



## Advanced Systems for Monitoring Underwater Sounds

Versatile units can be deployed at depths as great as 1 km.

*John F. Kennedy Space Center, Florida*

The term “Passive Acoustic Monitoring System” (PAMS) describes a developmental sensing-and-data-acquisition system for recording underwater sounds. The sounds (more precisely, digitized and preprocessed versions from acoustic transducers) are subsequently analyzed by a combination of data processing and interpretation to identify and/or, in some cases, to locate the sources of those sounds. PAMS was originally designed to locate the sources such as fish of species that one knows or seeks to identify. The PAMS unit could also be used to locate other sources, for example, marine life, human divers, and/or vessels.

The underlying principles of passive acoustic sensing and analyzing acoustic-signal data in conjunction with temperature and salinity data are not new and not unique to PAMS. Part of the uniqueness of the PAMS design is that it is the first deep-sea instrumentation design to provide a capability for studying soniferous marine animals (especially fish) over the wide depth range described below. The uniqueness of PAMS also lies partly in a synergistic combination of advanced sensing, packaging, and data-processing de-

sign features with features adapted from proven marine instrumentation systems. This combination affords a versatility that enables adaptation to a variety of under-sea missions using a variety of sensors.

The interpretation of acoustic data can include visual inspection of power-spectrum plots for identification of spectral signatures of known biological species or artificial sources. Alternatively or in addition, data analysis could include determination of relative times of arrival of signals at different acoustic sensors arrayed at known locations. From these times of arrival, locations of acoustic sources (and errors in those locations) can be estimated. Estimates of relative locations of sources and sensors can be refined through analysis of the attenuation of sound in the intervening water in combination with water-temperature and salinity data acquired by instrumentation systems other than PAMS.

A PAMS is packaged as a battery-powered unit, mated with external sensors, that can operate in the ocean at any depth from 2 m to 1 km. A PAMS includes a pressure housing, a deep-sea battery, a hydrophone (which is one of

the mating external sensors), and an external monitor and keyboard box. In addition to acoustic transducers, external sensors can include temperature probes and, potentially, underwater cameras. The pressure housing contains a computer that includes a hard drive, DC-to-DC power converters, a post-amplifier board, a sound card, and a universal serial bus (USB) 4-port hub.

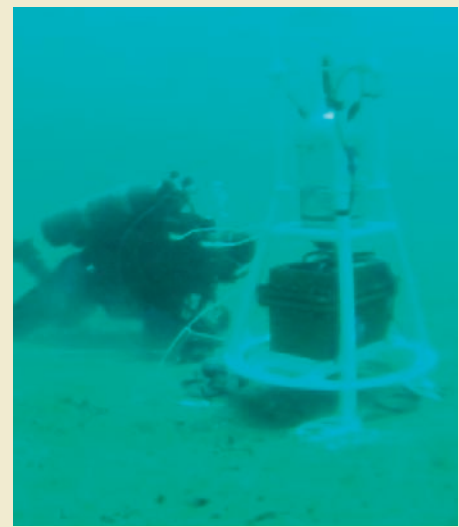
Typically, a PAMS is lowered into the water by use of a deck hoist, then guided to its assigned position by divers for a shallow deployment (see figure) or by crew members in miniature submarines for deployment at a greater depth. Alternatively, if great precision is not required, a PAMS can be simply allowed to sink to the selected location. The PAMS is then left in place to record data for a predetermined time or until it exhausts battery energy or data-storage capacity. Currently, the PAMS can be deployed at sea for four days, but the deployment time and sampling are battery and hard-drive dependent. For example, at a sample rate of 22,050 Hz, the data acquired was 3.5GB per 24 hours using a 40GB hard drive. However, at 44,100 Hz



PAMS on Deck



PAMS on Hoist



PAMS and Diver on Ocean Floor

A PAMS Is Hoisted into the water, then guided into position by a diver.

sample rate, the data acquired was 7.1GB per 24 hours.

The PAMS is subsequently retrieved and its recorded data are downloaded to a computer, which can be used to either process the data or record the data

on a disk for transfer to another computer for processing. The PAMS can then be prepared for another deployment.

*This work was done by Michael Lane and Steven Van Meter of Kennedy Space Center;*

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## **Wireless Data-Acquisition System for Testing Rocket Engines**

**Time-consuming, error-prone wiring tasks are eliminated.**

*Stennis Space Center, Mississippi*

A prototype wireless data-acquisition system has been developed as a potential replacement for a wired data-acquisition system heretofore used in testing rocket engines. The traditional use of wires to connect sensors, signal-conditioning circuits, and data acquisition circuitry is time-consuming and prone to error, especially when, as is often the case, many sensors are used in a test.

The system includes one master and multiple slave nodes. The master node communicates with a computer via an Ethernet connection. The slave nodes are powered by rechargeable batteries and are packaged in weatherproof enclosures. The master unit and each of the slave units are equipped with a time-modulated ultra-wide-band (TM-UWB) radio transceiver, which spreads its RF energy over several gigahertz by transmitting extremely low-power and super-narrow pulses. In this prototype system, each slave node can be connected to as many as six sensors: two sensors can be connected directly to analog-to-digital converters (ADCs) in the slave node and four sensors can be connected indirectly to the ADCs via signal conditioners. The maximum

sampling rate for streaming data from any given sensor is about 5 kHz. The bandwidth of one channel of the TM-UWB radio communication system is sufficient to accommodate streaming of data from five slave nodes when they are fully loaded with data collected through all possible sensor connections. TM-UWB radios have a much higher spatial capacity than traditional sinusoidal wave-based radios. Hence, this TM-UWB wireless data-acquisition can be scaled to cover denser sensor setups for rocket engine test stands. Another advantage of TM-UWB radios is that it will not interfere with existing wireless transmission.

The maximum radio-communication range between the master node and a slave node for this prototype system is about 50 ft (15 m) when the master and slave transceivers are equipped with small dipole antennas. The range can be increased by changing to larger antennas and/or greater transmission power. The battery life of a slave node ranges from about six hours during operation at full capacity to as long as three days when the system is in a "sleep" mode used to conserve battery charge during times between setup and

rocket-engine testing. Batteries can be added to prolong operational lifetimes. The radio transceiver dominates the power consumption.

The software running in the computer enables users to do any or all of the following:

- Remotely controls the sleeping/awakening schedule of the slave nodes.
- Manage the sampling rates and latencies of readings of specific sensors to satisfy specific requirements and maximize utilization of the system.
- Synchronize the operations of all nodes.

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*Refer to SSC-00231, volume and number of this NASA Tech Briefs issue, and the page number.*

## **Processing Raw HST Data With Up-to-Date Calibration Data**

*Goddard Space Flight Center, Greenbelt, Maryland*

On-the-Fly Reprocessing (OTFR) is a collection of data-processing routines that work within the context of the Hubble Space Telescope (HST) pipeline data-flow system. The purpose served by OTFR is to generate, on demand, scientifically useful data products from raw HST data stored in an archive. First, on the basis of the requested final data products, OTFR retrieves the corresponding sets of raw data from the archives.

Next, OTFR processes the raw data sets to remove artifacts and to establish proper header and other template information. Finally, the calibration routines appropriate to the specific data sets are invoked to produce the requested data products, and the data products are released to an archive distribution system for transmission to the requesting party. OTFR offers two notable advantages: (1) Inasmuch as calibrated data occupy

about 8 times as much storage space as do raw data, by obviating storage of calibrated data, OTFR reduces the storage capacity needed by the archive; and (2) the calibration routines can be updated to give requesters the benefit of the most recent calibrations.

*This work was done by Warren Miller of Space Telescope Science Institute for Goddard Space Flight Center. Further information is contained in a TSP (see page 1).*