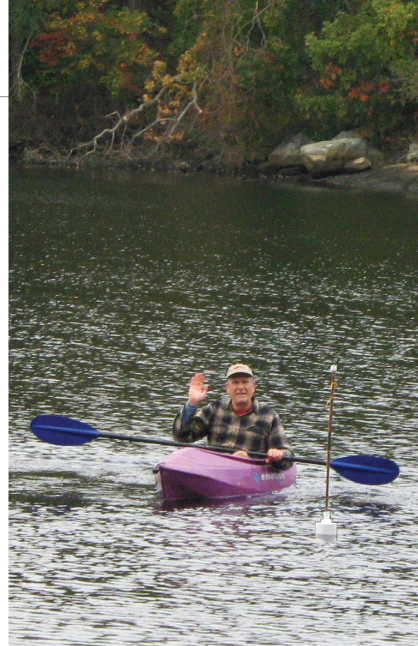
ARRL Education and Technology Program Space/Sea Buoy



Remote measurement technology can be the beginning of many rewarding classroom experiences.

Mark Spencer, WA8SME

"As hurricane Irene approaches, the sustained winds are 75 MPH as reported by a buoy located in Long Island Sound."

"The west coast is on high alert after an earthquake hit Japan a few hours ago."

"The tsunami early warning buoy system is being monitored for the first signs of potentially dangerous waves that are generated by seismic events of this magnitude."

"The debate about global climate change is again heating up, discussions on both sides are being supported from environmental buoys reporting weather data from the North Pole."

All of these fictitious scenarios have one thing in common — remote sensing from seaborne or airborne buoys. But how does that work?

A Hands-On Teachable Experience

The latest addition to the ARRL's Education and Technology Program (ETP) portfolio of offerings is a Teachers Institute-2 based on just that question — the technology behind environmental buoys. The current cost of a single seaborne environmental buoy with simple temperature and pressure sensors is approximately $16,000, excluding the cost of deploying the buoy and the satellite data link time to report out the data collected. Obviously the cost is far outside the reach of most schools, yet our lives can depend on this technology.

The goal of the ETP is to allow schools to access, study and participate in the use of this kind (and other kinds) of technology in an affordable, hands-on way. It also provides the teachers with the fundamental understanding of the technology so that they can in turn develop lessons to teach the technology to their students. Yes, the ETP encourages schools to include Amateur Radio in their curriculum, but not necessarily as a standalone subject. Amateur Radio more importantly provides a conduit, avenue or tool that schools and teachers can use to support the study of other curricular areas.
In other words, Amateur Radio provides a gateway to discovery. The ETP Sea/Space Buoy project is an example.

The ETP Sea/Space Buoy Project

This introductory article summarizes the sea/space buoy system that has been developed. This development is a work in progress; modifications and improvements will be made as the system develops. This is an introductory article because the scope of the technology cannot be covered adequately in one printed article. Consequently, the details of the individual components of the system will be provided online through links on the ARRL website as they are developed. The buoy is called a sea/space buoy because the system can be deployed either in a surface buoy or attached to a weather balloon payload and deployed into near space.

The purpose of a buoy is to access remote areas for long periods of time that are either too dangerous, too expensive or too remote to visit and to make direct observations for study and monitoring. Setting up the technology to make the observations is one thing; getting the information out of the buoy in a timely manner is another matter altogether.

The weather services around the globe deploy weather balloons many times a day to take climatological readings in the upper atmosphere.

These readings are data linked down by a transmitter, and the balloons are tracked by ground stations to make wind measurements. At a predetermined altitude, the balloons burst and the sensor packages return to Earth,

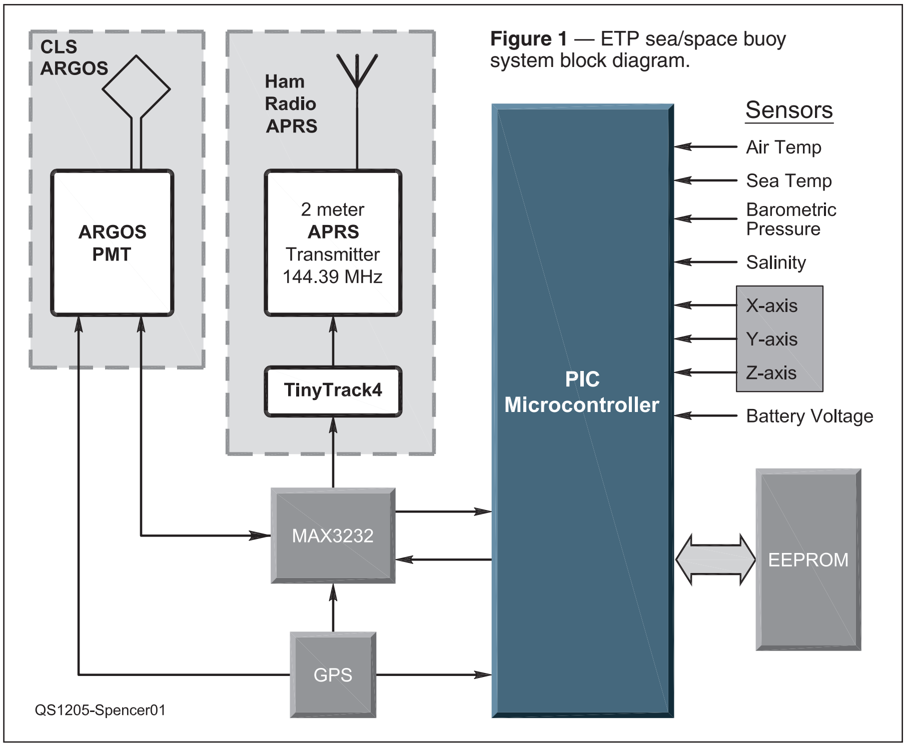


Figure 1 — ETP sea/space buoy system block diagram.

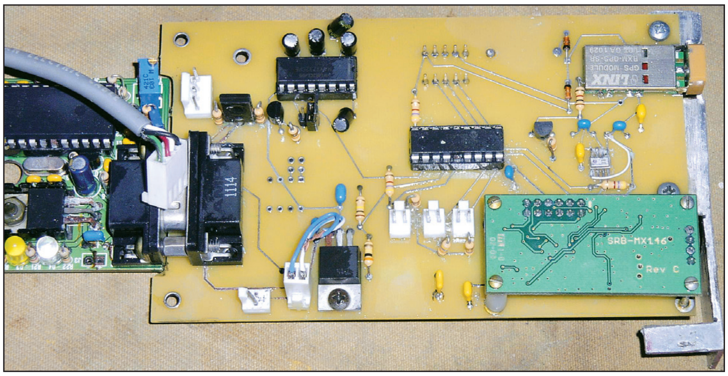


Figure 2 — Sensor package circuit board mounted on buoy body top hatch below the 2 meter data link vertical dipole antenna.

ARRL's Education and Technology Program

This curriculum was developed as part of ARRL's Education and Technology Program (ETP). The ETP is funded by donations from individuals and clubs in the amateur radio community. The ETP is an outreach program to US schools to introduce teachers to Amateur Radio as an instructional resource and to provide an educationally sound curriculum focused on wireless communications. The goal is to offer the resources to build a foundation of wireless technology literacy among American teachers and students. Find more information about the ETP at **www.arrl.org/etp**. To make a donation, visit **www.arrl.org/education-and-technology-fund**.

in all likelihood never to be seen again.[1] Government and education institutions are doing climate change studies by deploying sea and ice borne buoy systems around the globe and in the regions of the Earth's poles.

Measuring Data Remotely

The battery operated sensor packages take temperature, pressure, salinity and other environmental readings and transmit the information to passing NOAA weather satellites using a commercial package carried on the satellites called Advanced Research and Global Observation Satellite (ARGOS). Once the data is in the ARGOS system, it is disseminated to interested users via the Internet. The use of the ARGOS system is not limited to environmental research. Users also track wildlife in remote areas.

Position information can be transmitted from on-buoy (or attached collar when tracking animals) GPS systems or the ARGOS system can use the Doppler shift of the transmitted signal to determine the transmitter's location with remarkable accuracy. The ARGOS system is a subscription service and is not free. The ETP sea/space buoy system is intended to simulate, in the typical classroom environment, the actual buoy systems used. Amateur Radio and the Automatic Position Reporting System (APRS) is a perfect, alternative, affordable fit for this project for the data link.

What's in the Package?

The ETP sea/space buoy system is depicted in the block diagram of Figure 1, and the prototype board outside the buoy body is shown in Figure 2. The centerpiece of the system is the microcontroller that is used to manage the attached sensor packages. The system is flexible enough to adapt the sensors to a particular application. In the case of the ETP sea buoy, the sensors include air and sea temperature sensors, an air pressure sensor, a salinity probe, a three axis accelerometer to measure wave activity and a GPS module to report position information. Alternatively, if the system were to be deployed as a balloon payload, the sensor package might include just the air pressure sensor, air temperature and accelerometers.

Because the space buoy package will have a short mission duration, and the data is to be collected at a shorter time interval (seconds or minutes versus the hour duration between data points in the sea borne application), power limitations (battery life) are not a factor but data link stability is. Consequently, the space buoy has an onboard recording capability to back up the data link so that the collected data can be recovered when the payload is retrieved.

Internal and External Data Links

Besides the microcontroller and sensors, the other integral part of the buoy system is the data link. The ETP system is flexible enough to interface to the ARGOS transceiver for a professional application, or use the ham radio APRS system. The majority of the schools that will use the ETP Space/Sea Buoy system as an educational resource will use the APRS as a data link. The ETP system interfaces to the Byonic TinyTrak 4 modem and the SRB Electronics SRB-MX-146 APRS 2 meter transmitter module.

The sensor/microcontroller interface requires the extensive use of basic electronics from Ohm's law, to voltage dividers, voltage regulation, current limiting, filtering and beyond. Basic algebra skills are employed to calibrate the sensors and to translate the raw data collected (basically proportional voltages and currents) into useable data (temperature in degrees C and pressure in millibars, for example).

The intrasystem communications between the microcontroller and the sensor systems use a number of the common communications strategies including universal synchronous asynchronous receiver transmitter (USART serial communications) and inter-integrated circuit bus (I2C) protocols. For voltage and current measurements, the microcontroller's analog to digital converters (ADC) are used.

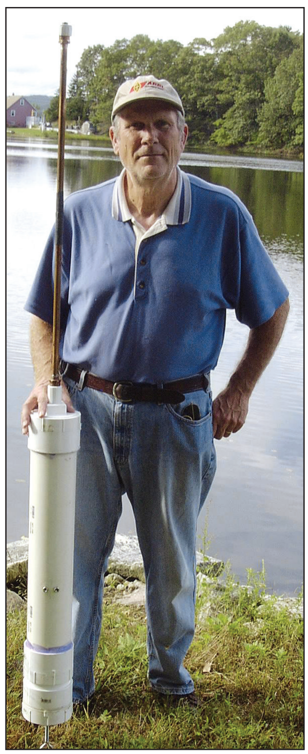


Figure 3 — Buoy body constructed out of common PVC plumbing fixtures available in home improvement retail stores.

All of these topics and some basic C language programming techniques for the microcontroller will be introduced to the teachers during the Teachers Institute and will be covered in greater detail in the supporting web-based articles on this project.

The Physical Plant

The sea borne buoy body is constructed out of common household building supplies that can be found at home improvement stores. Figure 3 illustrates the construction of the "spur" ETP buoy. The sensor package, battery pack and ballast are located inside the buoy body. The sea temp and salinity

[1]The US National Weather Service attaches a return mailing sticker so the finder can simply drop the sensor package in the mail to return it to the NWS.

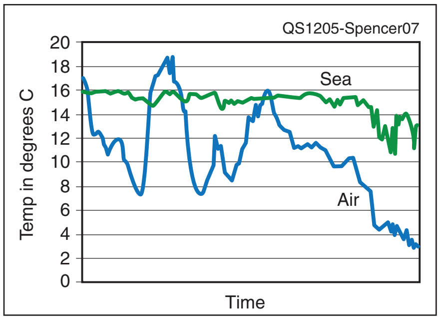


Figure 7 — Air and sea temperature data.

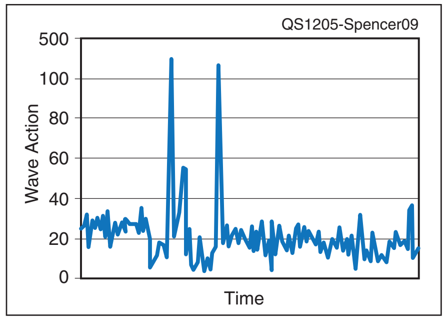


Figure 8 — Wave action data.

sensors are mounted on the outside of the buoy below the water line. The air temperature sensor is mounted in the tip of the 2 meter vertical dipole antenna used for the APRS data link. The buoy is ballasted to sink to a predetermined level to keep the GPS antenna above the water surface while having the center or gravity and buoyancy well below the water line for stability.

Setting it Free

The prototype sea borne buoy was deployed for "wet" bench testing and shakedown in a brackish water cove located near the mouth of the Thames River in Connecticut where it spills into Long Island Sound (see Figure 4). In operation, the data is collected at 30 minute intervals and packaged as UNPROTO text that is sent via the APRS system. Once captured by the local APRS node, the data is disseminated through the Internet to interested users. Using *FindU and call sign* in a Google search, users can access the raw data. Figure 5 is a map display of the buoy location from a *FindU* server. The raw data as captured and relayed by APRS is illustrated in Figure 6.

Figure 4 — The buoy is ballasted to keep the GPS antenna above the water line.

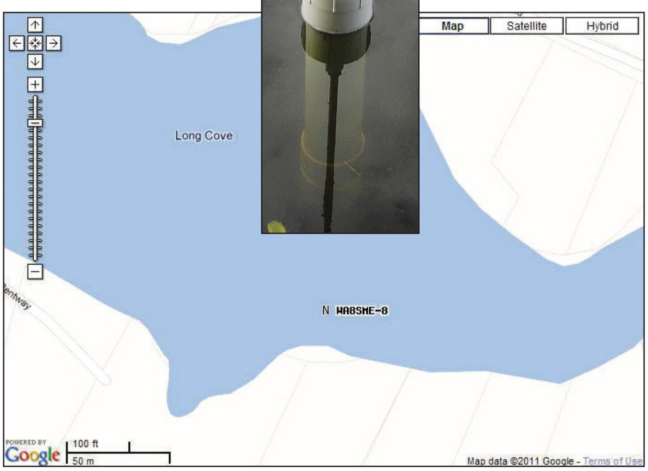


Figure 5 — Map plot of buoy location generated by **findU.com**.

After the identification, time, location and routing fields, the sensor data is shown in comma-delimited fields that can be imported into an *Excel* spreadsheet for interpretation. The system owners would have to publish the algorithms needed to translate the reported data into meaningful information — and that is where the rubber meets the road for this project. Figures 7 and 8 show representative graphs of environmental data generated during the wet bench testing of the system and represent the end product that would be generated, interpreted and used in the classroom. There is not sufficient space to go into the interpretation of this data set here, but suffice it to say that the teachable moments you are looking at are *huge*!

Alternatively, the buoy sensor package can be modified and adapted for a balloon payload and launched with a weather balloon. This is a very popular school activity. There are, however, a few notes of caution about both the sea and air buoy systems. If you are going to deploy the systems, you have to assume that they will be lost.

There are also numerous liability issues that need to be addressed, particularly with balloon launched systems. I hope the liability concerns that some schools might have about ballooning activity and retrieving sensor packages that land in less than ideal locations is obvious. But frankly, even the discussion of potential liabilities is a teachable moment.

The Next Steps

I hope this introduction to the ETP sea/space buoy project has piqued your interest. More details will be published and posted on the ARRL web pages as they are finalized. If you can't wait, feel free to contact me for the specifics that are immediately available. For those teachers who are interested in this project and would like to participate in the Teachers Institute-2 this summer, fill out and submit an application at **www.arrl.org/teachers-institute-on-wireless-technology**.

There are two prerequisites for this TI2. First, the applicants must have attended a basic TI, and second, because the system depends on ham radio for the data link, the applicant must have an Amateur Radio operator's license. See the sidebar for more on the Education and Technology Program.

Photos courtesy of the author, unless otherwise noted.

Mark Spencer, WA8SME, is the ARRL Education and Technology Program Director. You can reach him at **mspencer@arrl.org**.

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Figure 6 — Data reported through the APRS system and posted on **findU.com**.