Office of Naval Research

Ocean Atmosphere & Space
Science & Technology

Naval-Industry R&D Partnership Conference
August 2004

Gustave Courbet (1819-1877)
"The Stormy Sea"
(or "The Wave")
1869

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Ocean, Atmosphere, Space S&T Focus

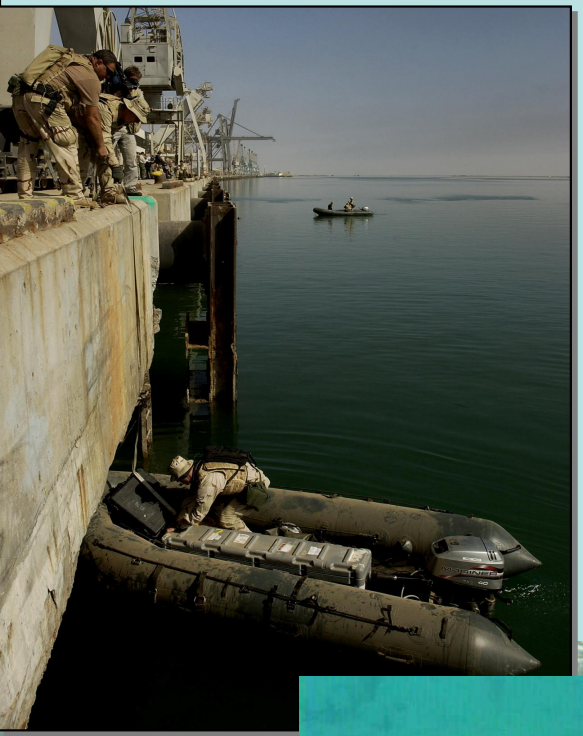
- **Anti-Submarine Warfare - (ASW):** Detecting, localizing, and classifying submarines with active and passive acoustics as well as non-acoustic means. New projects reflect Task Force ASW requirements and emerging ASW CONOPS.

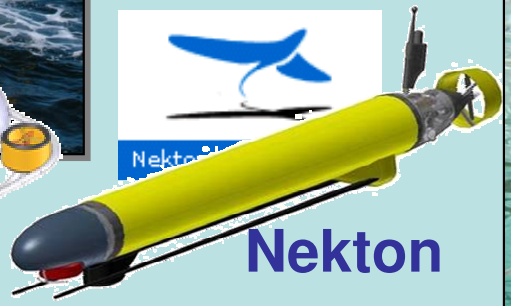
- **Mine Warfare - (MIW):** Detecting, localizing, identifying, and neutralizing mines in both the ocean and littoral environment, and improving offensive mining capabilities. Also includes Naval Special Warfare/Explosive Ordnance Disposal.

- **Battlespace Environments - (BSE):** Observing, modeling, and predicting both small and large scale processes in the air/ocean/shore environments. Efforts to treat environment as intelligence in forward, contested areas.

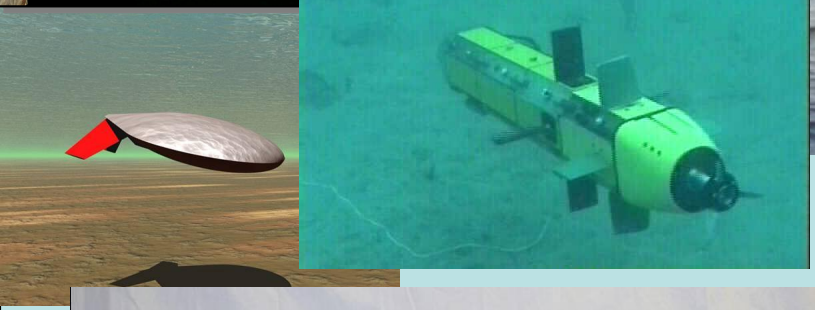
Autonomous Sensing – Overarching theme for MCM, Oceanography, ASW

- Covert, networked, mobile, persistent, scalable
- Intelligence Preparation of the Battlespace – before all platforms



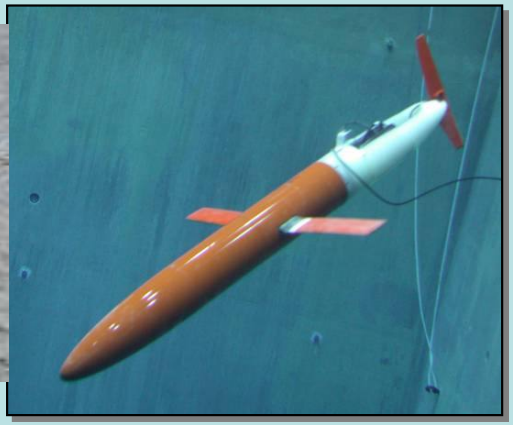


Nekton



Bluefin

HYDROID



WEBB RESEARCH

Chinese Military Aviation
www.strompages.com/jetfight

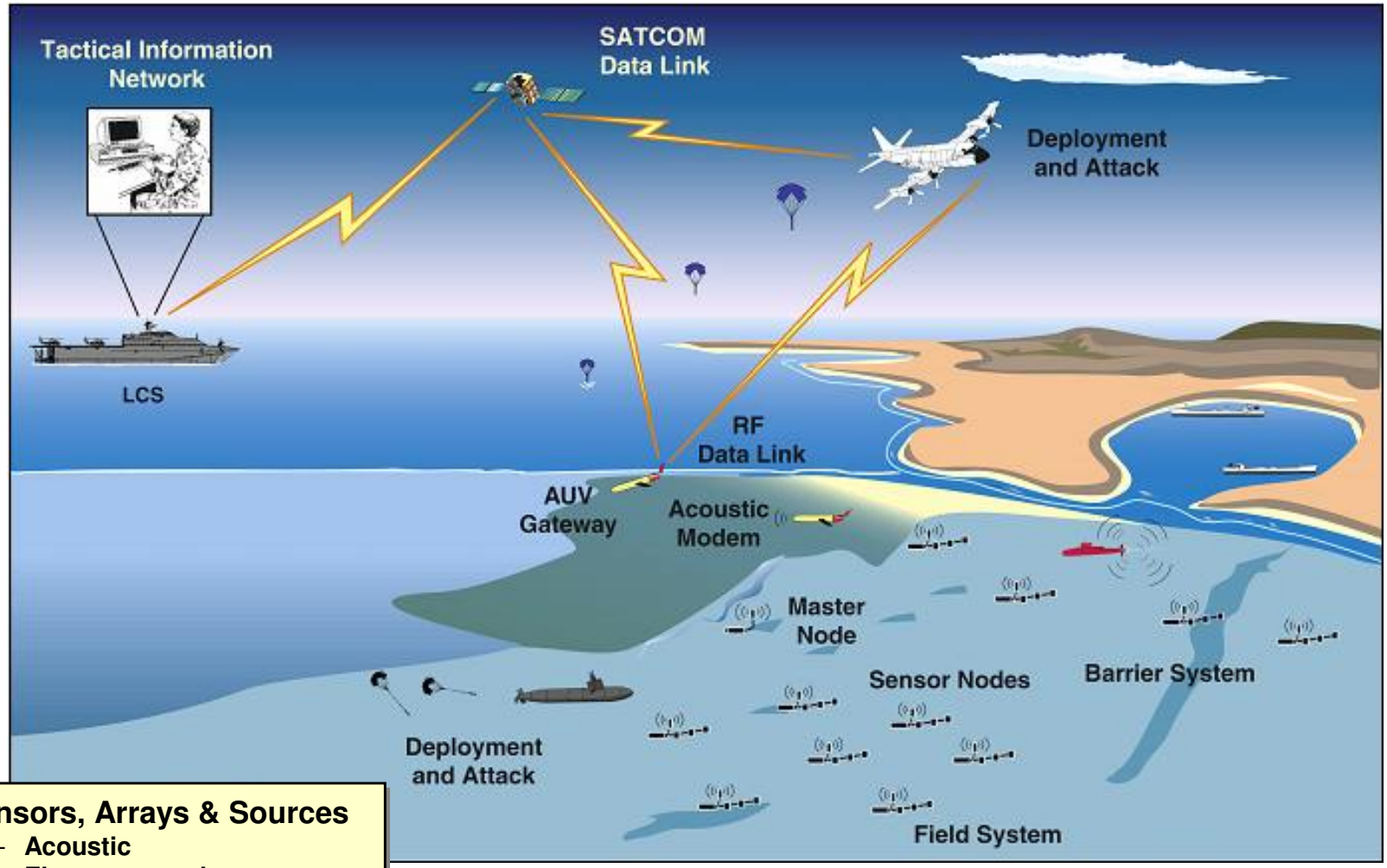
ASW

www.strategypage.com -

“in May two photographs were taken of a different, rather larger submarine, also at Wuhan shipyard. It appears the new submarine is as large or slightly larger than the 244 foot long (2350 ton displacement) Kilo Project 636. The DOD disclosed that this new class of conventional submarine has the code name “Yaun.”…

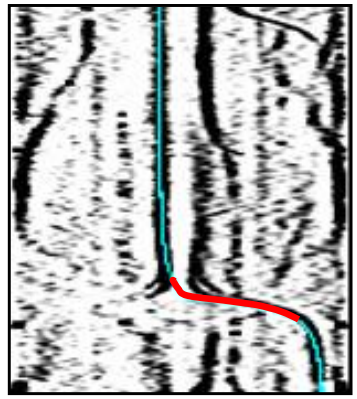
…There's been some claim that the new Chinese sub is a radical "surprise" for the U.S. Navy. Despite the charges that the Navy "didn't know" they were building it, in fact the Navy did. The "surprise" was that the boat was ready sooner than expected, but it's really hard to tell when a boat will be finished, given that they're always built under a shed. As for its capabilities, well, a lot is being said, but while the new boat seems to be different from the previous class, it's not clear that she's a major leap forward.”

Deployable Autonomous Distributed System (DADS)



Barrier Demo planned for FY05

Sensor Data Fusion



- **Sensors, Arrays & Sources**
  - Acoustic
  - Electromagnetic
- **Communication Links**
  - RF buoys
  - Acoustic modems
- **In-Node Signal Processing**
  - Acoustic, passive & active
  - Electromagnetic
  - Sensor data fusion
- **Master Node**
  - Network control
  - Network data fusion

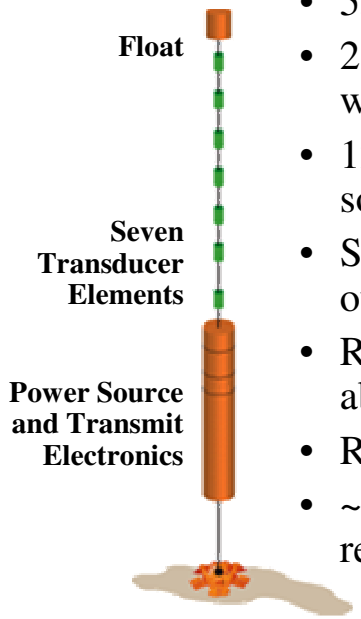
Moored and Mobile Gateways

Magnetic and Acoustic Sensors

Littoral ASW Multistatic Program (LAMP)
LWAD 03-4 / SHAREM 146 Results

- East China Sea, 5 – 7 October 2003
- Shallow Water, <100 m
- Environment Harsher than Expected with Strong Gradients below Mixed Layer

LELFAS (as deployed)



LELFAS SOURCE OPERATIONS

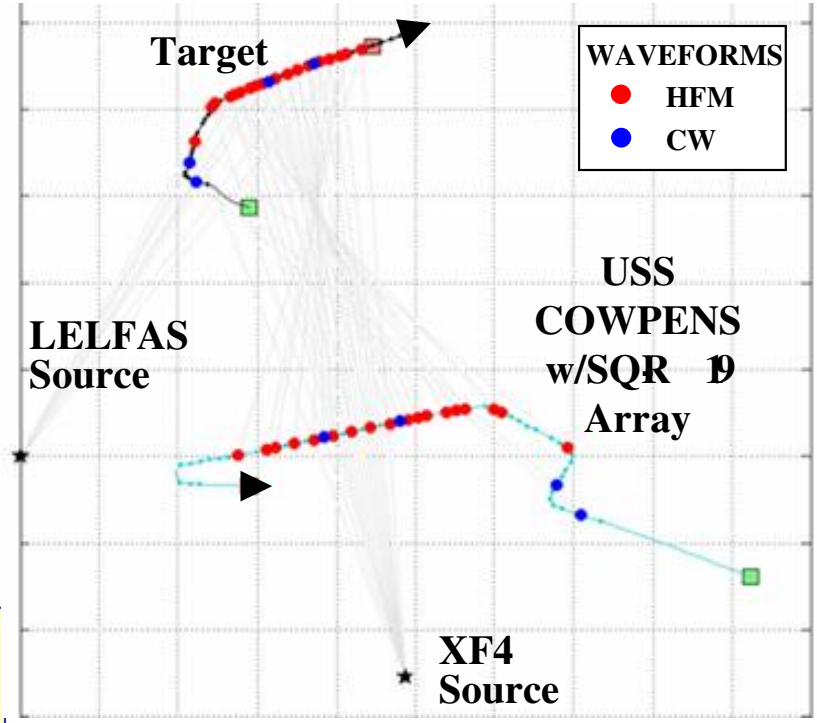
- 55 hrs nominal in water operation
- 214 pings, including library of 28 ASW waveforms
- 1225 seconds of pinging @ XXX dB max source level
- Successful unit operation via RF Comm link out to 7 nm range
- Real time adjustment of array depth to get above acoustic layer
- Real time adjustment of transmit power
- ~ 30% discharge of main battery- 70% remaining capacity

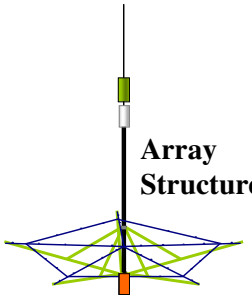
Successful Fleet demo:

- **Detected and localized diesel submarine**
- Autonomous **off board acoustic source**
- Fleet operated receivers
- Relevant **shallow water** operating area
- Tactically **significant ranges**
- **Cue for re acquisition and kill**

LAMP DETECTION OPERATIONS EXAMPLE

- Multistatic Operations with LELFAS and XF4 Transmissions Interleaved
- Real Time Detections using MARS Processor
  - Installed on USS COWPENS in Sonar Control
  - Processor Operated by COWPENS crew
- Detections Passed to Helo via CIC for Cue to Kill





Each buoy now an internet node allowing OTH P 3 Ops

Multi-Mode Magnetic Detection System (MMMDS)

Product Description:
Technical design package and ADM for a high performance magnetometer sensor and real-time, autonomous detection and localization algorithms for use in a UAV

S&T Issues:

Integrated sensor, control electronics, ancillary sensors and real-time processing aboard UAV

P2K He4 Magnetometer

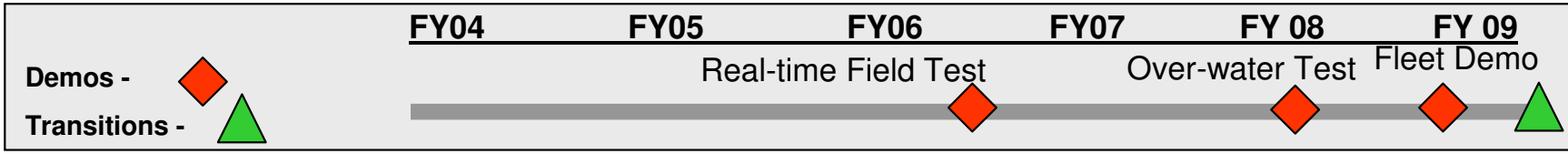
Planned Demos/Transitions:

FY 08 Over-water tests on manned and unmanned aircraft against threat representative platforms; FY 09 Fleet Demo

FY 09 Transition to NAVAIR PMA 263/264

Warfighting Payoff:

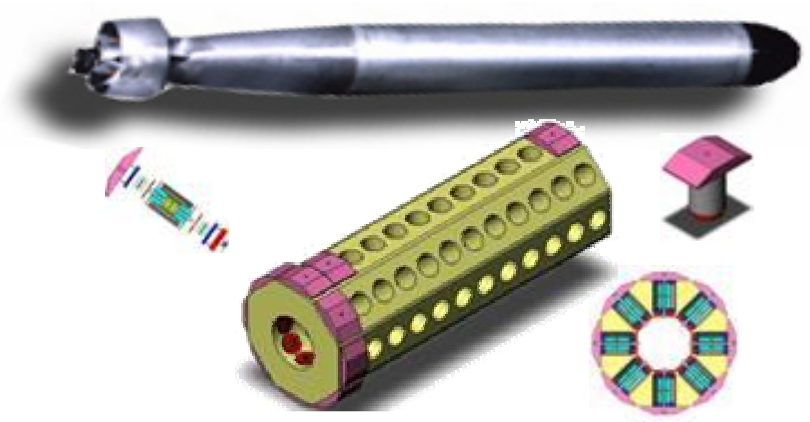
- Supports Sea Power 21 Sea Shield Capability Pillar
- 3-D precision localization in a UAV-compatible package
- Detection, localization, and tracking capability in small, light-weight, ultra-sensitive, low power, multi-mode,



Counter Torpedo DCL

Major Products	Benefits
Threat Recognition Processing	Detection, Classification, & Localization for Salvoes of 4 Low False Alarm Rate
Compact High Power Source	Extended Range Threat Tracking of 4 Targets
Experimental Receive Array	Early Warning Detection & Tracking of 4 Threats

Compact High Power Source



- High Power Active Detection of Threats
- Active Interrogation of Up to 4 Threat Torpedoes
- Active Search Capability for Some Threats
- Towable from existing Nixie winch
- Early Warning Passive Detection of Threat Salvoes
- Acoustic Intercept of Active Transmissions
- Receiver for High Power Source Echoes
- Resolution of Bearing Ambiguity

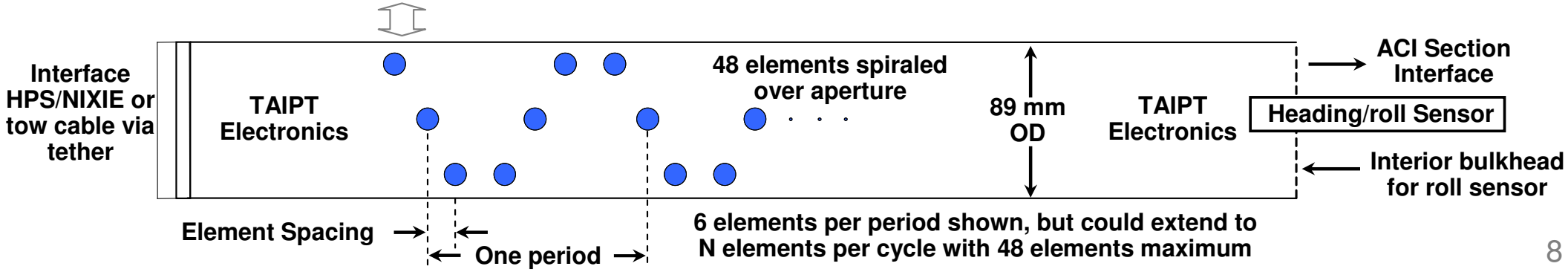
AN/WSQ-11 System

- Combined Towed Sensor & Countermeasure
- Anti-Torpedo Torpedo All Up Round for all Threats
- Enhanced AN/SLQ-25A Improvements

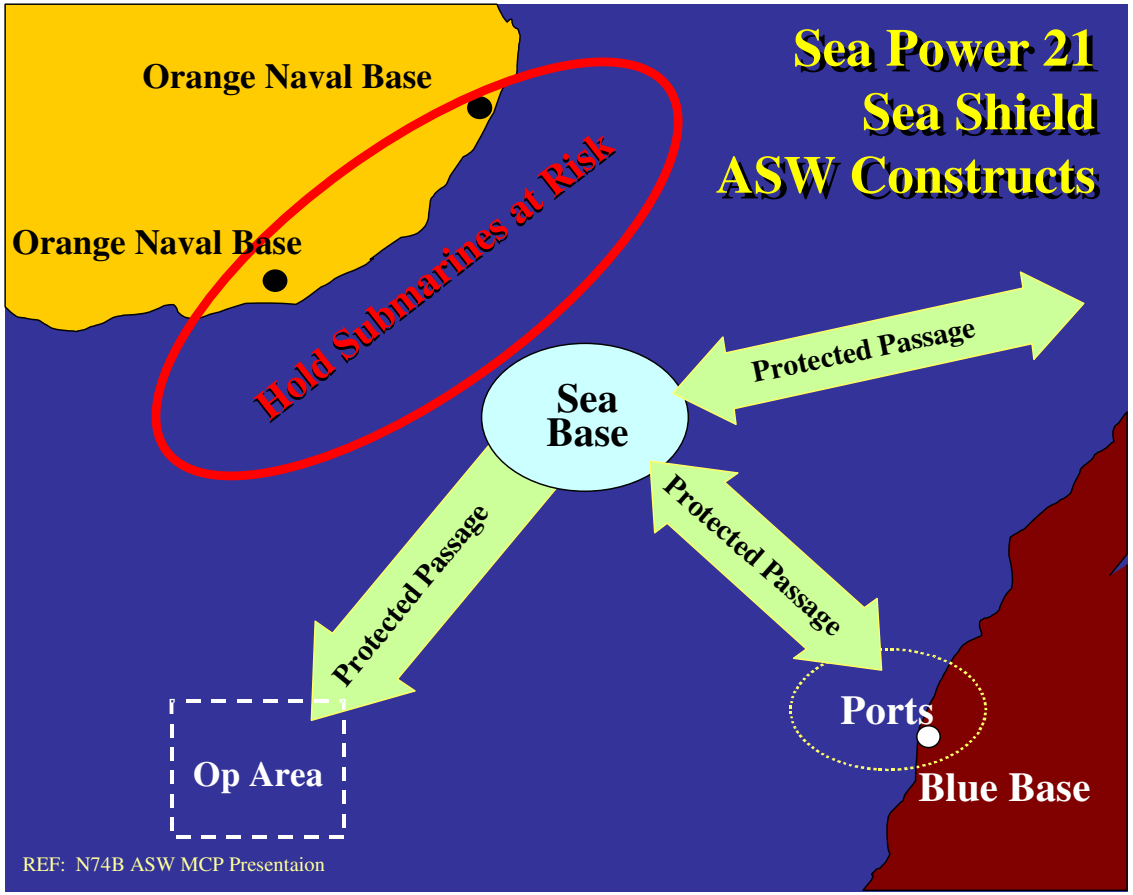
Advanced Threat Recognition Processing

- Detection, classification and localization of up to 4 threat torpedoes
- Targeting data for Anti-Torpedo Torpedo
- Integrated surface picture for low false alert rate
  - Surface Search Radar
  - 360° Camera

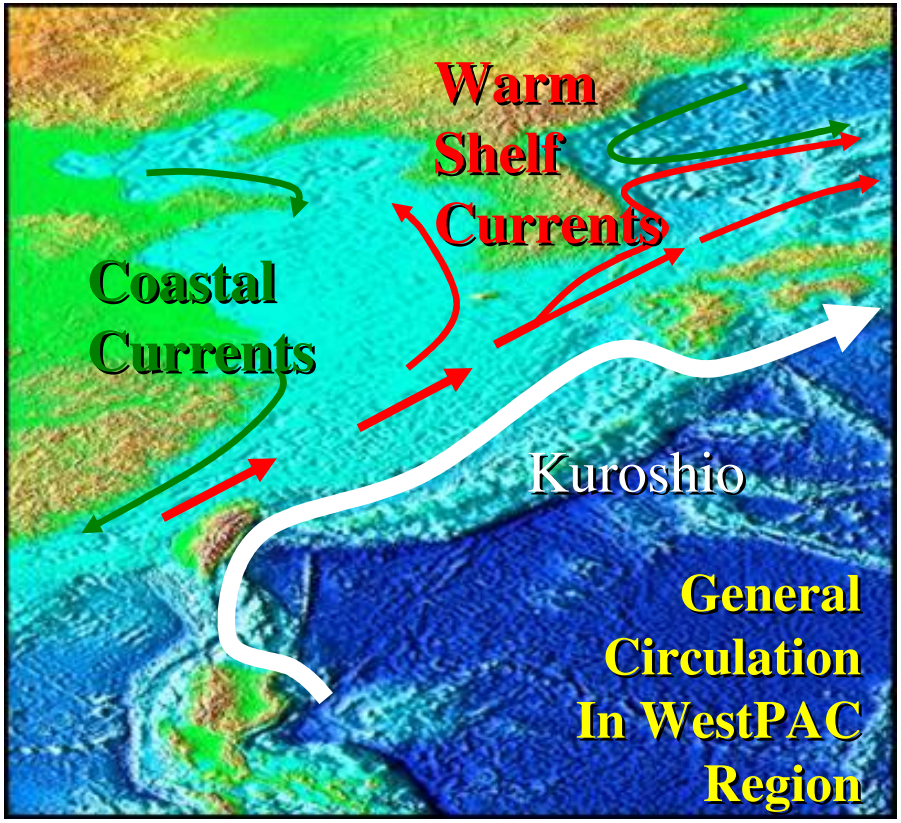
Experimental Receive Array



Persistent Littoral Undersea Surveillance
Operational Capability Sought



Provide Persistent ASW Surveillance in complex operating environments



Develop And Demonstrate:

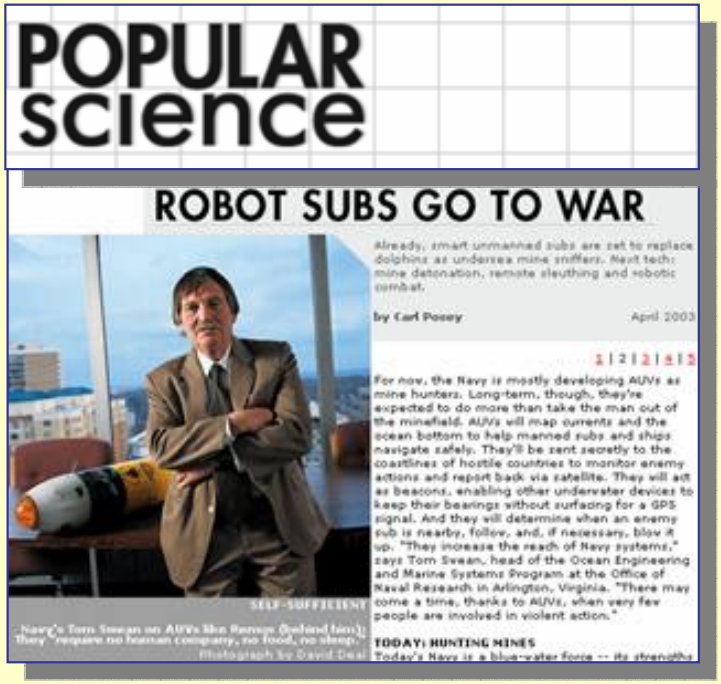
- Autonomous Survivable Sensors
- Communications
- Power
- Field Command And Control
- Environmental Adaptability
- Deployability
- Scalability
- Affordability

Reduce the "detect-to-engage" timeline in a *sensor-rich* approach

Tentatively:
6.2 - FY05-07 $35M
6.3 - FY06-10 $125M

MIW

REMUS and BPAUV


POPULAR science

ROBOT SUBS GO TO WAR

Already, smart unmanned subs are set to replace dolphins as undersea mine sniffers. Next tech: mine detonation, remote sleuthing and robotic combat.

by Carl Posey April 2003

1 | 2 | 3 | 4 | 5

For now, the Navy is mostly developing AUVs as mine hunters. Long-term, though, they're expected to do more than take the man out of the minefield. AUVs will map currents and the ocean bottom to help manned subs and ships navigate safely. They'll be sent secretly to the coastlines of hostile countries to monitor enemy actions and report back via satellite. They will act as beacons, enabling other underwater devices to keep their bearings without surfacing for a GPS signal. And they will determine when an enemy sub is nearby, follow, and, if necessary, blow it up. "They increase the reach of Navy systems," says Tom Swean, head of the Ocean Engineering and Marine Systems Program at the Office of Naval Research in Arlington, Virginia. "There may come a time, thanks to AUVs, when very few people are involved in violent action."

TODAY: HUNTING MINES

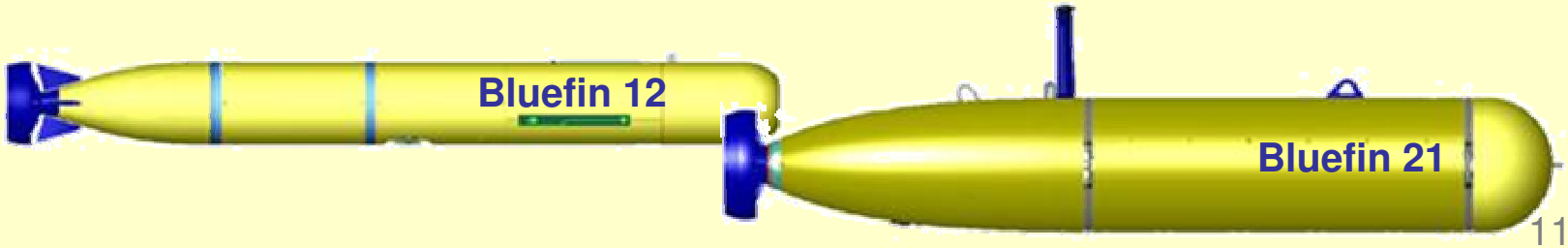
Today's Navy is a blue-water force -- its strengths

HYDROID

East Falmouth, MA

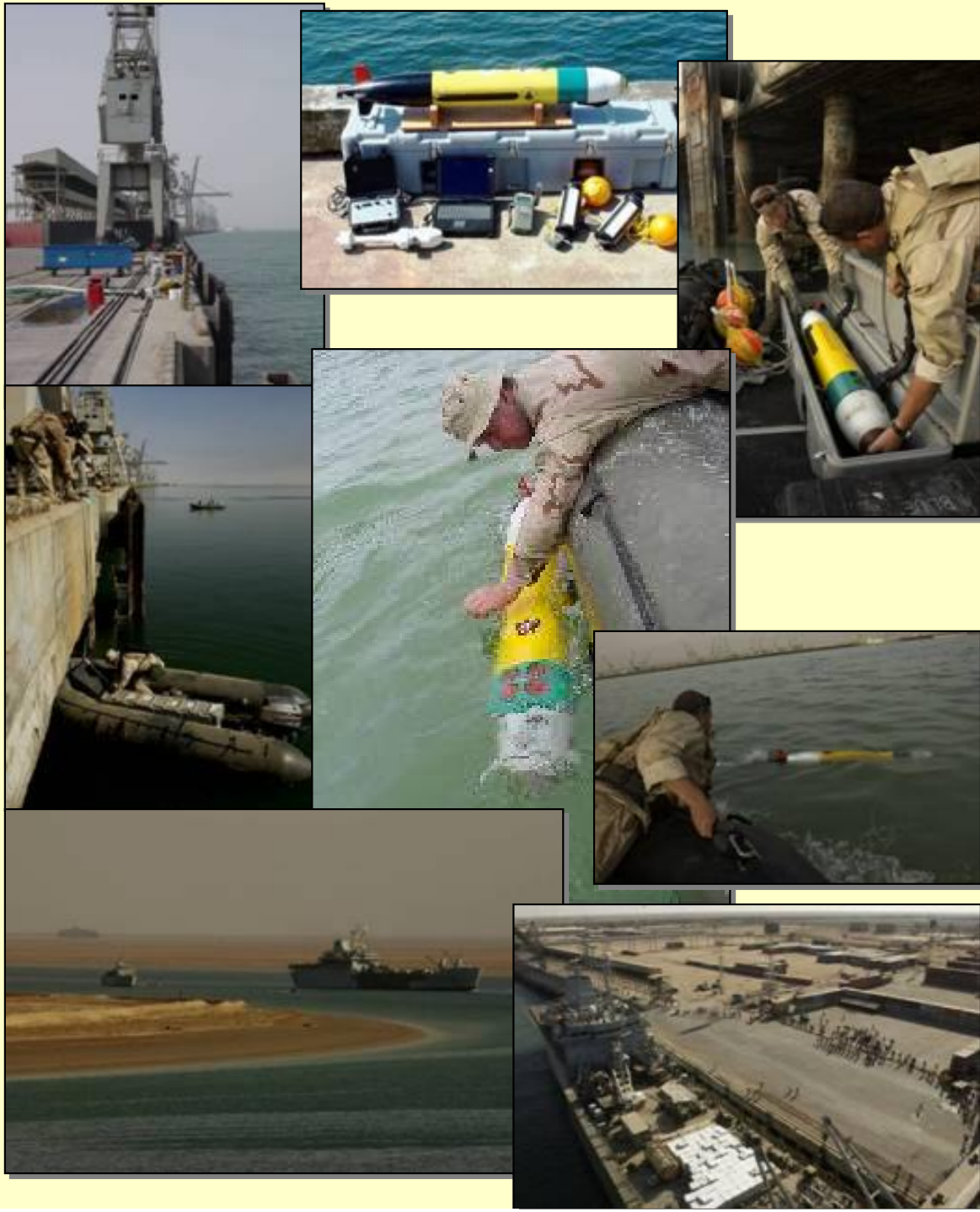
Cambridge, MA

Extended Operations: 17 hours w/Lithium Polymer batteries
Rapid Turn Around: < 30 minutes, battery exchange and mission prep



Ports of Umm Qasr/Az Zubayr Operation Iraqi Freedom

- **Naval Special Clearance Team ONE**
  - deployed to the Arabian Gulf in OIF
  - assigned to clear the Ports of Umm Qasr and Az Zubayr
- **Operated the ONR-developed REMUS UUV**
  - first in a multi-sensor approach to declaring the harbor clear of mines
  - only prototype system taken to a wartime environment and extensively used during OIF
- **Minimal logistics support requirements**
  - 6 UUV's and support equipment took 3 of 108 aircraft pallet positions for command deployment
  - Only req. 20' x 8' area on support ship
  - Two week "fly-away" UUV package loaded in 2 hours and inserted by helo
- **Quick Startup** - First UUV started within 2 hours of arriving in Umm Qasr, First 3 berths searched in a 4 hour mission
- **UUV Statistics at Umm Qasr:**
  - 10 Missions/16.5 hrs vehicle run time
  - 2,500,000 sq meters searched
  - 97 man-made shapes identified
  - 36 Tires, 55 Misc. Debris, 4 Wrecks, 2 Oil Drums
- **UUV Statistics at Az Zubayr**
  - 940,000 square meters searched
  - 2 Missions/5 hrs vehicle run time
  - 40 Tires, 1 Anchor, 1 Piece of Debris



Multi-Vehicle Collaborative Systems
Key Enablers: Communications and CAD / CAC / CAI

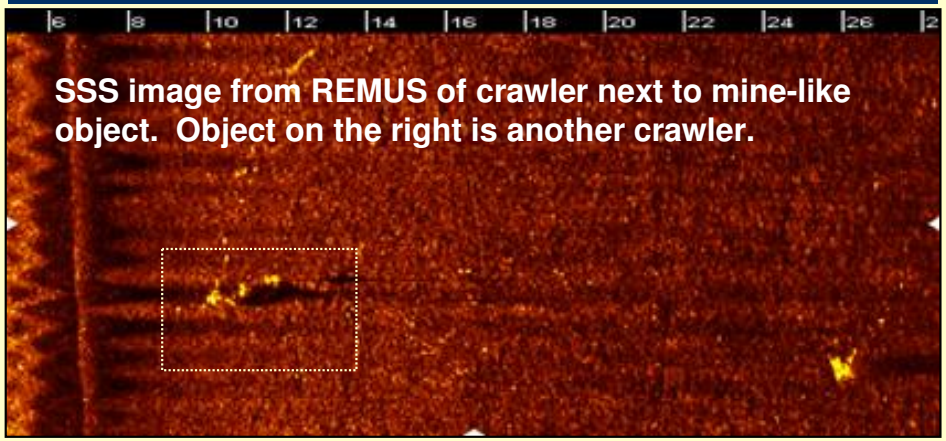
REMUS

TAR & Talon Crawlers

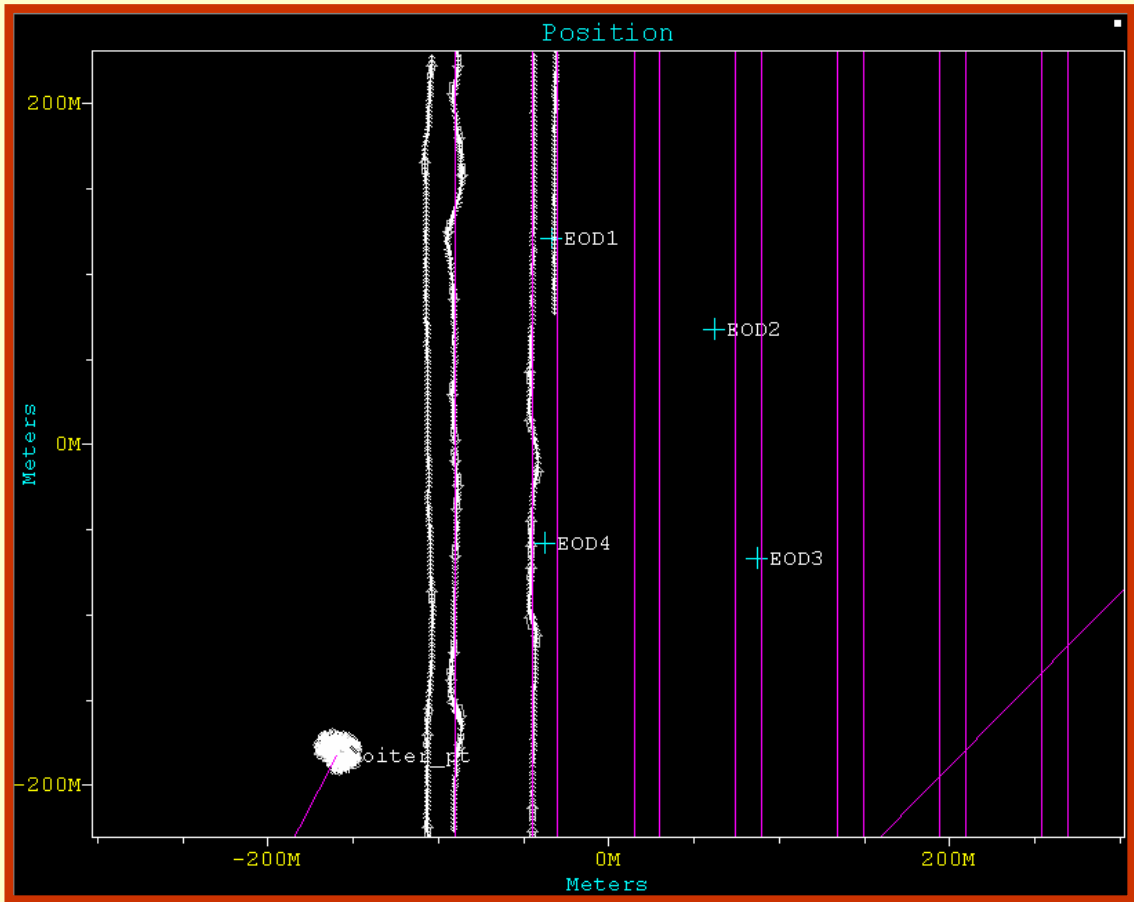
Micro-Modem

Objectives:

- Operate and control multiple UUVs concurrently using the WHOI gateway buoy, digital transponders, and the micro-modems.
- Perform automatic reacquisition of contacts (response to CADCAC messages) and automatic re-tasking (response to re-direct commands) between vehicles
- Demonstrate the Reacquire, Id, and Neutralize (RIN) sequence using automatic vehicle-vehicle re-tasking



SSS image from REMUS of crawler next to mine-like object. Object on the right is another crawler.



MCM UUV Mission Modules

Program Initiated in FY03
- Two UUV contracts

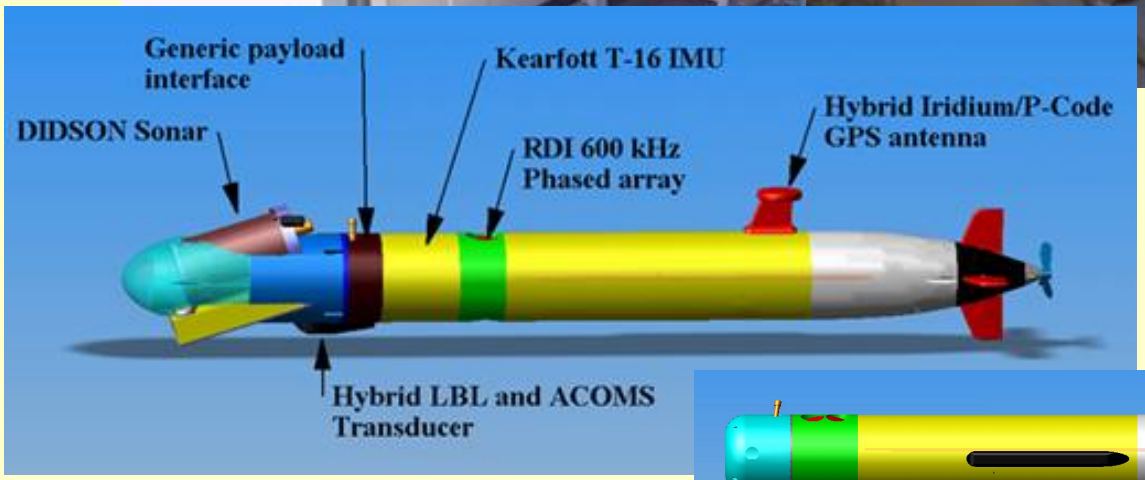
Modules Built and Delivered in Augus
- Completed outfitting in Oct

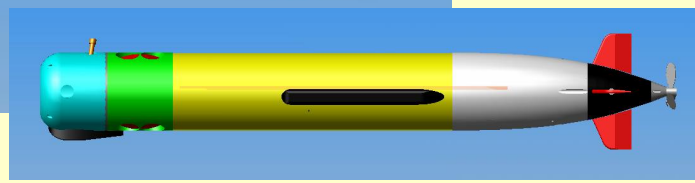
UUV Delivery FY04
- 4 BPAUV 21” UUVs (Search)
- 6 REMUS 8” UUVs (search/ID)

Fleet Operator Training Mar 04
- 2 teams from CMWC

Experimentation on HSV 2
- NATO Blue Game: May 04
- CJTFEX 04-2: June 04
- RIMPAC: July 04
- Sea Viking: Oct 04
- CJTFEX 05-1: Dec 04
- Kernal Blitz: June 05

CONTECH Wargame Series
- Supports UUV HSV/X-Craft Experimentation





Standoff Mine & Obstacle Breaching Warheads

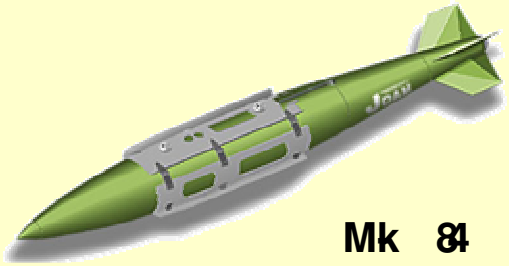
Concept:

- Precision Guided CMCO Warheads
- Aircraft and Naval Gun Delivery
- JDAM Assault Breaching System (JABS) } Near Term
- Aircraft & Naval Gun Delivered CM Darts } Far Term

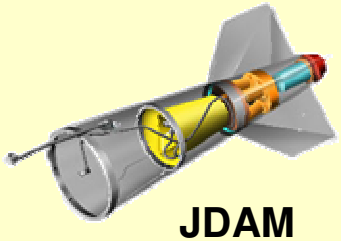
Team:

- Boeing Phantom Works
- Lockheed Martin Advanced Projects
- SAIC
- NSWC-IHD
- NSWC-PC
- NAWC-CL

Near Term



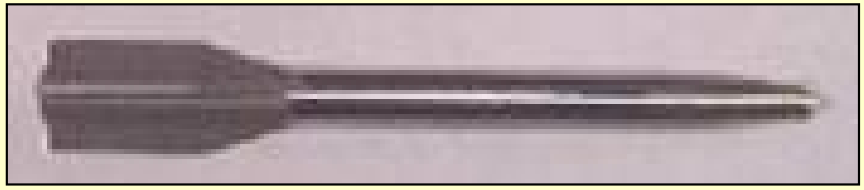
Mk 84



JDAM Tail Kit

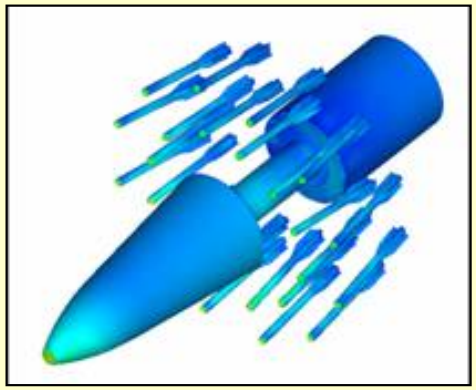
Far Term

MODS Dispenser



Countermine Dart

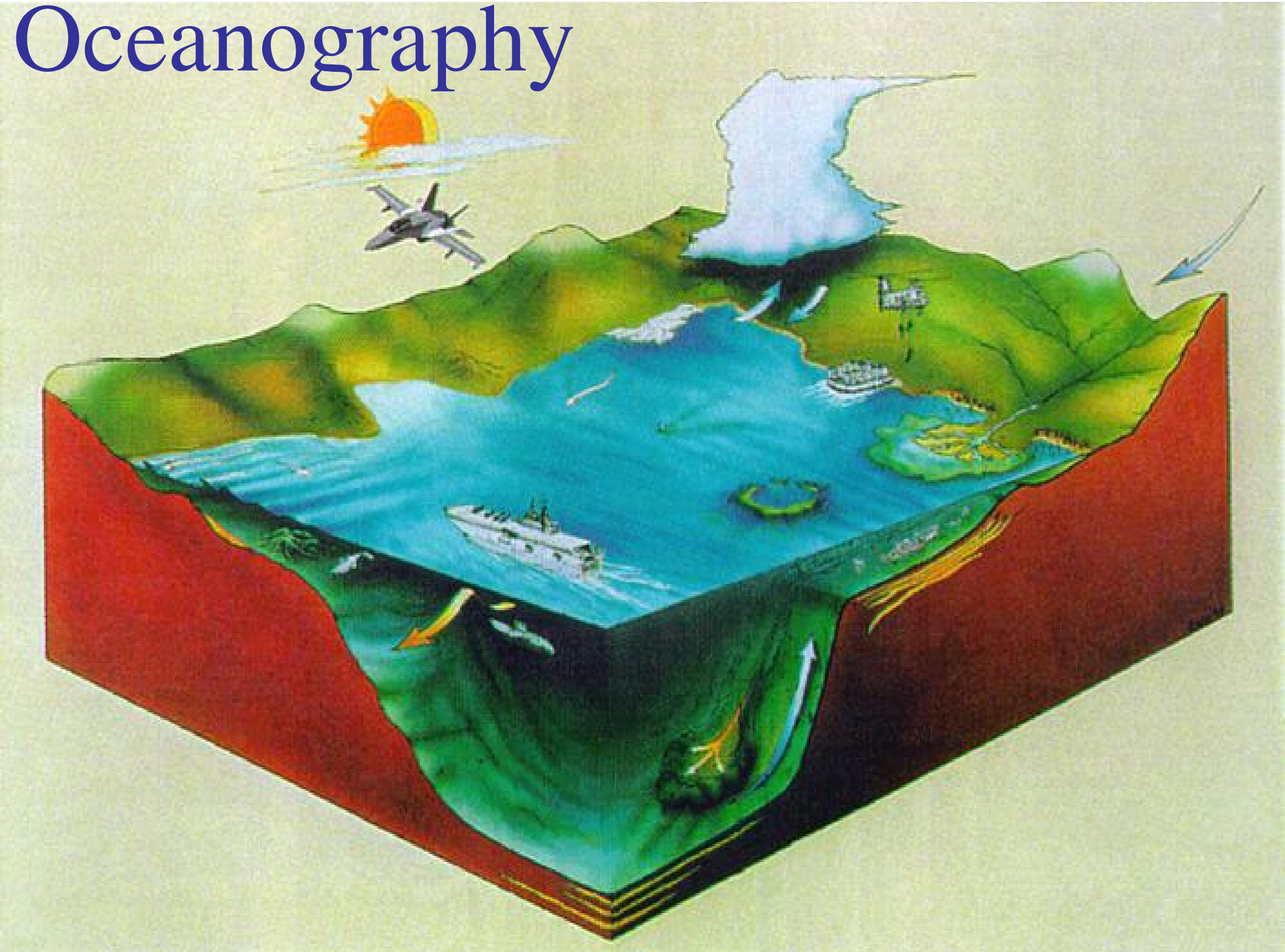
Dart Dispense



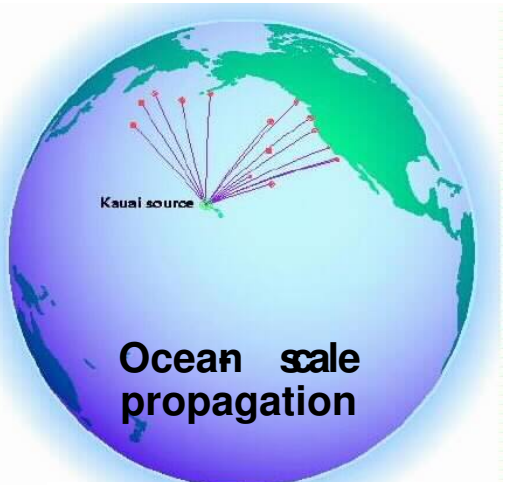
CFD Simulation

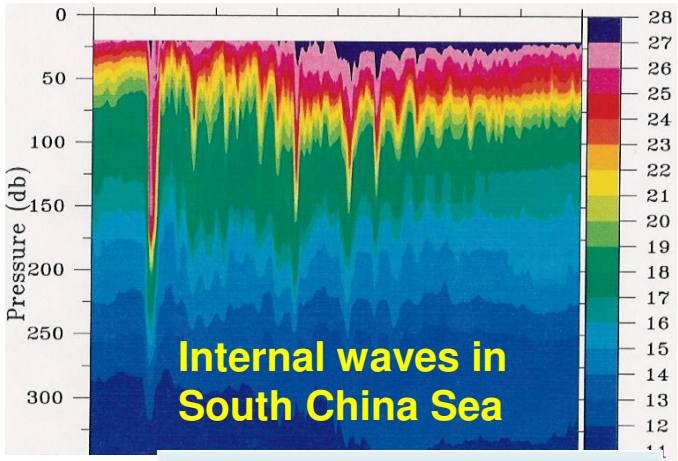
Target Damage

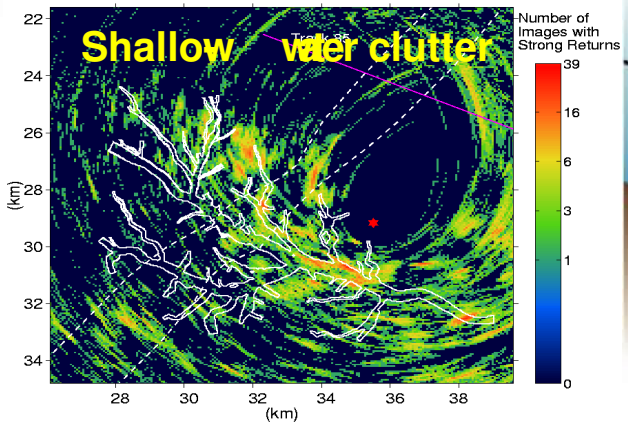
Oceanography

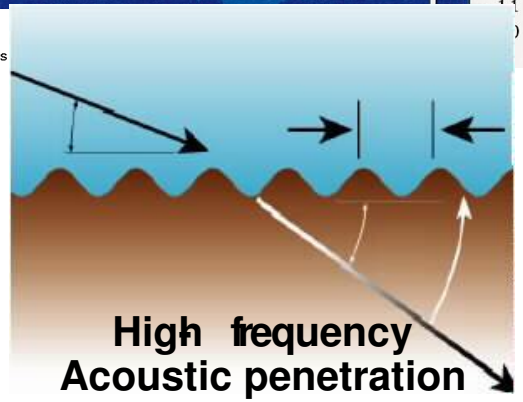


Ocean Acoustics NNR









Objectives

Basic research unique to Navy needs

- ASW:Long range acoustics for basin scale applications and shallow water acoustics for littoral waters
- MCM: Sediment acoustic research in support of improved performance against present and future mines
- Comms: Physics of underwater acoustic communications
- Recruitment: Cultivation of a viable acosutics research community to solve present and future Navy needs

Component Projects

Shallow Water Acoustics

- Field work: Geo-clutter, ASIAEX, SW06
- 3-D propagation; effects of internal waves; bottom inversion
- Sources of clutter: geology, biology

Sediment Acoustics

- Field work: SAX99, SAX04
- Low-grazing angle penetration; Sound-speed dispersion; Poro-elastic acoustics

Long-Range Propagation

- Field work: NPAL, LOAPEX, SPICE04
- Acoustics of spice, sea-mounts, internal waves

Special Awards; monograph series

Deliverables

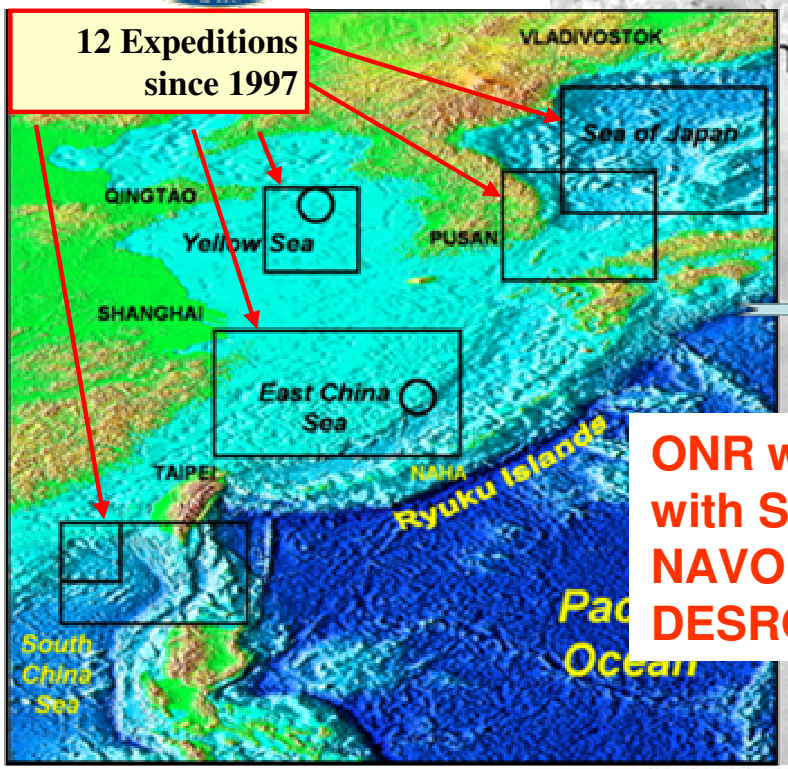
Field experiments:

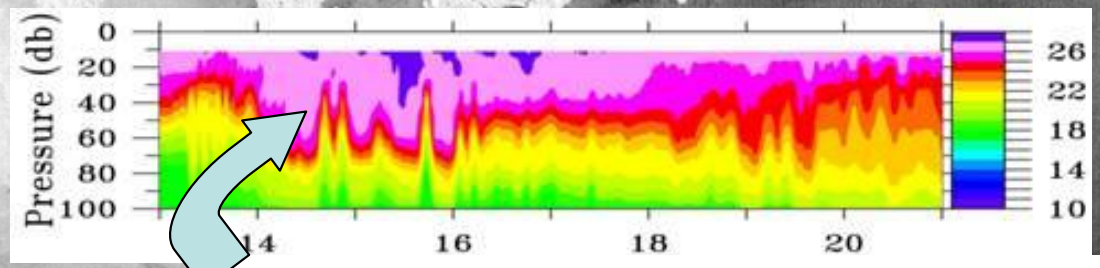
Models and theories:

- Shallow water clutter models
- Propagtion through internal waves
- Long-range horizontal refraction
- Rough interface scattering models
- Geoacoustic inversion methods
- Poro-elastic bottom model
- Sediment acoustic penetration model

Monographs and journal publications

WESTPAC Oceanography – Supporting future fleet Ops

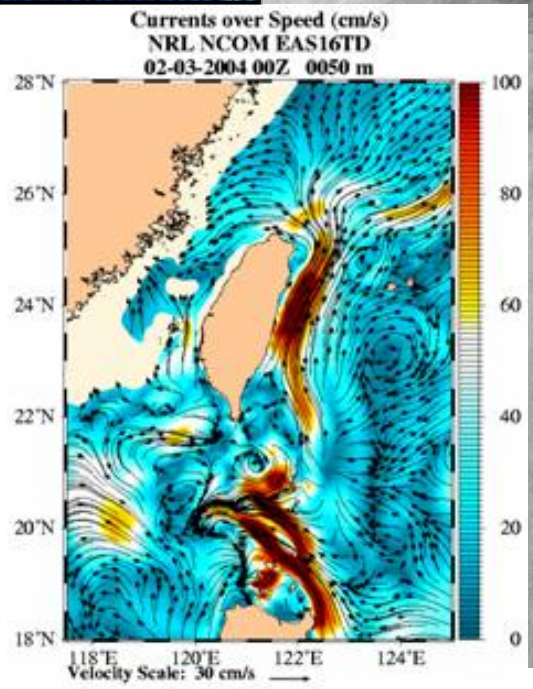


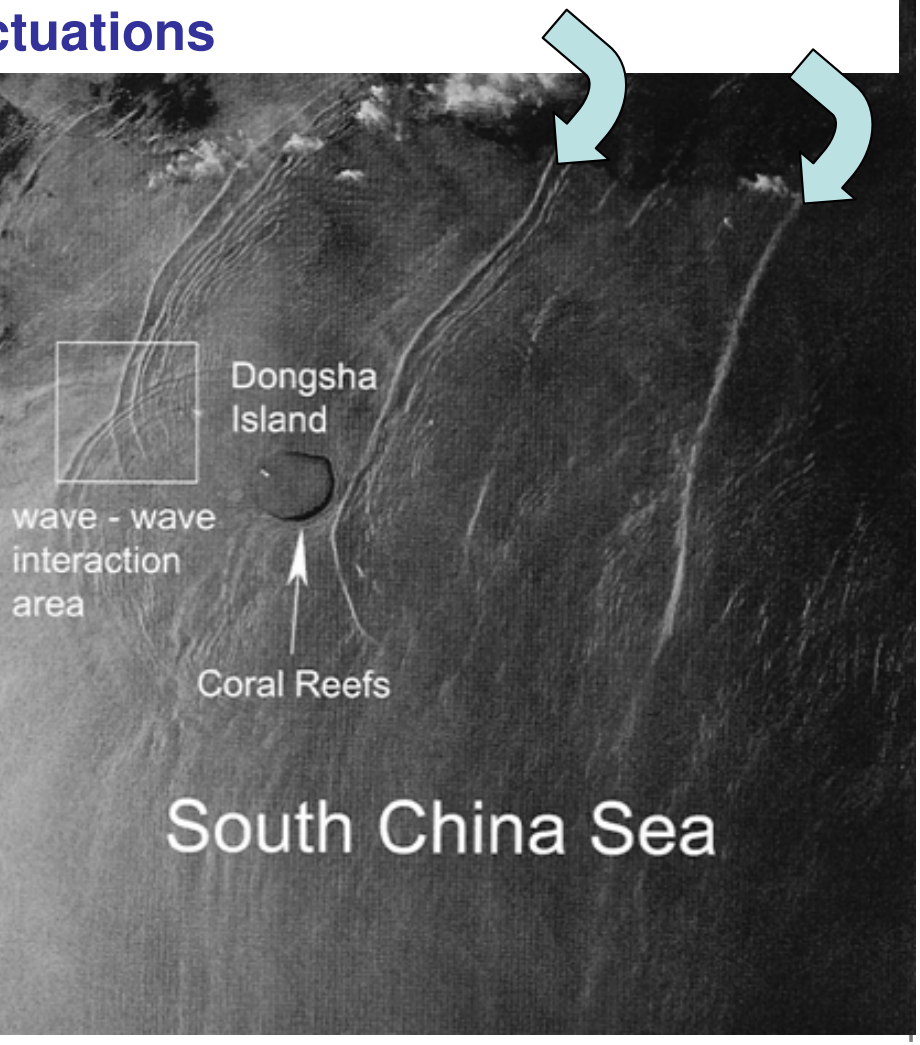


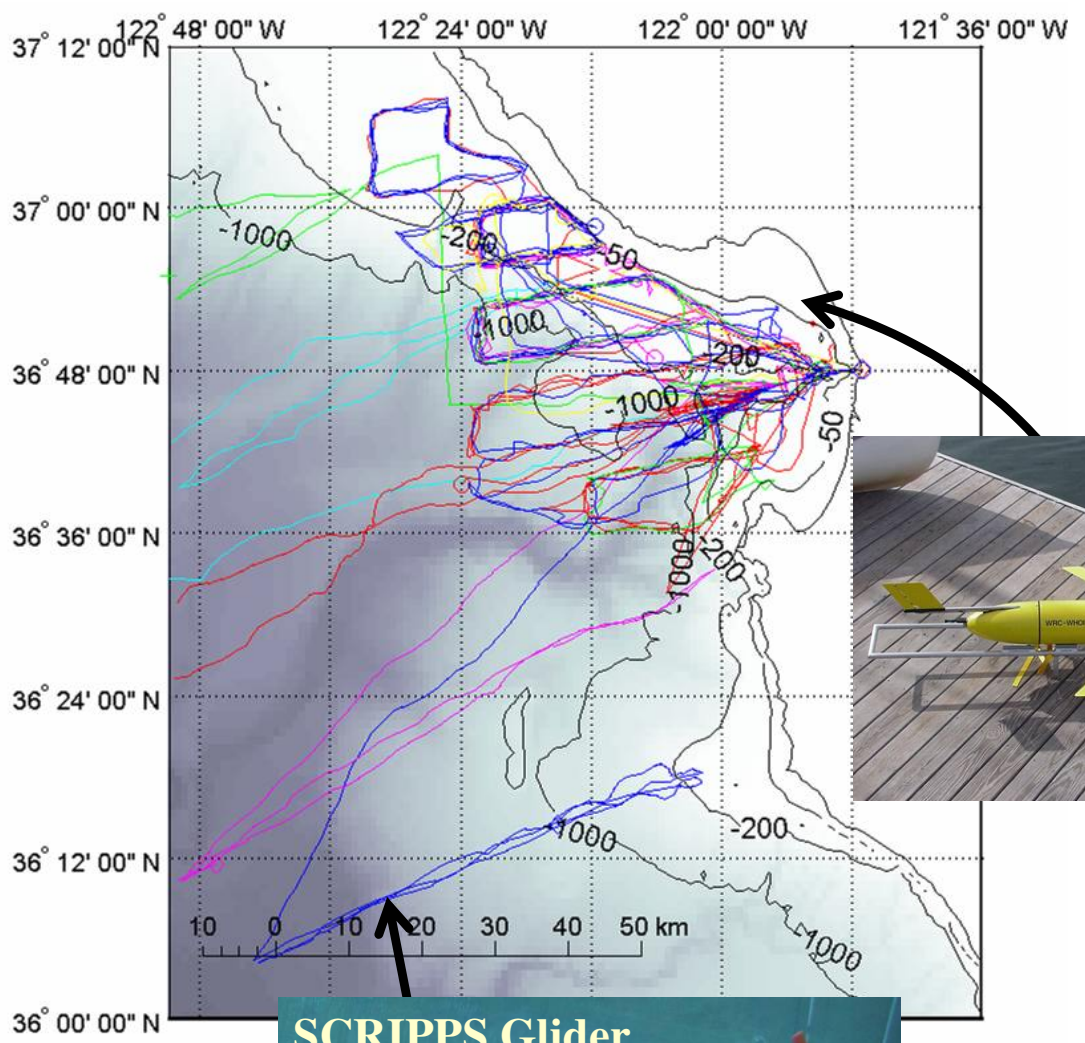
Internal Waves cause up to 15 db signal fading and intense buoyancy fluctuations

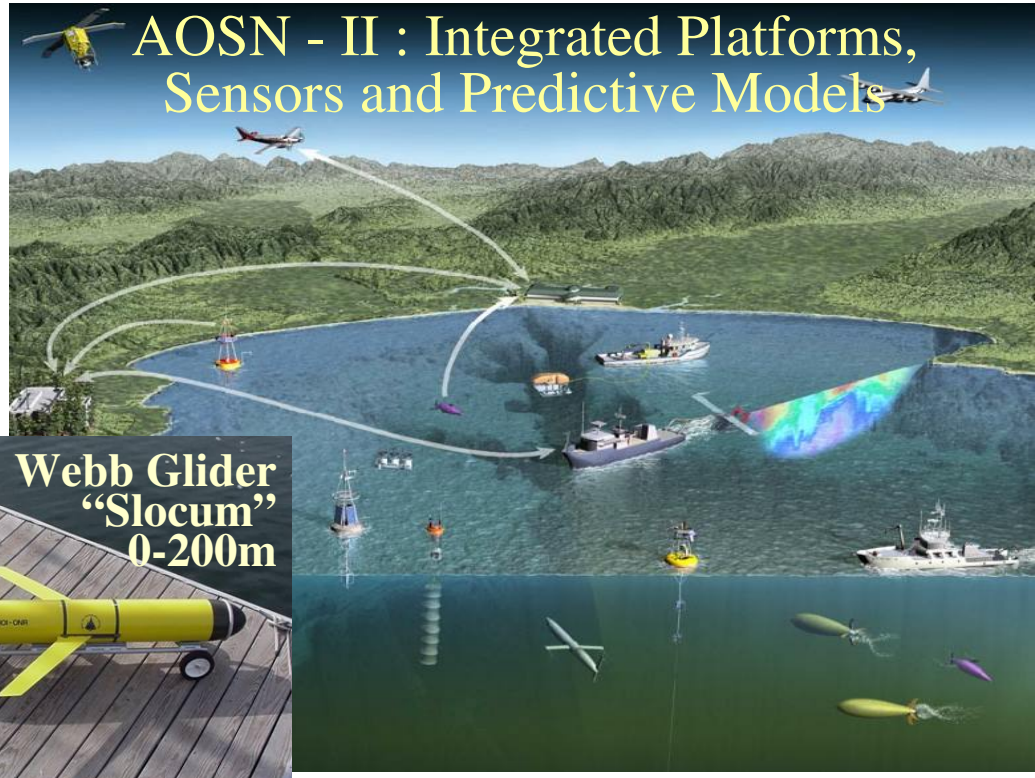
ONR working with SUBPAC, NAVO, and DESRON 15

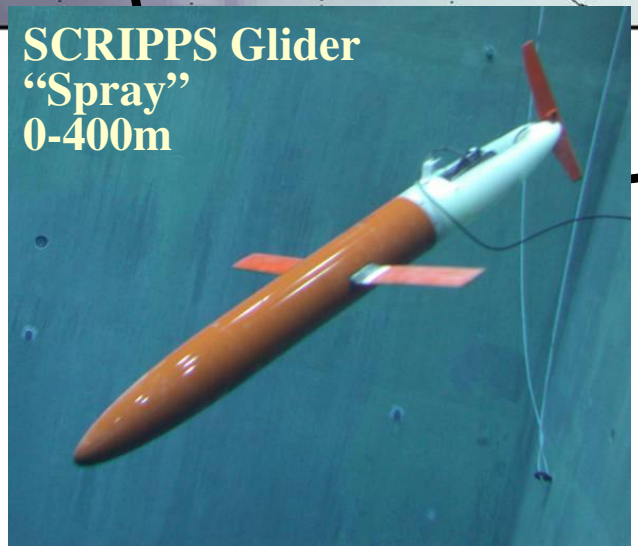
- High Resolution and Numerical Models
- Understanding Acoustic uncertainty and reverberation causes

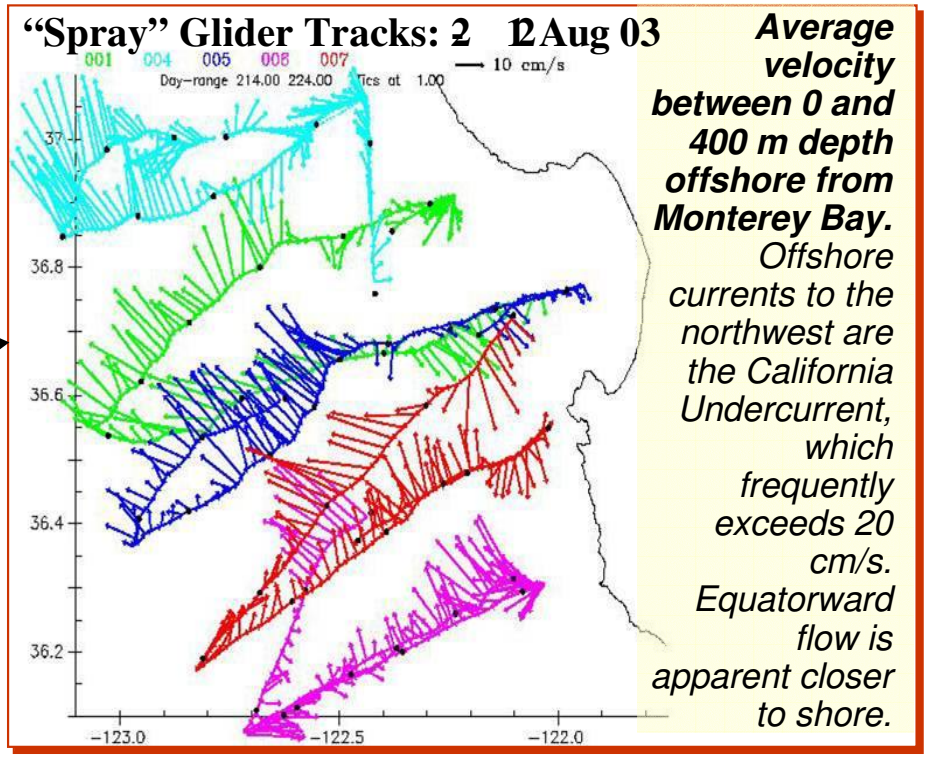






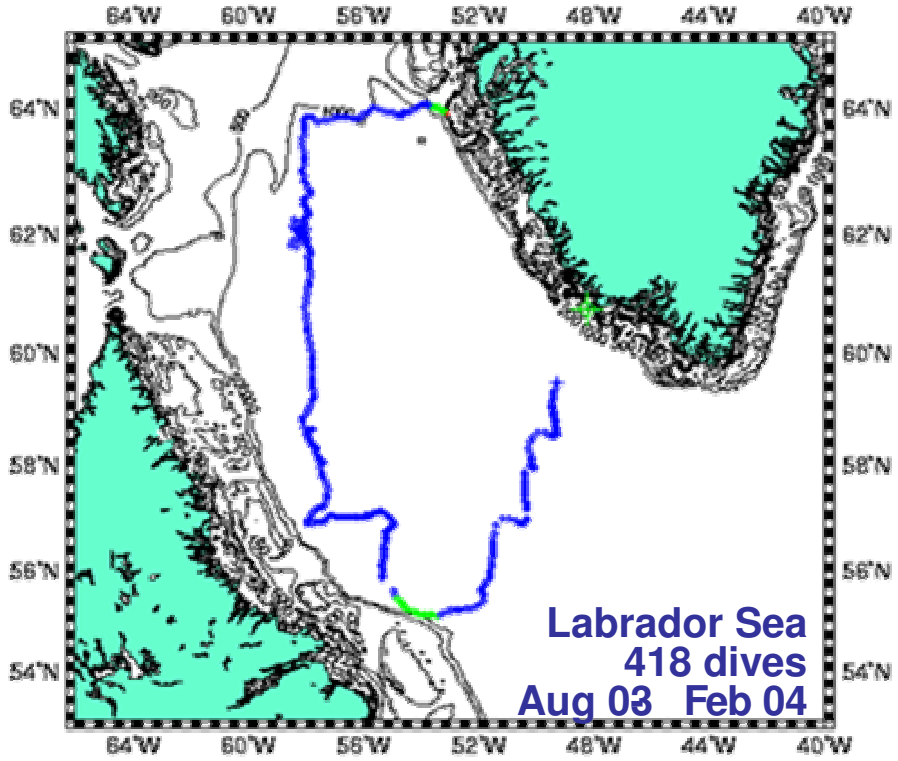


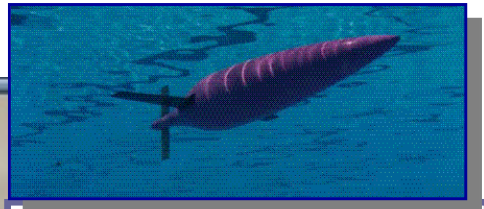


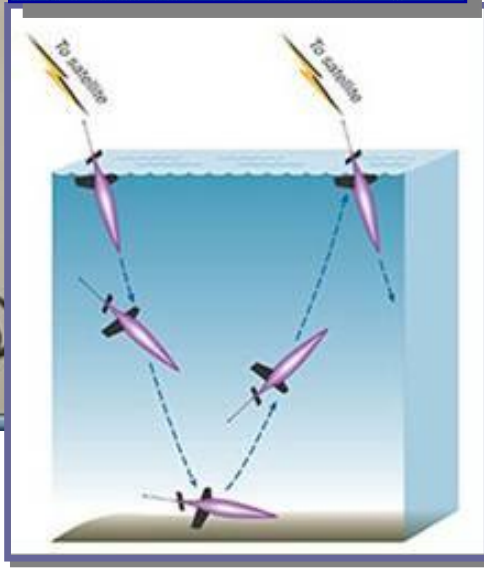


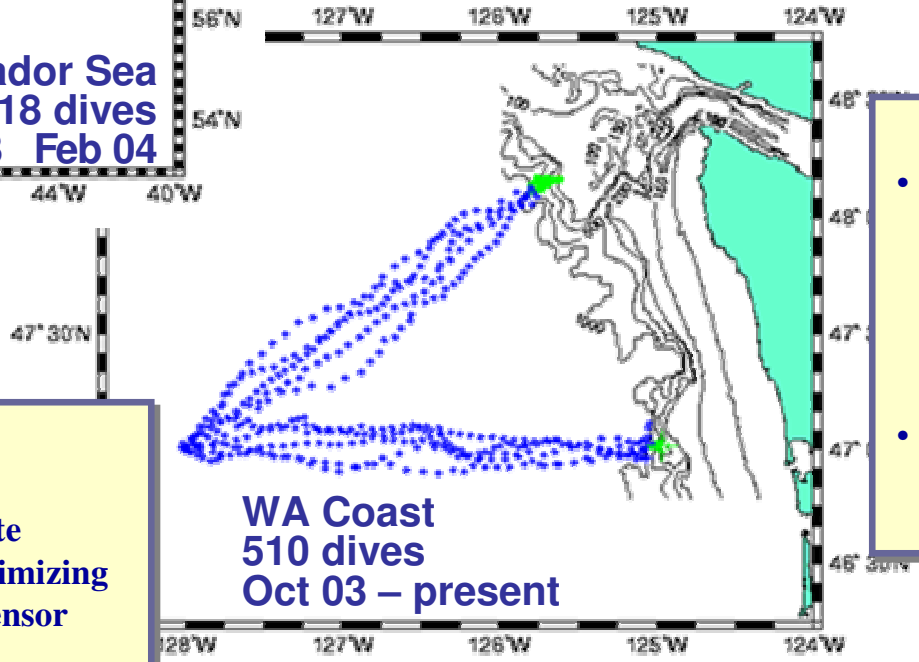
Average velocity between 0 and 400 m depth offshore from Monterey Bay. *Offshore currents to the northwest are the California Undercurrent, which frequently exceeds 20 cm/s. Equatorward flow is apparent closer to shore.*

Seaglider Surveys









RIMPAC 04

- **Improve fleet ASW capability**
  - Glider data merges into **MODAS/Lite**
  - **Capture diurnal variability** for **optimizing sensor / platform placement and sensor settings**
- **Ocean acoustic variability** contribution to **sensor performance uncertainty**
- Data merges into **MEDAL** and **MIW/SPECWAR** operators

Undersea Dominance 04

- **Provide CTD** (Conductivity, Temperature, Depth) and **Current** measurements for **determining SVP** (Sound Velocity Profile) and major current in this area
- Distributed quasi-real-time for **ingest to MODAS** and/or acoustic models

The Environment as Advance Force Intelligence

BACKUPs

Ocean Acoustics NNR

Sea Shield

Strong Field Program

- 3-yr cycle: major experiment per year, followed by 2 years of analysis; alternate between 3 thrusts
- multi-institutional and multi-disciplinary; with detailed envt'l measurements
- thorough planning & analysis workshops
- DURIP commitment towards instrumentation
- experiments & analysis ~50% investment

Adequate & Stable $ Per Investigator

- *fund key PIs at > 50%* available research time
- move towards 3+-year grants

Healthy "Pipeline"-Young Investigators

- *special research awards* ($1.17M in FY04) in ocean acoustics
- young participation in workshops & experiments

Research Focus areas:

Shallow Water:
- internal waves effects
- scattering due to seafloor
- surf zone ambient noise
- bottom inversion
- time reversal

High Frequency:
- physics of sub-critical acoustic penetration of the seabed
- acoustic coupling to objects at the seabed: proud, buried
- underwater acoustic comms

Long Range:
- fundamental limits of ocean-scale acoustics
- shadow-zone acoustics
- ray vs wave modeling
- long range comms

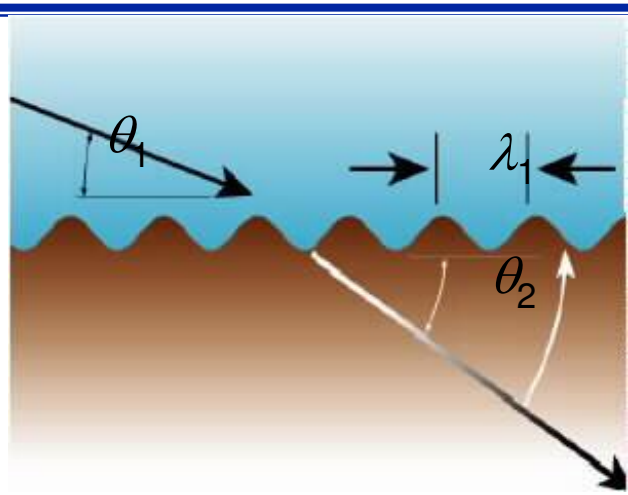
Ocean Acoustics NNR

Sea Shield

First and the model ***National Naval Responsibility (NNR)***

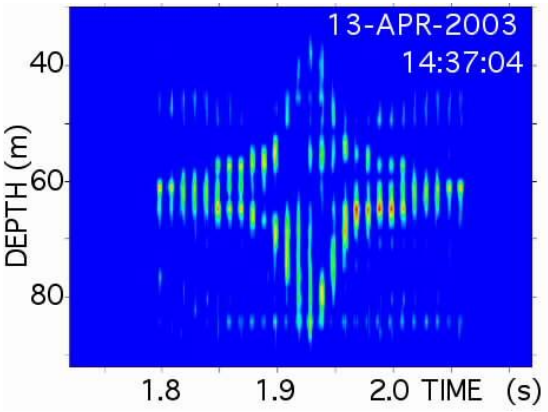
Supports Sea Shield through S&T that:

- develops understanding of physics of ***buried mine detection*** through broadband/synthetic aperture sonar
- explores capabilities and limitations of ***acoustic comms*** for Forcenet and persistent undersea surveillance
- produces faster, more accurate ***bottom inversion methods*** that are key to a successful littoral ASW strategy
- supports the understanding and exploitation of ***acoustic vector sensor data*** as applied to MCM and ASW scenarios
- determines and models the mechanism for ***sound penetration of shadow zones***

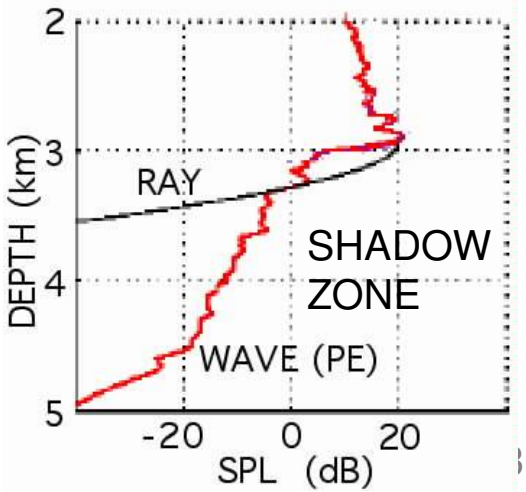


High-frequency: Acoustic penetration below critical angle by rough surface scattering for buried mine detection

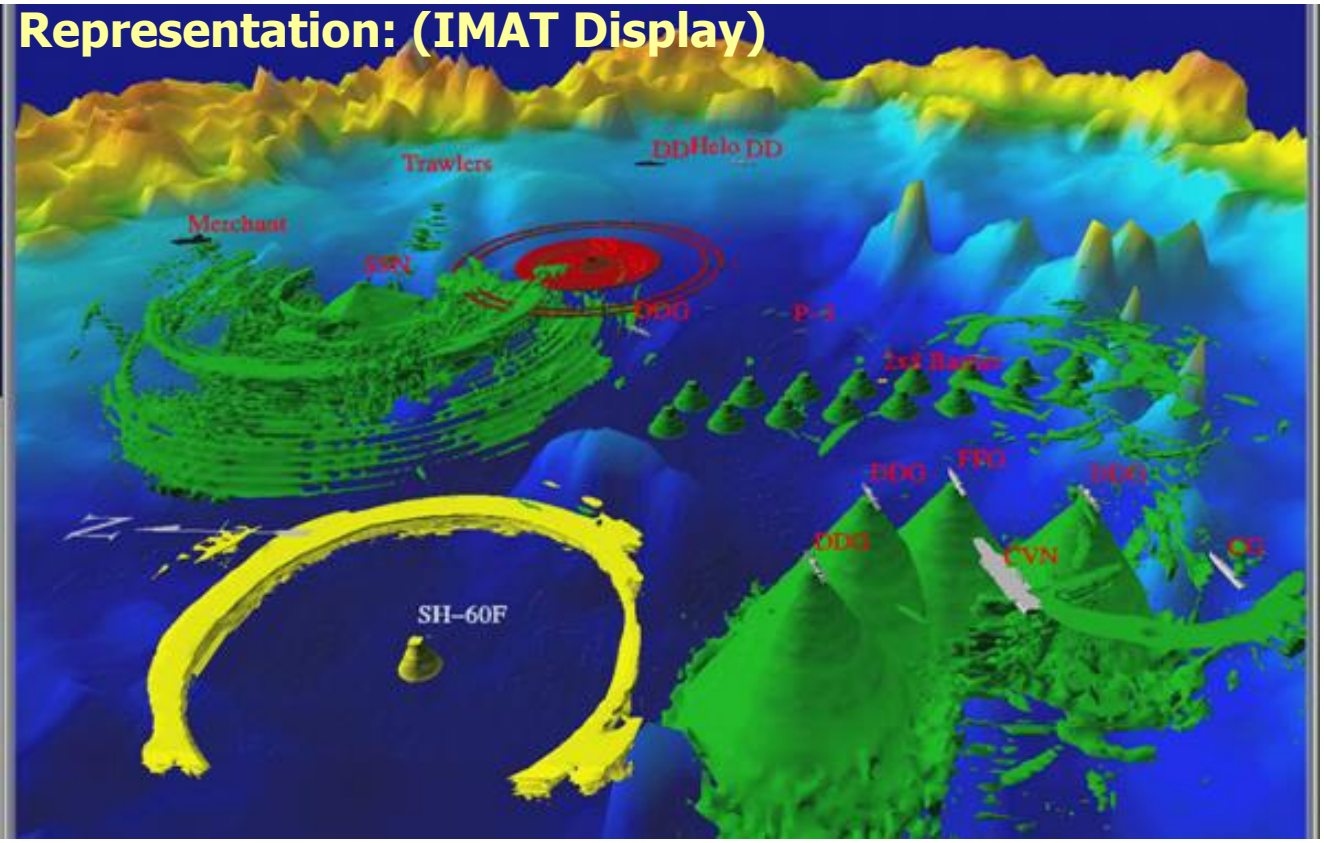
Shallow-water: Demonstration of sound control in space and time - for ASW and MCM

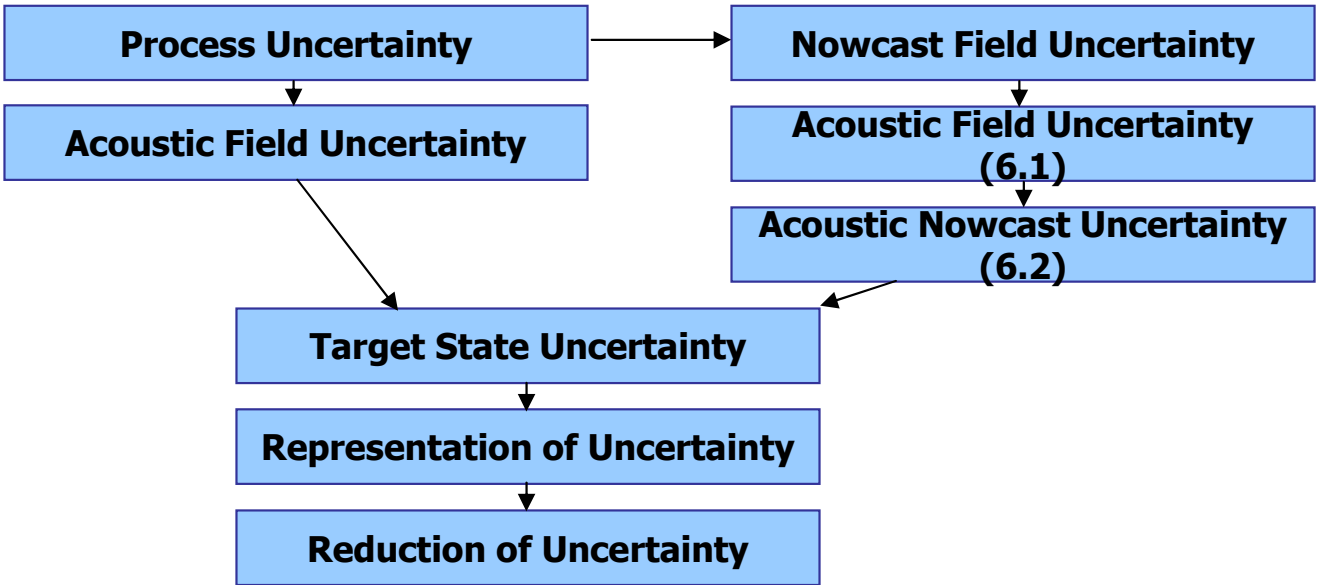


Long-Range: Shadow-zone acoustics for ASW - need further analysis for improved Navy models



Capturing Acoustic Uncertainty





Objective

Incorporate and display the variability of the real ocean and acoustic fields to allow development of tactical decision aids.

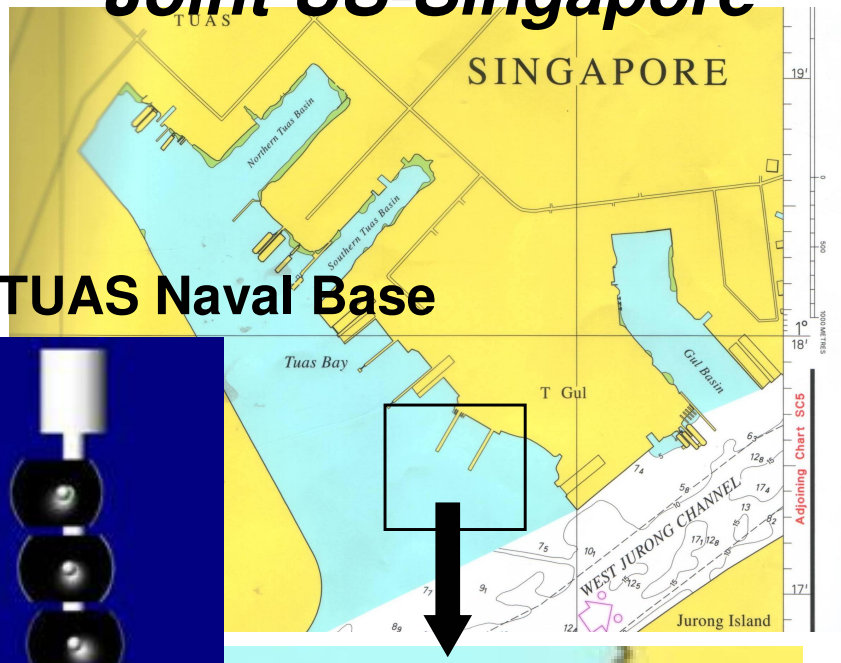
Progress

New, model-based TDA's will show the range of variability of the environment in South China Sea

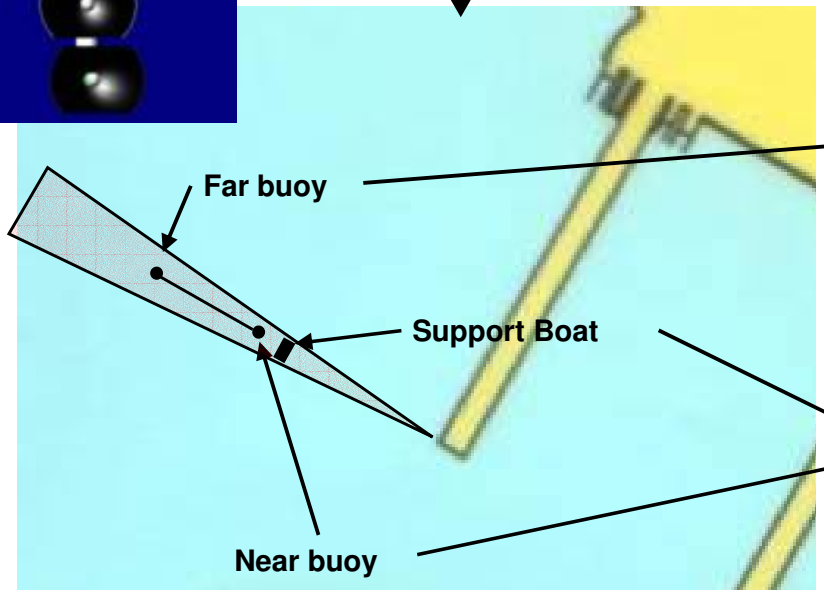
- Custom acoustic climatology for one year of variability

Swimmer Detection Sonar Network

Joint US-Singapore



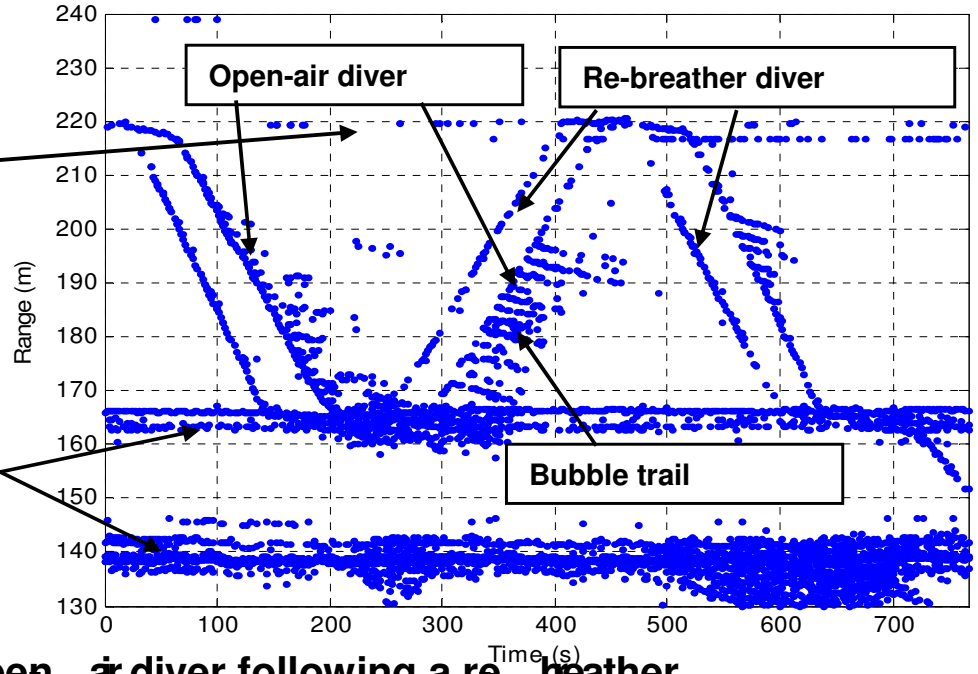
TUAS Naval Base



- Defend the Changi Naval base against swimmer attacks
- Integrate affordable system with a broader harbor defense system
- Have a preliminary multinode system installed by May 2005

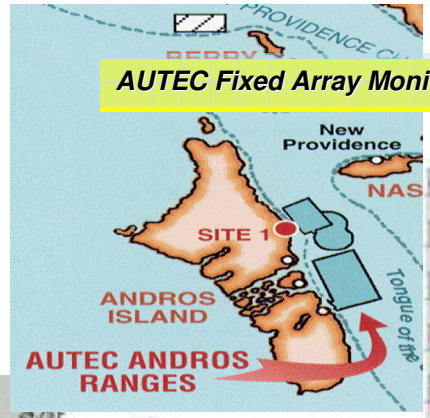
Detections on order 200m

SINGLE NODE TEST – April/May 2004

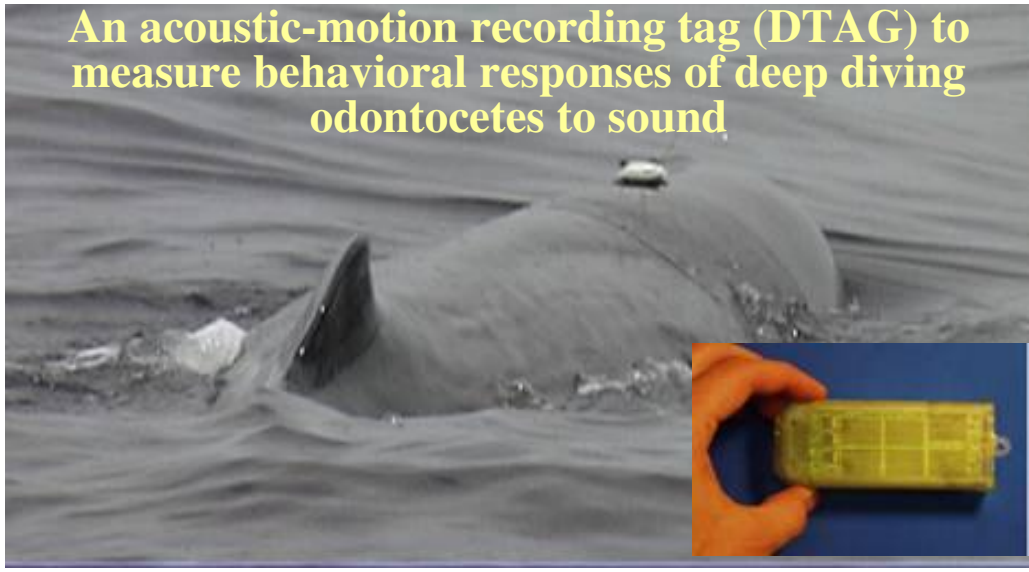


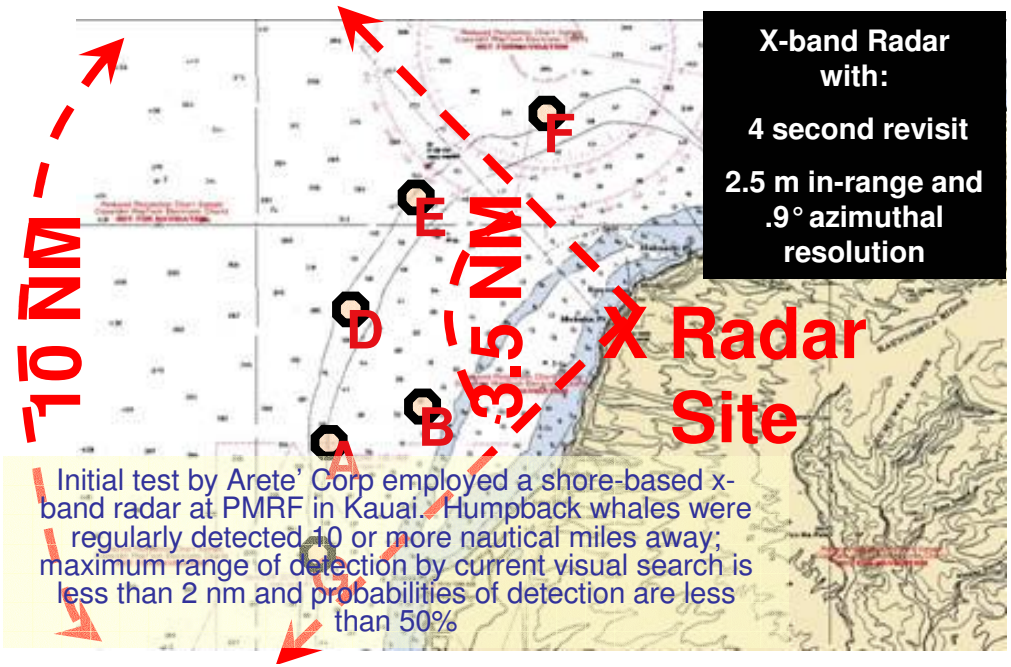
Two divers swam between buoys, on open air diver following a re breather

Marine Mammal Mitigation



Relative amount of marine mammal detections during a month prior to a test, using existing seafloor sensors. Also tracks during test.



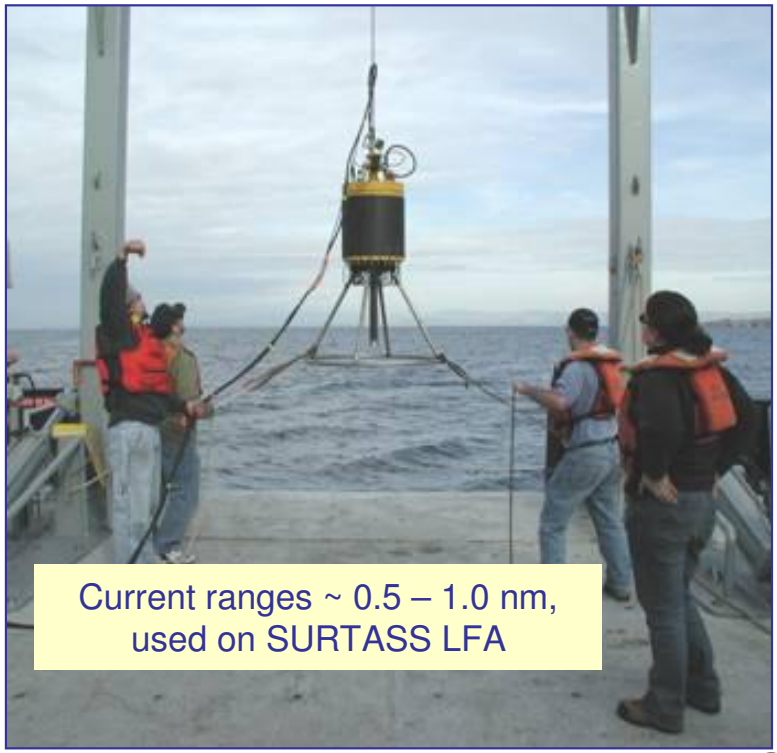


X-band Radar with:

4 second revisit

2.5 m in-range and .9° azimuthal resolution

Initial test by Arete' Corp employed a shore-based x-band radar at PMRF in Kauai. Humpback whales were regularly detected 10 or more nautical miles away; maximum range of detection by current visual search is less than 2 nm and probabilities of detection are less than 50%



Current ranges ~ 0.5 – 1.0 nm, used on SURTASS LFA