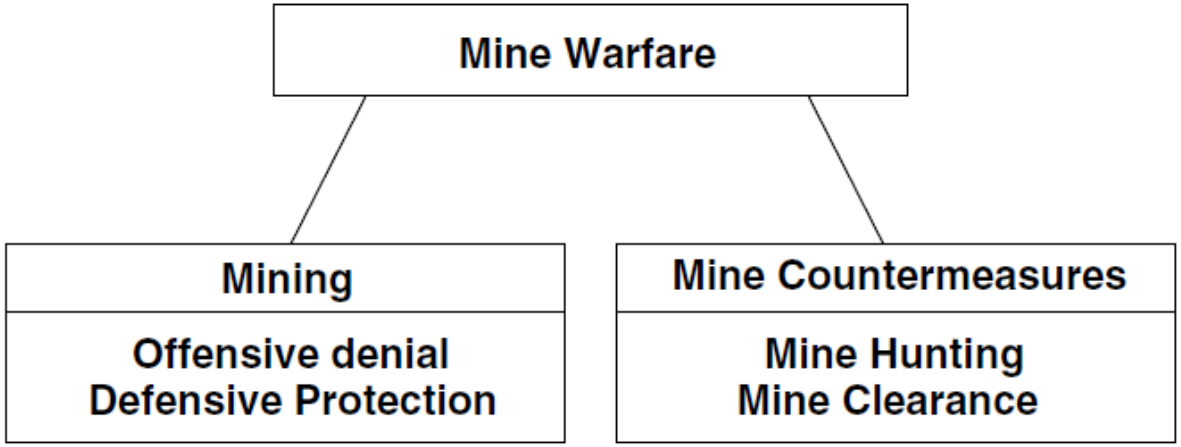
Manned MCM Operations

Introduction of Unmanned Systems

ACTUV CONOPs Development

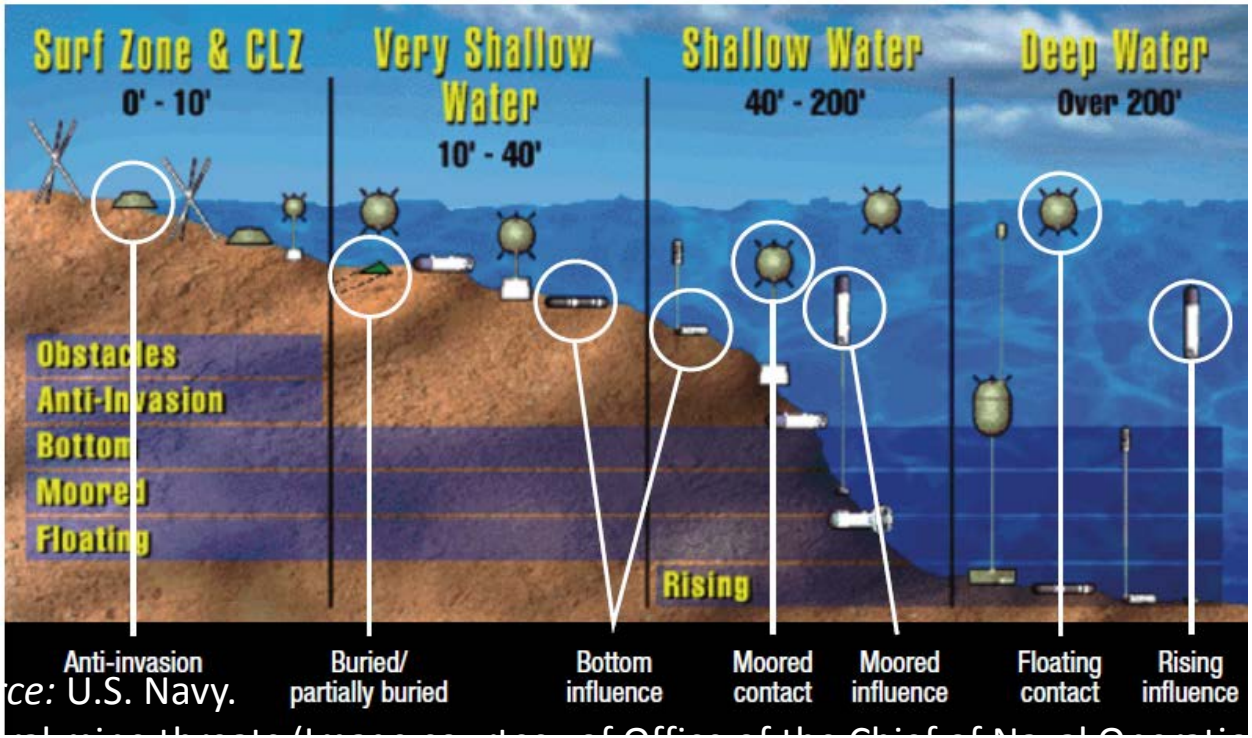
General Consideration for MCM Operations

Introduction



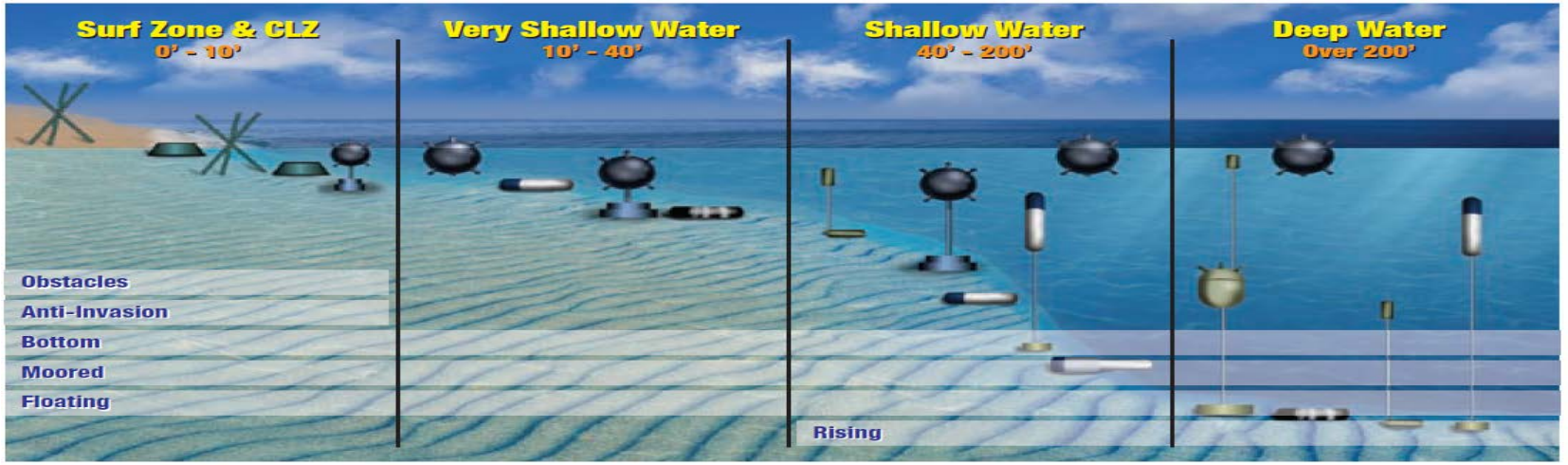
The two operational subdivisions of naval mine warfare: mining and mine countermeasures (MCM). Mine laying can deny hostile forces access to a strategic location while also protecting home waters. MCM includes the search for and destruction of emplaced mines.

MINE THREAT SPECTRUM

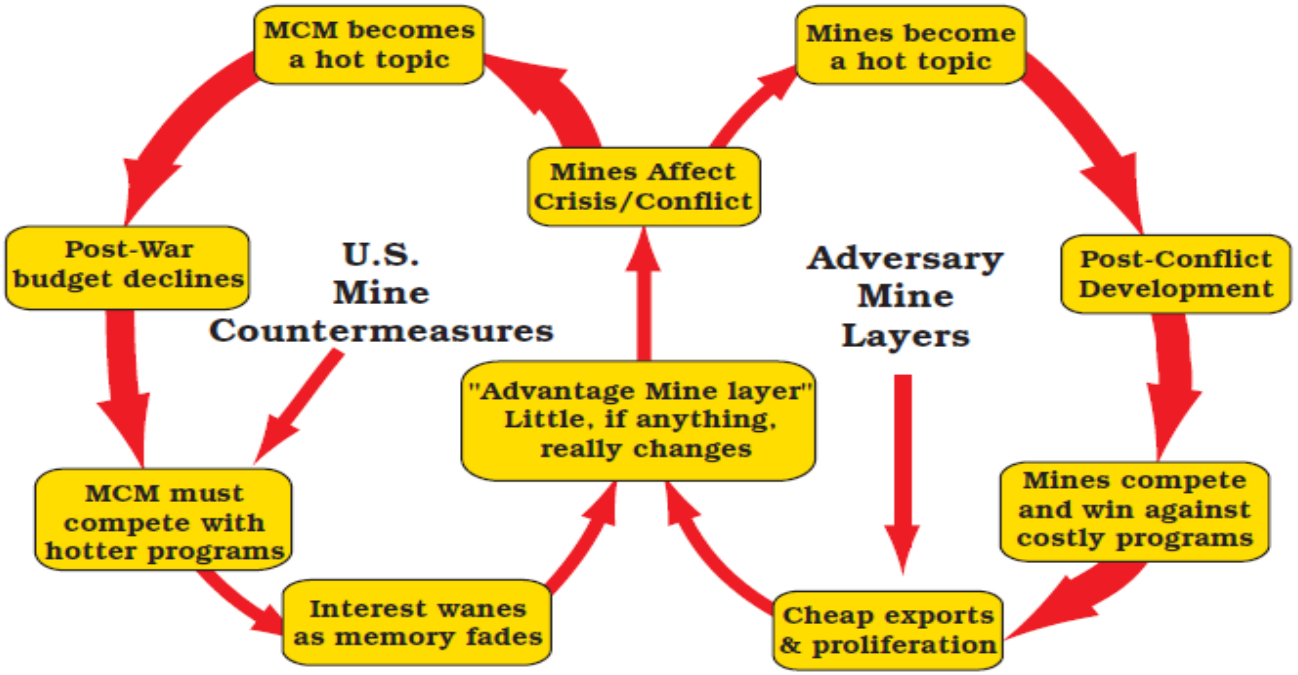


ce: U.S. Navy.

Floating Mine , Buried , Bottom Mines



Mine Warfare Today



*Source: Unmanned Vehicles in Mine Conuntermeasures, NRAC(Naval Research Advisory Committee, 2000)

MIW Operating Area

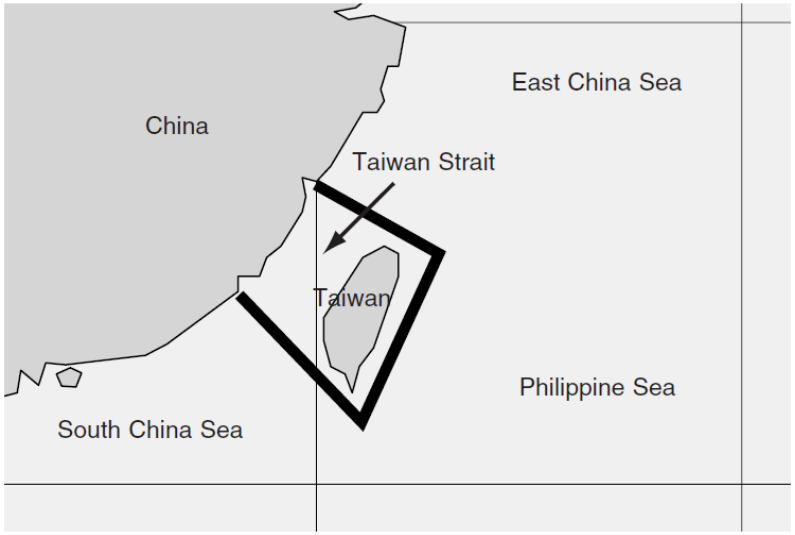
SLOCs, Sea Lane of Communications

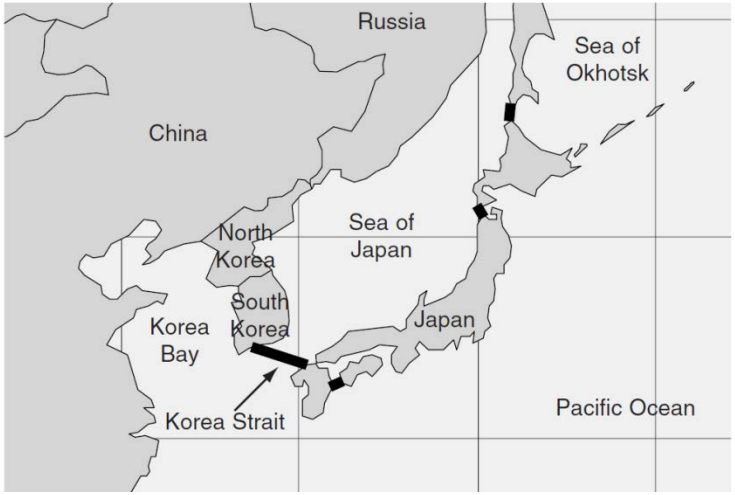
Ship-to-Objective Maneuver (STOM)

Port Break in/out Operations

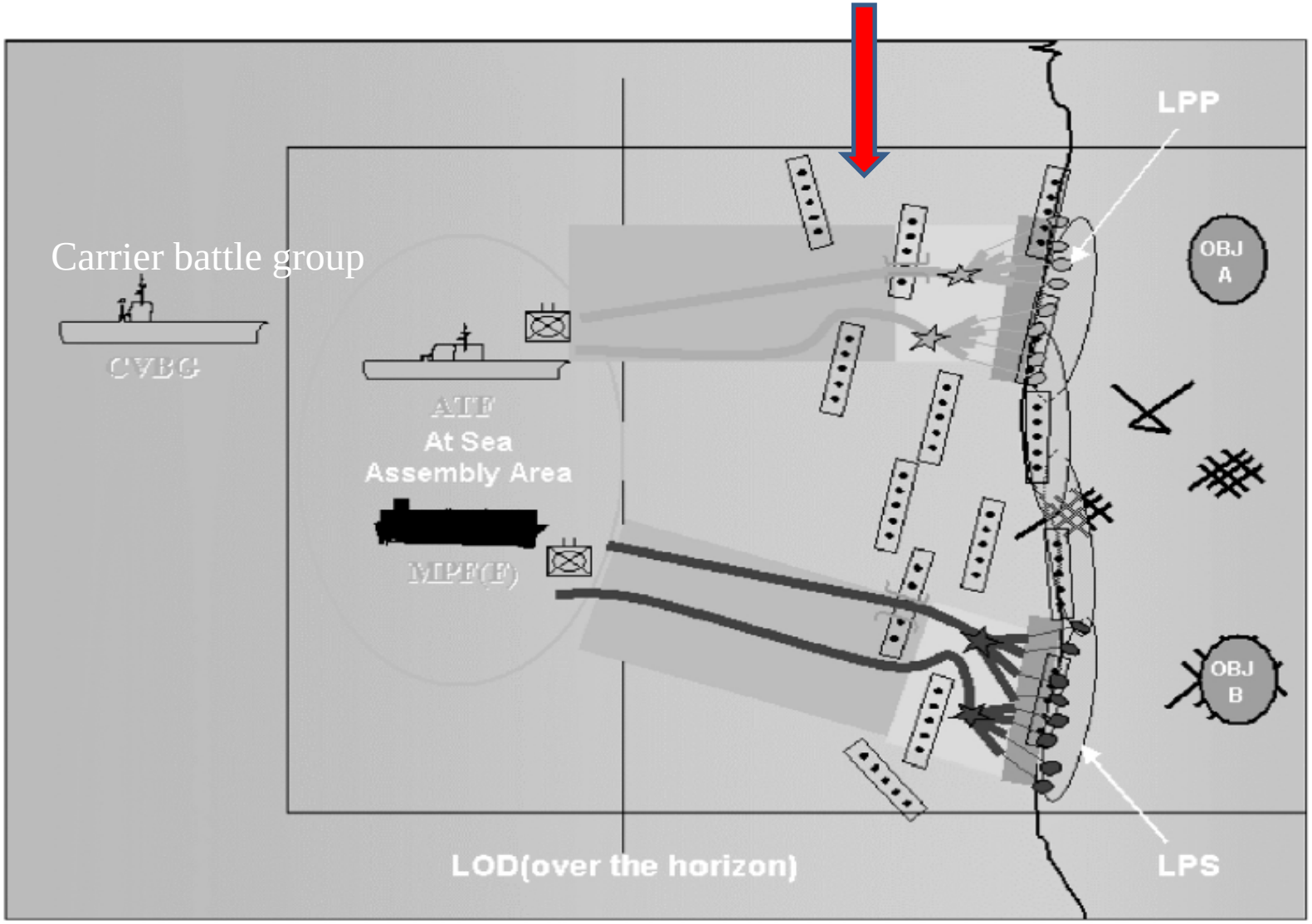
Independent Operations

Major International SLOCs

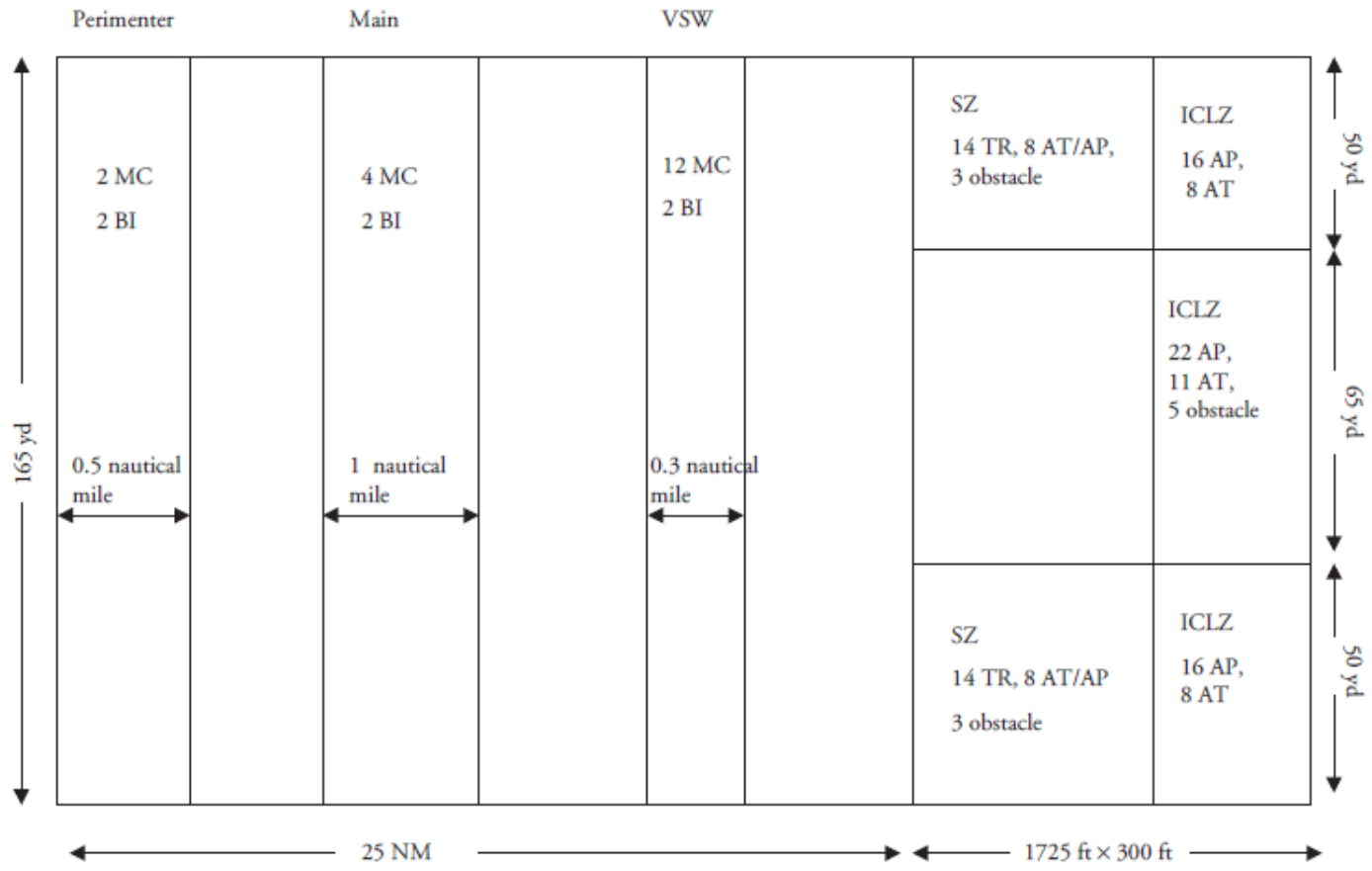




Example: Mines in the Amphibious Operation



Mines at Amphibious Region



Mine and obstacle density per transit/assault lane. MC = moored contact; BI = bottom influence; AP = antipersonnel mine; AT = antitank mine.

Mine Countermeasures

Passive

- Limit all influence signals emitted from target vessels

Active

- Mine hunting – The search for mines using magnetics, visual, and sonic means ether through the use of divers, unmanned undersea vehicles (UUVs), or hull-mounted and towed instrumentations.

- Mines weeping – Detonation using both mechanical and influence methods. Minesweeping methods are highly dependent on mine characteristics and need to be continually altered for new mine types.

Goals for Naval Mine Countermeasures(MCM)

- Elevate Status of MCM in naval operations:
  - Full commitment of naval leadership to well –equipped and trained MCM forces
  - Treat MCM as an equal among major warfare mission areas.
  - Provide more significant MCM personnel training.
  - Integrate MCM, totally and realistically, into joint and fleet training exercises.

- Develop a command and control, communications, computers, and intelligence (c4I) architecture that supports the full range of MCM operations

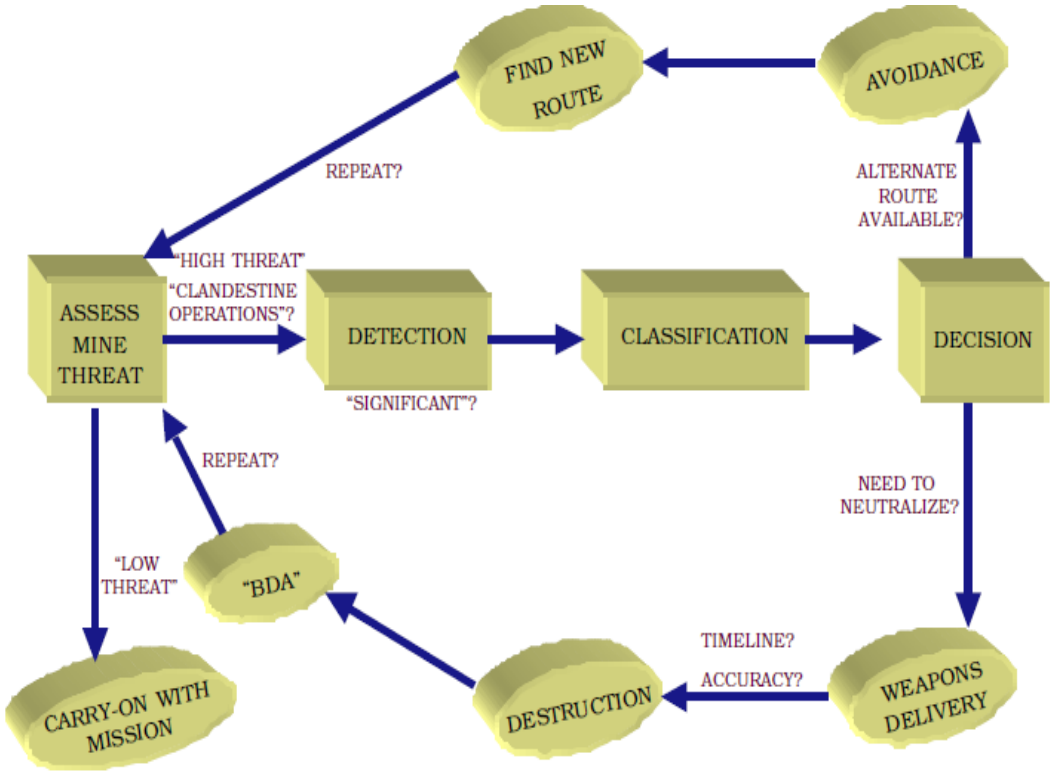
- Develop supporting and organic MCM systems that are capable of :
  - Rapid deployment and employment,
  - high-area search rate with low false alarm generation,
  - Rapid and wide-area detection, classification, and identification of mines,
  - Automatically adapting to the environments,
  - Autonomously destroying mines, and
  - Supporting avoidance and in-stride mine and obstacle breaching from deep water to inland objectives.

- Develop an all-source precision database with the capability to provide real-time environmental assessments and forecasts and make it available to all MCM forces.

- Develop self-protection measures, including mine avoidance, signature manipulation, and shock hardening.

*Source: Rhodes and holder, 1998

Problem Statement of MCM

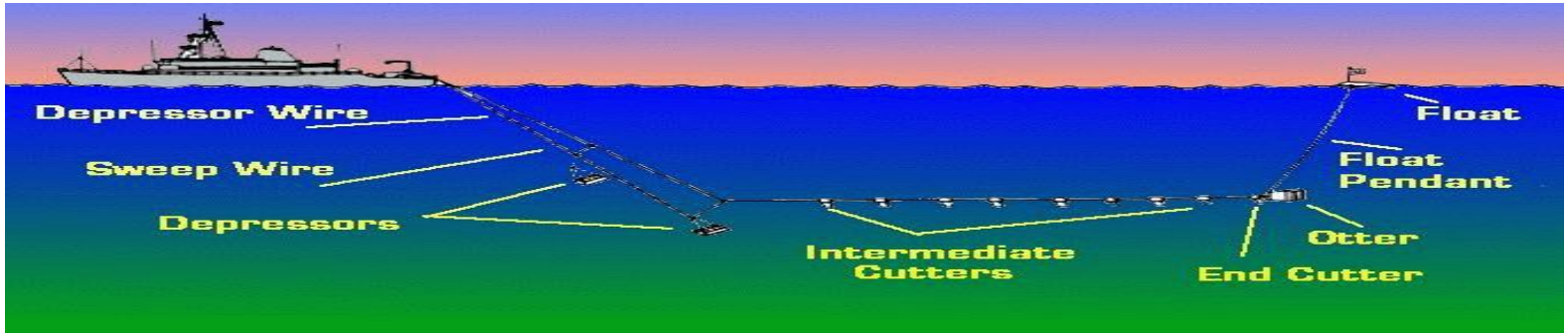


*Source: Unmanned Vehicles in Mine Conuntermeasures, NRAC(Naval Research Advisory Committee, 2000)

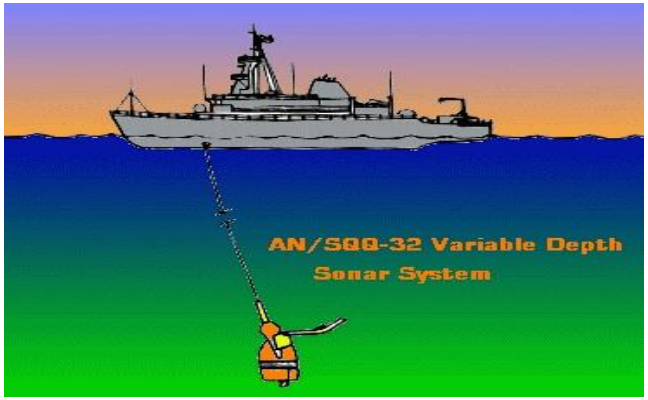
Minesweeping, Neutralization, Clearing(1/2)

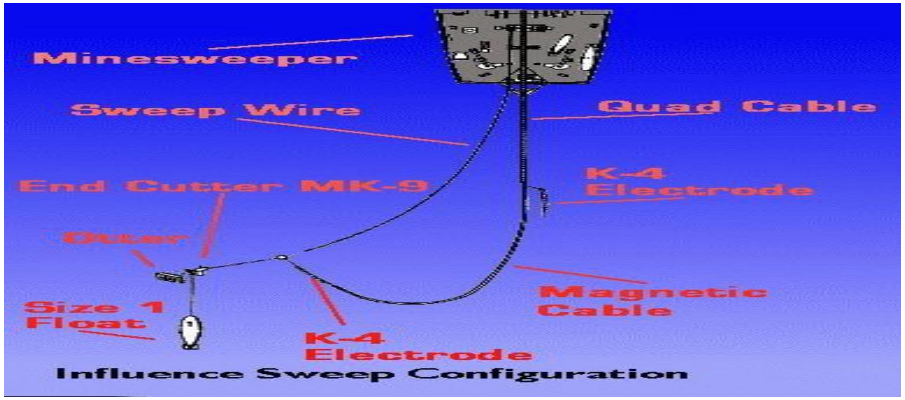
Minesweeping can be performed by human, ships or aircraft. There are several types of minesweeping.

Mechanical Sweeps are designed to sever the cables of moored mines.



Influence Sweeps involve simulating the passage of a ship in order to "fool" the mines into detonating. In this case, a magnetic or acoustic sweep system is towed by a ship or aircraft.





Minesweeping, Neutralization, Clearing(2/2)

A magnetic sweep utilizes a magnetic field to simulate the field created by a passing ship. A magnetic field can be produced via an electrical current passing between two non-insulated cables. This resulting field will induce magnetic mines to detonate.

An acoustic sweep is accomplished by simulating the sounds created by a target ship. Various noise makers utilizing compressed air, explosives, hammers or propellers are towed near acoustic mines to detonate them.

Pressure Minesweeping involves sending a large object such as a barge or derelict ship into a minefield to purposely strike mines. This method is not currently practiced.

Combinations of different methods of countermeasures is called a combination sweep. A common combination is a magnetic/acoustic sweep, which simulates the sound and magnetic field of a passing ship.

Other Dedicated Mine Countermeasure(MCM) Assets

Airborne MCM (AMCM): MH-53E

- 24 HM-14/HM15 aircraft
- 450 NM range
- Five-seven person crew
- Mechanical sweep (Mk 103)
- Influence Sweep (MK 104, Mk 105)
- Mine hunting (AQS-14 sonar)

Underwater MCM (UMCM): Explosive Ordinance Disposal (EOD)

- 17 mobile MCM detachments
- A detachment consists of one officer and seven enlisted personnel
- PQS-2A sonar
- Mk 16 non-magnetic underwater breathing apparatus

Underwater MCM (UMCM): Marine Mammal System (MMS)

- 12 mammals
- Four systems available and one under development

  (1) Mk 4 - employs four dolphins for close-tethered, deep-moored minehunting and neutralization. The Navy employs this capability to neutralize all buoyant mines.

  (2) Mk 5 - employs four sea lions for acoustic object recovery. Sea lions attach recovery pendants to exercise mines, torpedoes, and other objects.

  (3) Mk6- employs six dolphins for swimmer and diver detection and defense of harbors, anchorages, and individual ships.

  (4) Mk 7- employs eight dolphins for mine detection, classification, location, and neutralization of bottom mines.

  (5) Ex 8 (under development) - will employ six dolphins for exploration and reconnaissance of in-volume moored and bottom mine-like contacts in the very shallow water (VSW) zone.

Source: Mine Warfare Command, 1999

Airborne Mine Countermeasure Operations

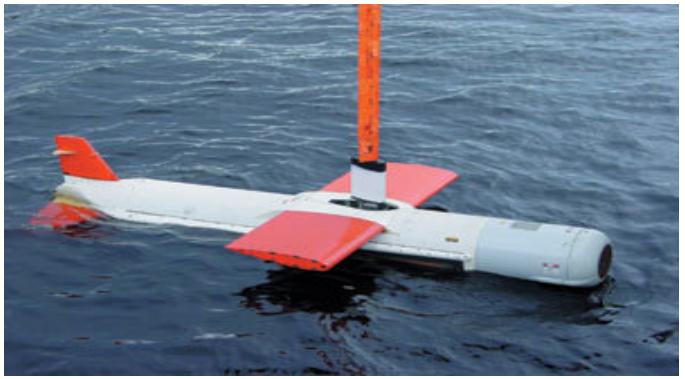
Other Dedicated Mine Countermeasure(MCM) Assets

Rapid Airborne Mine Clearance System

The MH-53E Sea Dragon class of helicopters have minehunting and sweeping capabilities using a variety of towed gear.

An early version of the Airborne Laser Mine Detection System. Northrop Grumman Photo

Airborne Mine Neutralization System

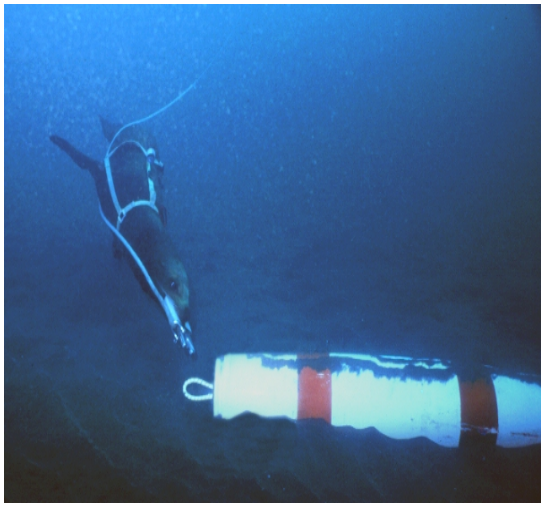


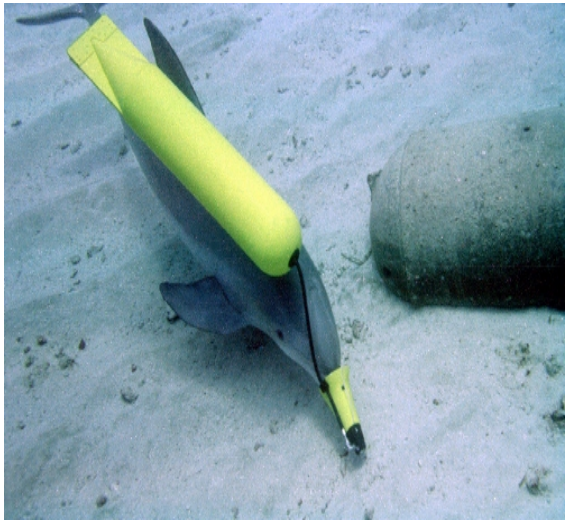
The Raytheon AN/AQS-20 Minehunting Sonar System, shown above, is the primary minehunting sensor system for the MH-60S helicopter, as well as the AN/WLD-1 Remote Minehunting System.

Organic Air and Surface Influence Sweep System

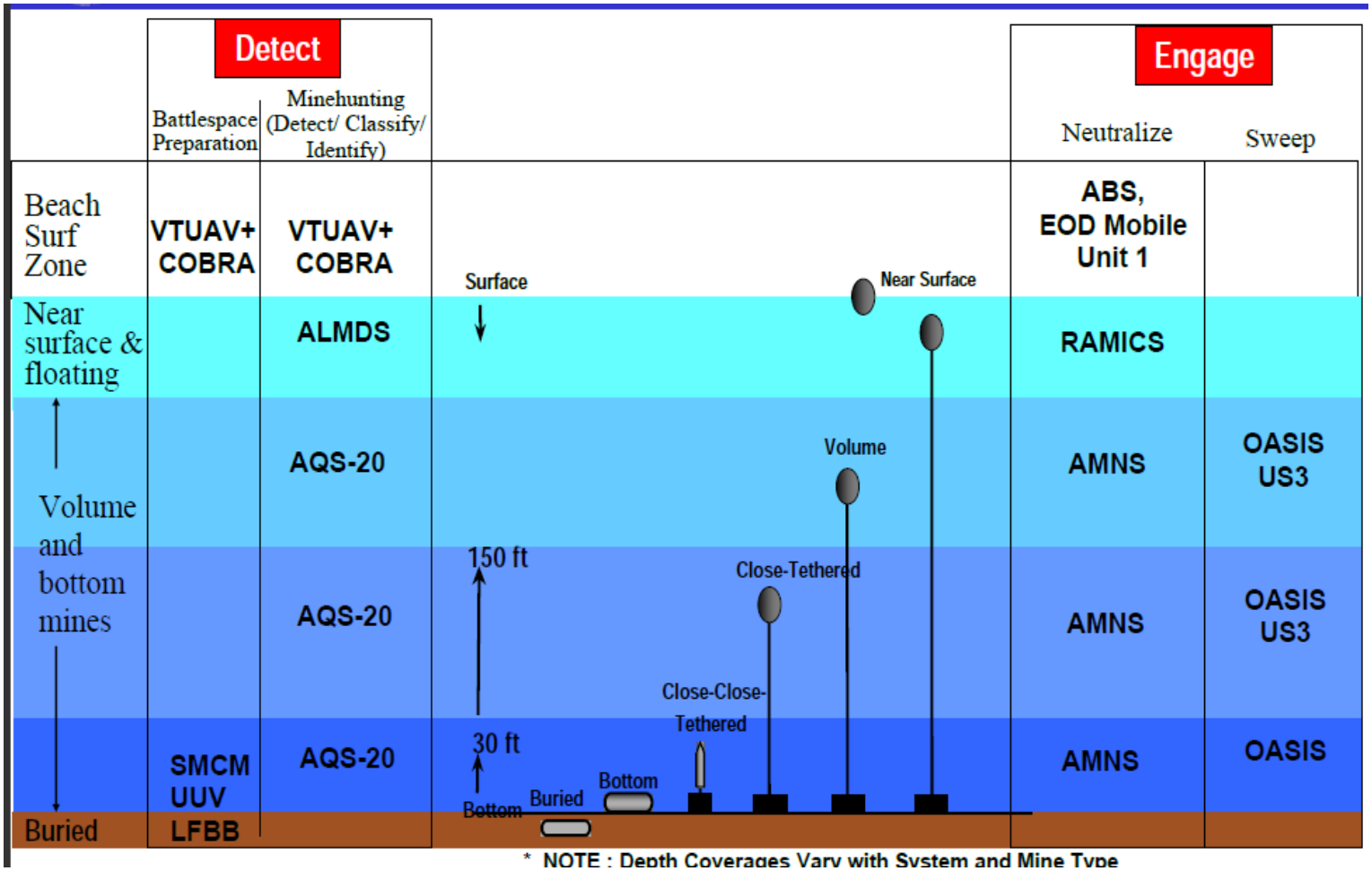
The Lockheed Martin AN/WLD-1 Remote Minehunting System is shown here with its snorkel folded for storage. The unmanned diesel submarine uses its snorkel for air intake and as an antenna mast while deployed in the ocean.

Navy Seals, Sea Lions & Dolphins



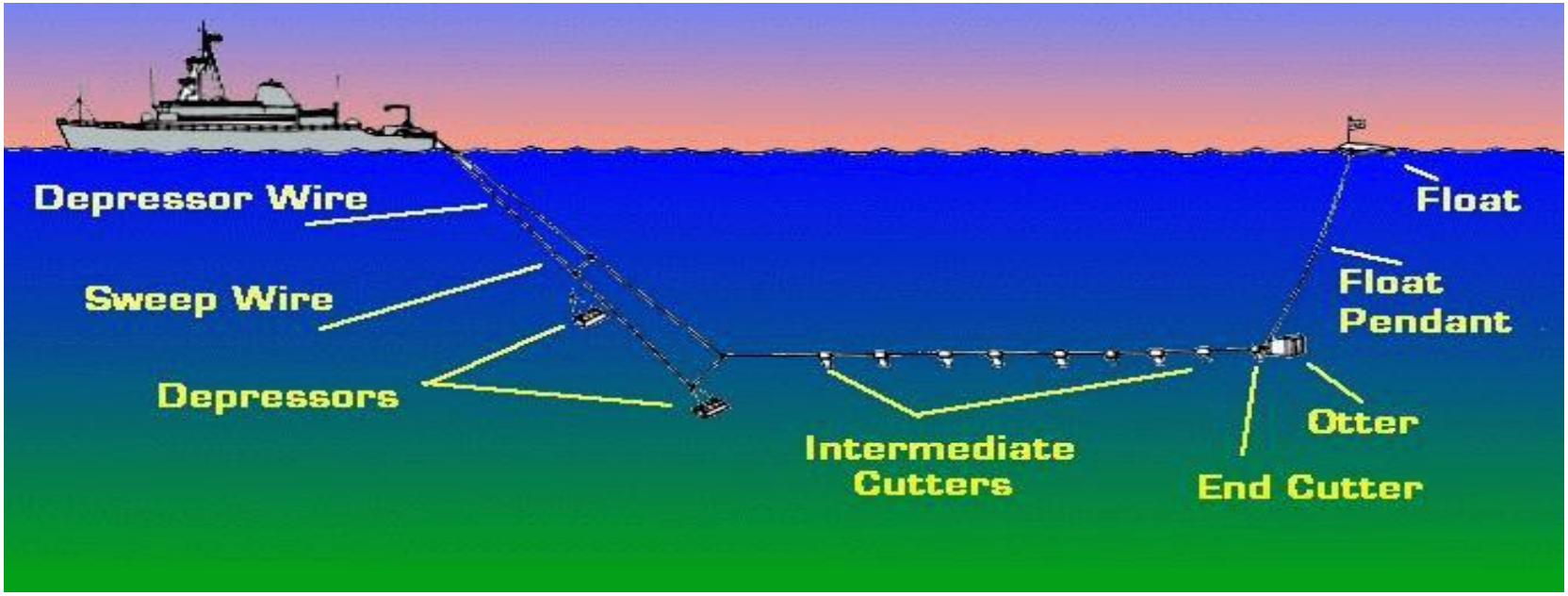


Hierarchy of MCM Missions



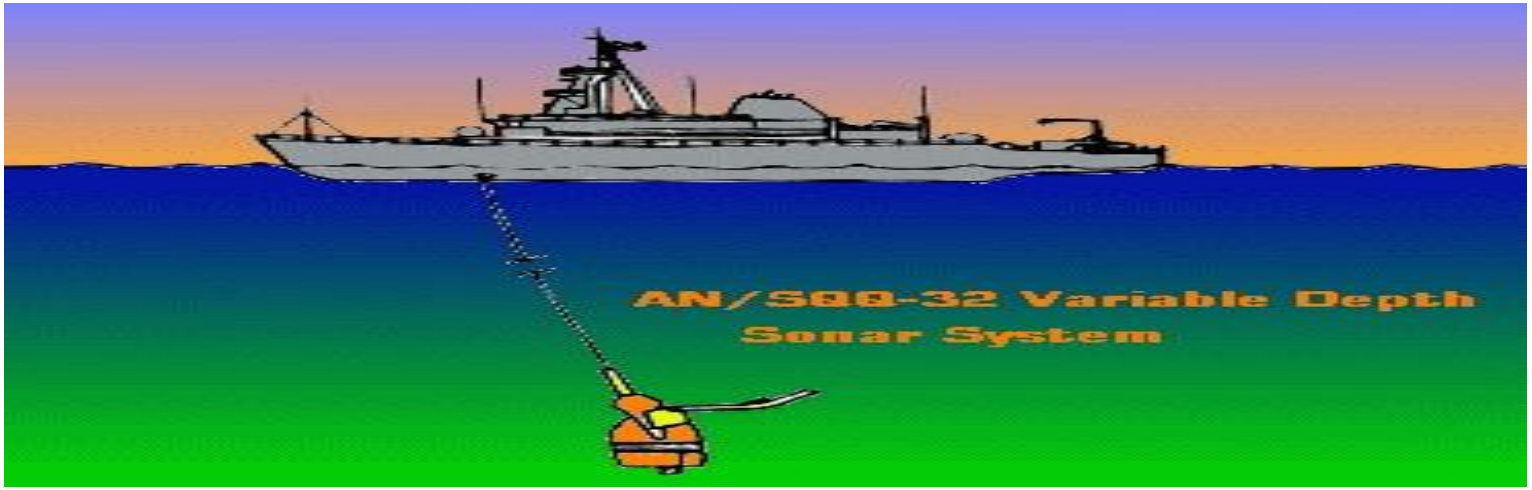
MCM Operations

- Reconnaissance Detection Localization
- Mine Neutralizations
  - Mine Hunting and Localization
  - Mine Sweeping : H/W, S/W Out of Function
- Battle Damage Analysis(BDA)

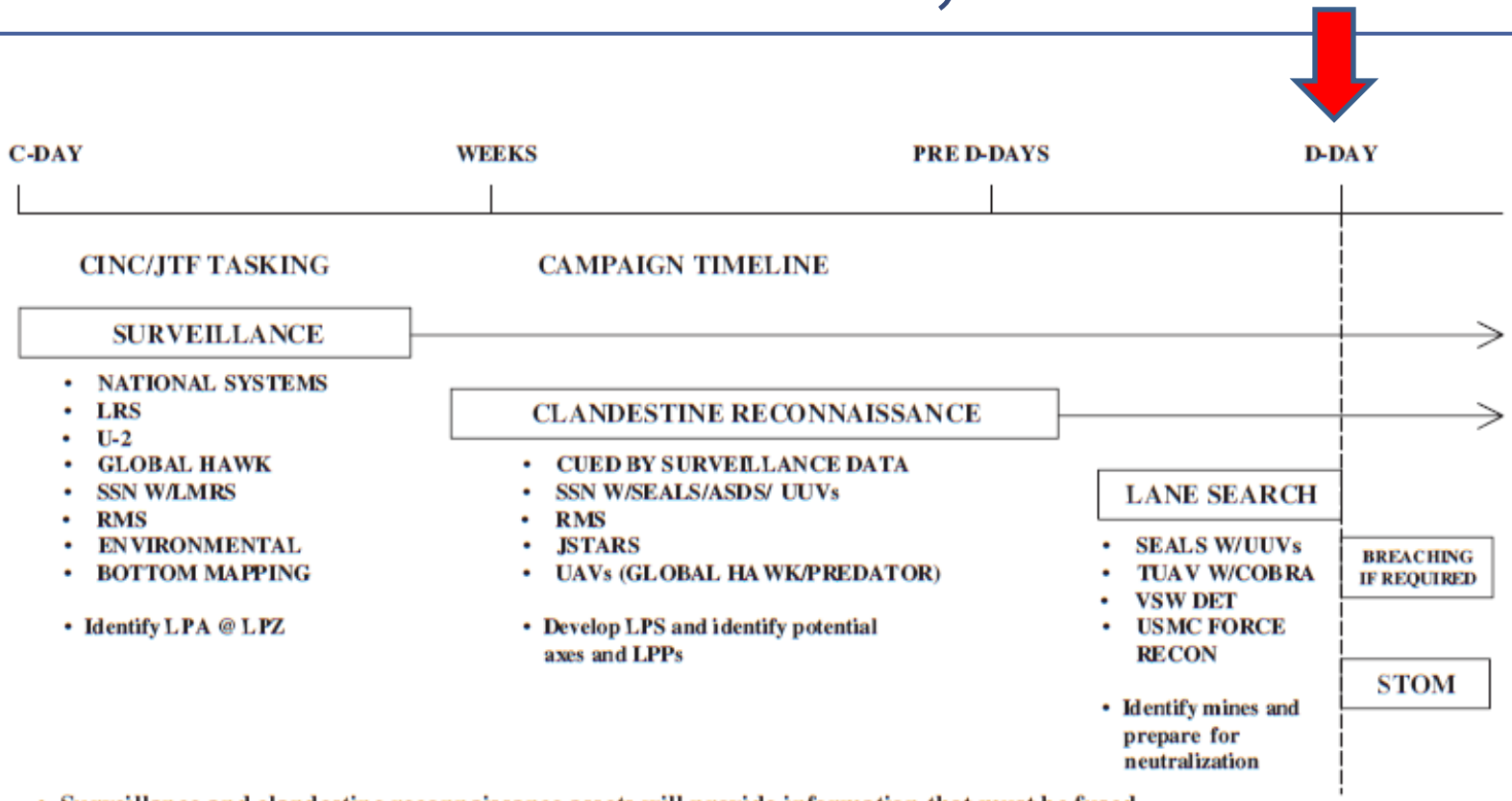


MCM Operation

- Environmental Picture
- Mine Reconnaissance and Surveillances
- Situational Awareness, C4ISR, Comms.
- Safety of MCM Forces
- Technology, Logistics Risk Mitigations



Reconnaissance Detection, Localization



- Surveillance and clandestine reconnaissance assets will provide information that must be fused in a common tactical picture.
- This combined with the INTELINK contingency planning tools (Appendix A) will give commanders a robust intelligence capability to support STOM operations from the sea base.

ISR assets for mine countermeasures in support of Ship to Objective Maneuver (STOM) (2000 to 2010). See Appendix F for definitions of acronyms used.

Importance of Environmental Data at MCM Operations

The environmental impact
that without a thorough description of the battlespace successful outcome is in jeopardy.

The capability must exist to exploit the battlespace environment, from the upper atmosphere to the sea floor, in real, or near real-time.

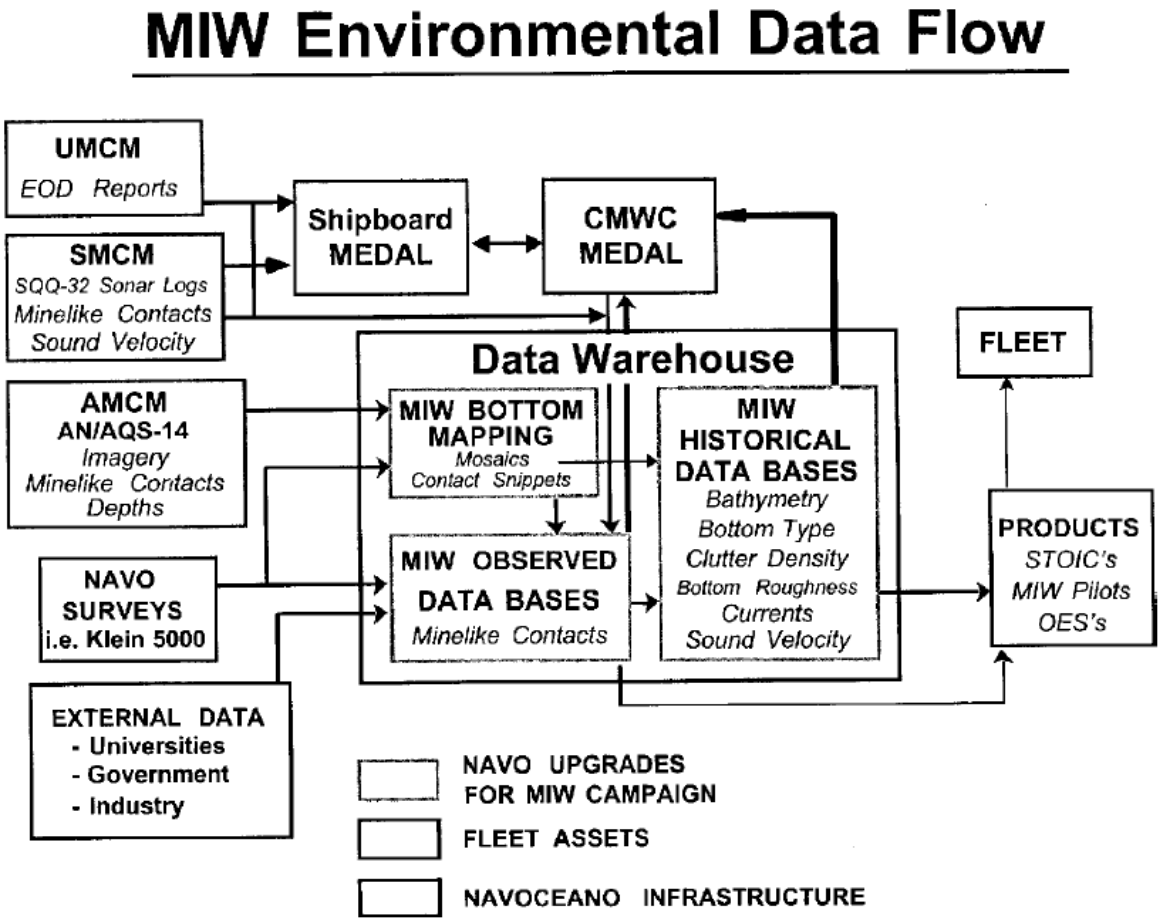
The common tactical database and TDAs, decision aid software and the force's common environmental picture
will be driven by fused data from extensive multi-source collection and analysis efforts, off-board forecasts, and the historical environmental database.

Environmental Data for MCM

Important environmental characteristics:

- **Meteorology:** wind, air temperature / humidity, cloud cover / precipitation
- **Geography:** topography, vegetation, soil characteristics, urbanization / land use
- **Oceanography:** bathymetry / salinity profile, clarity, tides, currents / upwelling, sea-state, ambient noise, biologics, sediments / bottom type.

MIW Environmental Data Flow



Mine warfare environmental data flow between Naval Oceanographic Office (NAVOCEANO) and Commander, Mine Warfare Command (COMINEWARCOM).

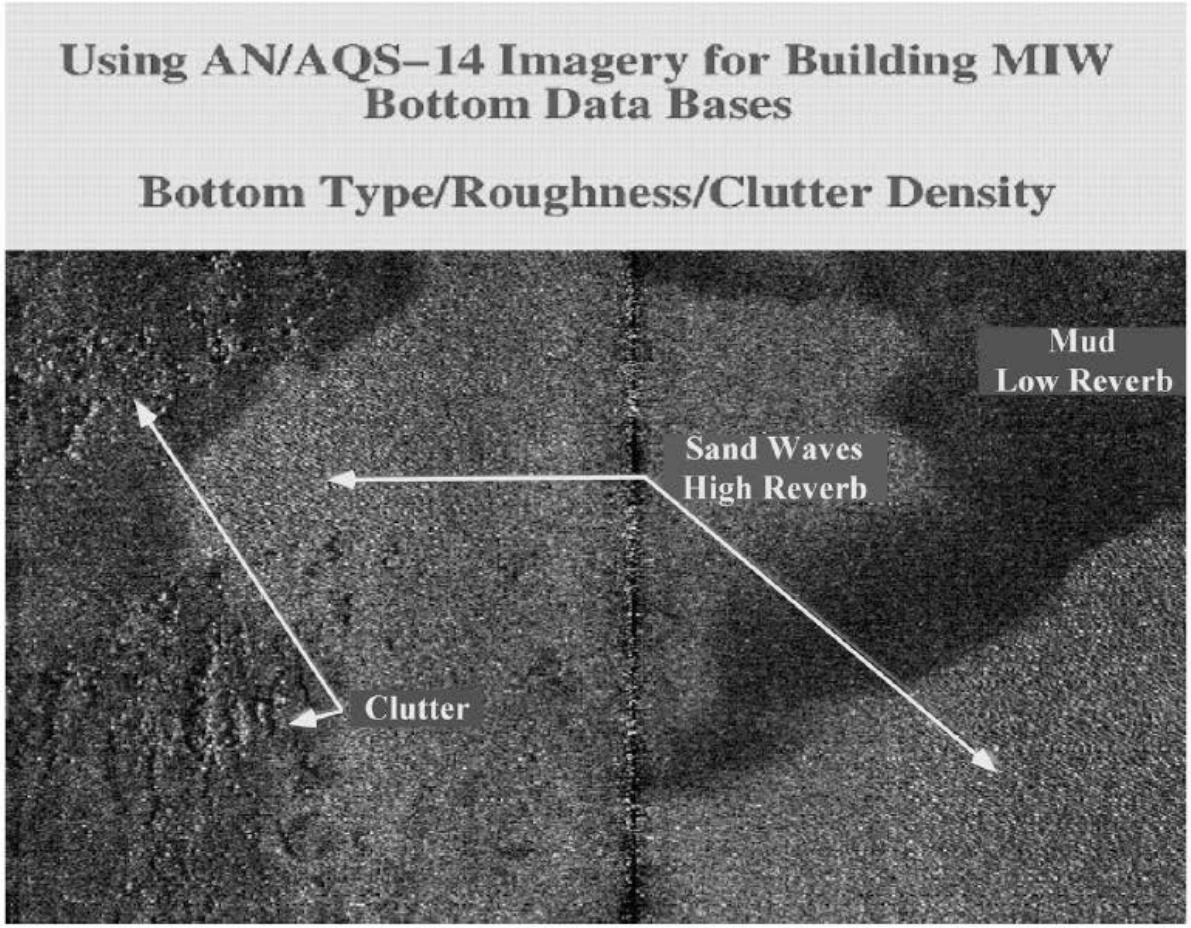
Examples of mine likely images

Identification of MLO

An acoustic imagery mosaic with one meter resolution. On this image numerous "pockmarks" can be seen. These features are likely to have resulted from seafloor release of hydrocarbon gases.

Examples of mine likely images

AQS-14 imagery



Acoustic imagery mosaics can be used to determine bottom type, roughness, and clutter density. In this image, an area of low reverberation, which has been interpreted as muddy sediment, can be seen in the upper right and high reverberation in the center of the image has been interpreted to reflect sandy sediment. An area of high clutter can be seen on the left.

Introduction of Unmanned MCM System

- Large Displacement UUV
- ACTUV
- LMRS
- MRUUV
- USV/AUV

COP

Concept of Operations

Constraints: Vehicle tows a sonar through the water.
Use existing sonar and vehicle systems.

- 1) Vehicle Alternatives

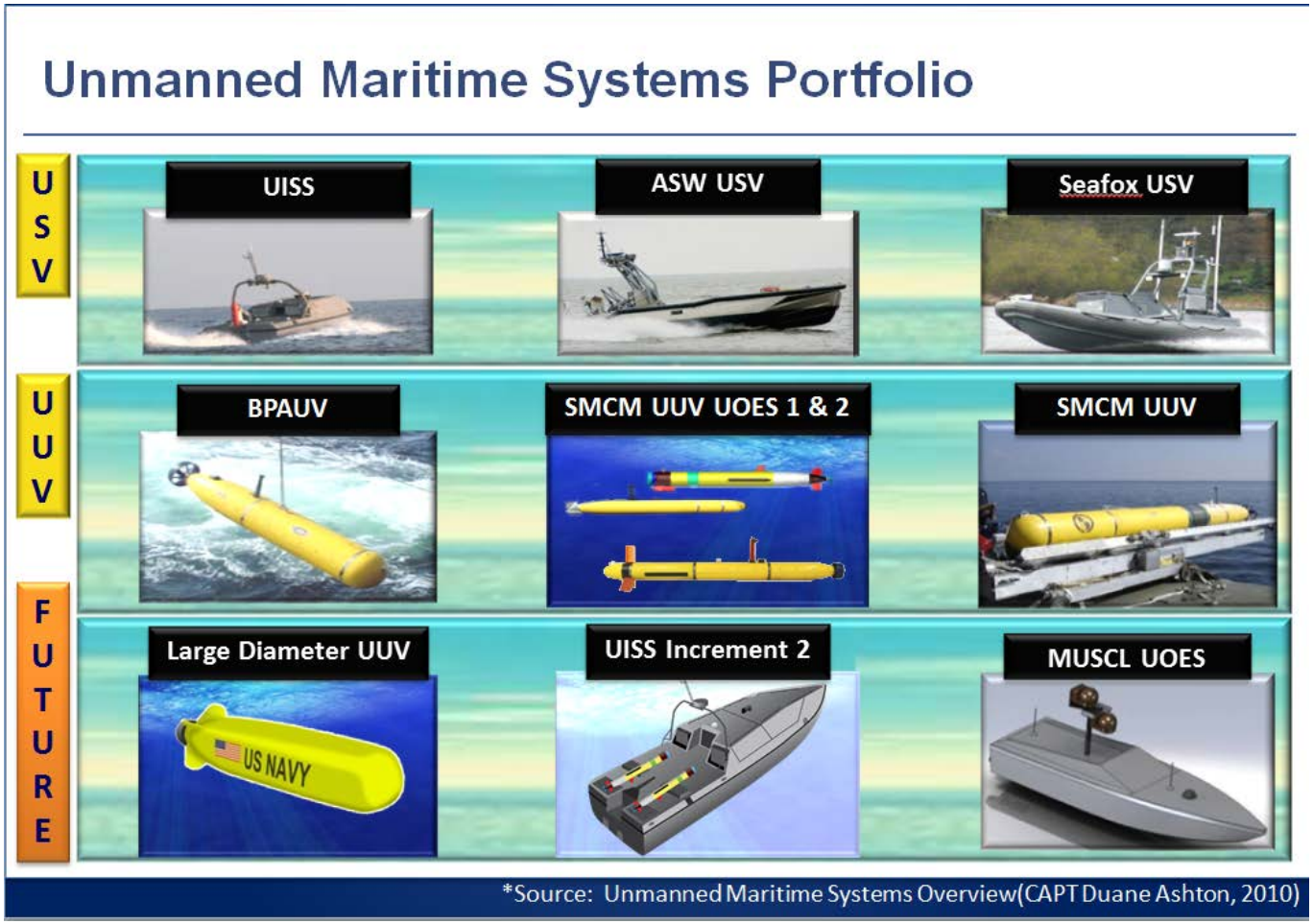
Alternative	Useful in own territory	Useful in enemy territory	Safe from striking mines
Unmanned surface craft	X		
Unmanned helicopter	X		X
Unmanned submersible	X	X	

- 2) Sonar Alternatives
  - Pair 3 vehicle alternatives with 2 sonar alternatives
- 3) Time and cost calculations

Benefits of Adapting Autonomous Systems

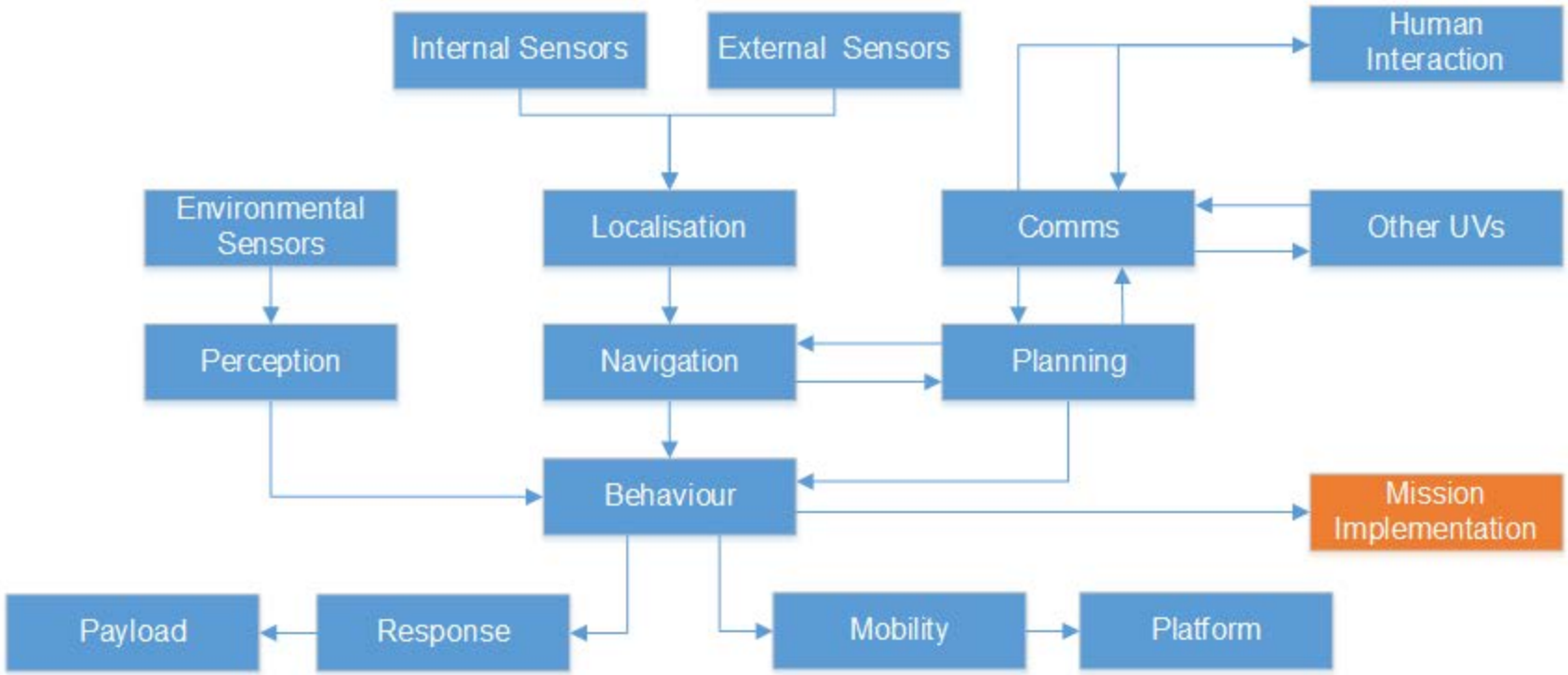
Enable Missions that cannot be performed by manned systems
Risk Reduction
Low Profile
Deployability
Environmental Adaptability
Persistence
Low Cost
Scalable
……

Unmanned Maritime Systems Portfolio



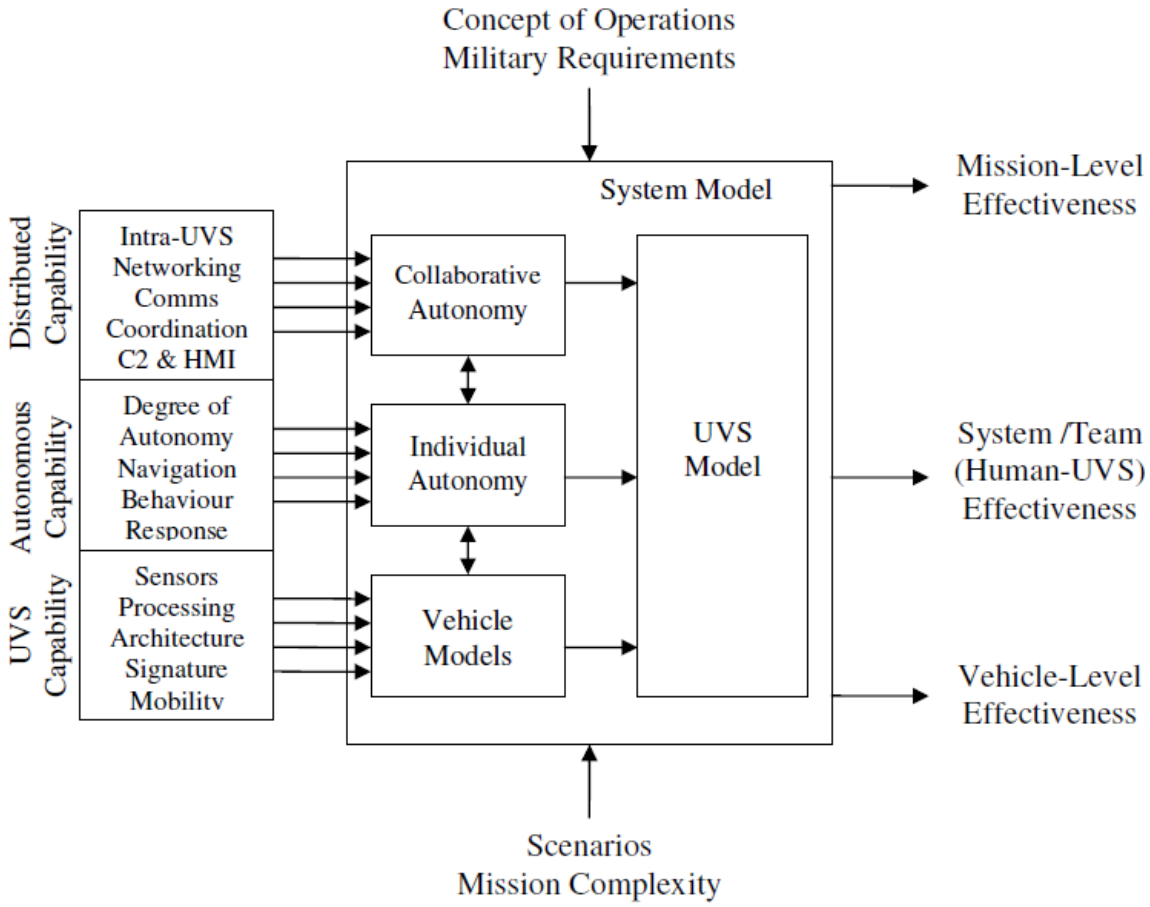
Difficulty of Unmanned System Working at Combat

The key functional relationship for an autonomous UVS



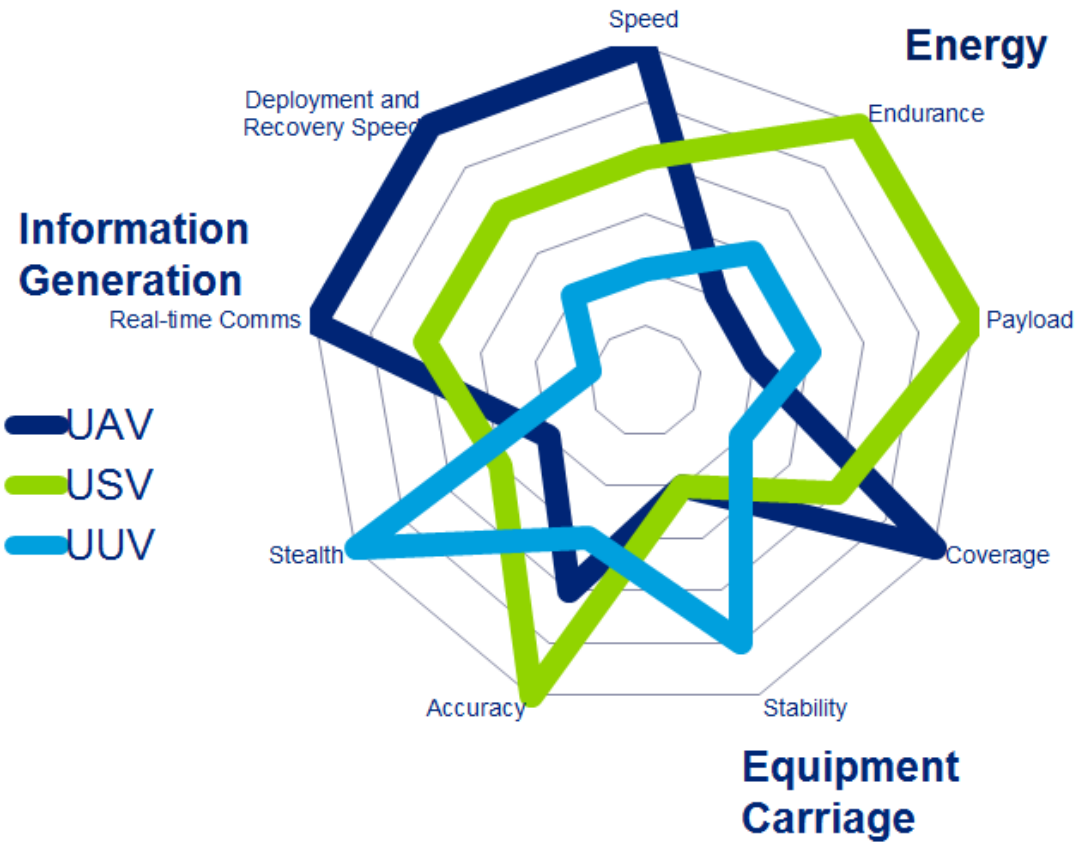
*UVs: Unmanned Vehicle Systems

Unmanned System Efficiency



System model for determining UVS effectiveness

UxVs Characteristics



USVs have unique attributes for many missions

Displacement Platforms
- Large Payloads
- Long Endurance

Air Breathing Propulsion
- Long Range
- Long Endurance
- High Speed

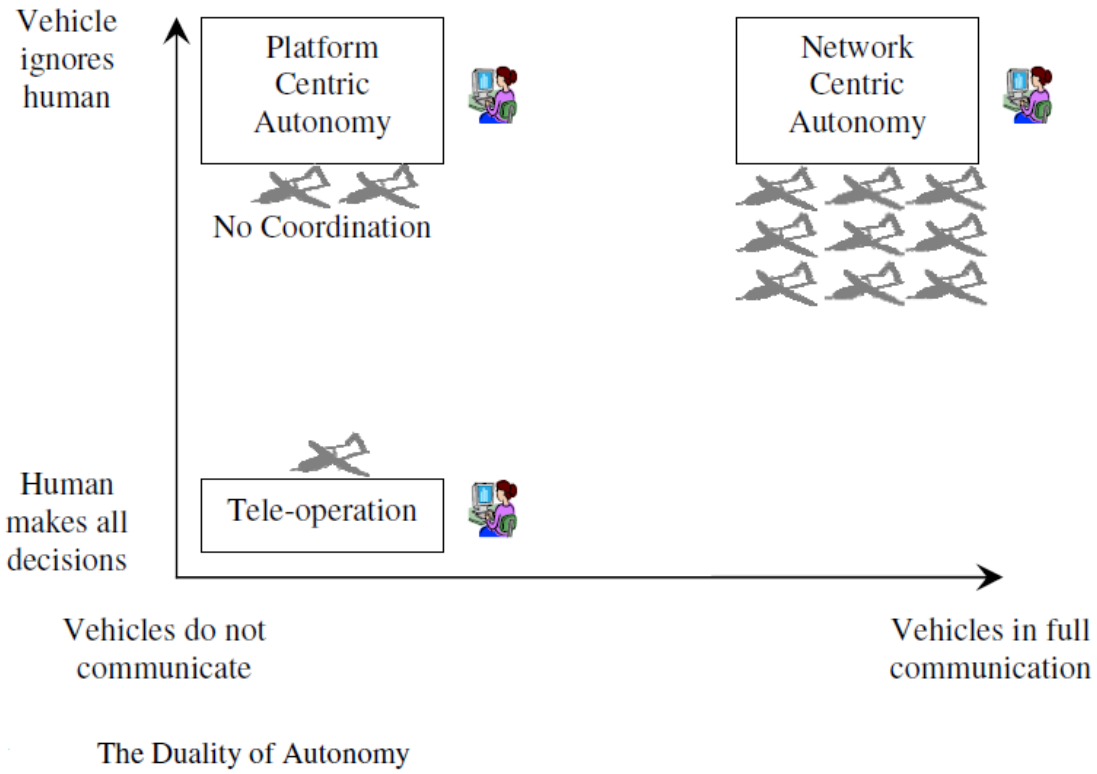
RF Communications
- Real-time connectivity

Moderately Stealthy

Low-Cost / Technical Complexity

 Source: AUCVI Program Review 2010 (ACTUV Brief, Rob McHenry) data based on an analysis of published UxS Characteristics circa 2000

C4I Prospective of Unmanned Systems



The Duality of Autonomy

Vision for unmanned Systems

- **Integration and operation of unmanned systems** in each domain the Navy operates to enhance capabilities
  - Manned platforms with UxS in different domains
- **Seamless manned and unmanned systems integration**
- **Unmanned systems are compelling** where the human is a limitation to mission success or a viable alternative to "traditionally" manned missions
- **Common control systems and modular** "plug and play" payloads within an open architecture = flexibility
  - One operator controls more than one vehicle in more than one do main
- **Team with other Services and Agencies**, our Allies, academia and industry to capitalize on emerging technology and to gain cost savings and synergy in order to increase warfighting capability

A Navy force that integrates manned and unmanned systems to increase capability across the full spectrum of maritime and littoral missions while remaining fiscally achievable. - CNO -

Source: US Navy Maritime ISR Roadmap

MCM Environment

AFSB – Afloat Forward Staging Base
ALMDS – Airborne Laser Mine Detection System
AMNS – Airborne Mine Neutralization System
EOD – Explosive Ordnance Disposal
LCS – Littoral Combat Ship
MCMC – Mine Countermeasures Mission Commander
MOC – Maritime Operations Center
RMS – Remote Minehunting System
UISS – Unmanned Influence Sweep System
USV – Unmanned Surface Vessel
UUV – Unmanned Underwater Vessel
VTUAV – Vertical Takeoff Unmanned Aerial Vehicle

Multiple Systems and Host Platforms Operating in Concert

*Source: Mine Warfare Association, OPNAV N952

Future MCM Operation with New Technology

LCS System connected Operations

The two variants of the Navy Littoral Combat Ship — LCS-1 Freedom and LCS-2 Independence – side by side.

Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)

- **The Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)** is developing an unmanned vessel optimized to robustly track quiet diesel electric submarines. The program is structured around three primary goals:

  - **A new design paradigm emerges** architecture elements such as layout, accessibility, crew support systems, and reserve buoyancy. The objective is to generate a vessel design that exceeds state-of-the art platform performance to provide propulsive overmatch against diesel electric submarines at a fraction of their size and cost.

  - **Advance unmanned maritime system autonomy** deploying systems capable of missions spanning thousands of kilometers of range and months of endurance under a sparse remote supervisory control model. This includes autonomous compliance with maritime laws and conventions for safe navigation, autonomous system management for operational reliability, and autonomous interactions with an intelligent adversary.

  - Demonstrate the capability of the ACTUV system to use its unique characteristics to employ non-conventional sensor technologies that achieve robust continuous track of the quietest submarine targets over their entire operating envelope.

DARPA

*Source: DARPA News

Prospective for USV with MCM Operations

- **MCM behaviors:**
  - **"Reconnaissance":** That phase of the exploratory objective designed to make a rapid assessment of the limits and density of a minefield.
  - **"Search":** the use of sonar or divers to detect and classify mines or mine-like objects.
  - **"Hunting":** the act of searching for mines. Hunting operations can also include marking and neutralization of mines.
  - **"Breaching":** breaking through a minefield, thereby opening a clear path or channel.
  - **"Clearance" or "clearing objective":** removal of detectable mines from an assigned area. Since it is generally impossible to guarantee that all underwater mines have been detected and cleared, a goal is assigned to coincide with a percentage of risk that a potential number of mines remain.
  - **"Sweeping":** the act of towing mine countermeasures gear intended to actuate mines by generating a ship-like signature, or mechanically cutting mooring cables of moored mines.
  - **"Jamming":** overwhelming an influence-activated mine's sensors with external influences, such as noise or a strong magnetic signature, thereby masking a passing ships signature and causing the mine to not detect the passing vessel.
  - **"Signature":** the characteristic pattern of a ship's influence as detected by an influence sea mine (such as magnetic signature, acoustic signature, pressure signature).

Detailed Operation Sequences

- The full range of MCM mission types must be brought to bear to meet these requirements against the myriad mine threat types and operational environments. The lexicon of mine countermeasures includes the following terms and their definitions:
  - **"Detection":** the discovery by any means, of the presence of a mine or mine-like object with potential military significance.
  - **"Classification":** the evaluation of an object to determine if it is non-mine like or mine-like.
  - **"Localization":** establishing the precise position of an underwater object relative to a specific geodetic position.
  - **"Identification":** determination of the exact nature of a mine-like object as a mine. Current doctrine specifies visual identification by a diver or camera, but advances in sonar technology may provide adequate capability in the foreseeable future.
  - **"Neutralization":** rendering (by external means) a mine incapable of firing on a passing target or sweep.

ACTUV MCM Operation and Conditions

- MCM Reconnaissance and Surveillance
- C4ISR Connection to the Combat Zone
- Data Processing for Identification and Classifications
- Mine Neutralization and Sweeping

  - Mechanical, Explosive and Influential Sweeping

CONOPs Development

- Single ACTUV Operation
- Two ACTUVs Operation
- Several ACTUV Operation
- ACTUV and UUV, AUV Operation
- ACTUV and Surface Vehicle Operation
- ACTUV and Airborne Assets Operation
- ACTUV, Airborne and Surface Vehicle Operation

Single ACTUV Operations

- **Mine Laying**
- **MCM ISR and Localization**
- **Sweeping Mine Operation**

Required Device : Forward Looking Sonar(FLS)
Side Scan Sonar(SSS)
Synthetic Aperture Sonar(SAS)
LIDER

Several ACTUV Operations

- ISR with Stereoscopic Picture Identification
- Buried Mine Search
- Cooperative Mine Sweeping

Basic Consideration for ACTUV Missions

- **Autonomy**

Capabilities are needed that can adapt to changes in environment and mission profiles. Pre-deployment programming of vehicle mission plans will not be sufficient to handle the dynamic nature of some missions. The challenge is to provide auto-adaptive behaviors that are currently resident in human-in-the-loop systems. Multisystem autonomous, cooperative behaviors will be a required future capability

- **Obstacle & Collision Avoidance**

All USVs except the smallest special purpose vehicle must have the ability to autonomously avoid obstacles. These include:

- Land masses
- Watercraft
- Low-hanging obstacles such as, bridges and tree limbs for inshore operations
- Submerged shallow obstacles such as hulks, reefs, and sandbars
- Interface obstacles, such as, swimmers, buoys, and floating debris
- Submerged obstacles for USVs that tow systems.

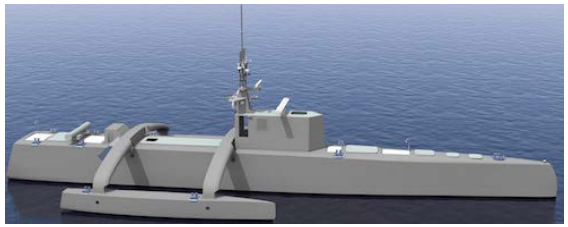
- **Threat Avoidance**

Most of the JCA missions require the autonomous avoidance of threat systems. This includes ships, boats, aircraft, active sensor systems (e. g., radar), and to the extent possible, passive detection systems. The tradeoff here is between vehicle vulnerability to interdiction or destruction and the complexity and sophistication (and hence, cost) of its self-protection suite.

- **Automated Target Recognition(ATR)**

ATR is required to facilitate both Obstacle and Threat Avoidance in all mission areas, and is needed for primary mission accomplishment in MCM, MS, ASW, and SUW missions.

ACTUV CONOPs



An Overarching Concept of Operations (CONOPs)

An overarching concept of operations (CONOPS) for future counter mine warfare forces must be established.

- **The combined dedicated and organic MCM capabilities** must be optimized with a systems view
- **Procedures for selecting the best route and MCM Sequences** based on ISR data bases are confirmed
- **The benefits and limitations** of real-time mine detection and avoidance techniques used by individual warships and USV is considered

An End-to-End, Overall Systems Approach for the New Systems and Technology

- **The mine threat and Situational Awareness** including future trends
- **Effective C4I ISR Operation** and Information Share
- **A contingency plan** for joint countermine warfare operations forces and ISR assets

An Overall System Architecture Consideration

- **A various technical issues** related to communications and interoperability, navigation/position errors for sensor contacts, type of sensor information are confirmed
- **Environmental databases, CAD/CAC** algorithms and associated thresholds for detection and classification,
- **An overall MCM systems architecture** is needed to ensure that common standards
- **Compatibility with MEDAL** should be a given.

Specific Check off List for the CONOPs

The U.S. Navy's UUV systems have moderate levels of autonomy today.

Examples of their autonomous capabilities are:

GPS/Doppler-aided navigation

- Autonomous path planning and execution based on onboard world map
- Terrain - following, keep-out zone avoidance
- Autonomous decision making and cue generation for noncombat missions
- Dynamics re-planning based on sensor input(acoustic, radio frequency[RF], chemical, etc.), vehicle health, and mission objectives and priorities
- Cross-desk advanced autonomy on multiple classes of vehicle – interface to various vehicle controllers and payload controllers.

Specific Check off List for the CONOPs

The Navy is working on developing higher levels of autonomy the Navy for UUVs. These include:

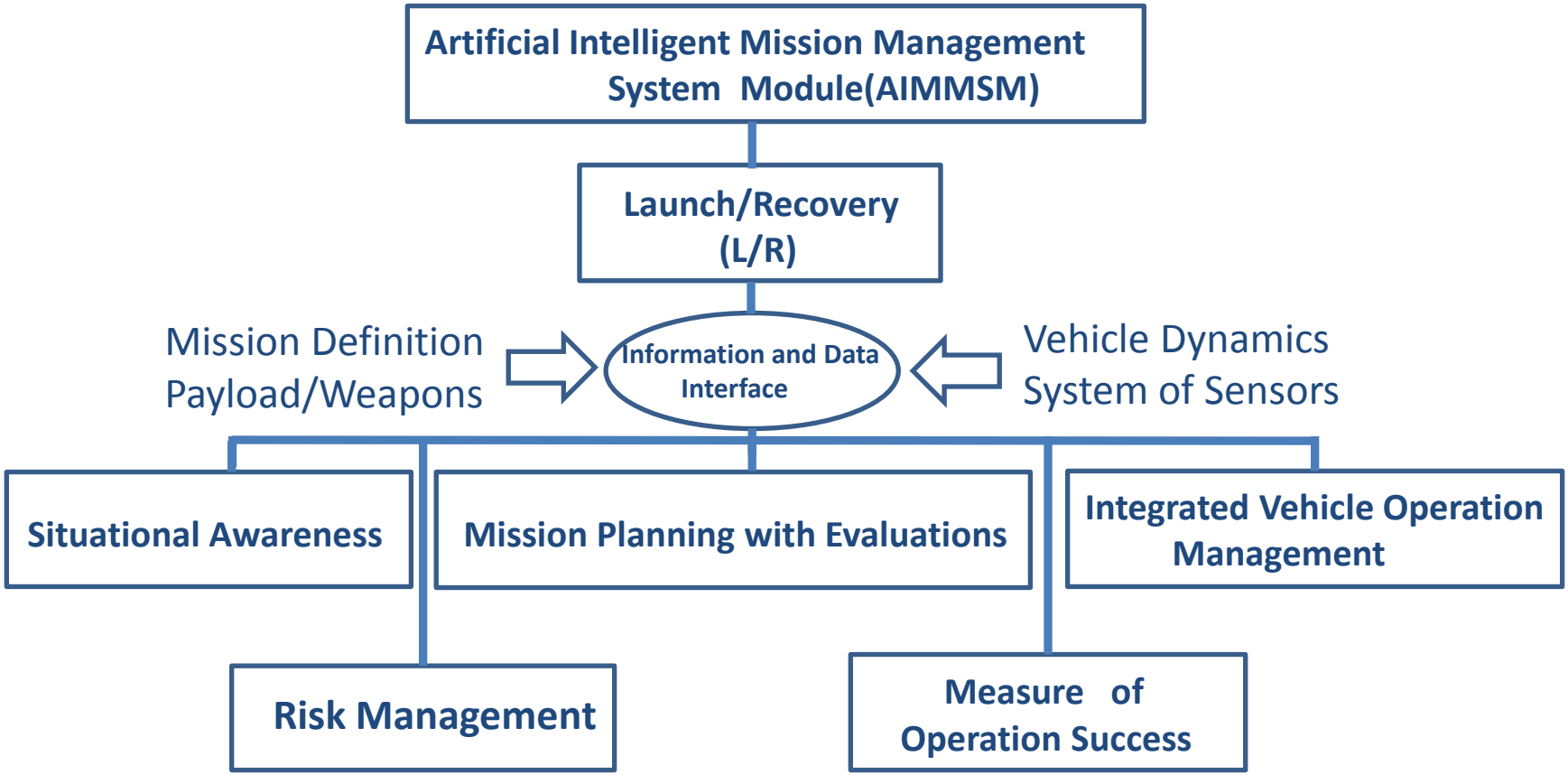
- Long transit and autonomous planning and control to precise local insertion without GPS-aided navigation (i.e. bottom map matching/feature-based navigation)
- Adaptive area surveys with automated target detection, classification, and recognition
- Robust sense and avoidance of hard-to-image/classify obstacles
  - Surface vessel detection and avoidance
  - Finish gear detection (based on cues)
  - Threat avoidance (perception is the hard part)
  - RF spectrum threat counter detection
  - Autonomous sensor data fusion
  - Collaborative behaviors
  - Fault detection and response
  - Autonomous sensor reconfiguration to meet changing mission needs

Specific Check off List for the CONOPs

The Navy envisions that even higher levels of autonomy will be needed in future operations. These more sophisticated forms for autonomy will probably be achieved only in the long-term

- Fishing net detection, avoidance, and extraction
- Counter-detection awareness and response
- Dynamic threat perception and adversary intent
- Autonomous decision making to support use of weapons
- Advanced collaborative behaviors
- Survivability for long-duration, complex missions.

USV Autonomy Structure



Initial Documentation MCM CONOPs

Situational Awareness Data

Logistics, Capability and C4ISR

Basic MCM Operational Sequences Setup

Analysis of Alternatives (AOA)

Threat /None threat Situation Analysis

Proof of Concepts, Confirmations of Sequences

Measure of Mission Effectiveness

Contingency Planning

Risk Management

Cost Effectiveness

Wargame/Simulation/Field Exercise