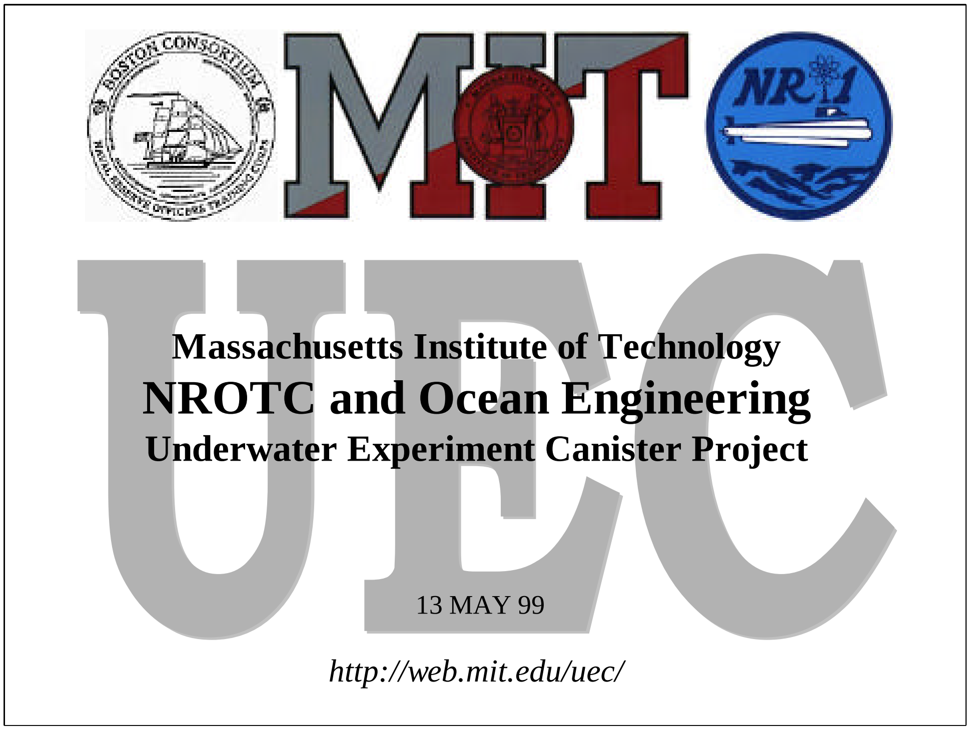


Welcome ladies and gentlemen.

I'm really exited to present our project to you today. You'll have to scale back your thinking from hundreds and thousands tons warships, to about 40 lbs worth of instrumentation.

The UEC (Underwater Experiment Canister) project was inspired when I visited submarine NR-1 in April of 1998. They were commenting on the difficulty of easily carrying more missions on board.

The next several pages give some the background behind the project.

The last side is a bunch of useful web addresses for these sorts of projects.

UEC Project Goals

The goal of the UEC Project is to build a small family of devices that serve as a standardized and modular method of placing secondary experiments on research submarines and submersibles. Placing additional projects on these ships is a way of accomplishing more experiments per deployment, with minimal interruption of the ship's routine.

The United States Navy's deep diving research submarine, NR-1, is serving as the platform for the project. We are also currently looking for additional platforms (Navy or civilian) that would be interested in hosting UECs onboard.

The project provides MIT Midshipmen with ocean related engineering experience.

UEC Project Background

The idea for the UEC project was inspired by NASA's Small Shuttle Payloads Project (SSPP). In this program, NASA provides a family of containers in which organizations and institutions can place their experiments. These containers cover a range of sophistication levels, and are placed in the otherwise unused space of the Shuttle's cargo hold.

The UEC is the underwater version of the SSPP. It was envisioned to require no (or very little) supervision from the ships crew. In essence the experiment would just be tagging along for the ride.

The Electric Boat Corporation's NR-1 planning office suggested that additional stand-alone experiments could be placed in NR-1's NAVNET launch tubes, if a chassis were built to allow this.

Possible UEC Versions

Four (4) types of UEC devices have been envisioned:

A Free Flooding Unit: (UEC-1x) This unit is a canister that is open to the sea and had mounting hard points on the inside. It might be good for testing materials and small components under real operating conditions.

A Data Collection Unit: (UEC-2x) This unit has a sealed electronics bay for onboard data collection and experiment control.

A Water Sample Collection Unit: This unit is designed to take water sample at regular intervals. Time stamps, noted with each sample, can be later correlated with the navigational plot to determine the sample's location.

A Bottom Resting Unit: This unit is jettisoned by NR-1 at a specific location and rests on the bottom, running it's experiment. It is one of the three types mentioned above. Upon completion it would either return to the surface or be recovered by NR-1.

To date we have envisioned 4 types of UEC devices.

The first type of UEC (UEC-1) is just a free flooding compartment with the needed hardware for mounting things on the inside and attaching it to the host platform. It is most suited for long term material testing at pressure. It has been built and deployed.

The second type of UEC (UEC-2x) has an on-board power supply and microprocessor for experiment control and data logging. It too has been built and deployed. Much more work is needed to improve the data logging capacity and pressure transducer.

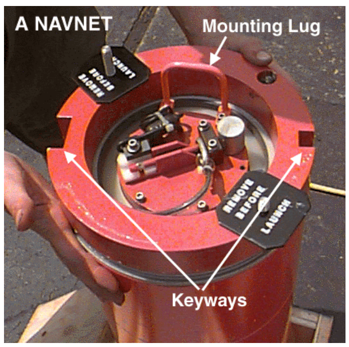
The third type UEC will be able to take and store water samples, at preset intervals. We are also looking at ways in which a sample could be taken on command from the ship. Our goal is to be able to store 20 to 40 samples. This would allow NR-1 to take samples without breaking SUBSAFE. If the package is small enough the third generation UEC could also be placed on AUVs to take samples.

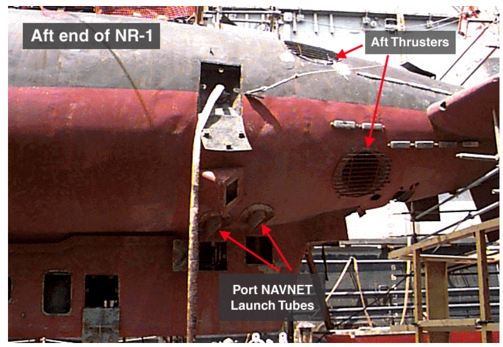
The fourth type will will be one of the previous three types that executed is experiment on the bottom, and then is retrieved or returns to the surface.

How are UECs Deployed?

UECs are currently deployed on Submarine NR-1 in the ship's NAVNET tubes

Other Possible Platforms:, AUVs, Buoys, etc.





UECs are currently deployed on Submarine NR-1. Al Ruditzky of the NR-1 Project Office at Electric Boat Corporation suggested then we use NR-1's NAVNET tubes for deploying UECs.

As long as our equipment has the same mounting footprint as a NAVNET, the ship's divers have an easy time installing and removing the UECs.

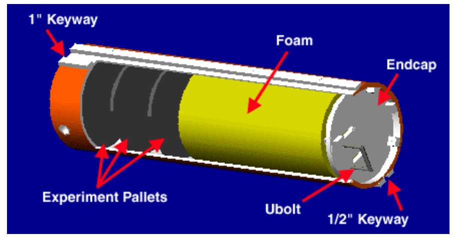
Once we get the second generation further along and certainly when the third generation of UEC is built, we will start look for additional methods of sending UECs to sea.

Options include: AUVs, ROVs, Buoys, and other Navy or WHOI assets.

As a side note, you can see in the photo above that the NAVNET tubes are right next to the aft trusters on NR-1. When the ship does bottom ops, the UECs come back covered in mud. Which leads to question, could you do bottom sampling from a UEC.

UEC-1

UEC-1, the first UEC ever Built!



The ProEngineer model of UEC-1.

UEC-1 is a free flooding version.

It taught us how to work with NR-1

It went to sea for 6 weeks in the fall of 1998

Ok, here is UEC-1. It is a glorified piece of 8 inch orange PVC pipe. It is free flooding UEC. It was built last summer by myself, MIDN Dennis Evangelista, and MIDN Nicole Justis. If went to sea on NR-1 from SEP to NOV of this past year.

We have built a second version that can be built with three parts, four cuts, and four holes. So if NR-1 ever wants to mount something else in their NAVNET tubes they can do this with a trip to Home Depot, $20, and about 30 minutes worth of work.

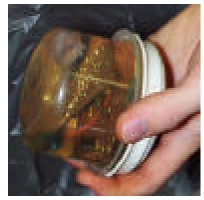
UEC-1 mainly served to teach us how to work with NR-1.

Individual experiments are loaded onto pallets and the pallets are mounted in UEC-1.

We are still working on a naming scheme for the UEC devices. Submarines are named after states and cities, cruisers are named after famous battles, we are thinking of naming the UEC devices after marine parasites. Appropriate don't you think? So email us your favorite marine parasite and we'll name a UEC after it.

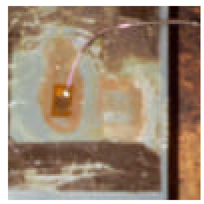
UEC-1's First Experiments

Electronics Potting Compound Test



Pressure Test of Homemade Syntactic Foam

Strain Gage Protective Coating Experiment



Three experiment went out initially on UEC-1

First was our first attempt at oil compensating electronics. We tried putting the circuits in tupperware filled with transformer oil. This was not successful. The tupperware draws a slight negative pressure on the content, so some seawater leaked inside.

The second experiment was our homemade block of syntactic foam. We made it by mixed microspheres from 3M and marine epoxy. We were limited in the size blocks we could cast by the heat generated by the curing process. Even our block that was 8"dia. and 2" thick got hot enough to crack partway through the cur. By the end of the cur the crack was gone. We were curious to see if the block would survive the pressure cycling. It did.

The final experiment was the most interesting. It was a test of our ability to mount and protect strain gages from seawater. We tested several different combinations of epoxies, waxes, and coatings. All worked reasonably well.

UEC-2x Housing

- **2 separate oil or seawater filled bays for experiments**
- **Latches in NR-1 NAVNET tube**
- **Can be built in 24 hours**
- **Unit Cost: $185**

This is the second of the second generation UEC.

Each bay can be independently filled with either oil or seawater. When deployed the oil or seawater is at ambient pressure. This means there is NO pressure differential across the structure, allowing it to be very light, cheap, and safe. Most commercial electronic components will survive at 10,000+ psi.

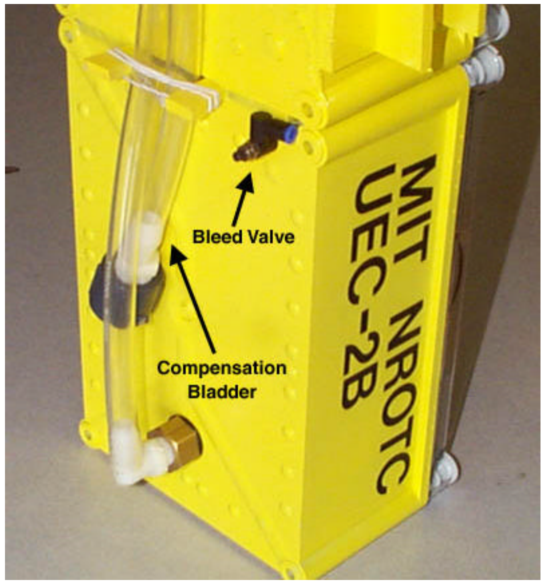
UEC-2A was tested to 2000psi at Electric Boat Corporation

All the parts can be ordered from the McMaster-Carr catalog for less than $200.

Assembly takes about 24 hour, including glue drying time.

The keyways and latch bar allow easy mounting in and removal from the NR-1 NAVNET tubes by divers.

UEC-2x Housing Features



This figure shows the air bleed valve and compensation bladder.

Oil is lightly more compressible that seawater. At pressure the oil will need less volume then on the surface. The blabber provides makeup oil to prevent a pressure difference from developing across ridged parts of the structure at depth.

The bladders are secured to the back of the UEC with rubber bands. Rubber bands are also used to compress the bladder slightly. This keeps the oil inside very slightly above ambient sea pressure. If there are any leaks, the oil will leak out rather then seawater leaking in.

The bladder is also used to fill the bay with oil. During filling the air is bled out of the a bay trough the air bleed valve.

Wires can connect the upper and lower bays via the bladders. The upper and lower bladders are connected and wires through them.

UEC-2+ Power Supplies

Compensated Lead Acid Batteries

D-Cell Pipe Pressure Vessel

Compensated D Cell

We studied three different types of power supplies for the UEC-2 series.

The first, is compensated lead acid batteries. This technique is in common use through the ocean engineering industry. One uses a standard sealed solid electrolyte lead acid battery. Holes are drilled in the battery to allow oil to fill the void spaces in the battery housing.

Advantages: Easy to modify (drill and put in oil), rechargeable, and full ocean depth

Disadvantage: Worst of three in capacity per weight and volume.

The second, is D cell batteries house in a stainless steel pipe pressure vessel. The pipe and end caps can be ordered out of the McMaster-Carr catalog. Teflon grease is used to get an airtight seal. We tested these by getting about 15 double male fittings, filled them with sand (to eliminate the implosion hazard) and putting on the end caps. These were tested to 2000 psi at WHOI. 2 of 30 end caps leaked 6% failure rate. {talk about crap in photos!!!}

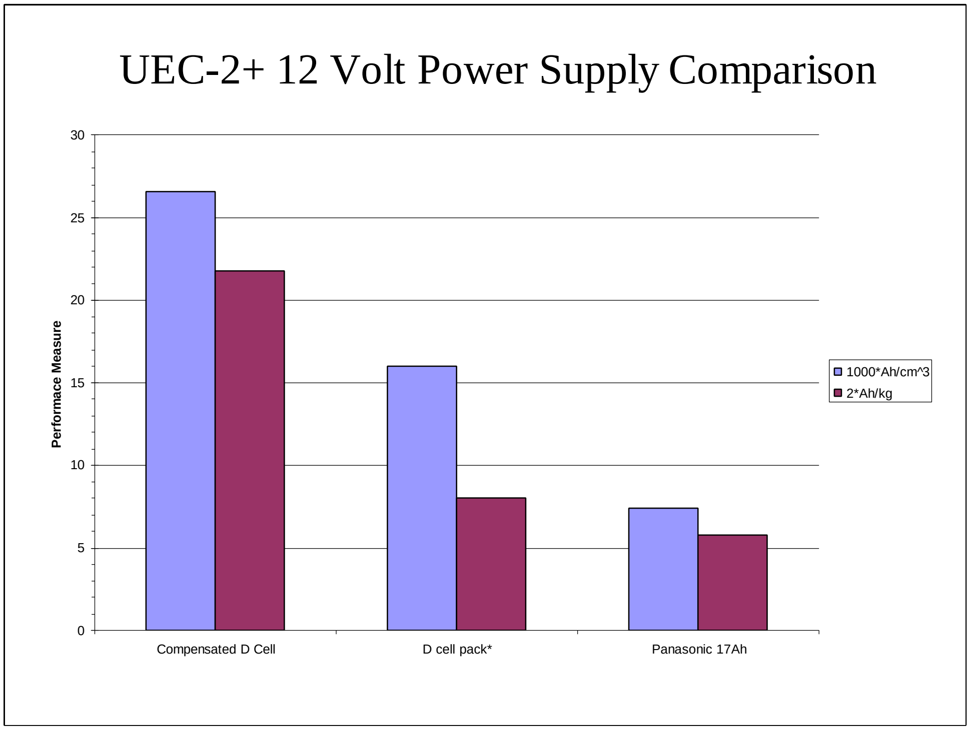
Advantages: easy to replace, better then Lead-A in cap per volume and mass.

Disadvantages: Implosion hazard, crush at 3000m, could leak, limited geometry.

The third option, is compensating D cell batteries, in a manor similar to the lead-acid batteries. Holes are drill and the void spaces filled with epoxy (not oil). Brand name makes a difference (Duracell good) because the of internal construction. It take a little practice to learn the technique. A battery can be compensated in about 15 minute. No one at WHOI has tried this to our knowledge.

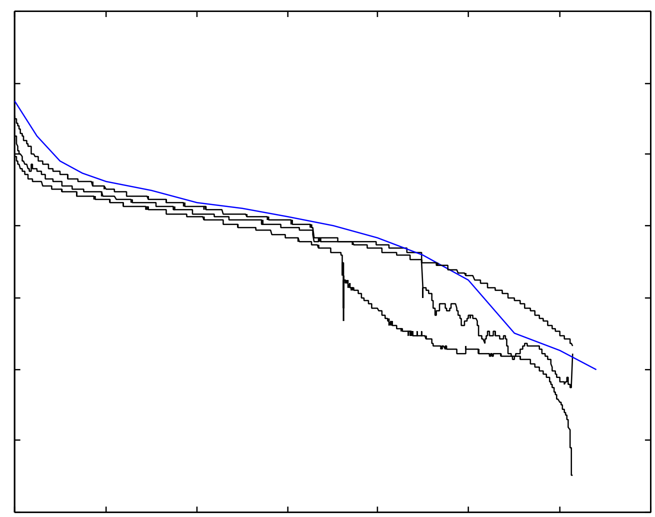
Advantages: Best capacity per unit volume and mass, flexible mounting geometry, can be potted completely and immersed in seawater, good to full ocean depth.

Disadvantages: they take time to make, one time use



The blue bars are a measure of AmpHours per unit volume, and the red bars are AmpHours per until mass.

The comp-D cell has 3.6 times the capacity of the lead acid by unit mass and 3.8 times by weight.



The blue curve is the manufacture's specified curve for discharging a D cell through a 10 ohm resistor.

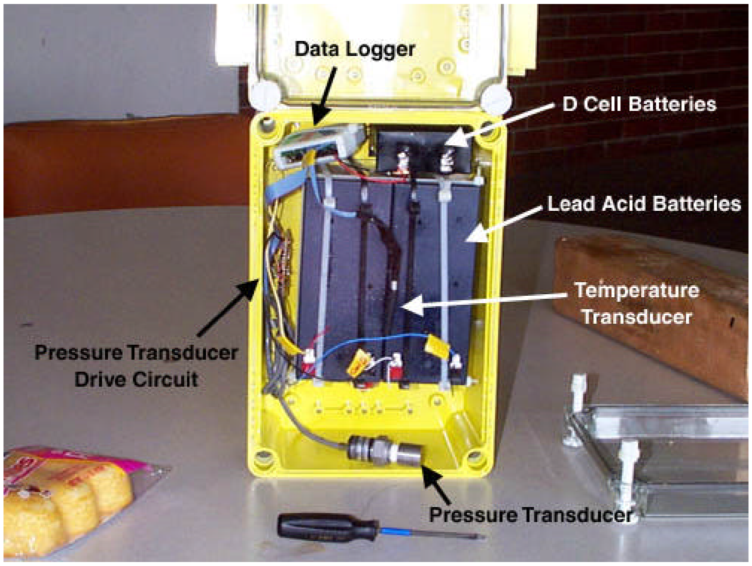
The black curves are the characteristics for three D cells that were taken to 2,000 psi for 30 min and then returned to atmospheric pressure. The batteries were characterized at atmospheric pressure.

This plot shows our test to verify that compensated D cells would not loose capacity after being subjected to pressure.

The blue curve shows the discharge curve specified by Duracell for their D cell batteries.

The three black curves show the discharge curve of 3 compensated D cells after they were take to 2000psi for 30 minutes.

UEC-2x Data Collection



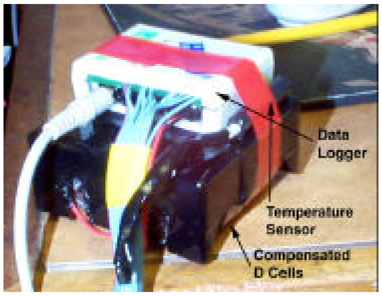
This slide shows the instrumentation layout for UEC-2B's first deployment during the last week of April 1999. Both compensated D cells and compensated lead-acid batteries are used. The D cells are used to power the data logger. The lead-acid batteries are used to power the pressure transducer.

The pressure transducer drive circuited needs a +-12 volt power supply so the lead-acid battery was a quick last minute solution. Future variants of the driving circuit will use a lower voltage power supply.

UEC-2x Data Collection

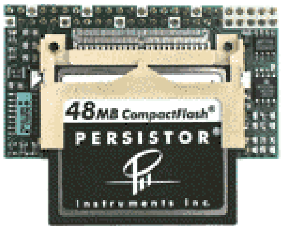
HOBO 4 Channel Logger

- •Replace Crystal
- •Attach Wires
- •32K of storage
- •$87



Persistor Instrument's CF1

- •Attach Wires
- •Cut PCB to size
- •Pot in Epoxy
- •4 to 48MB of storage
- •$395



The top data logger shown here is the same one that was deployed in UEC-2B. It is a HOBO data logger made by Onset Computer Corp. It can store 32K measurement from 4 channels. It sells for about $87 dollars. It takes about an hour to modify for deep ocean use. The mod involves removing the lithium battery and attaching one of the previous mention power supplies. The lithium button cell was pressure tested at WHOI to 10,000 psi and appeared to be intact afterwards, but more tests are needed.

The other component that needed to be replaced for deep ocean use is the crystal oscillator. These get crushed by the pressure. We have developed a technique for armoring the crystals in ceramic and epoxy to allow them to function at high pressure. These armored crystals have been tested to 10,000 psi.

This is a great package for the price, but beyond a black box recording recording it is very limited. We plan on using it on future UECs to monitor battery capacity, temperature, and pressure over the course of the mission. it is not much use for experiment control.

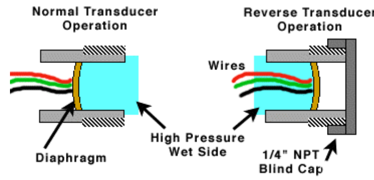
The other data logger we are testing for undersea use is the CF1 from Persistor Instruments. This has up to 48MB of data storage. The micro processor is a Motorola 68020 (Mac LCII). It has a lot of advanced feature and is coded in c

The crystals are not easily replaced on the CF1's PCB so we are working on potting the whole computer in epoxy. Our first attempt failed when the epoxy got to hot in the curing process and cooked the CF1

Pressure Transducers

Requirements:

- •Cheap
- •Fully Immersed
- •Low Power



None met these requirements

We are using an off the shelf transducer and running it in reverse

We built our own driving circuit with a Burr-Brown Instrumentation OpAmp.

More tests are needed

Our pressure transducer requirements are a little unique.

It must be fully immersed in oil at pressure, cheap, and draw very little power.

After spending 4 days on the phone with vendors across the county, I was unable to find a cheap, off-the-shelf transducer that can be immersed to pressure of 6,000+ psi.

The problem is that the transducers require a DP across a diaphragm. When fully immersed and bolt sides are flooded there is no DP. First we tried plugging the back end of a transducer with epoxy. In this mode the transducer operates as usual. After this failed twice (oil leaking down the wires), we changed tactics.

We put a blind cap of the pressure port of the transducer and let the oil flood the backside of the transducer. In this case we are running the transducer's High Pressure (HP) wet side as the Low Pressure (LP) dry side and visa versa.

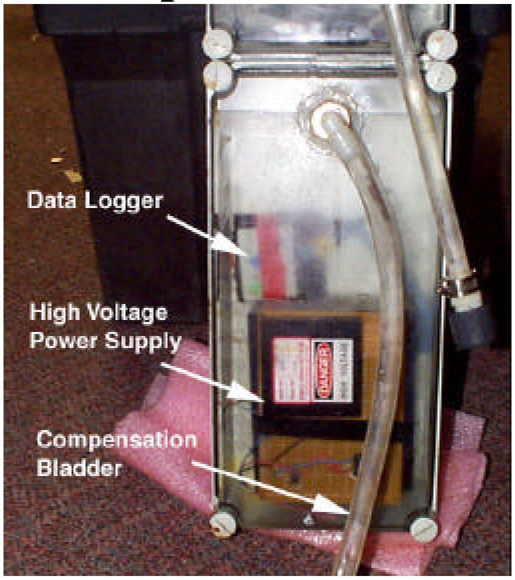
This necessitated build our own transducer driving and amplification circuit to read the strain gages running in reverse on the diaphragm. The driving and amplification circuit built in most transducers would not correctly read the deflected diaphragm.

More tests are needed but, it does pretty well for a cost of $120 and about 1 hour's worth of soldering.

UEC-2x Series Experiments

Piezo Electric Materials Test:

- •Currently Building Piezo Driving Hardware
- •Need to get CF1 working as a data sampler
- •Verify Control before running a new material



Here is UEC-2A. This was pressure tested at Electric Boat. It revealed many flaws with some of the detail of our original design of the UEC-2 series. Rather than fixing the shortcomings it was easier to just build a new one (UEC-2B).

This shows the 2500 volt power supply/signal generator which we plan on using for future piezo electric material tests. Prof. Chaing in the Mat. Sci. Dept. is developing a new piezo electric material for sonars and would like of do a long term characterization at pressure. To do this we must get the CF1 working at depth, attach strain gages to the material with the technique from the UEC-1 experiment, and connect the HVPS. Then we plan on testing a control piezo before testing the new one.

Twinkies Before Deployment

Where is the elastic yield limit of a twinkie? Let find out...

Twinkies After Deployment

The elastic yield limit of a twinkie is clearly somewhere less then 1500 psi. We seem to have a twinkie soup of some sort… maybe the dog will like it.

Goals for This Summer

- •Further Pressure Transducer Tests
- •Pot CF1 and Test at Pressure
- •Complete and Test Piezo Driver Circuit
- •Design and test some water sampling mechanisms.
- •Educational "Science Kit" Development

Most of this you have read about in the presentation already, except our science kit development.

The idea is this. NASA provide a means for elementary and high school students to put experiments into space (I.e. Do lima beans grow upright in space? Etc.) The UEC hardware is getting to the point where it might be used for the same purpose (underwater not in space obviously).

This might be a way to get children excited about science, the ocean, etc. Just another idea that we are going try and see what happens.

Project Members

Students

Roger Cortesi
Jeff Brown
Natalie Chouinard
Kevin Ferguson
Melissa Harness
Nicole Justis
William Vanderson

Faculty Adisors

Dr. Bales
CAPT Mahoney
CDR Whitcomb

These are the project members that worked on the project during the Spring 1999 semester.

During the summer of 1999 Eric Smith, Bret Winton, and John McNally (Mechanical and Electrical Engineering sophomores) will be working on the project.

Thank You

- The MIT Ocean Engineering 13A Program
- Submarine NR-1
- Electric Boat Corporation
- The MIT Hobby Shop
- The Papalardo Lab
- Woods Hole Oceanographic Institute
- Persistor Instruments Inc.
- MIT Edgerton Center
- MIT Sea Grant

The list is really much longer but that is all I could fit on an overhead.

Al Ruditky, Garry Mayer, Ed Eckelmeyer at the Electric Boat Project office have been a great help, and the project could not succeed without their supports.

Equally important is the help from the NR-1 officers and crew. These guys rock. We are very grateful for the chance to bolt something on the side of their ship.

Al Bradley and Karlen Wunnup at WHOI have also patiently answered many of our questions and let us use their really cool pressure tank.

Dr Jim Bales (MIT Edgerton Center) has been a huge help answering our questions, and putting us in contact with people.

Useful Web Addresses

- http://web.mit.edu/uec/
- http://web.mit.edu/
- http://www.whoi.edu/
- http://web.mit.edu/seagrant/index.html
- http://gulftour.tamu.edu/home.html (an NR-1 mission in the Gulf of Mexico)
- http://www.persistor.com/
- http://www.onsetcomp.com/
- http://www.mcmaster.com/
- http://www.digikey.com/
- http://www.parallaxinc.com/