

Background Information and Technical Specifications for Acoustic Vector Sensor Recording Nodes

NRL-12-PW01

1. Introduction. The United States Naval Research Laboratory (US-NRL) has a need for up to 32 individual acoustic vector sensor recording nodes.

An acoustic vector sensor recording node includes the hardware necessary to digitize and store acoustic data received on a single 4-channel underwater acoustic vector sensor (3-orthogonal-axis x, y, z accelerometers and omnidirectional hydrophone) and the vector sensor's associated auxiliary sensor information.

Each node will be deployed in a moored configuration in shallow water (100 meters or less depth). This system shall be capable of digitizing and archiving data from a 4-channel acoustic vector sensor at a maximum rate of 48 kHz per channel for a period of up to 88+ hours. In addition the auxiliary sensor information (compass heading, pitch, roll, depth, and temperature) may be recorded at a lesser rate. The auxiliary sensor package may be integrated into the vector sensor itself or may be separated so long as the orientation of the compass heading and pitch/roll tilt sensors are fixed relative to the vector sensor itself.

The system is intended to support a variety of investigations relevant to Navy sonar performance in littorals. The government's goal is to purchase a cost-effective, small size, low-weight, and low-power consumption system that minimizes new engineering design and development. Alternative approaches and technical specifications may be proposed if they result in a more cost-effective design. Efforts to minimize size, weight, and power consumption are preferred.

The system will typically be deployed from oceanographic research vessels such as those operated by the University-National Oceanographic Laboratory System (UNOLS), the North Atlantic Treaty Organization, and the U.S. Navy. The contractor shall furnish a system that includes the vector sensor, a single underwater pressure vessel, batteries, digitizing and storage electronics, and mounting points for a vertical moored deployment.

A 4-channel acoustic vector sensor (3-orthogonal-axis x, y, z accelerometers and an omnidirectional hydrophone) with an acoustic bandwidth of at least 3Hz to 10kHz is required, but higher bandwidths will be entertained. The vector sensor shall be compliantly mounted in an acoustically transparent enclosure as is standard practice for mounting underwater acoustic vector sensors.

In contrast to a hydrophone, which is usually rigidly mounted with a structure, a vector sensor is required to be placed underwater with minimum restrictions. Often, a compliant fixture is required to connect the vector sensor with a base structure. Since the vector sensor may have built-in pitch and roll and magnetic heading sensors, it can sense its own orientation relative to the earth. The orientation sensor shall be mounted to measure pitch, roll, and heading of the acoustic vector sensor to the required accuracy. Offeror shall address how they will mitigate compass/pitch/roll sensor noise contamination into the analog acoustic data stream.

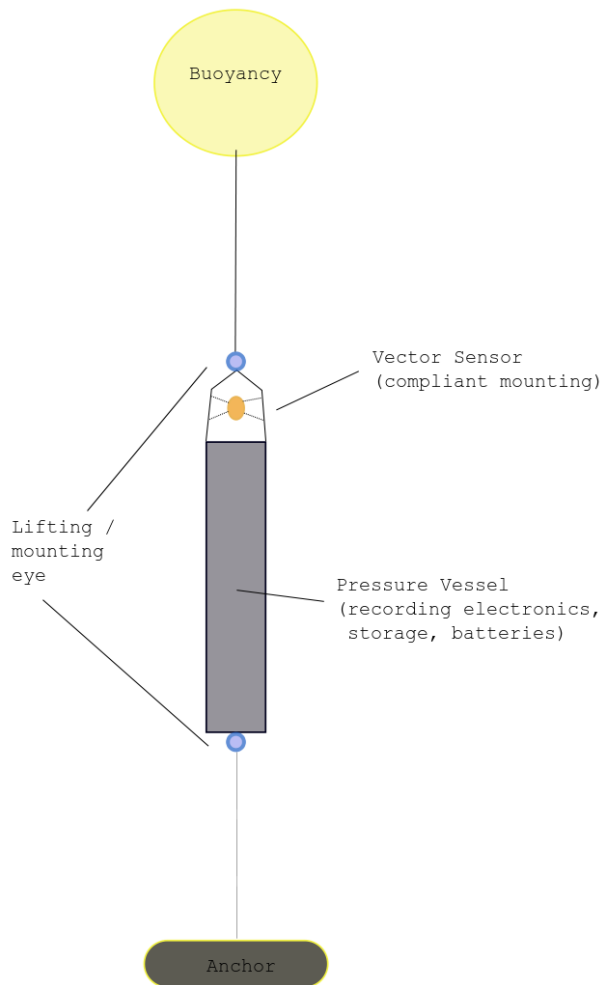


Figure 1: Illustration of moored Vector Sensor Recording Node.

2. General Requirements. The contractor shall provide acoustic vector sensor recording nodes with the following system components:

- (1) a single 4-channel vector sensor
- (2) a mounting frame for the vector sensor (compliantly mounted)
- (3) a digitizing and recording package capable of at least 16-bit dynamic range at data rates of 48 kHz simultaneous sampling per channel and 88+ hours data storage
- (4) recordation of auxiliary sensor data (pitch, roll, depth, temperature, compass)
- (5) a pressure housing capable of being bottom moored at depths up to 100 meters
- (6) an RS-232 data telemetry/communications cable for programming system setup prior to deployment
- (7) a user-replaceable and/or -rechargeable battery pack capable of operating all functions during a 96-hour mission
- (8) a provision for an external power supply for operation of sensor in the laboratory and prior to deployment and after mission recovery

a. Construction. The unit must be ruggedized for operation in the harsh marine environment and must be deployable, operable, and retrievable in conditions up to and including sea state 3. All non-sensor electronics and the battery power packs shall be located in the same housing.

b. Physical size. The size of the in-water unit must be such that it is possible to deploy the system from the stern A-frame of class II/III UNOLS vessels.

c. Operational depth. The unit must meet all specifications when deployed in the ocean between depths of 5 and 100 meters.

d. Frame (or strong-back) strength. The vector sensor recording node frame/harness/strong-back will be constructed from either aluminum or stainless steel that shall have eyes on both ends to attach mooring cables with marine shackles.

e. Weight. The goal for the weight of the vector sensor recording node is that it should not exceed 50 pounds or 22.68 kilograms (in water) for practical deployment of the entire mooring system. This in water weight includes the pressure vessel, including the internal power and data acquisition package. This in-water weight does not include either the flotation or the mooring weight.

f. Operating temperature and humidity. All in-water components must function and meet all specifications in temperatures of 3 to 30 degrees Celsius. All laboratory components (e.g., power supply, data telemetry interface, etc.) must function and meet specifications in temperatures of 0 to 40 degrees Celsius and relative humidity up to 90 percent.

g. Storage temperature. All system components must function and meet all specifications after being stored for an indefinite period of time in temperatures of 0 to 50 degrees Celsius.

h. Signal recording. All four channels received from the vector sensor shall be conditioned, digitized, and stored onto nonvolatile solid state or flash disk storage technology. Analog signal data shall be converted at sample rates of 48 kHz per channel, synchronized and simultaneous. Provisions for 24 kHz and 32 kHz sample rate data capture are desirable. All four channels of data conversion shall be synchronized and simultaneous. Sample resolution shall be 16 bits, minimum. Analog inputs shall be low-pass filtered prior to digitizing at or below the Nyquist sampling frequency. Auxiliary sensor data shall be recorded, time-stamped, and stored. The recorded acoustic and auxiliary sensor data shall be time synchronized with recorded the acoustic data.

i. Data storage. Nonvolatile solid state or FLASH media (solid state storage) totaling a minimum 128 gigabytes (GB) or more of storage shall be provided to store 88+ hours recorded data at 48 kHz sample rate (including auxiliary sensor and timing data). Data storage media shall be removable and replaceable by the end user for quick turnaround system redeployment. The government's preference is that data storage shall be expandable to 256 GB, 512 GB, and 1 terabyte by the addition or replacement of storage media. Consecutive files shall be continuous (no missing samples).

j. Clock accuracy. The real-time clock and digitizing oscillator shall be accurate to better than $\pm 1 \times 10^{-7}$ (over a 1-day period approximately 0.00864 seconds per day). System time and date shall be readable and settable via the removable tether cable pre/post-deployment and referred to a global positioning system (GPS) time and a 1 pulse per second (PPS) signal derived from standard commercial-off-the-shelf GPS unit. Net system time drift shall be measurable in units of microseconds, or better, directly after mission recovery and referenced to GPS time and a GPS unit associated 1 PPS signal. All data samples (acoustic and nonacoustic) collected and stored shall be referenced to the internal real-time clock.

k. Battery pack. The user replaceable and/or rechargeable battery pack shall operate the system for an entire 96-hour mission. The battery pack shall be removable and replaceable by the end user for quick turnaround system redeployment. The battery pack shall be internal to the pressure vessel. Provisions for extended operational time by the addition of higher energy density batteries or the addition of more batteries into the pressure vessel are preferred. Extending mission lifetime through the use of external power pack(s) will be considered and must be detailed in the proposal if offered.

l. Vector sensor requirements. Although the primary target operational frequency band is 3Hz–10kHz, a vector sensor recording node direct current to 24 kHz frequency band is more desirable. Therefore, in order to meet the frequency and receiver level requirements, it is acceptable to propose vector sensors with different sensitivities and bandwidths than the minimum requirements listed below:

Output sensitivity

Accelerometer: 2.0 V/g

Hydrophone: –166 dB re 1.0 V/uPa

Full-scale input range

Accelerometer: 1.0 g pk

Hydrophone: 200 Pa pk

Frequency response: ± 3 dB 3.0 Hz–10 kHz

Transverse sensitivity, maximum: 5.0%

Temperature accuracy: $\pm 1.0^\circ\text{C}$

Accelerometer noise intersection with Knudsen SS0, max: 1,000 Hz

Environmental

Pressure range

Operational, maximum: 1,500 psi

Absolute max: 2,000 psi

Operating temperature: -10°C to 60°C

Orientation and direction

Pitch and roll accuracy: $\pm 1^\circ$

Heading accuracy: $\pm 1^\circ$

The manufacturer and model number of a commercial-off-the-shelf (COTS) vector sensor shall be identified in the offeror's proposal. COTS vector sensors are preferred.

m. Frequency response. Frequency response of the post-amplifiers (if any) shall be flat ± 1 dB over the band 1 kHz to 24 kHz. Electronic self-noise floor shall not exceed the equivalent acoustic noise floor at sea state zero. The post-amplifier's input and output shall employ differential drive technology that minimizes crosstalk and external interference. Post-amplifier/transducer frequency response, equivalent electronic noise (referred to the input), and sound pressure sensitivity shall be specified in the proposal. Post-amplifier signal conditioning shall provide a range of –166 to –130 dB re 1 volt per micro-Pascal at the analog to digital converter (ADC). Post-amplifier channel gain, envisioned as 6 dB steps, shall be controlled/set over this range by an external cable/tether prior to deployment.

n. External power supply. Provisions for external power supply operation shall be included to operate the sensor node for extended periods in the laboratory, prior to deployment, and after recovery.

o. Warranty. The system shall be warranted against defects in materials and workmanship for one year from date of delivery. The contractor shall repair or replace at no charge any part that proves to be defective during the warranty period. This warranty does not apply if the item has been damaged by accident or misuse.

3. Mechanical Requirements

a. Pressure Vessel Components

Pressure vessel: Shall be designed for depths to 100 meters. Pressure vessel shall be constructed of aluminum or a plastic composite.

Seals: All pressure vessel joints shall have o-ring seals.

Finish: All exposed surfaces shall be designed to minimize deterioration of the structure by exposure to the ocean environment.

Attachment/lift points: The pressure vessel shall be fitted with a minimum of two mechanical attachment points for shipboard tie-down/storage and lifting/deployment. Lift points shall have an operating strength of at least 750 pounds or 340.19 kilograms.

Corrosion protection: Passive cathodic protection against corrosion shall be provided for the metallic components. The protection method shall have a minimum rated usage of one year.

b. Marine connectors. Shall be designed for a seawater environment and have a minimum operating depth greater than 100 meters. Each connector shall be provided with a waterproof protective end cap. The protective end cap shall be depth rated to 100 meters or greater if it is to be deployed with the system. A depth rating is not required for protective caps used solely during storage and transit. Connectors shall have either a protective mechanical guard or be located such that they are protected from accidental damage during movement, deployment, and shipping. A method of strain relief shall be provided that minimizes stress in the cable conductors and the connector. Each connector shall have a locking mechanism to prevent accidental disconnect. The data telemetry/communications connector shall be designed for pre-mission programming and pre/post-mission interrogation. The government desires recorded data snippet download while the system is not deployed.

c. Vector sensor compliant mounting. The sensor shall be compliantly mounted within an acoustically transparent tube, cage, or other mechanism as is standard practice for mounting underwater acoustic vector sensors. The durability of the vector sensor and its compliant mounting during shipping, transport, deployment, and recovery shall be detailed in the offeror's proposal.

4. Acceptance Testing

a. Duration. Offeror shall demonstrate 88+ hour recording capability and 96-hour battery powered lifetime at the 48kHz sample rate.

b. Clock accuracy. Offeror shall demonstrate the clock accuracy for both the acoustic data sample clock and the real-time clock over a period of 96 hours. All data recorded on the vector sensor recording node shall be referenced to the real-time clock. The real-time clock shall be referenced to GPS time and the 1 PPS signal provided by a COTS GPS units.

5. Required Documentation

a. Technical manual(s). One or more technical manuals, describing each contractor-supplied system component in detail, must be provided. Detailed drawings for all contractor-supplied custom hardware in the system must be included. A detailed list of all parts/components manufactured or supplied by third parties must be included. This list must identify the

manufacturer, manufacturer part number, manufacturer's address, telephone/fax numbers, and, if applicable, Web site. In addition, a separate list of all expendable items required to maintain, deploy, operate, and recover the system must be included. The technical manual must also include all conversion factors needed to convert sensor output voltages to engineering units. Delivery of the technical manual(s) shall take place with the delivery of the system. The technical manual(s) shall be delivered in electronic format—either Adobe Acrobat (.pdf) or Microsoft Word (.doc).

b. Operations manual. The contractor must provide one or more operations manuals that describe in detail how to operate all contractor-supplied components of the system. The manual must contain the procedures to be used for predeployment checkout, hardware and system preparation, and provide a checklist for all mechanical and electrical connections for the safe and successful deployment, operation, and recovery of the system. The operations manual must also include information on all required routine maintenance of the system and all procedures that need to be carried out when placing the system in or removing it from storage. The operations manual(s) shall be delivered in electronic format—either Adobe Acrobat (.pdf) or Microsoft Word (.doc).

6. Other Requirements

Additional individual tether cables shall also be listed as an option for purchase as separate line items.

7. Option for Calibrations and Pressure Testing

a. Calibrations. The vendor shall provide rough order of magnitude (ROM) cost for an optional vector sensor recording node end-to-end calibration that results in a sensitivity/frequency response curve traceable to a calibrated standard hydrophone (Underwater Sound Reference Division preferred).

b. Pressure test. The vendor shall provide ROM cost for a pressure test of the pressure housing. The pressure test may be conducted at a pressure test facility or at the same facility where the system is calibrated (if the facility has the capability to lower the in-water components to the required depth). If the pressure test is conducted at the calibration facility, it shall be conducted prior to the calibrations. The depth (or equivalent pressure) for this test shall be the system's maximum operating depth.