Acoustic Communications with AUVs and Autonomous Oceanographic Sampling Network Development

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1 LONG-TERM GOALS

The general objective is to investigate basic and applied problems associated with the efficacious reconnaissance of littoral waters in support of mine warfare and oceanographic tasks. The particular research topics are basic and applied problems associated with acoustic communications, monitoring, command, and control of AUVs in support of the AOSN concept.An underlying goal is to strive for cost-effective means to solve these problems. Specifically with this proposal, we wish to address acoustic communications between a submarine and an AUV and the implications of networking elements such as AUVs, moorings, and support vessels for oceanographic and mine reconnaissance tasks. As our capability matures we will focus on cooperation between network elements for more effective use of resources and expanding the scope of the network.

2 OBJECTIVES

This project pursues 3 complementary objectives all of which are related to communication with AUVs in support of oceanographic and military applications.

The first objective is to support the development and testing of the relevant hardware and software needed to demonstrate rendezvous and communication between a submarine and an AUV. This has been identified as a key technology for off-board sensor deployment from a submarine. The FAU Ocean Explorer vehicle provides a cost effective platform for the development and testing process.

The second objective is to support oceanographic and mine reconnaissance experiments by refining the capability in software and hardware to monitor and remotely command multiple platforms in coordinated sampling missions. The software refinements include a more robust and flexible

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architecture for mission planning and control using the limited computational resources on board the AUV. This will enable the execution of more complex missions involving both off-line and on-line planning especially the ability to remotely modify mission plans. We will use the FAU acoustic modem with its multi-node open channel protocol.

The third objective is to do exploratory development of a very low cost acoustic modem using COTS power line spread spectrum transceivers. A set of network communication links will be implemented and demonstrated in turn culminating in a multi-node network.

In particular these research objectives will be investigated through a series of at sea experiments with the FAU AUVs and associated communication and sensor systems.

3 APPROACH

3.1 Rendezvous and Acoustic Communication Between and AUV and Submarine

This task is a collaborative effort between FAU and NUWC. The technical challenges associated with acoustic communications will be addressed by NUWC. FAU will focus on the vehicle operation and mission control software. The primary operational challenges for the AUV are high speed long endurance and quiet operation. A typical Navy submarine as a minimum speed requirement for safe operation that is somewhat in excess of 4 knots. The faster the better. The Ocean Explorer AUV was designed for 3 knot cruising speed with a required propulsion drain of about 100 Watts. The Ocean Explorer’s maximum speed is nearly 5 knots with a propulsion power drain of nearly 400 Watts. The efficiency of the OEX at high speeds has been increased and self noise decreased by adjustments to the propeller, thruster, servos, and tail section. Because submarine time is so expensive the demonstration must be completed in one day. This means the AUV must be able to run for several hours without recharge. The ACOMS payload carries extra battery packs to increase endurance. The mission software has been modified to integrate the NUWC modem and to support remote commands from the mother submarine. Both long range low bandwidth and short range high bandwidth communications have been tested. An experiment was conducted planned in June 1998 in the Bahamas (Autec). This tested refinements to the communications system based on the 1997 results. This experiment tested remote control of the AUV from a Research Vessel and also upload from the AUV of video images all over the acoustic modem. Mission control software and vehicle reliability testing has been an ongoing effort throughout the year. Communications and Control of AUV in Moored Acoustic Network

3.2 AOSN Development for Mine Reconnaissance and Adverse Weather Missions

This project focused on continuing development of technology for integration of AUV sensors and systems into an AOSN type network based on a combination of wired, RF and acoustic modem links. The purpose of this effort is to enable feedback between the AUVs and the human operators. Reliable communications is the first step towards feedback adaptive sampling. The next generation low cost FAU acoustic modems have been developed and integrated into the AUVs with appropriate control software. The higher bit rate has allowed for more sophisticated control and telemetry messages. The protocol developed by FAU for the modems supports up to 16 modems using the same channel. We are refining this protocol as we gain experience.

3.3 Remote Modification of AUV Mission Plans

As the AUV mission goals become more ambitious and complex such as mine counter measures, docking, storm front and gradient following, and feature based navigation, it is important for the AUV software to be able to support such missions. The AUV should not only support pre-programmed missions but also emergency handling, acoustic modem commands that override or place new mission tasks for the AUV, on-line feature based navigation etc. The vehicle software has been enhanced to support 3 sources for commands to the navigator, namely, emergency manager, remote manager, and mission manager. The remote manager forward commands from the acoustic modem. The software has been designed so that virtually any mission command can be sent over the modem. This commands interrupt the normal mission commands but the mission commands resume once the remote commands are finished or finish if the remote commands cause the mission commands to be flushed.

3.4 Very Low Cost Acoustic LonTalk Transceiver

The Transceiver consists an Echelon PLC-30 spread spectrum power line transceiver (9 - 90 kHz), a coupling circuit to the amplifier, an amplifier, and acoustic transducer. This can be connected to any Neuron Chip module either as a control module or as part of a router. Together these constitute a very low cost acoustic modem. Total cost is under $1000. We are building 6 of these modems. Because these are Neuron based and use the LONTalk protocol for communications these modems will have nearly seamless integration into the AUV systems. One side of the router module is the powerline transceiver the other side of the router module can be attached to the vehicle twisted pair network. No special programming other than addressing is required to communicate over the modem. The modem will be used for short range communications between the AUV and dock. This will allow the AUV to notify the dock to prepare for docking and can also be used to initiate power transfer once the AUV has docked. A moored network of these very low cost modems will be set up spaced about 100 meters apart in a grid and the communications performance tested and quantified.

4 WORK COMPLETED

The NUWC ACOMS payload was modified to include a low drag fairing over the high frequency transducers to reduce drag. Further refinements in packaging were made to support the towed array. A video camera and frame grabber were added to the payload to support remote upload of acquired images.The AUV Software was updated to accommodate more complex remote mission commands. A 10 day cruise to the Bahamas was completed.

The new tail section redesign was completed and in water tested. New propellers have been designed and built.Further refinement is in progress. The new tail section uses a lower maintenance quieter design. Tank tests of the self-noise of the new tail section have been conducted at FAU. Further testing is planned for the NUWC tank in January.

The next generation FAU modems have been completed, at sea tested, and integrated into the AUVs. Testing and demonstration of acoustic communications on the AUVs is scheduled for the AUVFest in November and the MCM and Adverse weather experiments in December.

A detailed software design has been completed for a hierarchical state machine manager to replace our current mission manager. This will support full conditional execution. Implementation is underway.

Transducers and parts for the LonTalk acoustic transceivers have been obtained. The amplifier to be used is the same one developed for one of the FAU sonars. A coupling circuit has been designed.

A new cell phone modem antennae was installed on the Oceaneer. A test of a satellite packet modem was conducted.

5 RESULTS

The ACOMS Bahamas experiment went very well. In 9 days the AUV successfully completed 28 missions out of 30. The failed missions were due to a stuck servo and a ground fault. All the objectives for acoustic communications testing were completed. All the objectives for AUV remote control were completed. Highlights include, multi-hour missions under remote control. Video surveys of bottom objects with acoustic transmission of images. In one mission over 1000 images were successfully transferred. The WHOI modem regularly sustained data rates as high as 10 kbps.

The new FAU modem was successfully tested in water with reliable communications up to 1200 bps. The modem interface software on the AUV has been rewritten to accommodate the increased bit rate and packet size.

The new cell phone modem antennae significantly improved reliability. The ship to shore communications now support up to 4800 bps with few or no disconnects.

The new tail section is very quiet and has proven to be easier to maintain. The increased size improved the packaging allowing the new modems to fit in the tail. The new servos provide improved response and combined with the fuzzy sliding mode controllers with integrators provide significantly better stability than the old OEX tail sections.

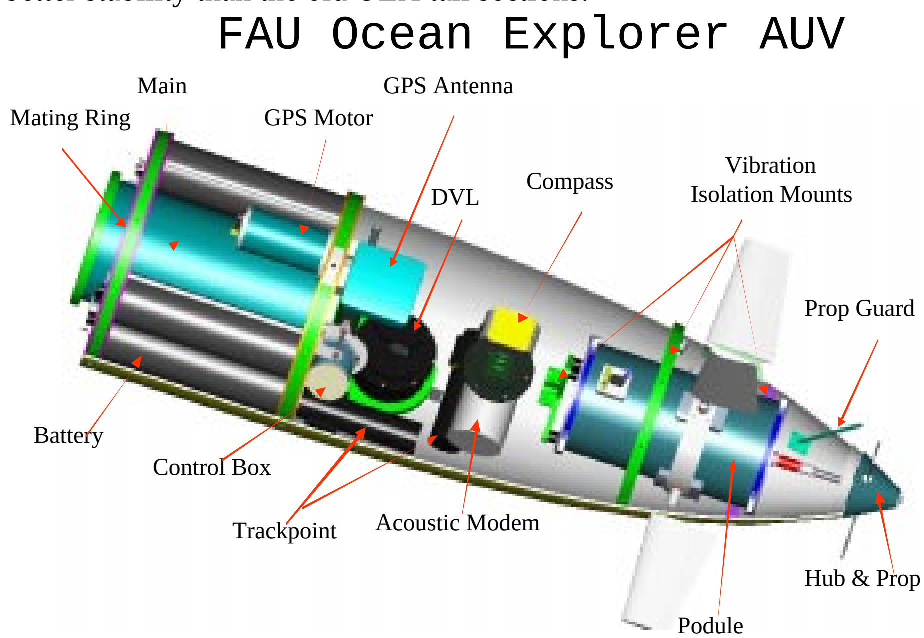
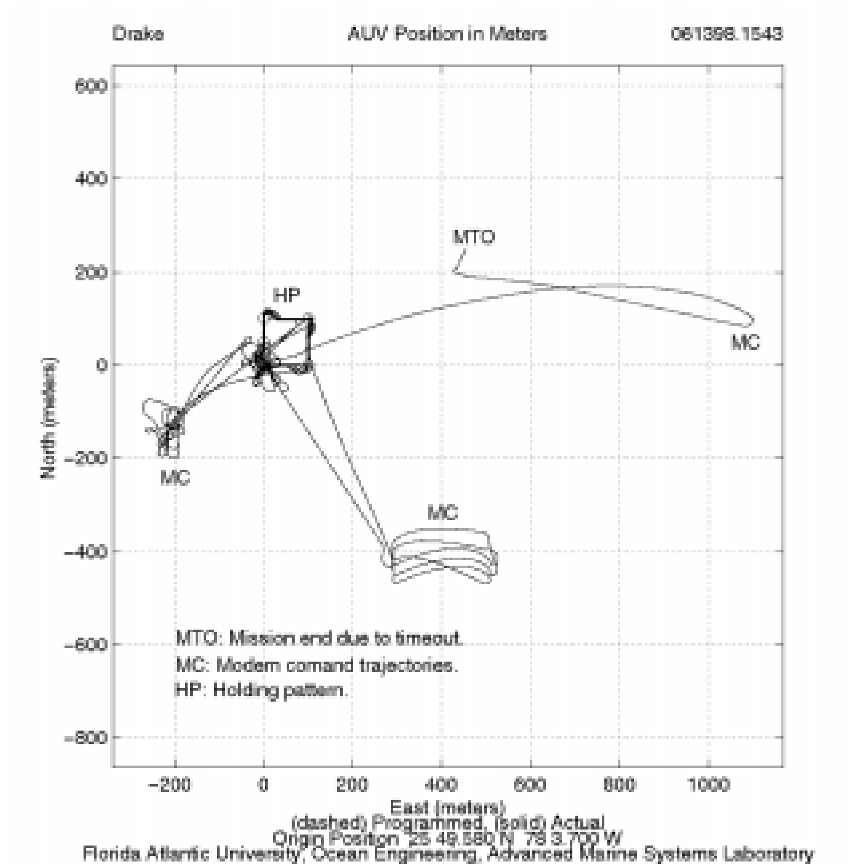


Figure 5.1 FAU Ocean Explorer B: Redesigned Tail Section.

6 IMPACT/APPLICATIONS

The ACOMS experiment has enabled the planned 1999 technical demonstration of acoustic communications between and AUV and submarine.

Low cost networking of AUVs has the potential to revolutionize the way data is collected in shal-



low water both for oceanographic and military missions.

The acoustic and RF modem communications capabilities we have demonstrated satisfies the related NAVO requirements for AUV hydrographic survey.

The basic acoustic communications technology infrastructure needed for AOSN has been enhanced. Remote control of AUVs using acoustic modems has been reliably demonstrated. What remains is the demonstration of cooperative multi-auv missions.

7 TRANSITIONS

The ONR ACOMS ATD is well on its way to demonstrating AUV to Submarine acoustic communications. The follow on to the ATD completion would be integration into the fleet.

8 RELATED PROJECTS

Sampling and Survey with AUVs in Adverse Weather Conditions, ONR.

AUV Navigation and Platform Development, ONR.

Remote Sampling and Survey of Shallow Water Using AUVs with Application to Mine Reconnaissance, ONR.

Acoustic Communications with AUVs and Autonomous Oceanographic Sampling Network Development. ONR

ACOMS Acoustic Communication between UUV and Submarine, ONR ATD.

AUV Hydrodynamics in Shallow Water during Adverse Weather Conditions, ONR.

Coordination of Experiments Using AUVs at the SFTF, ONR.

ONR MURI on Nonlinear Control

USF Projects, CoBop, UK Autosub, WHOI Remus, MIT Odyssey

Advanced Machinery Control Architecture (ACMA) Laboratory Development for Automated Navy Ship Auxiliary System Control, Reconfiguration and Failure Recovery, ONR.

Dependable Network Topologies with Network Fragment Healing for Component Level Intelligent Distributed Control Systems for Naval Shipboard Automation, ONR.

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