THE UNIVERSITY OF RHODE ISLAND

Autonomous Vehicles for Ocean Research

Dr. Harold “Bud” Vincent
Research Professor, Ocean Engineering
Director, Center of Excellence in Undersea Technology

THINK BIG WE DO℠

OUTLINE

- Introduction and Personal Background
- Current Status of Unmanned Systems and Unmanned Vehicles
- Unmanned Systems at URI (OCE and CoEUT)
- NSF MRI Proposal
- Unmanned Surface Vessels (USV) legal issues
- USV Concept of Operations

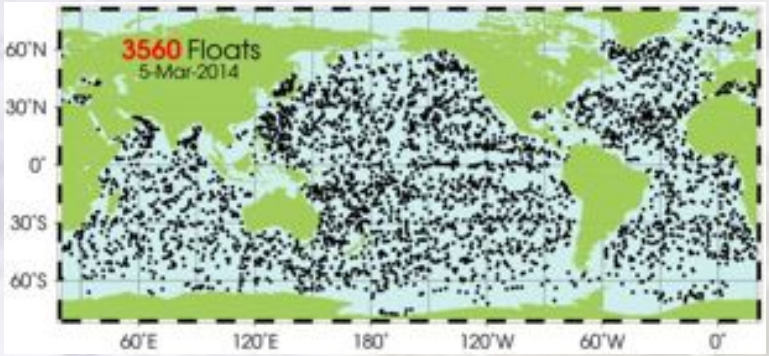
INTRO & BACKGROUND

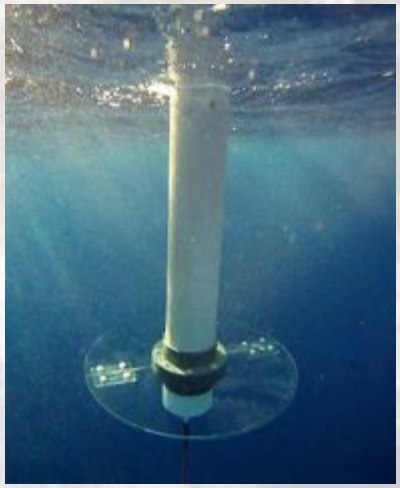
- US Navy (1985-2012)
  - Submarine Officer active duty 6 years (SSN-613,SSBN-617)
  - Salvage Engineer and Salvage Diver 21 years (NAVSEA,SUPSALV,ONR)
- Graduate Student URI OCE (1992-1994)
- SeaBeam Instruments (1994-1995)
- Naval Undersea Warfare Center (1995-2003)
- MIKEL, Inc. (2003-2008)
- URI Ocean Engineering (2008-present)
- More than 3 years at sea, participated in over 100 separate cruises (1 day – 4 months), over 25 different vessels

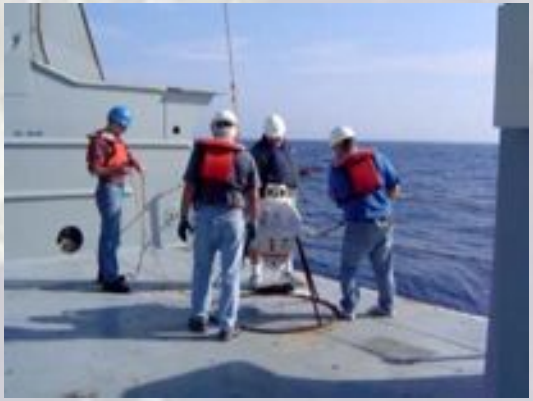
UNMANNED SYSTEMS

- ARGOS Floats (SOLO, Apex)
- MERMAID, Son-O-Mermaid
- Lagrangian Drifters
- Inverted Echosounders (IES)
- Ocean Bottom Seismometers (OBS)
- Geodetic Acoustic Beacons (GABBIES)
- Underwater Navigation Beacons
- Etc.

UNMANNED SYSTEMS





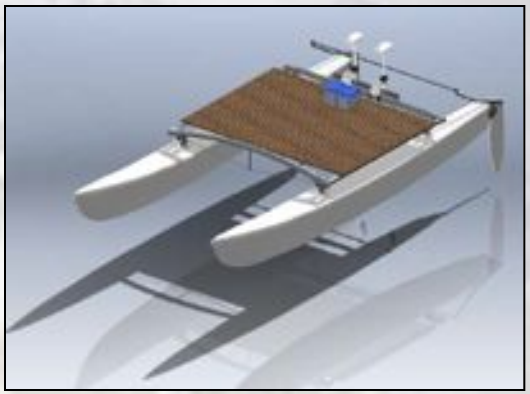


Unmanned Vehicles

- Unmanned Airborne Vehicles (UAV's)
  - Global Hawk, Predator, NRL XFC UAS
  - Quad Copter
- Unmanned Undersea Vehicles (UUV)
  - Autonomous Undersea Vehicle (AUV) Slocum Glider, SeaGlider
  - Remotely Operated Vehicles (ROV) DeepDrone, Hercules, SeaEye,Seabotix, VideoRay)
- Unmanned Surface Vehicles (USV) Autonomous Surface Vehicles (ASV)
  - URI SCOAP
  - URI Diesel-Hobie
  - Waveglider
  - Navy X-1 and X-2
  - Saildrone

Unmanned Surface Vehicles – Part 1

Diesel Electric Hybrid Survey Vessel (URI-CoEUT)

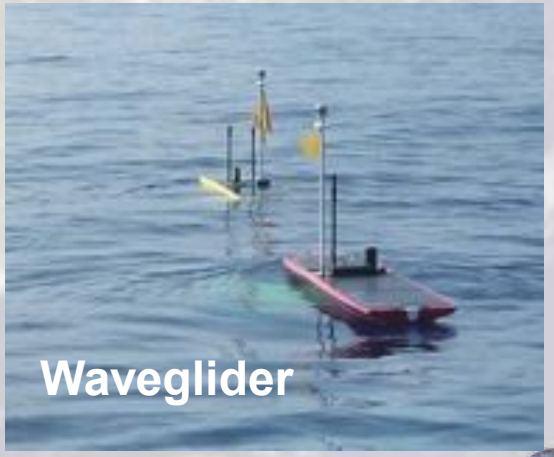


- 1 Week duration at 4 kts
- 70 Gal fuel
- 2 kW 24 VDC Generator
- 2 100 lb electic propulsion motors
- Payloads
  - Chemical (DO, Ch, N)
  - Sidescan
  - Sub-bottom
  - HF Multi-beam

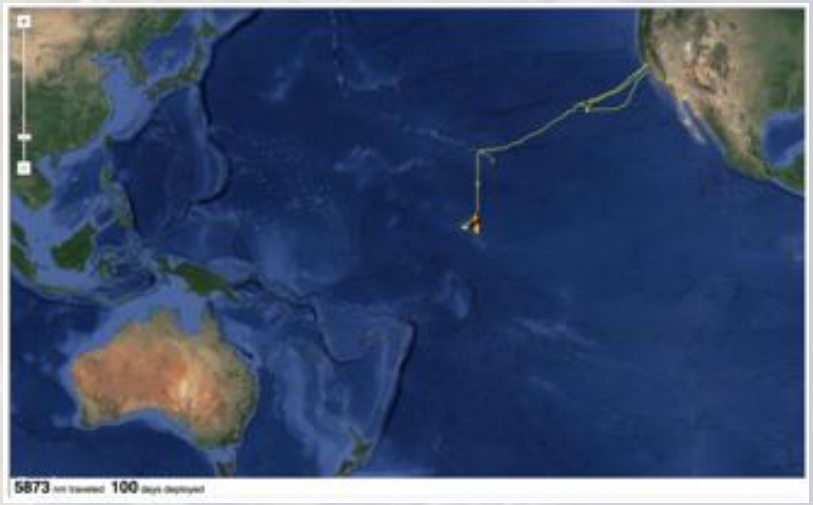
Surveying Coastal Ocean Autonomous Profiler (SCOAP) URI GSO

- Built by SeaRobotics, Inc.
- Twin-hull 36 ft LOA x 17 ft Beam
- 30 day duration at 4 kts
- Diesel-electric propulsion
- ADCP is primary payload
- Goal is to have autonomous profiling winch system

Unmanned Surface Vehicles – Part 2



Saildrone – Marine Science and Technology Foundation (MSTF) Schmidt Ocean Institute (SOI)



Waveglider – Liquid Robotics Corp.

PAC-X

Liquid Robotics Awarded Guinness World Record for PacX Journey Across the Pacific

Autonomous Surface Vessels

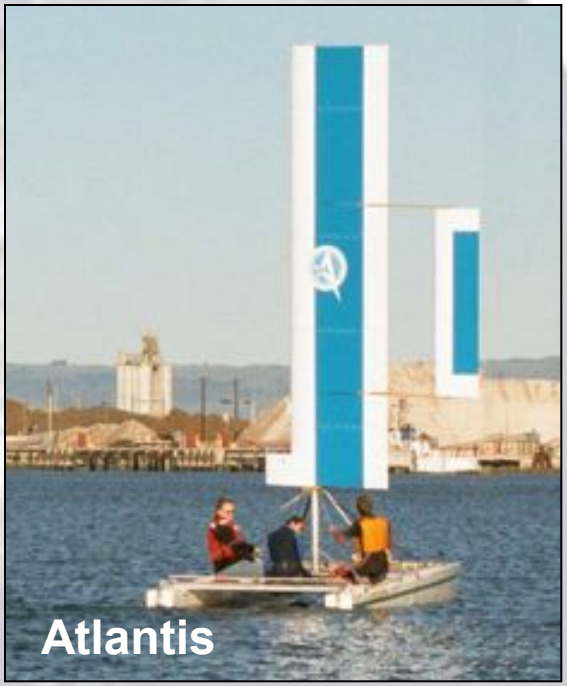
- Cost of Manned Oceanographic Surface Platforms is Growing
- Fuel and Personnel Costs are large percentage of total cost
- Unmanned systems remove a portion of the personnel cost (shore based operations – monitoring , command and control)
- Wind Powered Vessels (we avoid sailboats) remove the fuel costs
- Issues
  - Need larger vessel with more power for payloads
  - Coast Guard Permitting and Licensing
  - Insurance
  - Incorporation into UNOLS structure
- NSF MRI Proposal pending (submitted Jan 2014)

NSF MRI

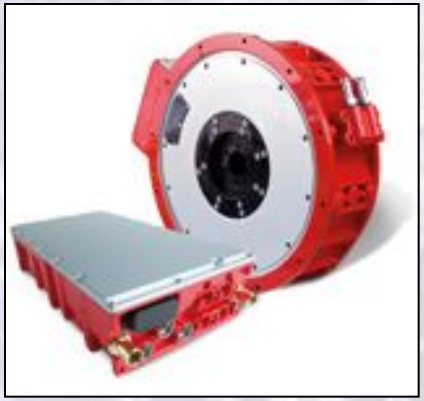
- Wind Powered Vessels X1 and X2

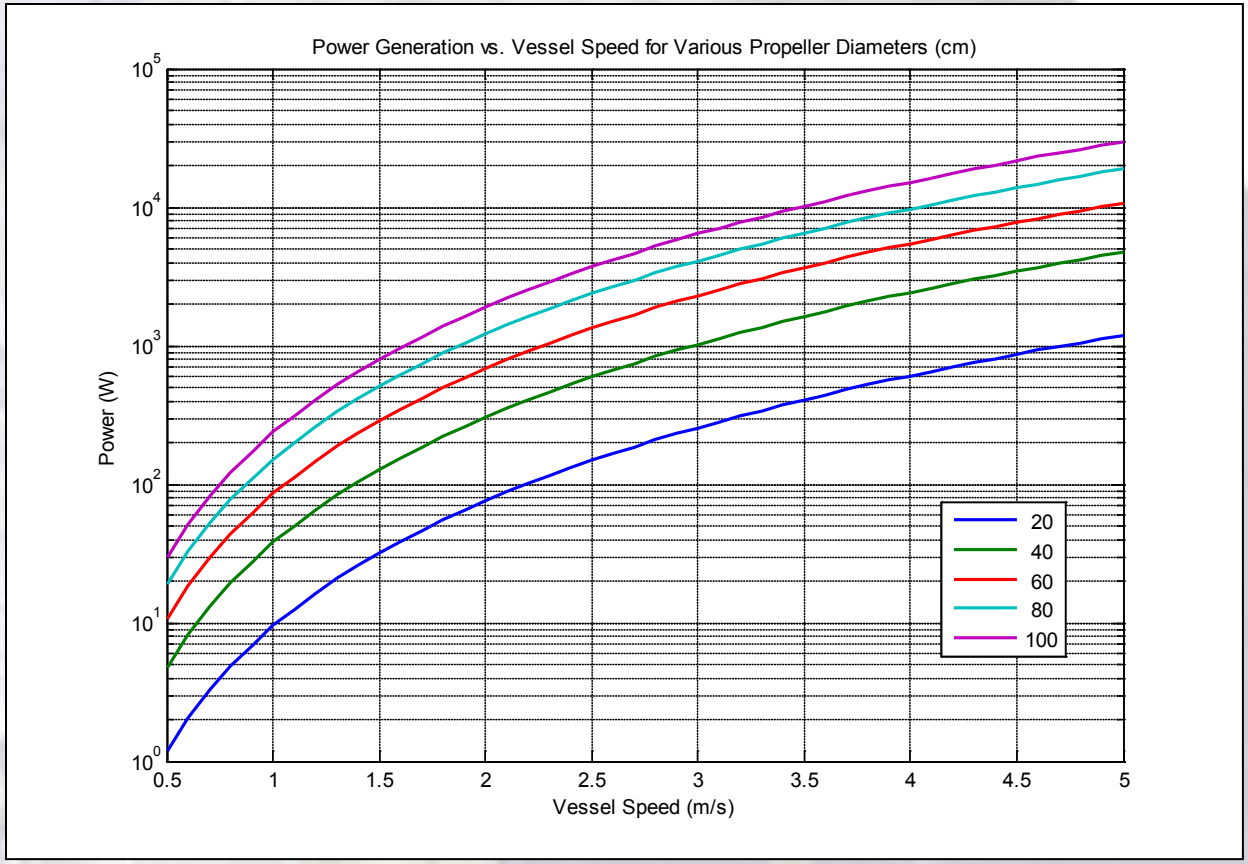
NSF MRI

- NSF MRI Proposed Tasks
  - Take title to Wind Powered Vessel X2 and transport to RI
  - Complete control system implementation (G. Elkaim, UCSC)
  - Implement motor-generator electric power generation
  - Install Multi-Beam (EM-302)
  - Address issues stated on previous slide
  - Conduct trials in increasing sea conditions
  - Long term open ocean deployment

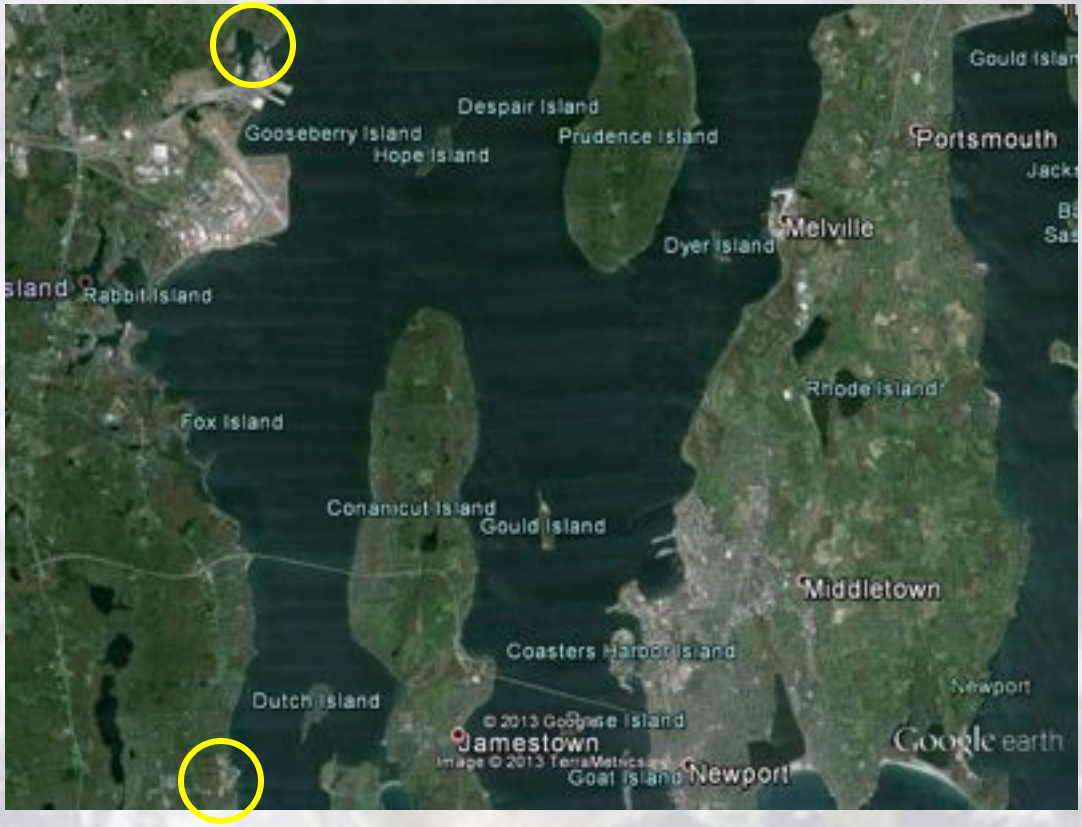


NSF MRI




Power Generation vs. Vessel Speed for Various Propeller Diameters (cm)
Power (W)
Vessel Speed (m/s)
20
40
60
80
100

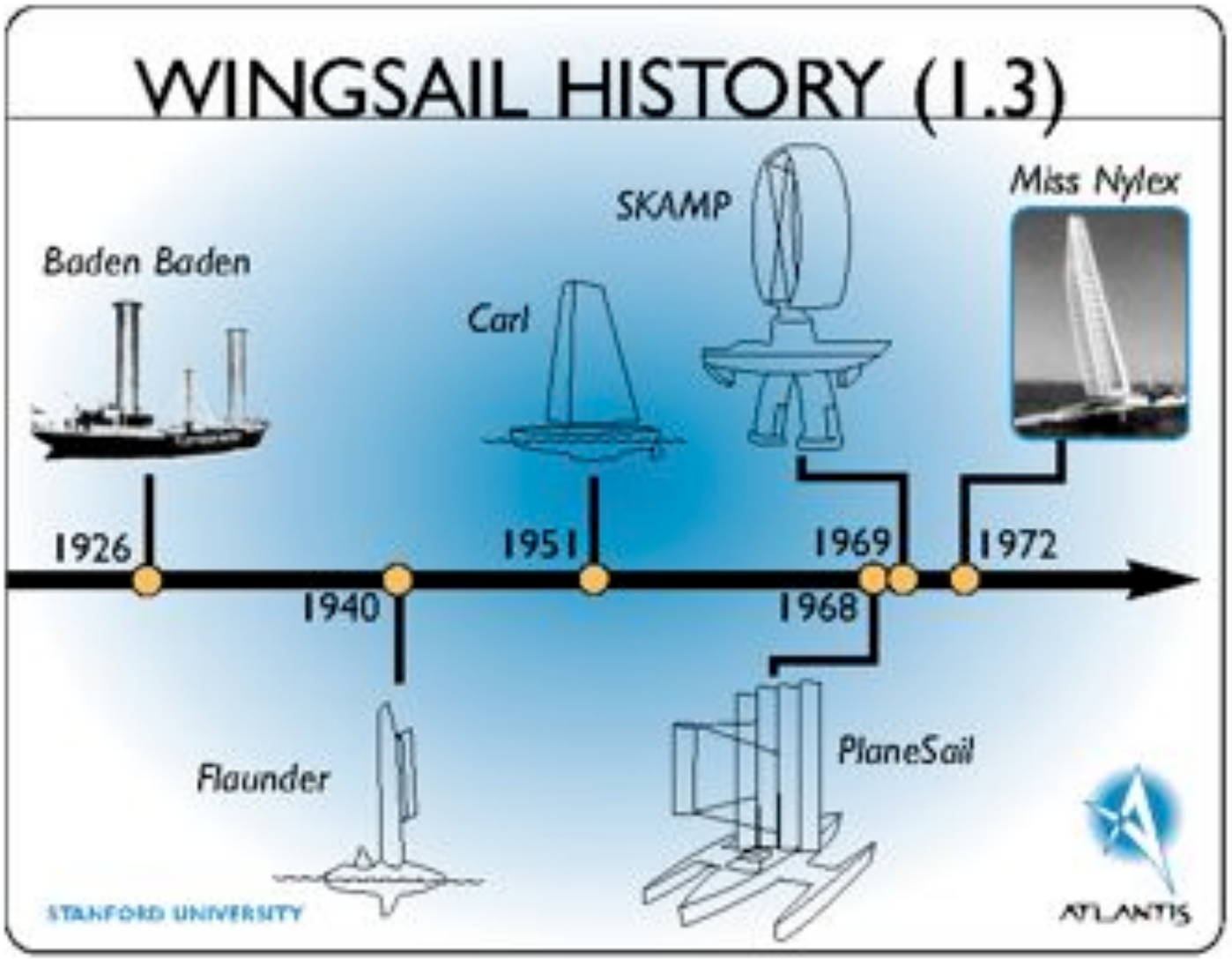
NSF MRI

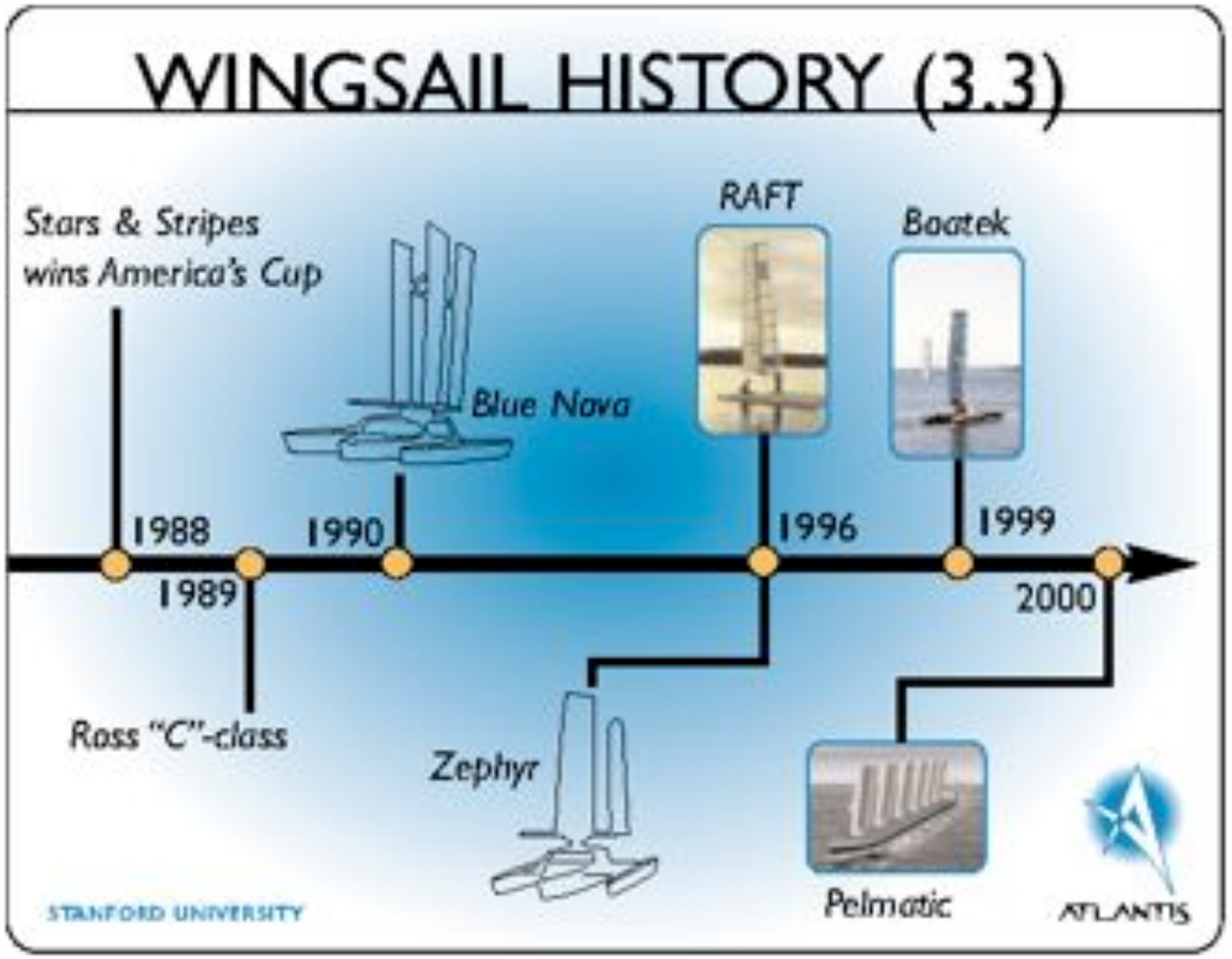


URI Allens Harbor Facility

NSF MRI

URI Allens Harbor Facility


WINGSAIL HISTORY (1.3)
Baden Baden
Carl
SKAMP
Miss Nylex
1926
1940
1951
1968
1969
1972
Flaunder
PlaneSail
STANFORD UNIVERSITY
ATLANTIS


WINGSAIL HISTORY (3.3)
Stars & Stripes
wins America's Cup
Blue Nova
RAFT
Boatek
1988
1989
1990
1996
1999
2000
Ross "C"-class
Zephyr
Pelmatic
ATLANTIS
STANFORD UNIVERSITY

AUTONOMOUS SAILBOATS

SKAMP project

- RCA Astro-Electronics division
- Uses two curved NACA 0030 wings
- Elastomeric hull
- Positioning via *Transit*
- Speed ~4 knots (2 m/s)
- "Station Keeping" within 0.2 nm (370 m.)

RELATIONSHIP project

- Technical University of Furtwangen.
- Conventionally sailed trimaran.
- Satellite link between boat and control.
- Currently anchored in Azores.

STANFORD UNIVERSITY

ATLANTIS

BACKGROUND SLIDES COEUT

What is a Center?

Centers, Institutes, Bureaus and Partnerships

- 8.90.10 Centers, Including Institutes, Bureaus, and Partnerships are **officially recognized academic organizational and administrative units** that shall be chartered to provide **interdisciplinary coordination either within a college or across college lines** directed at an issue **beyond the scope of a single discipline**. They may comprise many different disciplines or they may be single discipline based with secondary emphasis on contributing disciplines. The principal function shall be generally **research oriented**; however, in some instances, their **missions may include instruction** and/or service as **components of equal importance**. The facilities of a center need not be located in one location. A center shall be considered an individual entity and not tied to the demise or expansion of other centers.

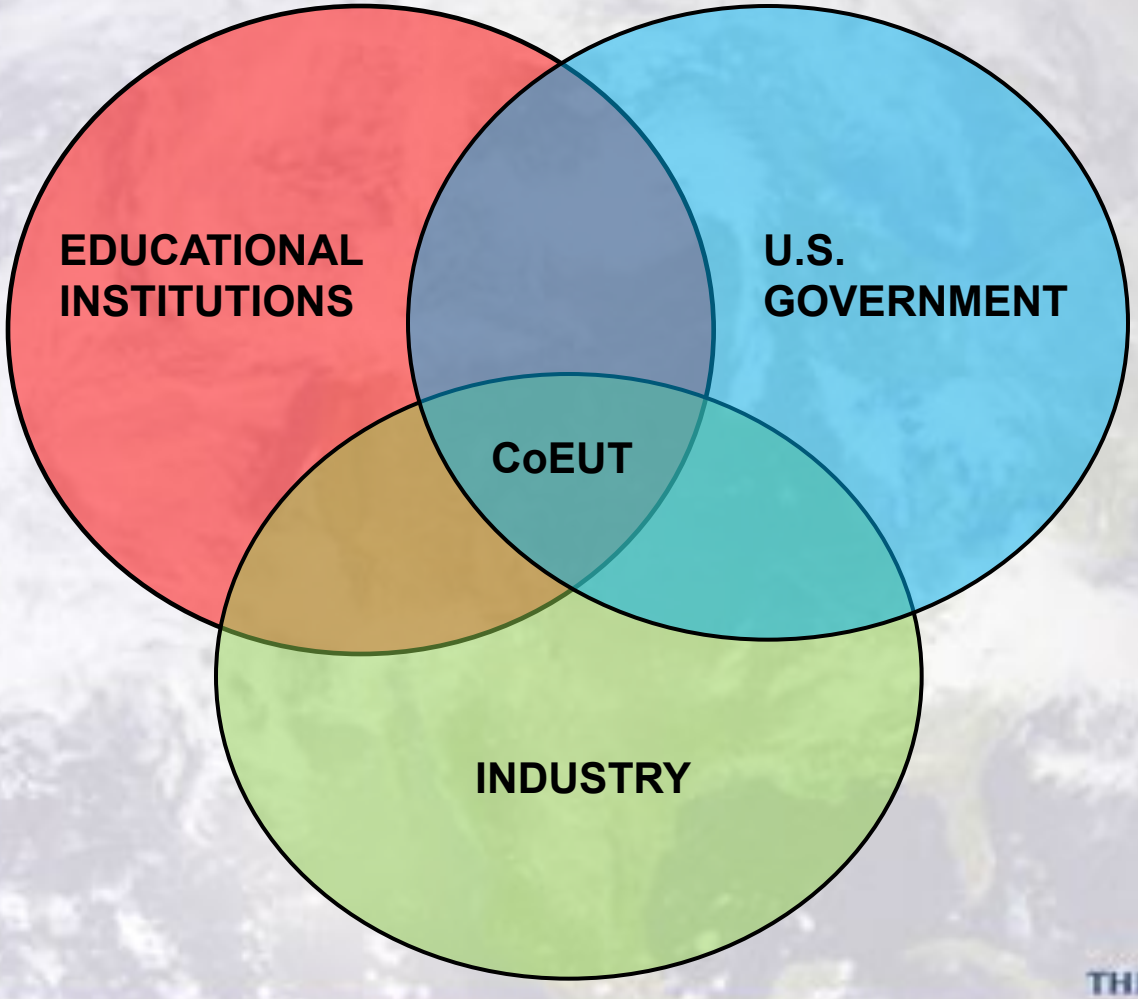
Example Centers at URI

- Center of Excellence in Undersea Technology
- Center of Excellence for Research on Offshore Renewable Energy (RORE)
- Center of Excellence for Explosives Detection, Mitigation and Response
- Inner Space Center
- URI Transportation Center
- URI Outreach Center
- ….

CoEUT Mission

Preeminent national center focused on the education and training of the next generation of undersea technologists and on the research, development, test and evaluation of undersea technologies and associated products for national defense, security, and industry

CoEUT Overview



CoEUT Partners

- Self selected, based on interest and ability to contribute to research and training in undersea science and technology
- Commitment to Center's vision and mission statements and goals
- Work cooperatively in consortium based model to achieve center objectives

CoEUT Partners

ONR
NUWC
NSWC
NSF
ESL
Rite Solutions
WetLabs
MIKEL
Marine Technology Center

ASA
ASC
Electric Boat
Far Sounder
Ocean Server
SAIC
Oceaneering
TSI

ARA
BTech
EmINENT
Purvis
Raytheon
SubChem
UTRC

CoEUT Partners

- College of Engineering
  - Ocean Engineering
  - Chemical Engineering
  - Mechanical, Industrial and Systems Engineering
  - Electrical, Computer, and Biomedical Engineering
  - Civil and Environmental Engineering
- College of Arts and Sciences
  - Computer Science
- Graduate School of Oceanography
  - Equipment Development Laboratory
  - R/V Shanna Rose

CoEUT Timeline

- Created 2006 (Temporary Designation)
- Continuing Status 2007 (RI BOGHE)
- NUWC Cooperative Agreement 2007-2012
  - 50 projects
  - $2.5 M
- NSWC engagement 2013
- Marine Technology Center MOU 2013
- Multiple active research projects

CoEUT Education

- On-site MS Program for NUWC – Systems Engineering, Undersea Distributed Networked Sensors UDNS-DUNS (2007-2011)
- Additional Tailored Courses (2010-2012)
- Electric Boat On-site (2012-2013)
- Graduate Student Advising – NUWC, Electric Boat, Raytheon, URI (2007-present)

CoEUT Research

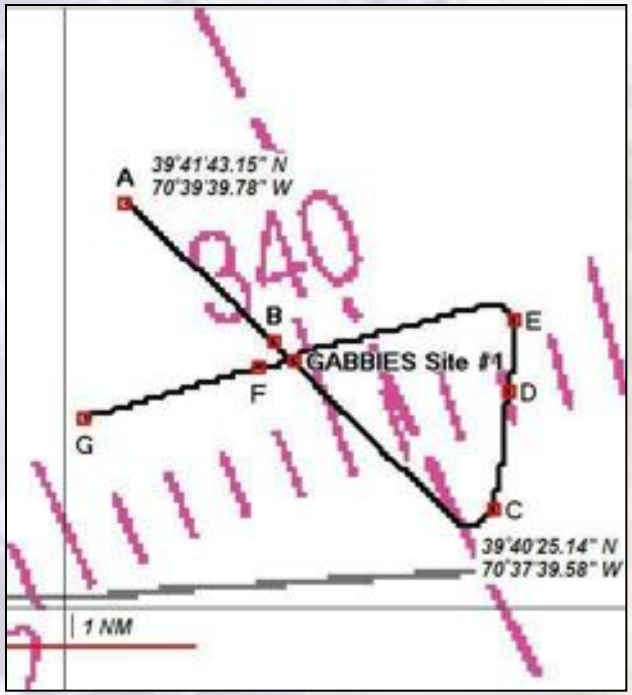
- Geodetic Acoustic Benchmark Beacon (Champlin Foundation, RIEP)
- Underwater Acoustic Navigation Beacon - MIKEL (Navy)
- Low Cost Acoustic Transmitter – Image Acoustics STTR (ONR)
- Wave Energy Buoy – Electro Standards Lab STTR (ONR)
- Diesel Electric Hybrid Survey Vessel (CoEUT)
- Son-O-Mermaid (Princeton University, NSF)
- Dive Helmet Noise Quieting – Triton Systems STTR (ONR)
- Wind Powered Vessels X1 and X2

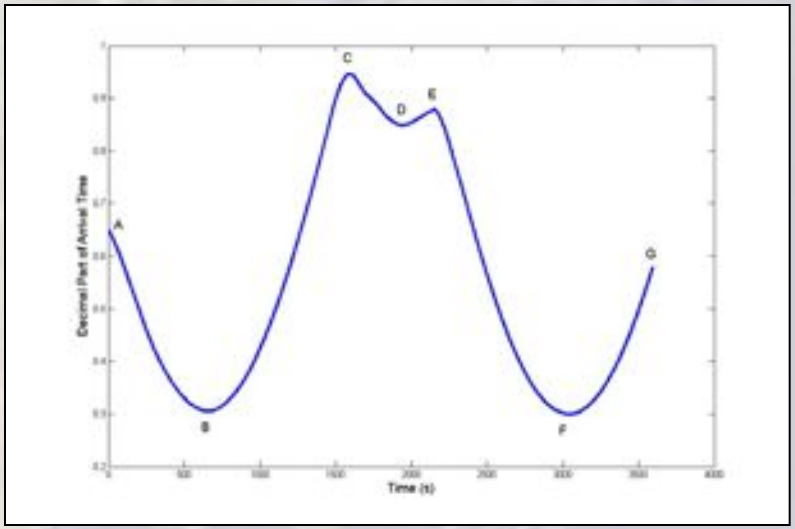
CoEUT Research

- Geodetic Acoustic Benchmark Beacon (Champlin Foundation, RIEP)

CoEUT Research

- Geodetic Acoustic Benchmark Beacon (Champlin Foundation, RIEP)





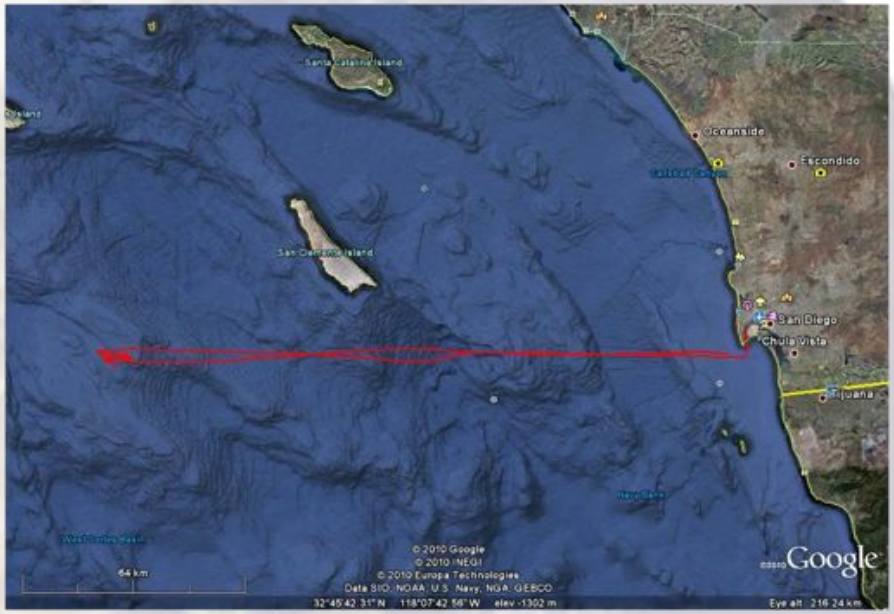
CoEUT Research

- Underwater Acoustic Navigation Beacon - MIKEL (Navy)

- 2007 URI-MIKEL-NUWC Collaboration
  - EX1, 6 months, Kao'olawe, HI
- 2008 Gen 2A - Kao'olawe, HI
- 2009 GEN2B - Kao'olawe, HI
- 2010 GEN2B - Kao'olawe, HI, SOCAL
- 2011 GEN3A – Kao'olawe, HI
- 2012 GEN3A – Kao'olawe, HI
- 2013 GEN3B - SOCAL

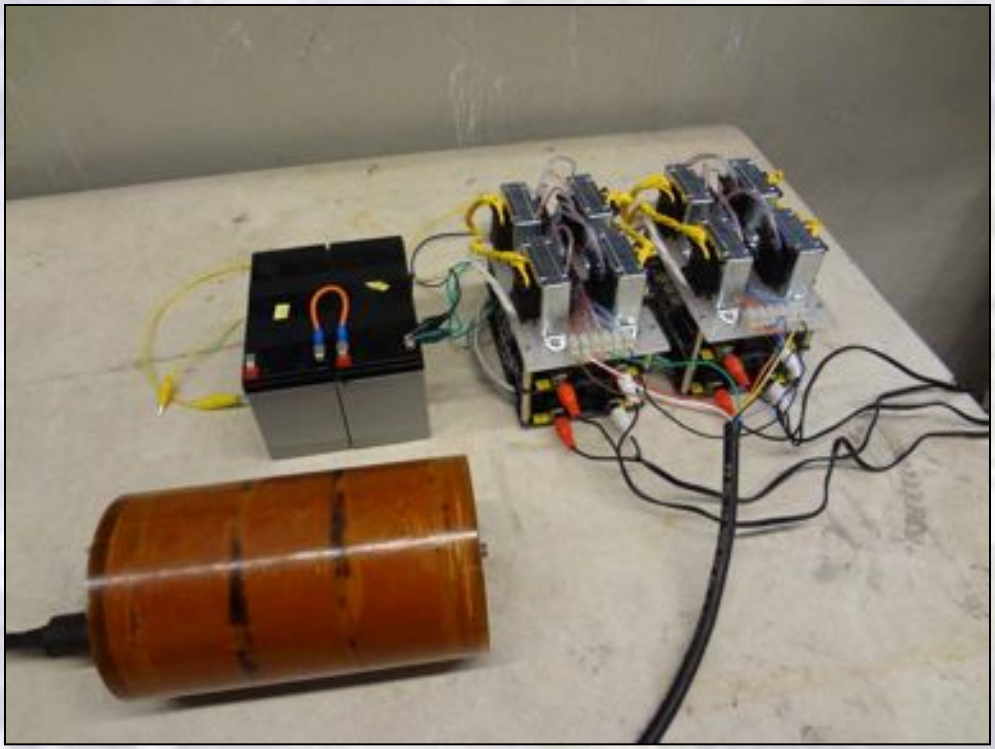
CoEUT Research

- Underwater Acoustic Navigation Beacon - MIKEL (Navy)



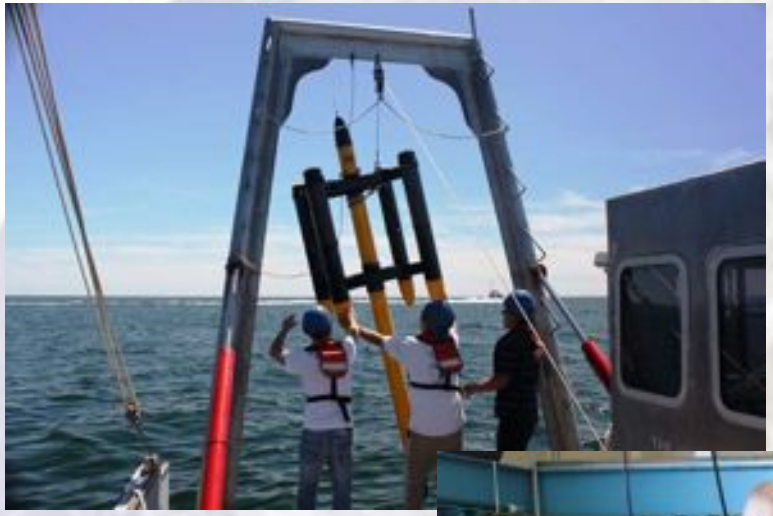
CoEUT Research

- Low Cost Acoustic Transmitter – Image Acoustics STTR (ONR)



CoEUT Research

- Wave Energy Buoy – Electro Standards Lab STTR (ONR)

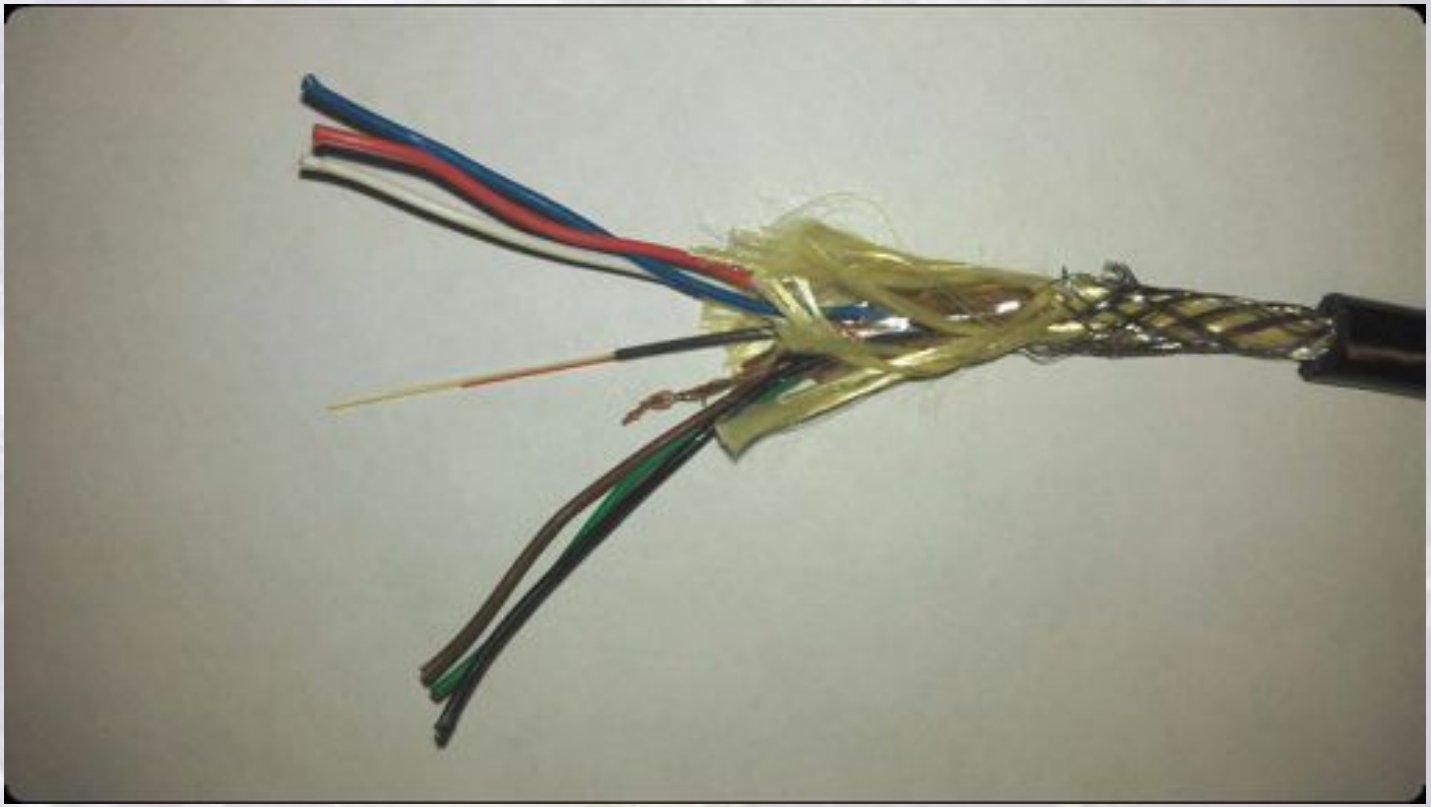


CoEUT Research

- Son-O-Mermaid (Princeton University, NSF)

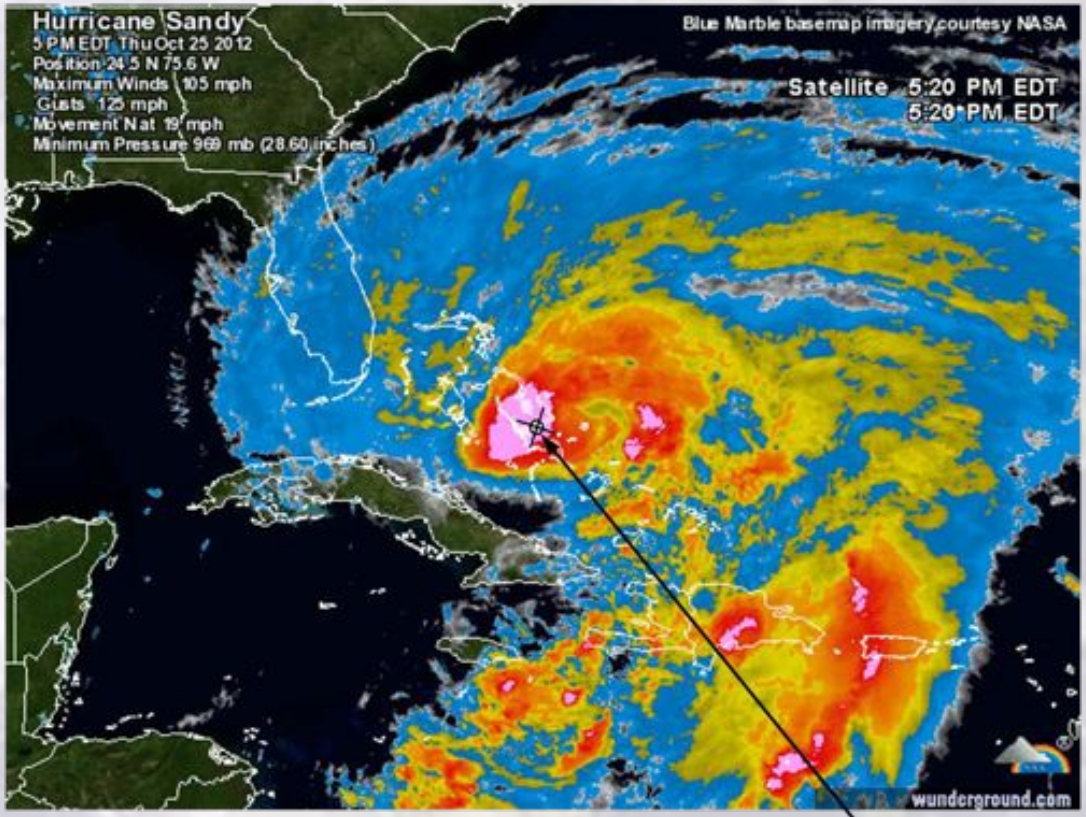
CoEUT Research

- Son-O-Mermaid (Princeton University, NSF)



CoEUT Research

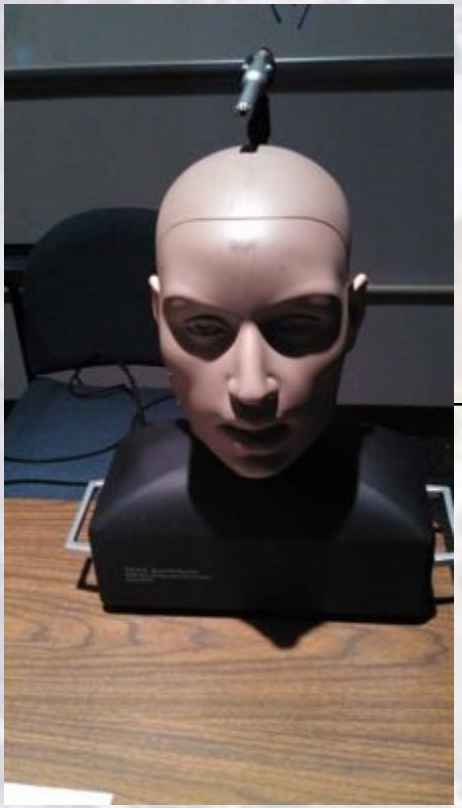
- Son-O-Mermaid (Princeton University, NSF)



SON-O-MERMAID SUFFERED A DIRECT HIT FROM HURRICANE SANDY (CATEGORY 2) BUOY LOCATION INDICATED BY CIRCLE

CoEUT Research

- Dive Helmet Noise Quieting – Triton Systems STTR (ONR)



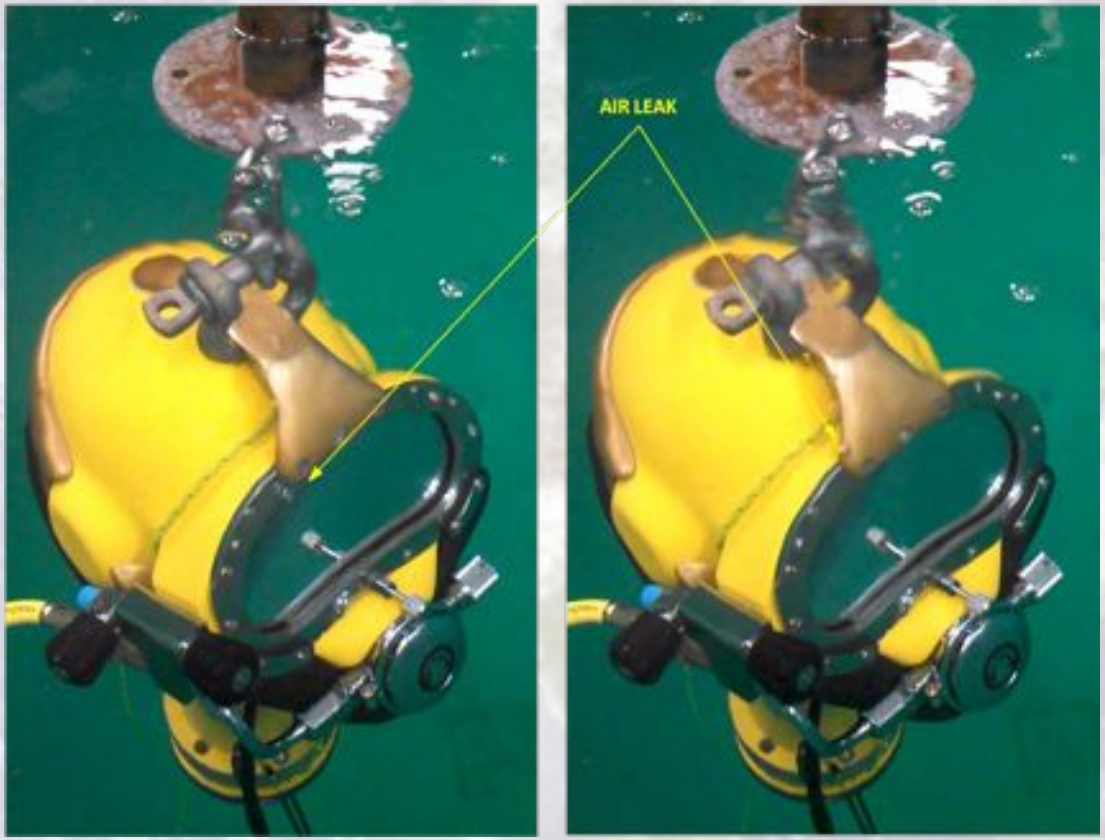
CoEUT Research

CoEUT Research

- Dive Helmet Noise Quieting – Triton Systems STTR (ONR)

CoEUT Research

- Dive Helmet Noise Quieting – Triton Systems STTR (ONR)



Vessels

1. USS Dace (SSN-607)
2. USS Flasher (SSN-613)
3. USS Alexander Hamilton (SSBN-617)
4. USS Santa Fe (SSN-XXX)
5. USS Cheyenne (SSN-XXX)
6. USNS Pathfinder
7. NUWC WB-30
8. NUWC 841
9. AUTEC Range Master
10. AUTEC Range Rover
11. AUTEC LCM-8
12. RV Endeavor
13. RV Argo Maine
14. URI CT-1
15. URI RV McMaster
16. URI RV Laura Lee
17. URI RV Captain Bert
18. URI RV CT1
19. URI RV Shock
20. US Army LCM Great Bridge
21. US Army LCM Panama Canal
22. US Army LCM-8 Kwajalein
23. Manao II
24. Kahana
25. Hanua Spirit of the North
26. McGaw
27. USN RSC-1
28. RV Acoustic Explorer