



Applied Physics Laboratory

University of Washington

1013 NE 40th Street
Box 355640
Seattle, WA 98105-6698

206-543-1300
FAX 206-543-6785
www.apl.washington.edu

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To: Dr. Robert Headrick
Office of Naval Research (Code 32)
875 North Randolph Street
Arlington, VA 22203-1995

From: Dr. Peter Dahl, Principal Investigator

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Encl: (1) Final Technical Report for Subject Grant
(2) SF298 for Enclosure

Enclosure (1) is the Final Technical Report for the subject grant along with the (2) SF 298 form. These documents constitute the Final Technical Report and deliverable for ONR Grant# N00014-20-1-2460.

cc: Grant & Contract Administrator, APL-UW
Office of Sponsor Programs, UW
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Seabed Characterization Experiment 2021

**Peter H. Dahl
Applied Physics Laboratory
University of Washington
Seattle, WA 98105**

15 July 2022

**Final Report
Award Number N00014-20-1-2460**

This final report cover research funded by the ONR grant entitled: “Seabed Characterization Experiment 2021”. The completion period of this grant covered June 2020 - May 2022, however the largest effort was focused during the months of May and June 2021 involving the field effort off New England. This focused-effort period was also significantly financially impacted by the quarantine requirements associated with Covid-19.

The grant effort was divided into three basic efforts:

1. Continuation of the development of the IVAR-2 system

The IVAR-2 system represents an improvement (but not a replacement) of the instrument known as the Intensity Vector Autonomous Recorder (IVAR-1) deployed during SBCEX2017. Both systems simultaneously measure acoustic pressure and particle velocity, with the combined result equal to vector intensity, being the focus of our research.

IVAR-2, is capable of operating at much greater depth than IVAR-1, of order 1000 m, such that it could be used in the May-June 2021 Pilot experiment field effort off New England (item 3). IVAR-2 development was started under ONR Grant (N00014-17-1-2170) with final completion and procurement of some of the high-valued components (e.g., acoustic releases) completed under this grant.

2. Testing of the IVAR-2 system in Puget Sound, April 2021

The IVAR-2 system was tested for the first time in Puget Sound over a 3-day period in April 2021. An extraordinarily interesting test occurred at the deployment site near the Kingston ferry terminal on the west side of Puget Sound at location 47.7877N, 122.4875 W, on April 15, 2021.

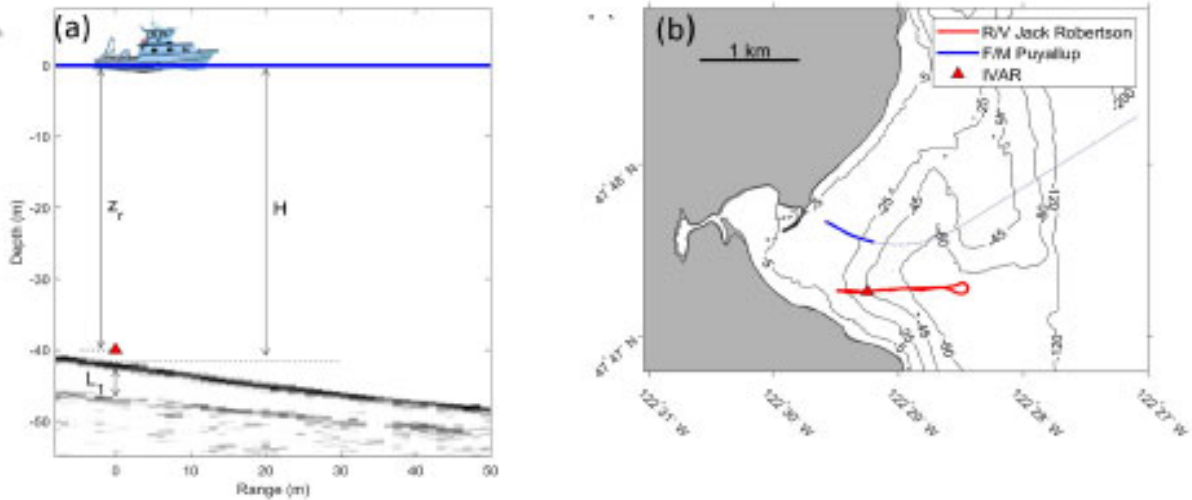


Fig. 1 (a) The R/V Jack Robertson (APL-UW research vessel) passes directly over the IVAR-2 sensor located approximately 1.5 m off the seabed (red triangle). (b) Course of the R/V Jack Robertson (red) and the nearby Washington State ferry (blue).

The location is within a small bay on the west site of Puget Sound (Fig. 1) containing Washington State ferry landing at Kingston, with the deployment site approximately 1 km distant from the landing, depth of 42 m. Two controlled transits were made directly overhead the system by the Applied Physics Laboratory's R/V Jack Robertson, at speed 7.5 knots.

The purpose of such measurements was to assess the variation of kinetic and potential energy when a vessel is directly overhead. The results (Fig. 2) of such testing motivated our team to repeat the experiment in May 2022 involving the R/V Neil Armstrong as part of SBCEX2022.

At this writing, a manuscript is nearing completion covering both the Puget Sound and SBCEX2022 results. However the upshot of this study is (1) directly below a passing vessel at CPA, there will be large excursions in potential over kinetic acoustic energy, and vice versa, and (2) the pattern of excursion, e.g. the ratio in dB, is sensitive to the seabed impedance properties and such data are quite amenable to geoacoustic inversion. For example the Puget Sound result (Fig. 2 red line) is suggestive of a seabed with initial layer of thickness 3.5 m, sound speed 1710 m/s, over higher-speed half space.

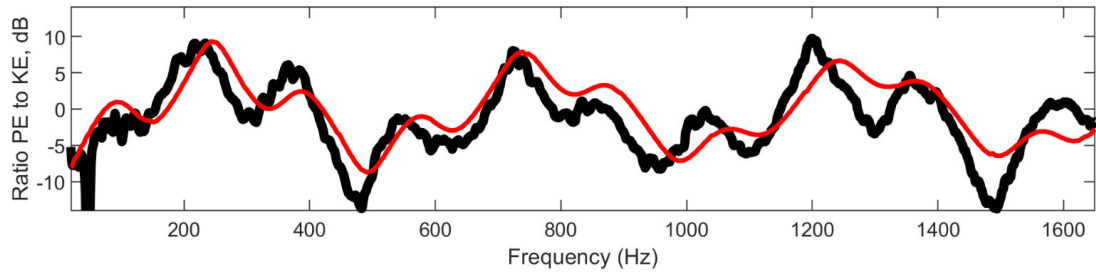


Fig. 2 Measurements of the ratio of potential to kinetic energy versus frequency (black line) from the direct overhead passage of the R/V Jack Robertson. A model (red line) is based on a plausible geoacoustic representation of the seabed at this site.

3. The Pilot Experiment

The APL-UW team (David Dall'Osto and Eric Boget) participated in the R/V Armstrong cruise AR56, which occurred between 22 May and 4 June. This phase of our effort was heavily impacted by the Covid-19 situation, for example, requiring the APL-UW team to undertake a two-week quarantine period in Falmouth, prior to boarding the R/V Armstrong.

The primary objective of the APL-UW team was to deploy the new IVAR-2 system, in the shelf break region associated with the NESBA 2021 and SBCEX2017 experimental areas. Planned deployments were at depths of ~200 m and ~300 m (Fig. 3).

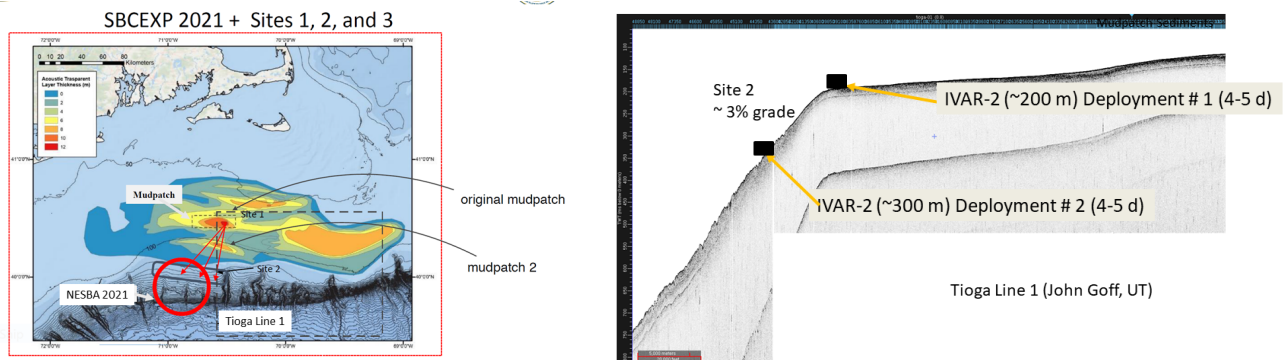


Fig. 3 (Left) Overview of the deployment area showing NESBA2021 and SBCEX2017 sites. (Right) Tioga Line bathymetry (from John Goff) showing nominal locations of the two deployments of IVAR-2.

This objective was completed: the 200-m deployment was at latitude 40.0614, longitude -70.9357 from 23 to 26 May, and the 300 m deployment was at 40.0010, -70.9376 from 27 May to 2 June; both sites reasonably close to the planned ones shown in Fig. 3.

Figure 4 (right) shows IVAR-2 upon recovery from the first deployment. Note that a shroud made of spandex-like material covers the frame surrounding the vector sensor, with purpose to reduce any induced motion due to bottom currents and also eliminate

flow noise. An underwater camera was mounted within the frame to verify that the sensor was not subject to excessive motion during the decent, and document the effectiveness of the shroud in reducing induced motion from bottom currents (Fig. 5). The camera operated continuously for the first two hours of each deployment confirming the effectiveness of the shroud.



Fig. 4 (Left) IVAR-2 system showing sensor within the protective upper frame; below this are data acquisition system (green) and expendable anchor that is released on recovery. (Right) IVAR-2 being recovered from the R/V Armstrong by David Dall'Osto (left), Eric Boget (right) and R/V Armstrong crewmember (center). A shroud (spandex-like material) covers the frame and sensor and provides a highly effective reduction in bottom currents which can result in flow noise and sensor motion that degrades measurement. The large buoy (31-inch diameter) seen in foreground floats 7 m above IVAR-2 and provides necessary flotation for recovery.

Additional data collected on the IVAR-2 platform included a Seabird (SBE) SeaCAT conductivity, temperature, and depth (CTD) sensor, with purpose to document temporal variability in water depth and sound speed at the IVAR-2 sensor depth.

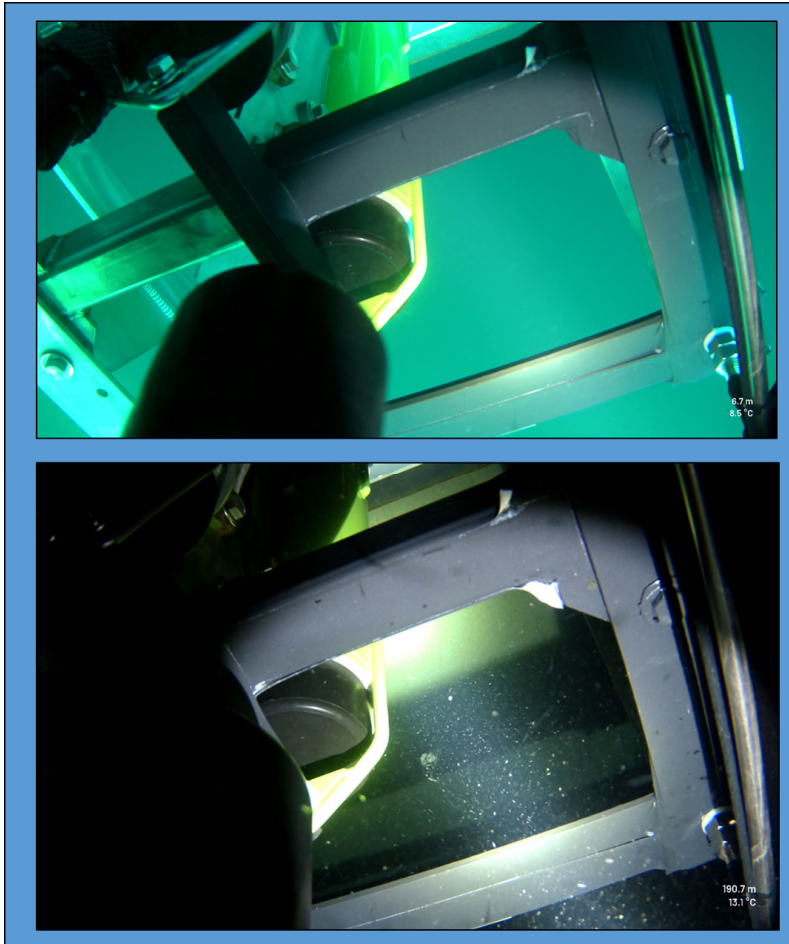


Fig. 5 (Top) Single frame of camera video during the first deployment of IVAR-2. The camera is oriented at a downward angle towards the sensor (black object at lower left). The acoustic release (green tube) is seen extending below. At this point IVAR-2 is at depth 6.7 m and water temperature is 8.5 deg.

(Bottom) Single frame extracted from near-bottom video. Marine snow can be seen flowing over the acoustic release however the IVAR-2 sensor remains motionless.

U.S. Navy Signal Underwater Sound (SUS) Charge Deployments

Over 400 SUS charges, a combination of 1.1 oz and 1.8 lb were deployed off the stern of the R/V Armstrong by NSWC SUS deployment specialists Greg Schoch and Aeren Nauman, between 23 May and 2 June. Deployment locations were planned by Chief Scientist David Knobles with times and locations carefully compiled at sea by David Knobles along with Mohsen Badiey and David Dall'Osto and made available to the larger experimental team.

Note that IVAR-2 has three systems for measuring acoustic pressure which will be of value in these high amplitude data: (i) The IVAR pressure sensor that forms the intensity vector (pressure-velocity) sensing system, (ii) A separate hydrophone (SoundTrap) recording continuously at HIGH gain, and (iii) A separate hydrophone recording continuously at LOW gain.

Narrow Band Source Tows

Approximately 27 h of narrow band source towing (Fig. 6) was completed using the WHOI Lubel Source which was made available to the Armstrong team courtesy of Ying-

Tsong (YT) Lin. This source was used by YT Lin during NESBA effort on the R/V Armstrong which occurred just prior to this cruise. Data from Lubel source were recorded on IVAR-2 and the University of Delaware VLA systems (Mohsen Badiey).

AR56 source tow log

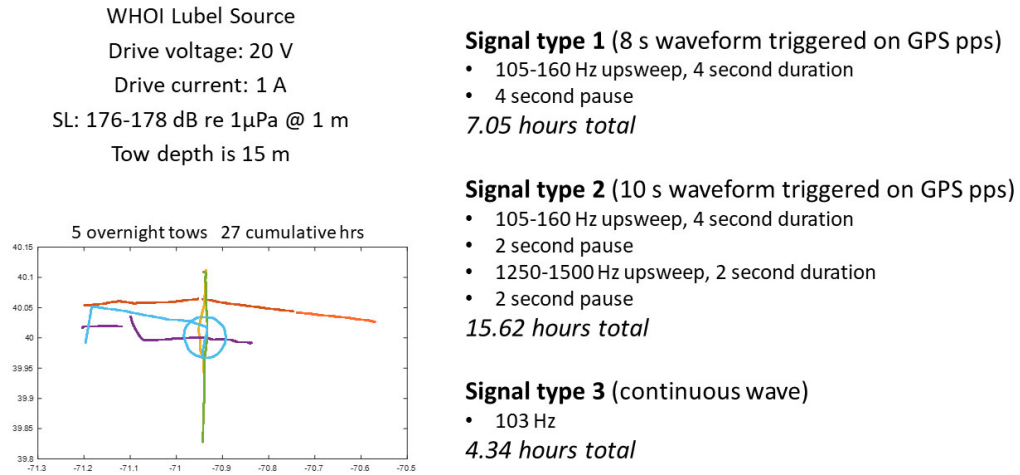


Fig. 6. Overview of the AR56 source tow effort consisting of 27 h cumulative hours.

Underwater Noise from Ships

Underwater noise from ships is of particular interest to our team from a vector-acoustics standpoint. Though shipping traffic was generally light, a few Closest Point of Approach (CPA) events were recorded by IVAR-2, along with several passes by the R/V Armstrong. These data will, for example, be used invert for seabed parameters as well as ship location information.

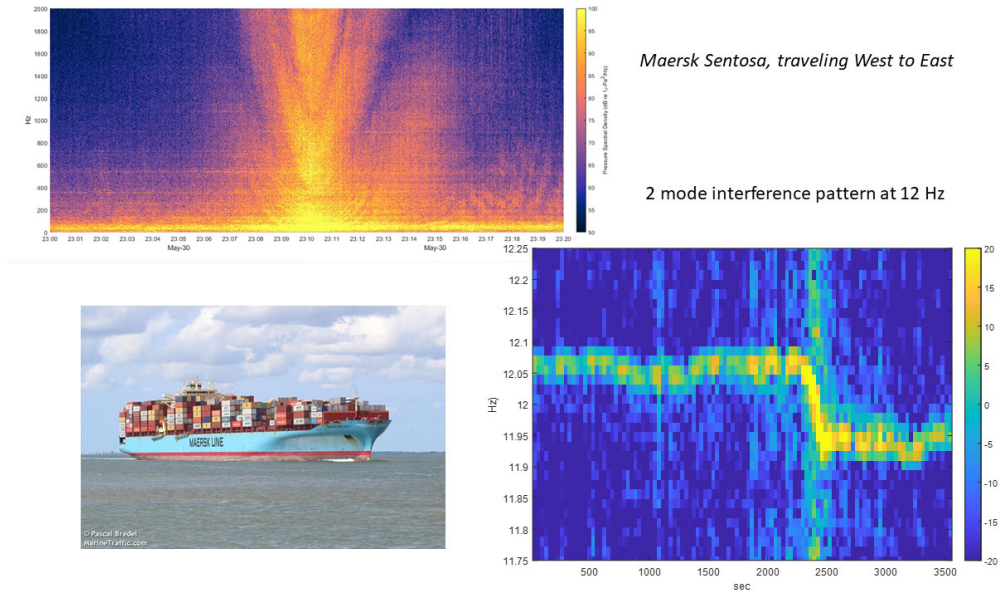


Fig. 8. Noise signature from the Maersk Sentosa as recorded by IVAR-2.

Although no publication has yet to emerge associated with the efforts under this grant, one (e.g., relating to Fig. 2) will be emerging soon as well as others as we move forward with the SUS analysis and the other observations.

Conference Presentations

1. D.R. Dall'Osto and P. H. Dahl, "Vector sensor measurements of dispersed arrivals from explosive signals, underwater sound (SUS), Acoustical Society of America Conference, Seattle, December 2021.

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