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*Agenda*

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**Maritime Systems Technology Office**

**Fuel Cells**

**Precision Navigation**

**Acoustic Communications**

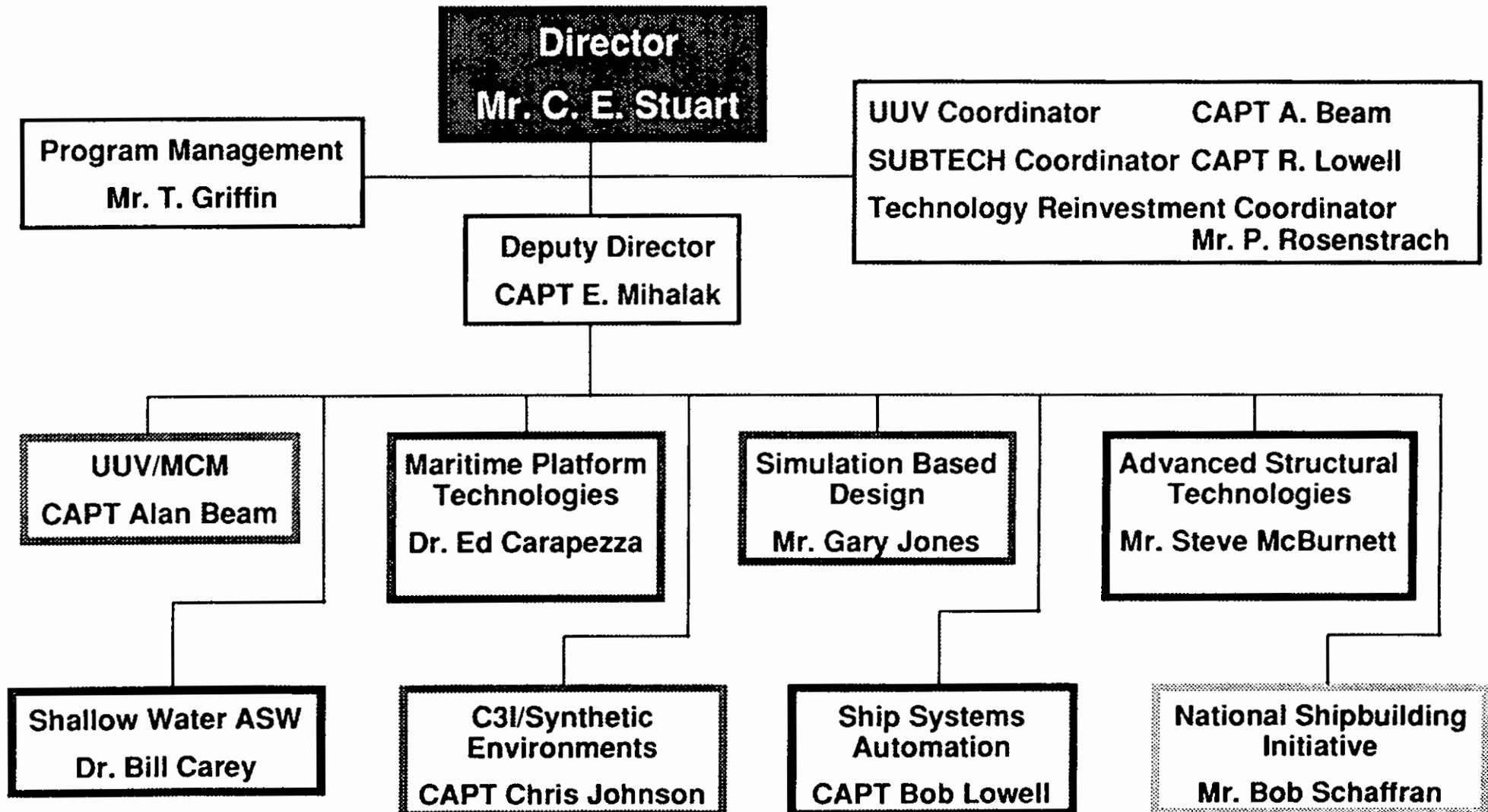
**Automated Surveillance Network**

**Magnetic Communications**

**Future Programs**

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# MSTO Organization

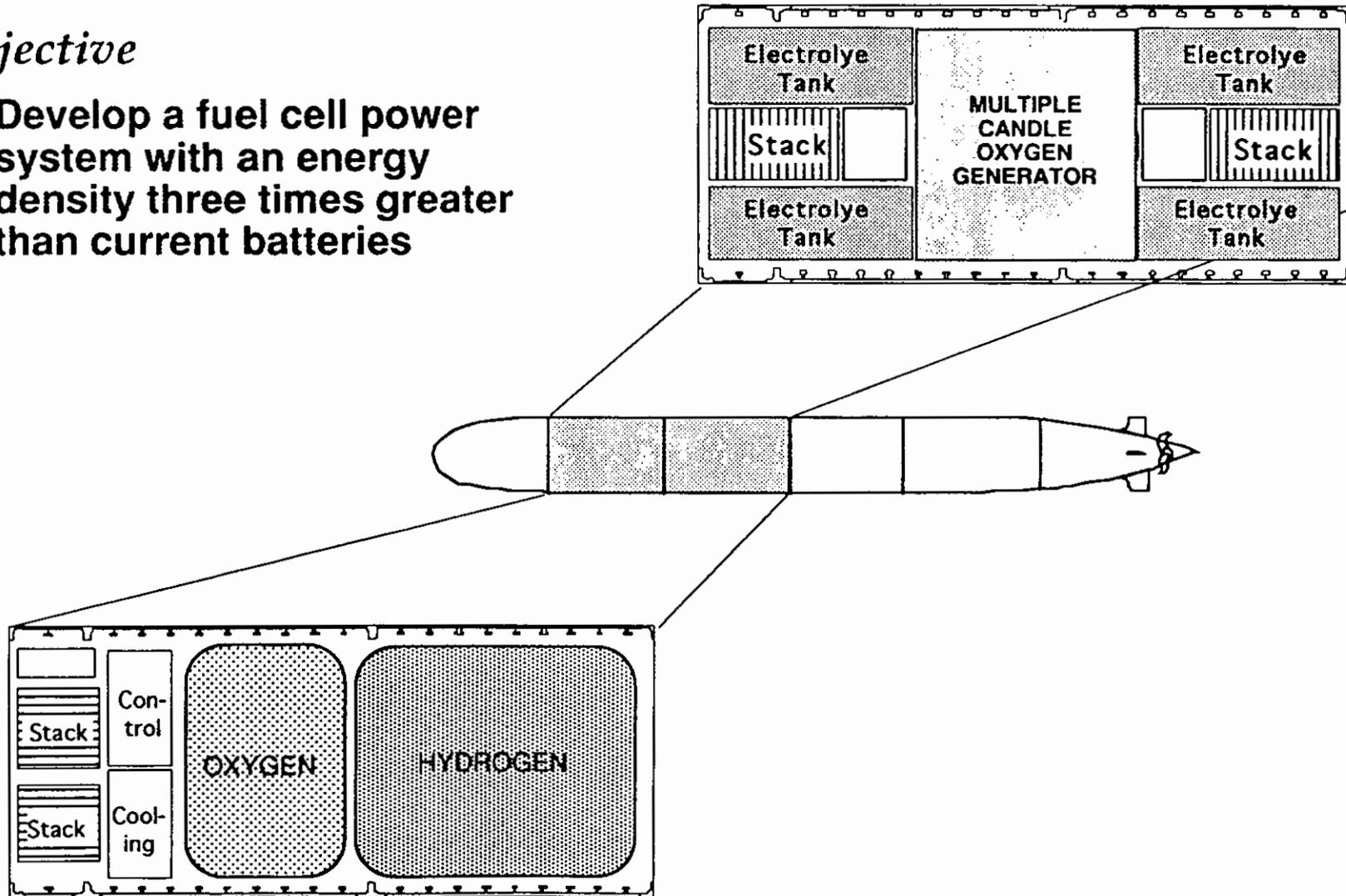


# UUV Fuel Cell Program

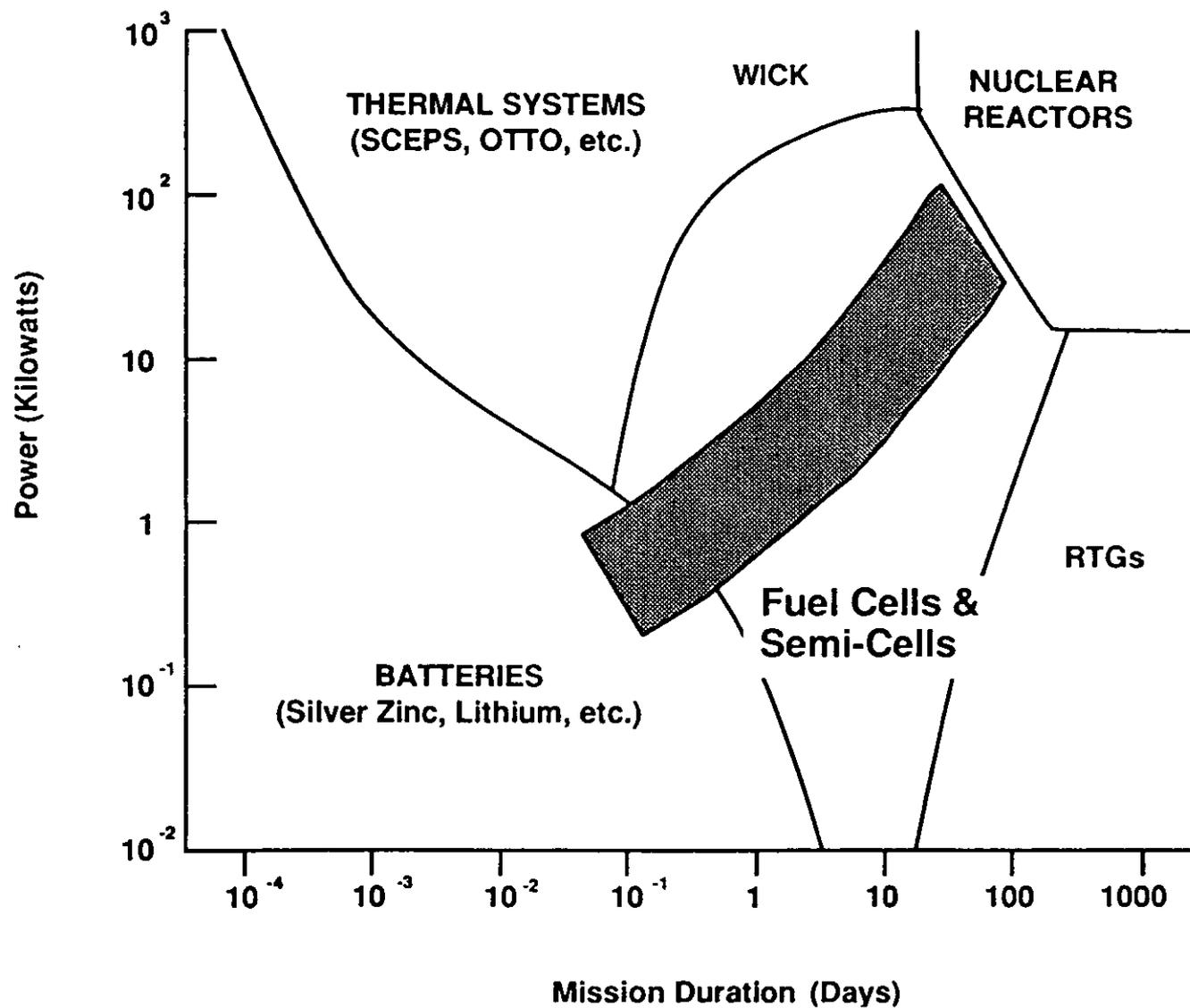


## Objective

Develop a fuel cell power system with an energy density three times greater than current batteries



# Energy Alternatives



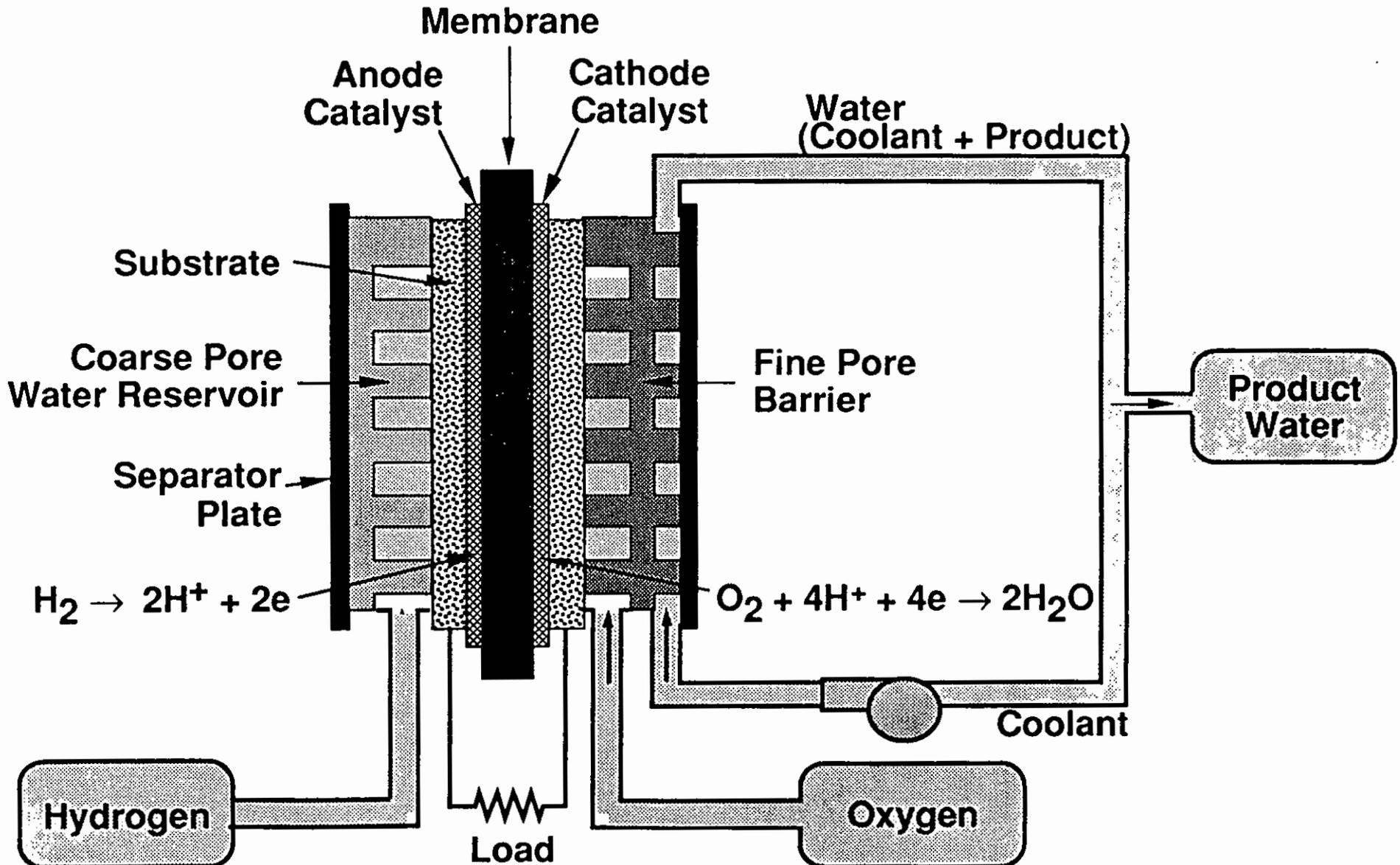
# *Fuel Cell Types and Applications*

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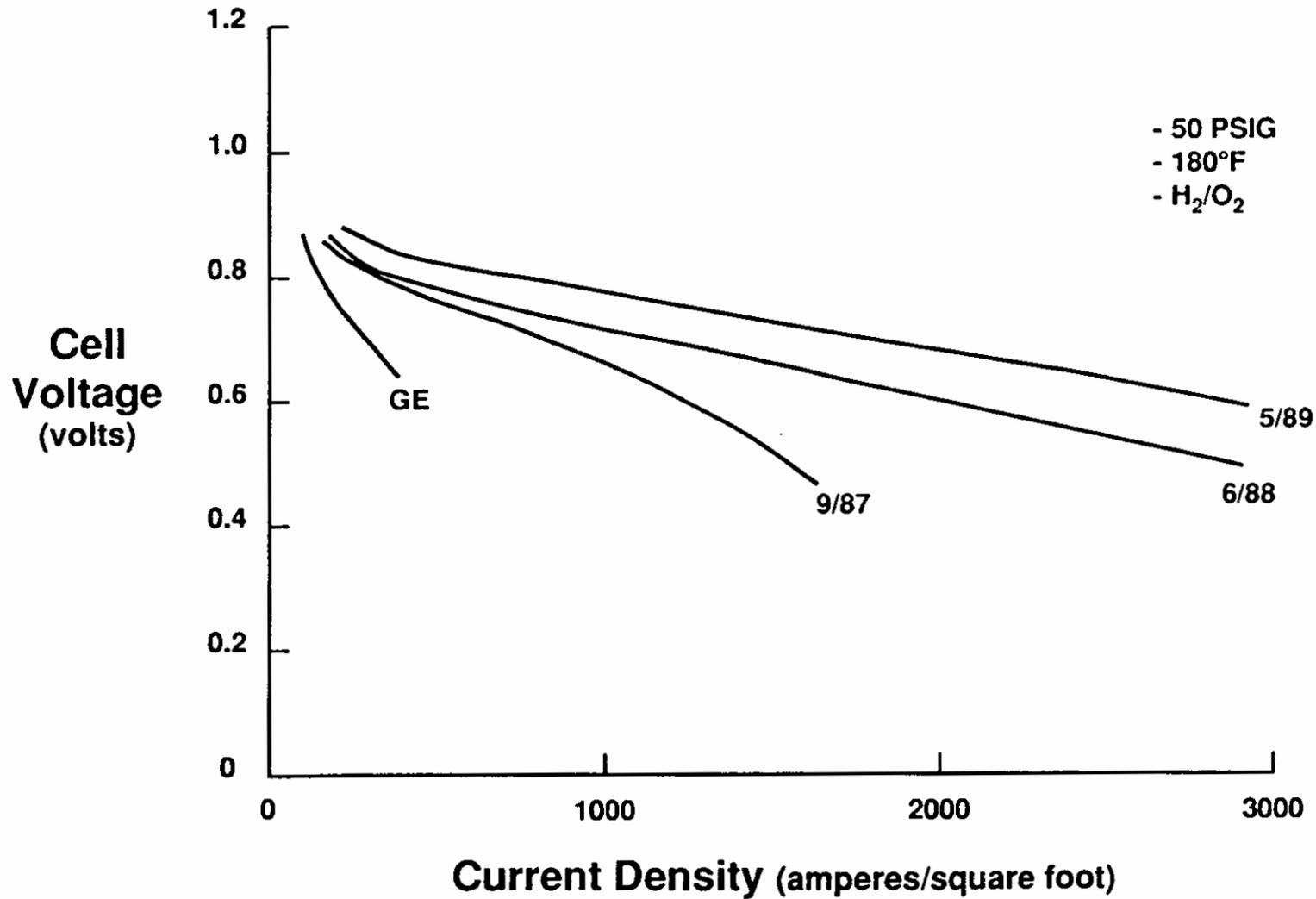


<u>Type</u>	<u>Advantages</u>	<u>Applications</u>
Proton Exchange Membrane (PEM)	<i>Commercial at small scale</i> Low temperature (fast starting)	UUVs and submarines Portable equipment Zero-emission vehicles
Alkaline	<i>In production for NASA</i>	Space
Phosphoric Acid	<i>Available commercially</i> Medium temperature	Stationary power
Molton Carbonate and Solid Oxide	<i>MCFC is nearly commercial, SOFC is developmental</i> High temperature (constant operation) Fuel versatile Very Efficient (molton carbonate)	Stationary power Large vehicles

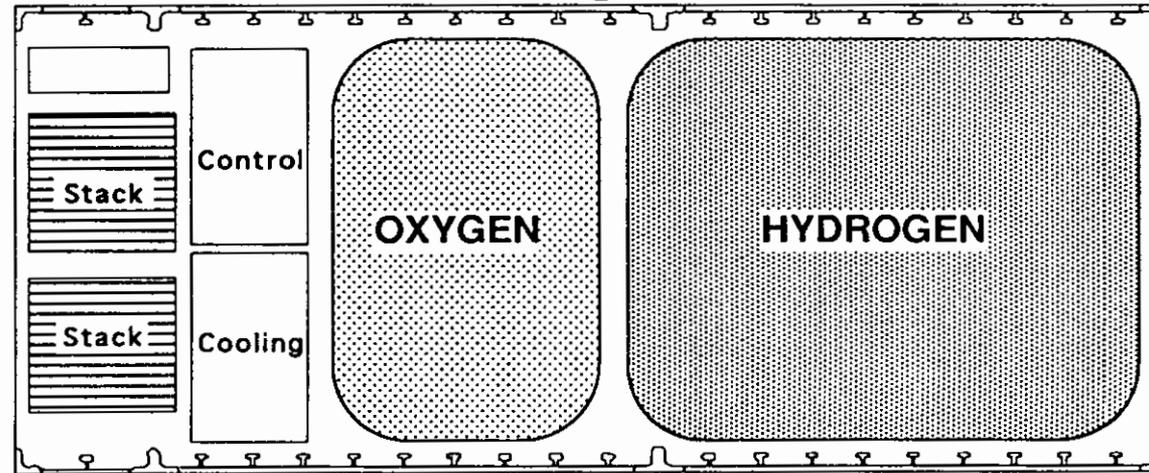
# Proton Exchange Membrane Fuel Cell



# PEM Performance Evolution



## Proton Exchange Membrane



## International Fuel Cells

### Technical Challenges

- Precision assembly of stack
- Passive water removal without Dryout or Flooding
- Thermal management
- Integration of packaging for high fuel and oxidant packing density

### Status

- 1st 80 cell stack completed
- Controller software developed
- 2nd stack assembly in progress
- Power plant test in September

## **A. F. Sammer Corp., Ringwood, New Jersey**

### **Purpose**

**Develop chemical-hydride hydrogen source for PEM fuel cells**

### **Phase 1 Accomplishments**

- **Tested various hydrides**
- **Control of hydrogen generation rate (load responsive generation)**
- **Design accomodated volume expansion of solid reactants**

### **Phase 2 Proposal Submitted**

- **Build system for use with PEM fuel cell in ARPA UUV**

# Semi-Cell Power Systems

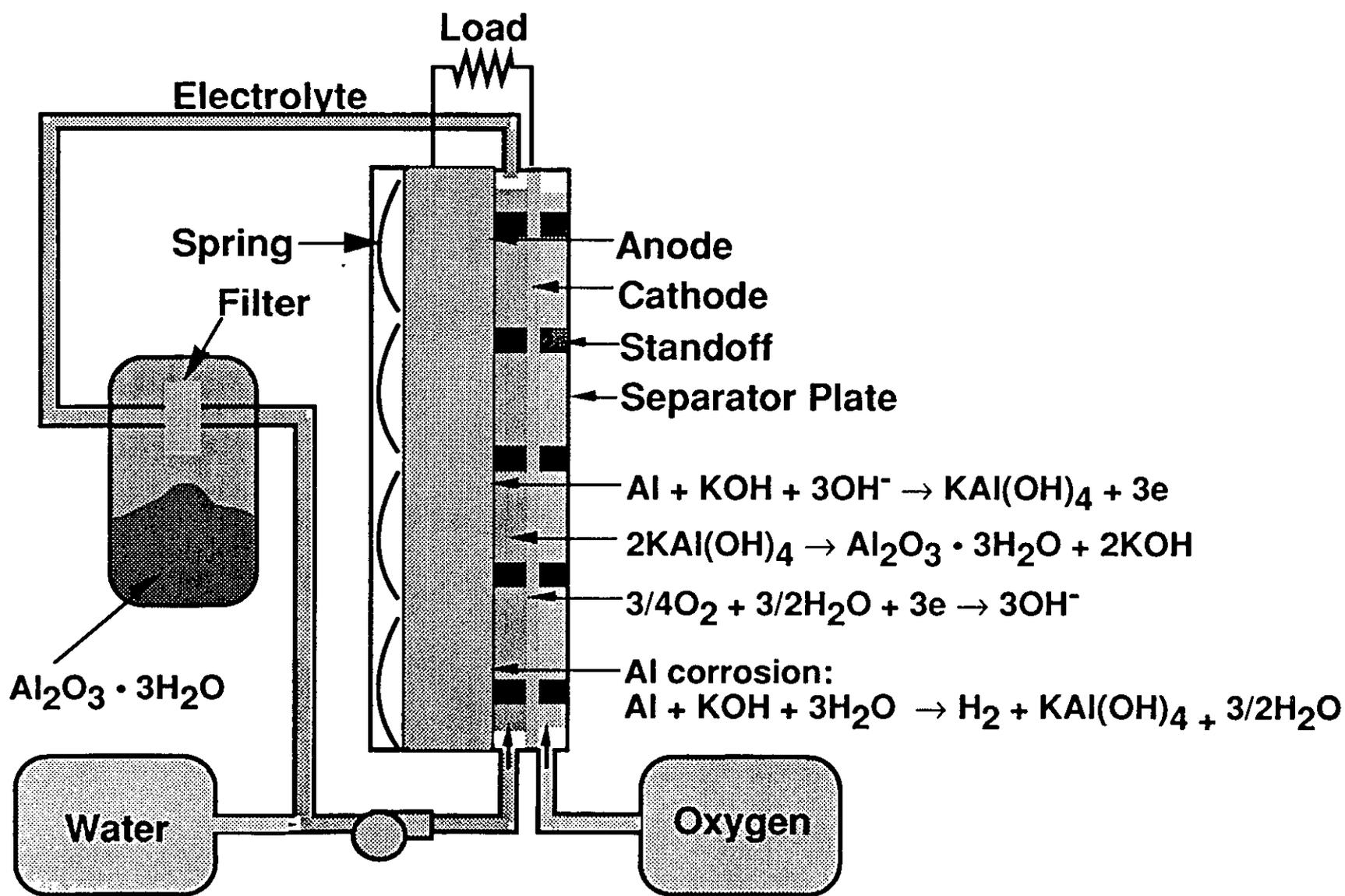
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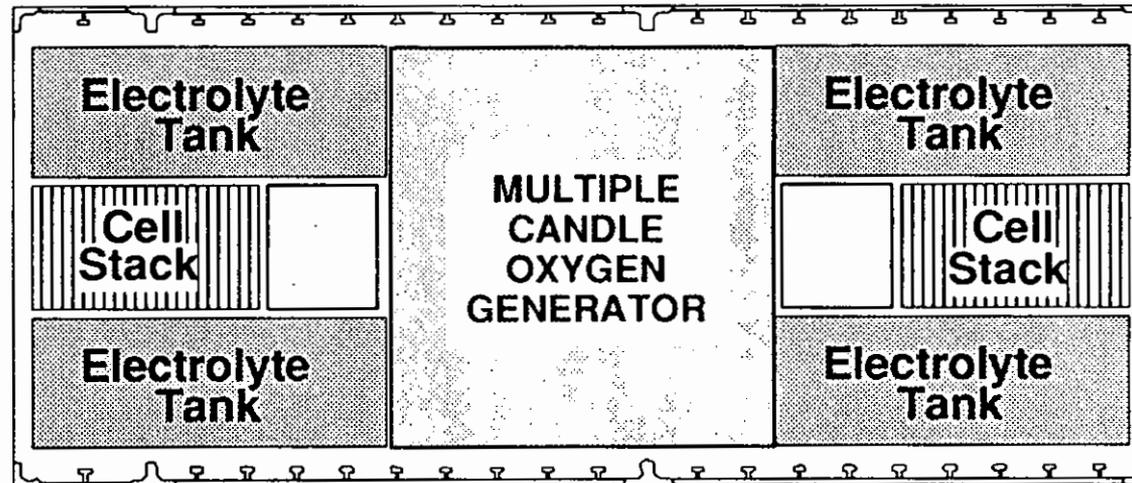
**Issue: Improved energy density**

<u>Candidate</u>	<u>Use and Issues</u>	<u>Energy</u>
Aluminum hydrogen peroxide	Demonstrated in laboratory by NUSC for torpedo application.	900 kWh in UUV
<i>Aluminum oxygen</i>	<i>High energy density, anode corrosion, product removal.</i>	<i>1300+ kWh in UUV</i>
Aluminum silver peroxide	NUSC developing for torpedoes. Demonstrated in laboratory. High rate of corrosion. Hard to power down.	1600 kWh in UUV
Lithium oxygen	Similar to Al-Oxygen, but very difficult to control. Energy gain.	1830 kWh in UUV

# Aluminum / Oxygen Semi-Cell



## Aluminum / Oxygen Semi-Cell



Loral / Eltech / NUWC

### Technical Challenges

- **Anodes**
  - High current generation
  - Low parasitic corrosion
- **Cathodes**
  - Catalyst wetting without flooding
- **Removal of aluminate from electrolyte**
- **Thermal management**

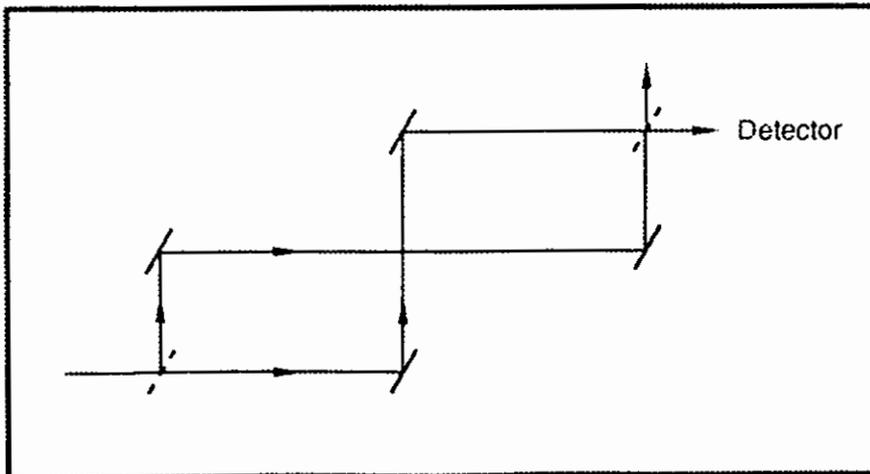
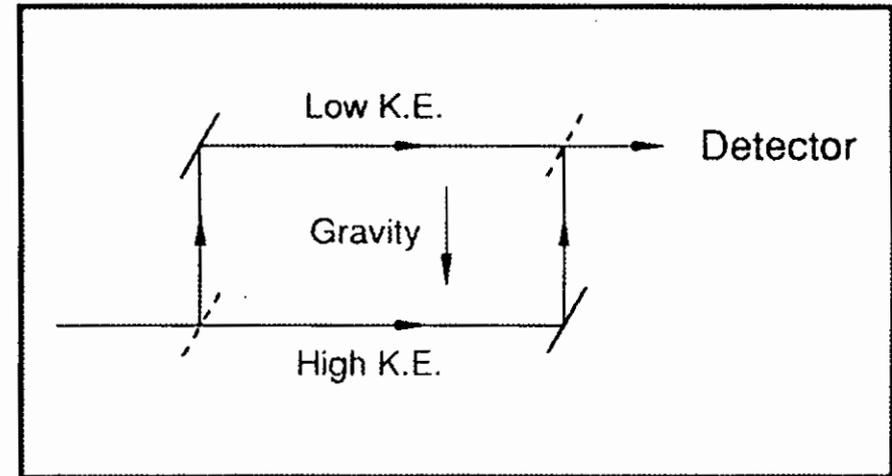
### Status

- **Full scale single cell testing**
- **Examining non-uniform cathode reaction**
- **NUWC MCOG program initiated**

## Atomic Interferometer

- Utilize wave properties of atoms to detect inertial effects
- Analogous to ring laser gyros
- Extremely sensitive ( $10^4$  improvement)
- Potential for gyroscopes, accelerometers, gravitometers, gravity gradiometers

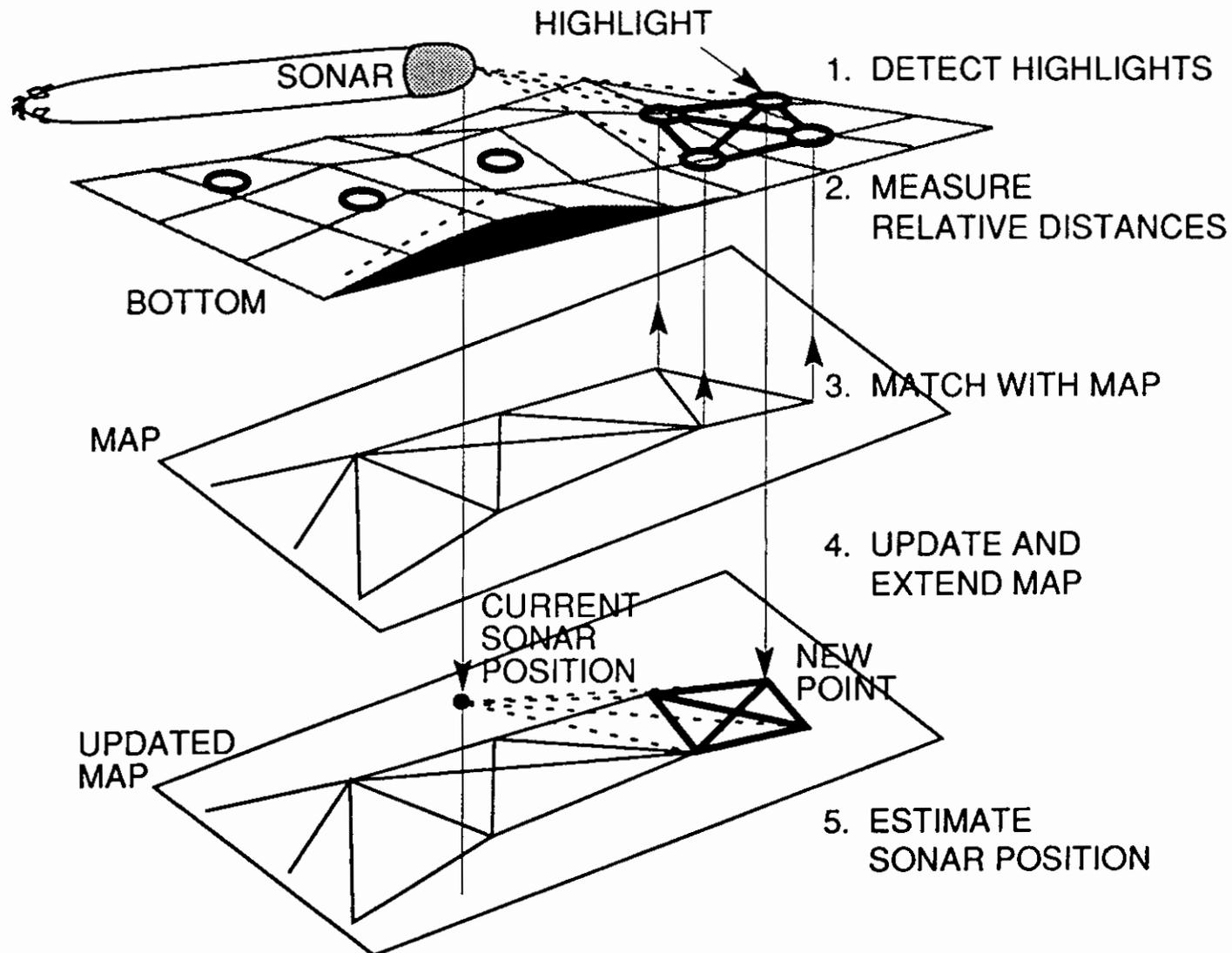
Wavelength - 1 Angstrom



## Gradiometer Implementation

- The phase shifts from rotation or acceleration have the opposite sign in the two loops and cancel out
- Signal is proportional to gravity gradient
- Easier to implement due to insensitivity to vibrations, etc.

# Sonar Aided Navigation

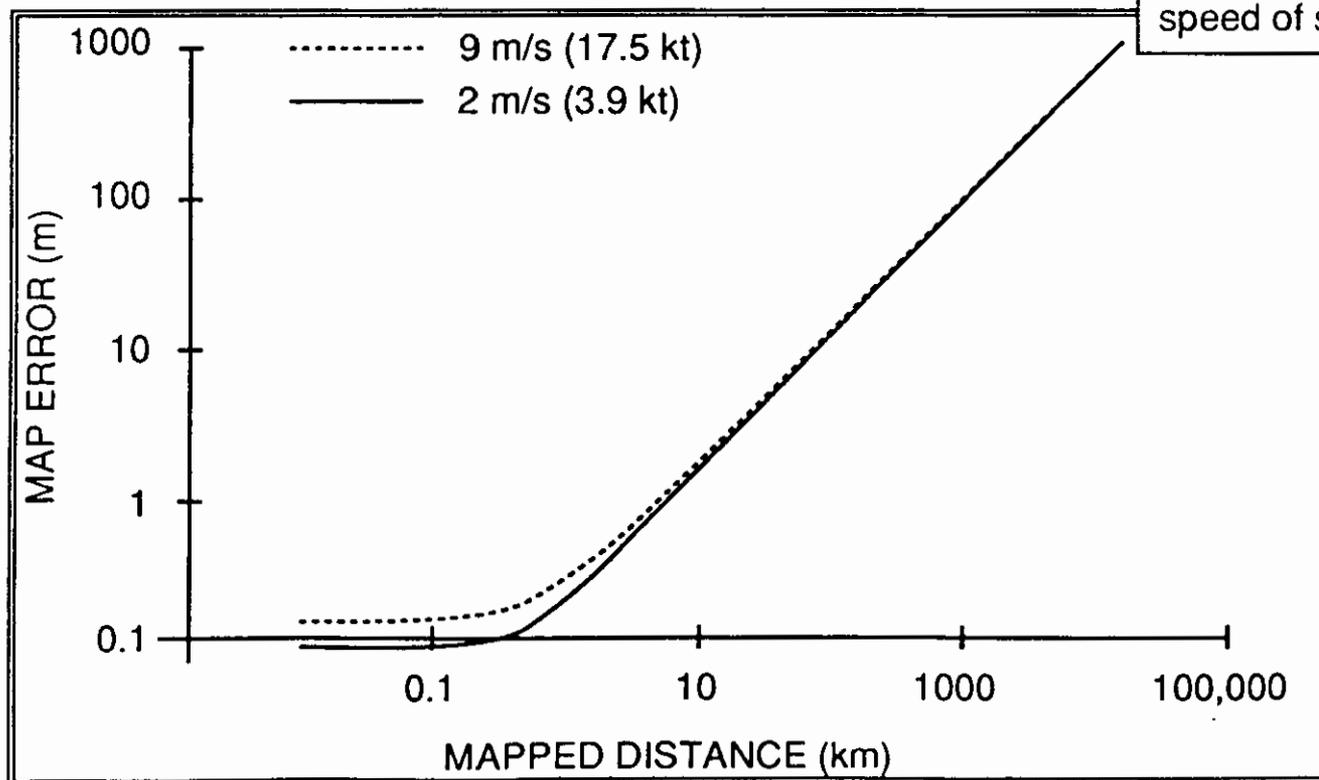


# Sonar Aided Navigation Accuracy



## Parameters

height above bottom	50 m,
range scale	2000 m
sector width	150°
area coverage	2.6 X 10 <sup>6</sup> m <sup>2</sup>
highlight density	1.5 X 10 <sup>-5</sup> m <sup>-2</sup>
number of detections	10 @ 9 m/s, 45 @ 2 m/s
range uncertainty	0.5 m
elevation uncertainty	0.5°
speed of sound bias	0.15 m/s

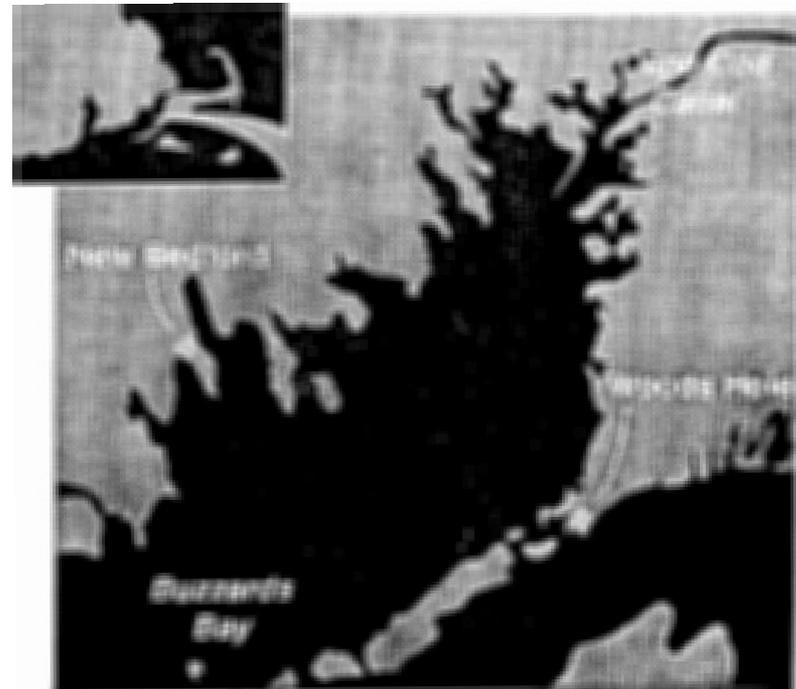


## Technical Concepts

- Coherent signal processing (4X bandwidth efficiency compared to incoherent)
  - Single receiver
  - Multiple receivers
- Diversity
  - Spatial (multiple receivers)
  - Temporal
  - Spectral
- Doppler tracking

## Buzzards Bay test

- 20 Kbit/sec at 4 nm
- Water depth 20-40 feet
- 0-7 knots doppler correction
- Modulation format: QPSK, QAM
- Transmitter 12-20kHz, 185 dB re uPa



# *Acoustic Local Area Network*

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**Goal:** Provide robust communications in very shallow water

**Approach:** Autonomous routing of messages between acoustic network nodes

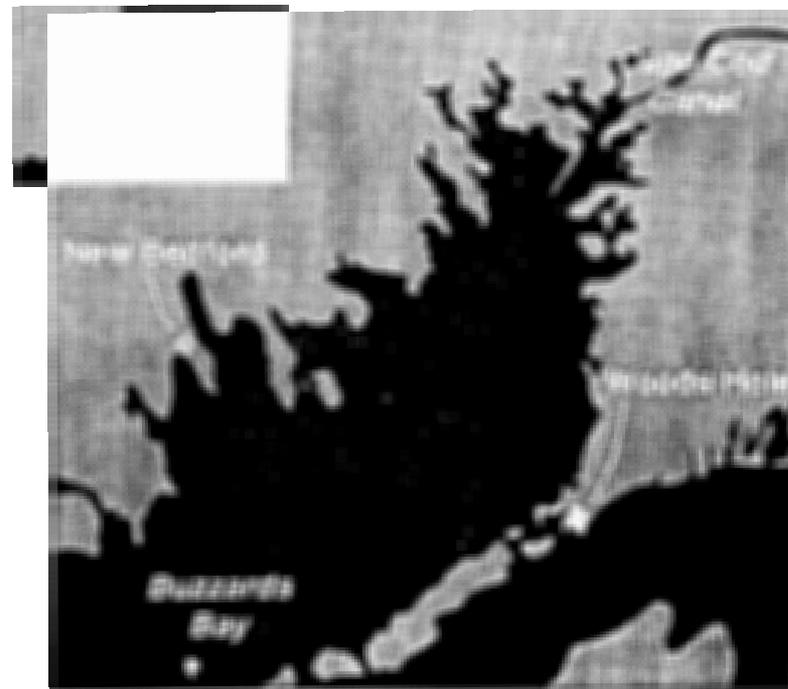
**Issues:** Message contention, error detection/correction, network control

**Data:** Overall throughput - 50 kbps @ 5-10 km  
Individual platform - 10-20 kbps

**Power:** >1000 bits/joule/km

**Interface:** Digital RF to shore, satellite

**Status:** pilot telemetry experiments Feb 92  
prototype system under construction  
first network deployment in Fall 93



# Autonomous Surveillance Network



- Develop a surveillance buoy system rapidly deployable by diverse platforms, including UUVs for detection of:

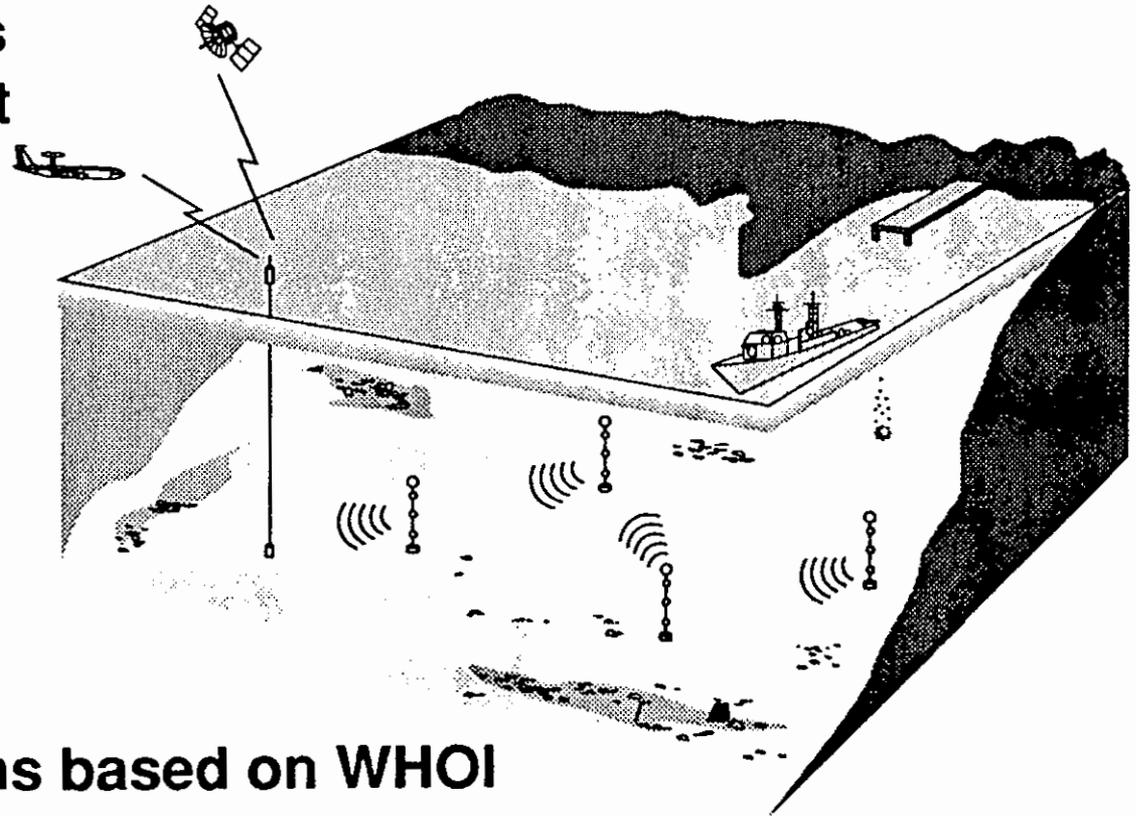
- mine laying operations
- submarine deployment

- Multiple sensor types

- passive acoustic
- active acoustic
- magnetic
- E-field

- Fuse multiple buoy data

- Inter-buoy communications based on WHOI technical developments





## *Technical Challenges*

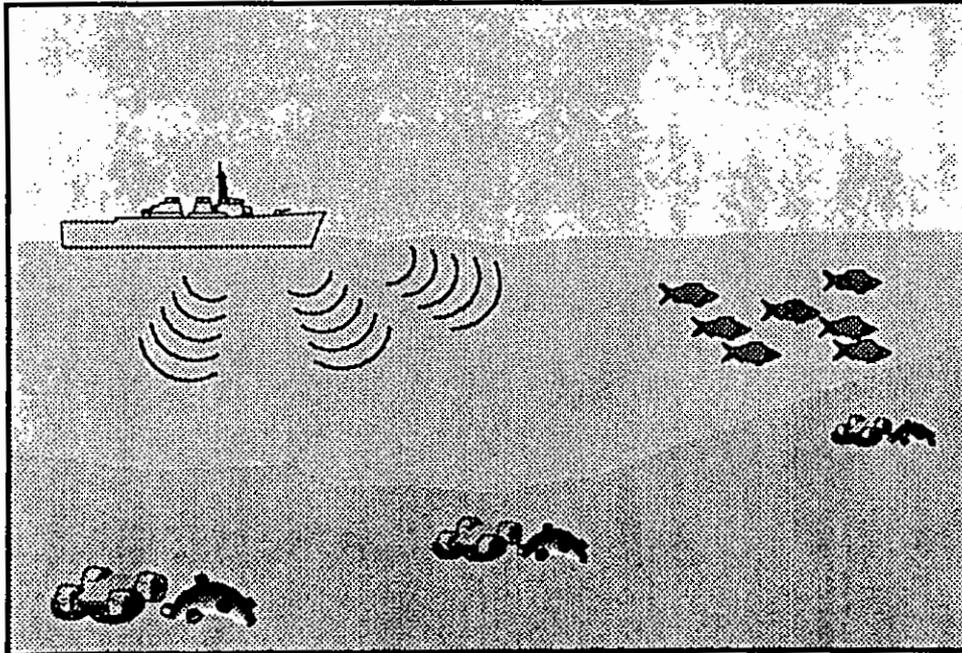
- **High Pd, low Pfa**
- **In-situ processing**
- **Miniaturization**
- **Autonomous Control**
  - **Across nodes (e.g., ping management, tracking)**
  - **Selectable processing**
- **Sensor cost**

# Magnetic Communications



## *Objective*

Develop underwater magnetic communication system for shallow water applications where acoustic communications are limited to short range



## APPLICATIONS

- Simultaneous command detonation of charges placed near mines
- SPECWAR communications
- Surface / subsurface communications
- Inter array communications

## CHARACTERISTICS

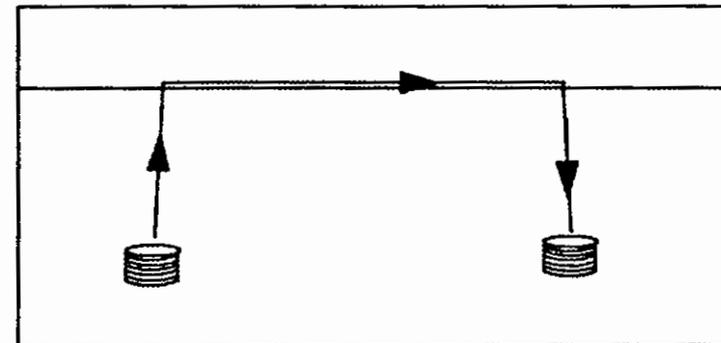
- Covertness (operation outside the conventional spectrum)
- Low susceptibility to jamming
- Operable in both air and water

# Magnetic Communications



## Phenomenon Exploited

- Lateral electromagnetic wave along the boundary between seawater and air
- Critical angle of 6.4 degrees



## Technologies Exploited

- New material / processes for magnetic sensors
  - Amorphous magnetic alloys
  - Magneto--strictive material deposition technologies
- Signal processing electronics developments

## Critical Issues

- Experimental validation of performance predictions (range, data rate)
- Size and power consumption of transmitter
- Size of receiver

