# APPENDIX VII

## Autonomous Underwater Vehicles (AUVs) Presentation

Autonomous Ocean Sampling Network

AVHRR

CZCS and AVHRR

3-D Ocean Field Estimation

Autonomous Ocean Sampling Network

Sampling Approach

Real-Time Oceanography Network Architecture

Shore Station Operations

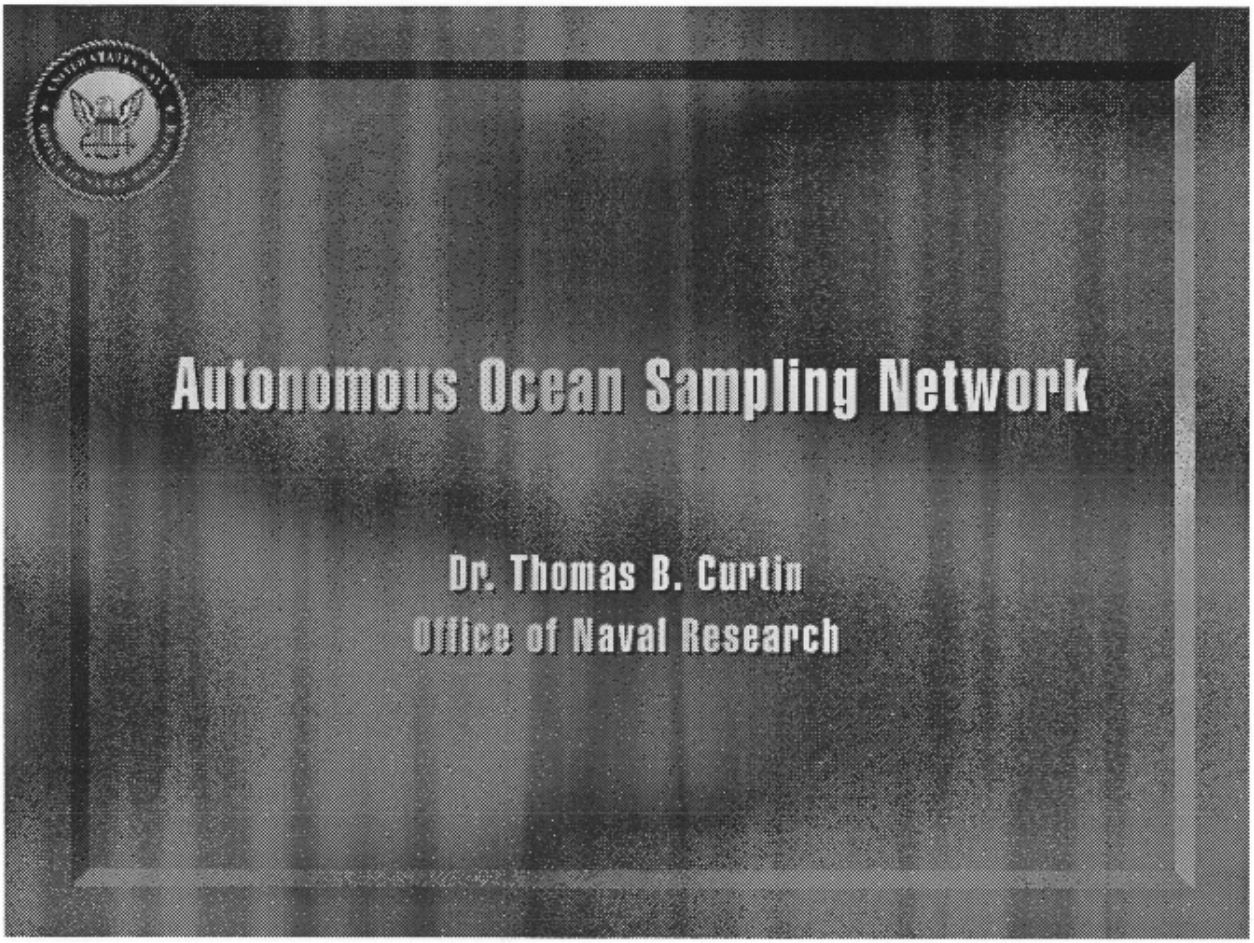
Network Advantages

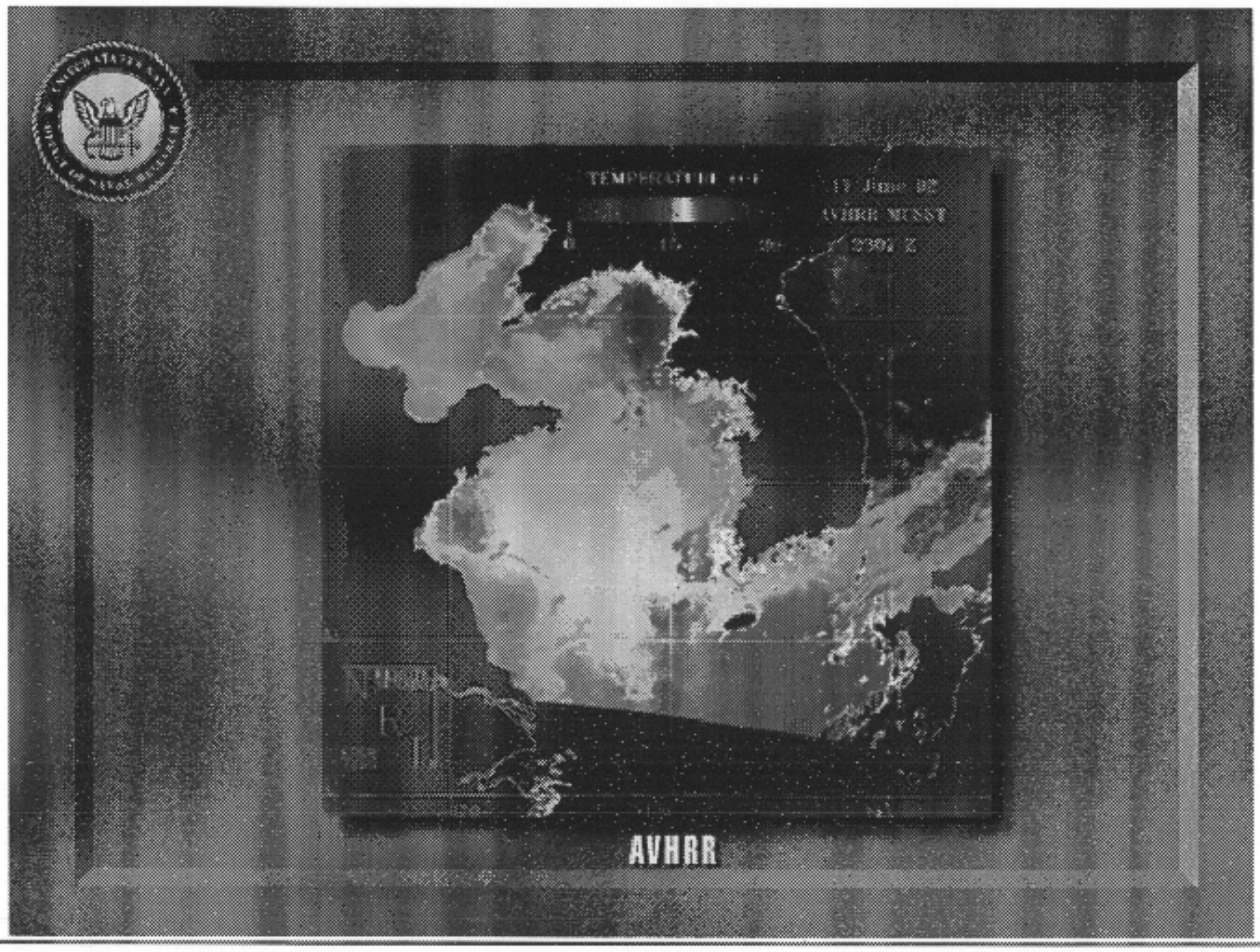
Network Interoperability (Standards)

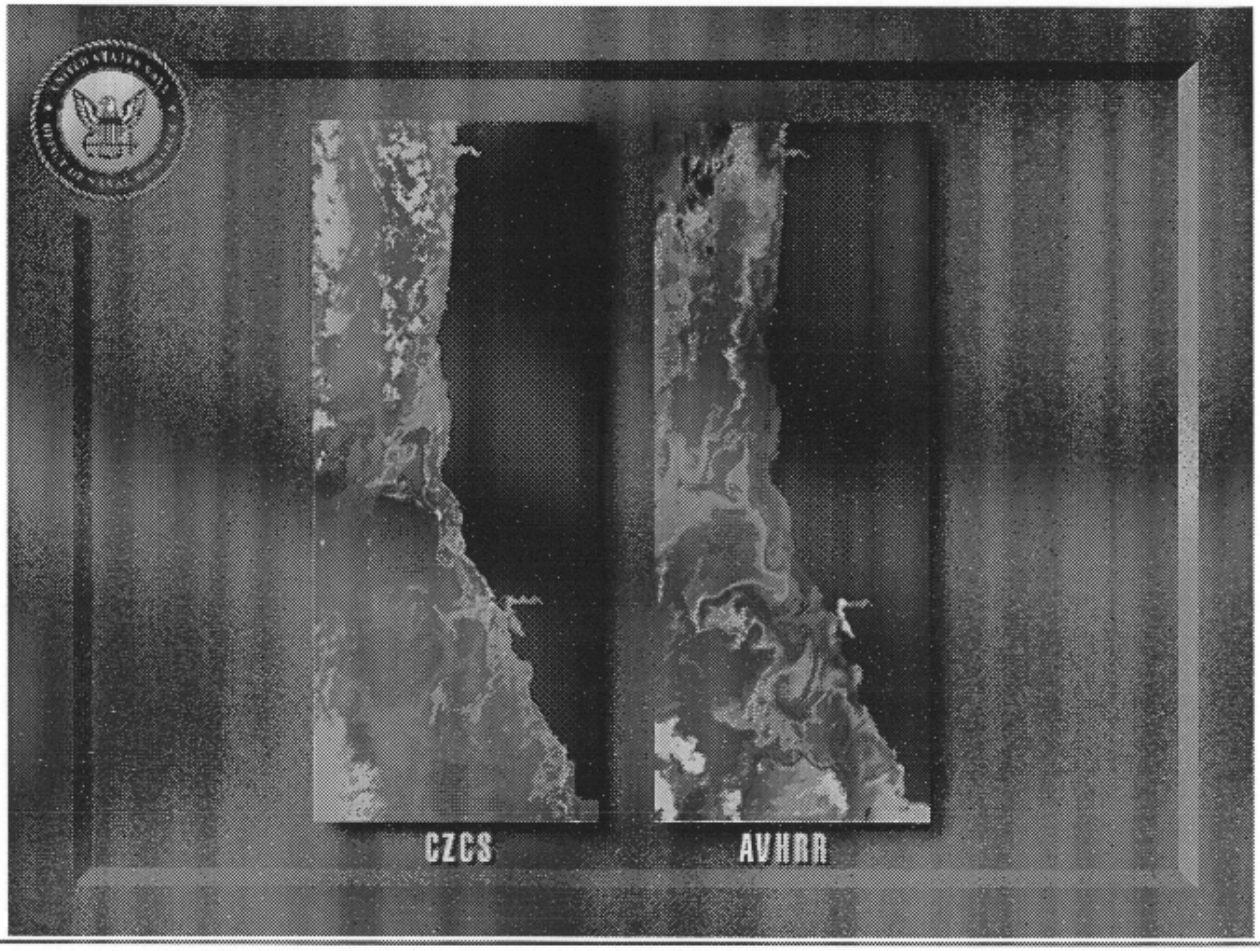
Key: Small, low cost vehicles

Technical Issues

- Control/Communication/Navigation - Page 1 and Page 2
- Sensor, Propulsion and Power


Autonomous Ocean Sampling Network
Dr. Thomas B. Curtin
Office of Naval Research

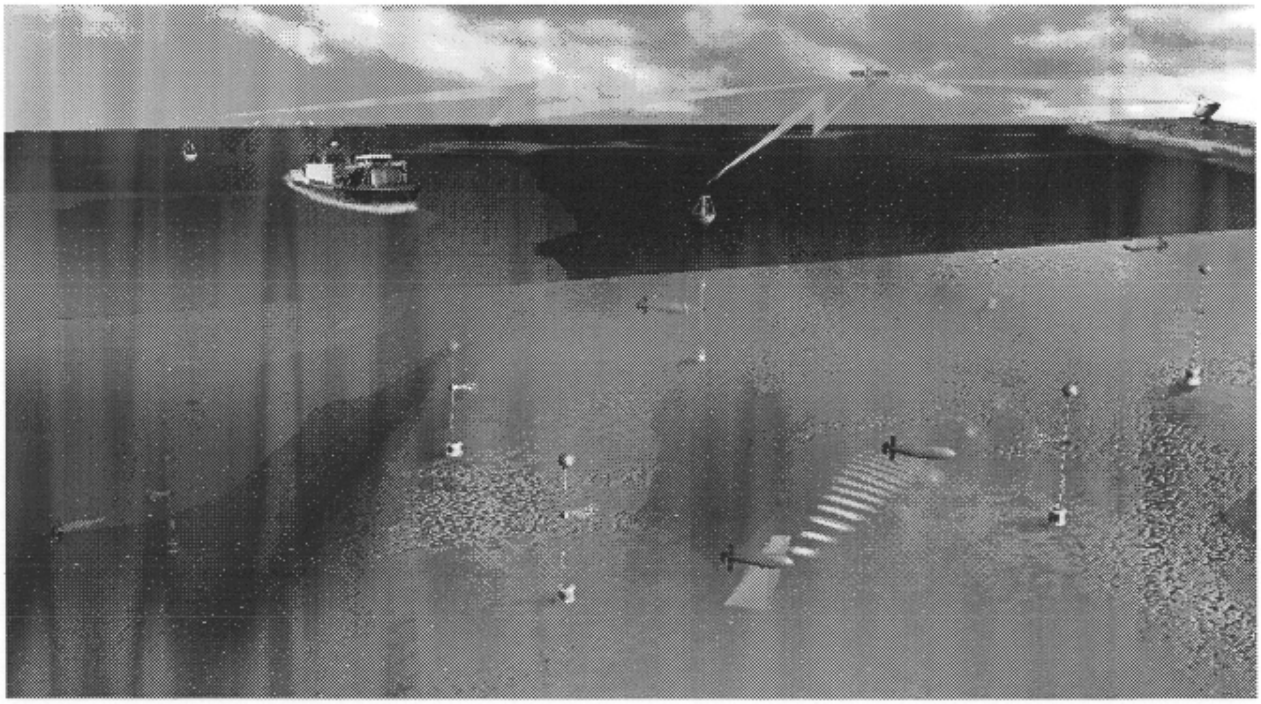

AVHRR


CZCS
AVHRR


3-D Ocean Field Estimation
Numerical Models + Observations (sensors, platforms)
For best estimate, observations should be:
• simultaneous at multiple points (gradient measurement)
• time variable, spatial resolution (adaptive sampling)

# Autonomous Ocean Sampling Network

## Fixed Nodes + Mobile Nodes



# Sampling Approach
## (Configuring the Network for a Specific Mission)

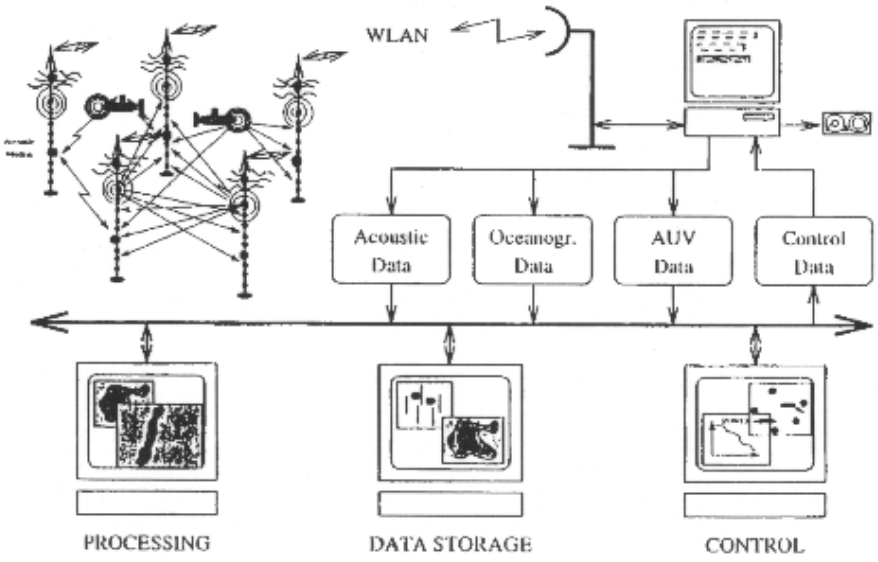
(1) Identify phenomenon of interest
(determine resolution)

(2) Determine ocean volume coverage
(define range)

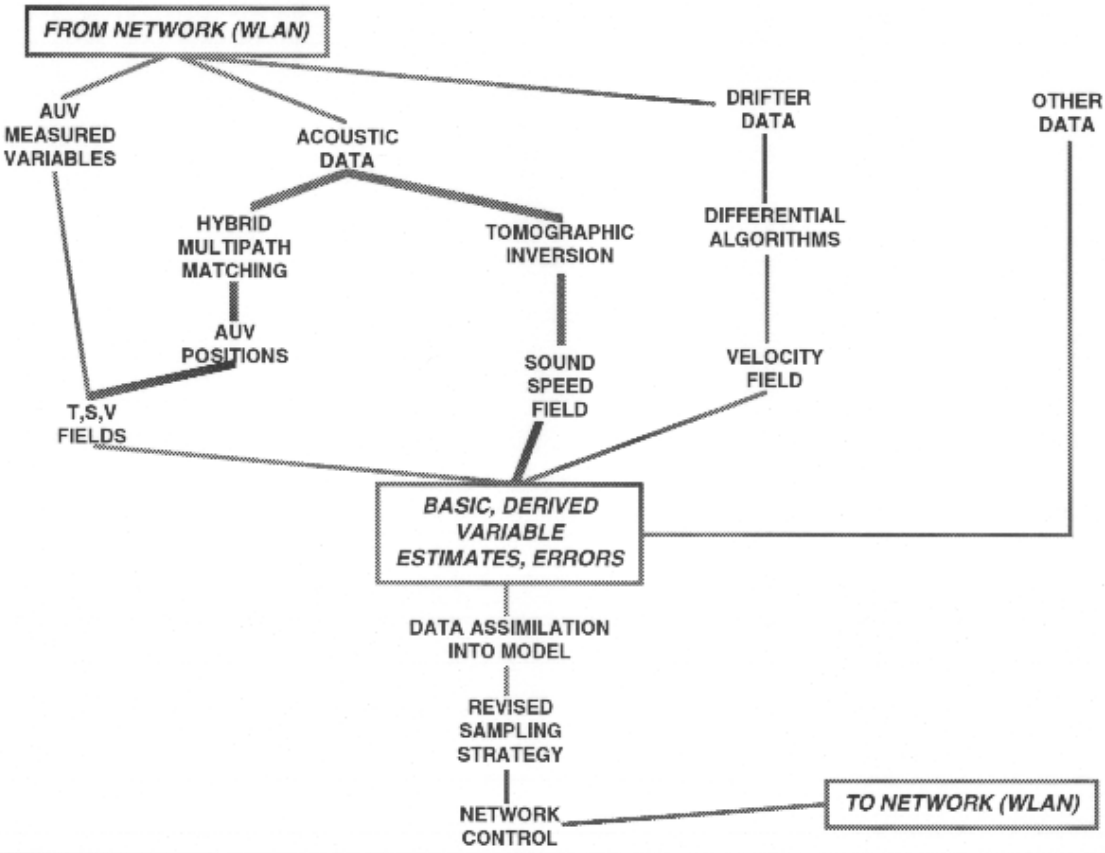
(3) Define acceptable error bounds
(specify precision)

(4) Specify sensors, node distribution, initial
sampling strategy (adaptive)

# Real-Time Oceanography Network Architecture

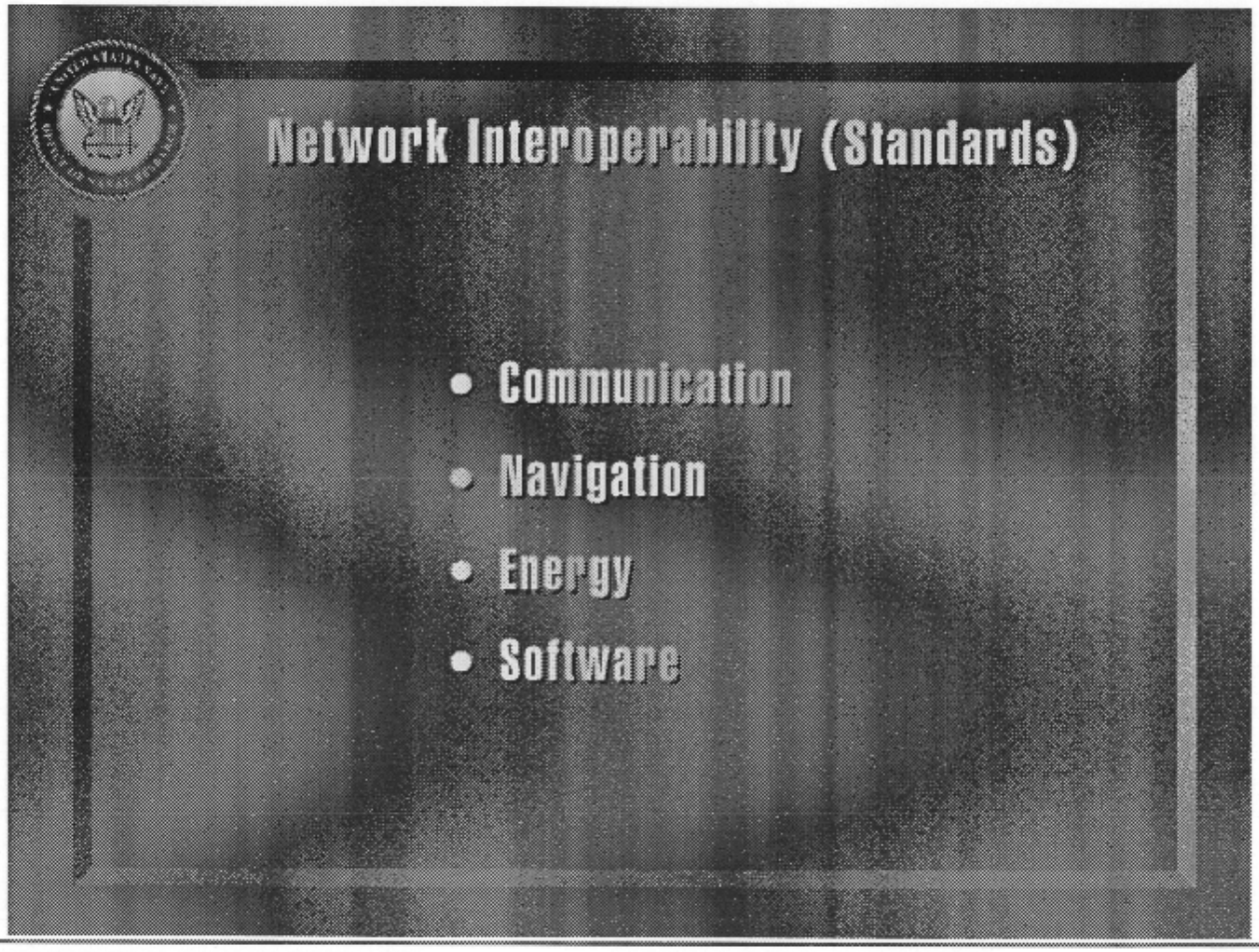


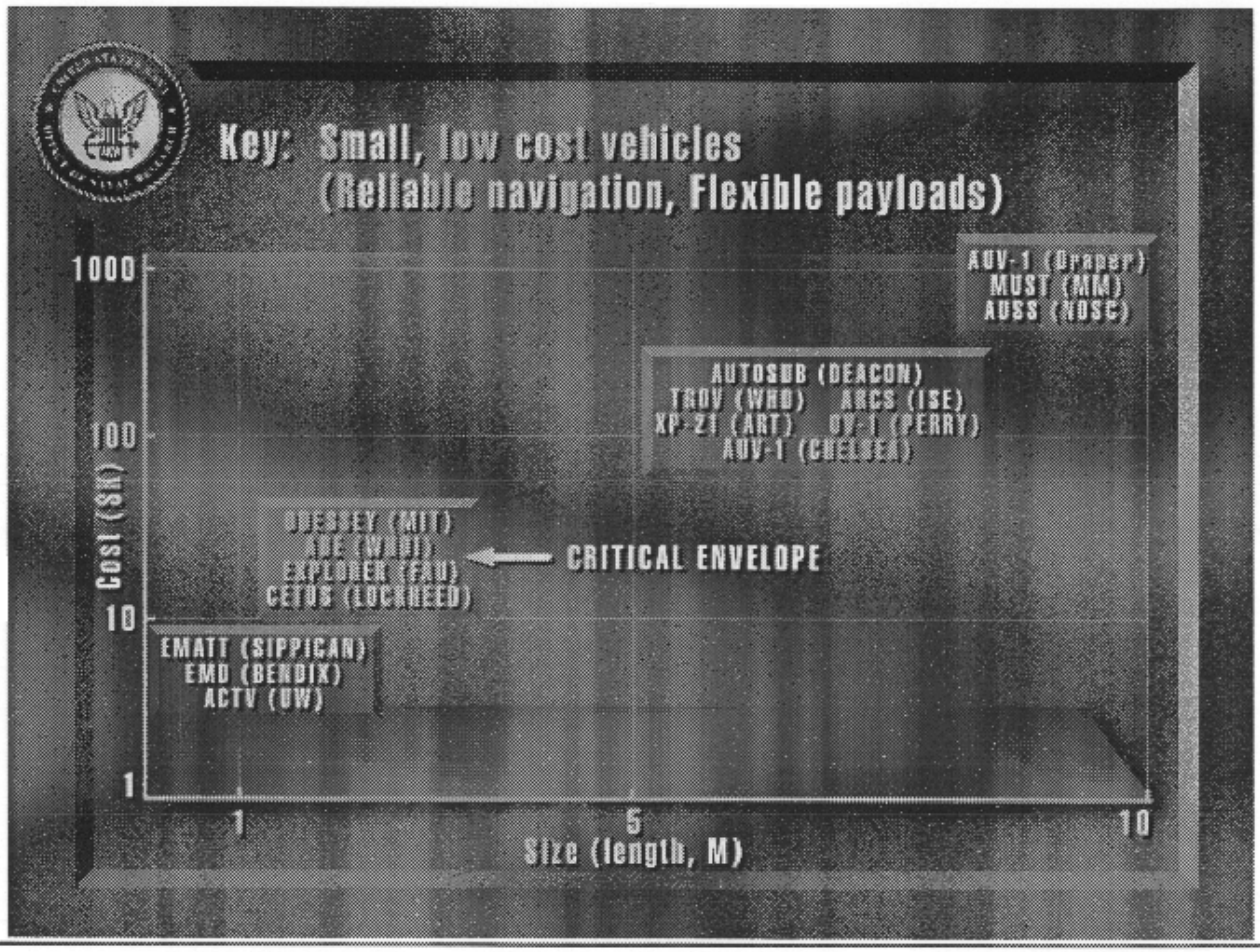
# Shore Station Operations



# Network Advantages

- Synoptic volume coverage
- Adaptive sampling (global/local knowledge)
- Flexible control options
- Energy limitation management
- Robust to component failure


Network Interoperability (Standards)
• Communication
• Navigation
• Energy
• Software


Key: Small, low cost vehicles
(Reliable navigation, Flexible payloads)
1000
100
10
1
Cost ($K)
AUV-1 (Draper)
MUST (MM)
ADSS (NOSC)
AUTOSUB (DEACON)
TROV (WHOI)
ARCS (ISE)
XP-21 (ART)
OV-1 (PERRY)
AUV-1 (CHELSEA)
ODESSEY (MIT)
ADE (WHOI)
EXPLORER (FAU)
CETUS (LOCKHEED)
CRITICAL ENVELOPE
EMATT (SIPPICAN)
EMD (BENDIX)
ACTV (UW)
1
5
10
Size (length, M)

# Technical Issues

**Control/Communication/Navigation**

- **Integration of autonomous mission management and human supervisory control**
- **Performance predictability of autonomous mission management**
- **Integrated reliability within an adaptive control environment**
- **Delayed control through long range acoustic communication links**
- **Arbitration of behaviors with competing objectives**
- **Compilers for high level mission description conversion into state table**
- **Survey, gradient/terrain following, docking, path optimization algorithms**

# Technical Issues

- Collision resolution multiple access (CRMA) acoustic data transfer among multiple vehicles in close proximity
- Integrated undersea/satellite network communication architecture, protocols
- Optimum search strategies related to mission goals, sensors, and communication constraints
- Measure of effectiveness in group performance
- Optimization in group behavior (individual capability versus inter-individual communication limits)
- Convergence of acoustic navigation precision by bootstrap methods
- Optimal initial deployment of multiple vehicles for desired adaptive behavior

# Technical Issues

- Sensor
  - MEMS technology for low power, low cost, wide dynamic range mechanical transduction
  - Fiber optic/spectrophotometer technology for optical, chemical biological sensing
  - Inversion of acoustic communication data packets for sound speed field (tomography)
- Propulsion
  - Structure-flow interactive systems
  - Performance optimization over wide speed ranges
  - Propeller, actuator efficiency
- Power
  - High pressure battery charging
  - Efficient underwater non-contact power coupling