

Data System Upgrades Within the National Deep Submergence Facility

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Abstract

The National Deep Submergence Facility (NDSF) is funded by the National Science Foundation to provide operational support for deep submergence research. Recent modifications to status of the facility's vehicles and to some subsystems of each of the vehicles have improved the data offerings from the facility. *Sentry* has replaced *ABE* as the operational NDSF autonomous underwater vehicle, and offers a more robust sensor and processing suite. HOV *Alvin* and ROV *Jason* are currently incorporating a high definition video pipeline, which offers improvement in both video and still image capture. All three vehicles now carry a well known 512 beam bathymetry sonar, which improves sampling resolution and post-processing flexibility. All three vehicles have added a state-of-the-art ultra short baseline navigation system that offers performance similar to long baseline navigation, with simpler post-processing. We detail these changes and offer recent examples.

AUV *Sentry* Joins NDSF



In June 2010 AUV *Sentry* was appointed to the NDSF. It replaces AUV *ABE*, which was lost on a dive in March 2010. In 2009 and 2010 *Sentry* has performed 62 dives on six scientific cruises and is now engaged in another in the Gulf of Mexico. *Sentry* is equipped with multibeam and sub-bottom profiling sonars, a machine vision camera with strobes for still photos, magnetometers, CTD, optode, and eH sensor with prior arrangement. *Sentry* can also carry sensor systems provided by science such as the TETHYS mass spectrometer, which has been used on *Sentry* to detect seabottom hydrocarbon seeps [1], seabottom CO₂ seeps, and midwater oil plumes at the Deepwater Horizon oil spill (above). *Sentry*'s mission controller is programmed with survey profiles tailored to a sensor such that, for instance, *Sentry* performs a multibeam survey at one altitude and track spacing and then continues into a photographic survey at lower altitude and narrower spacing. Using USBL equipment, *Sentry* reports recent sensor and status messages to the surface, where operators can use the information to alter *Sentry*'s mission plan by return message.

An effective use of the joint-mission scenario was employed on three research cruises. During these cruises *Sentry* survey dives were conducted sequentially or simultaneously with *Alvin*, *Jason*, and towed camera system operations. Science mission planners used low-altitude, high-resolution maps from *Sentry* to optimize use of these other platforms' observation and sampling strengths. In some cases a bathymetric product was preliminarily processed and provided to *Alvin* passengers within two hours of *Sentry*'s recovery.

Updates to Navigation Sensor Systems

In 2009 and 2010 NDSF added a variety of sensors to vehicle inventories in order to improve and simplify navigation systems and data products.

Primary navigation for each NDSF vehicle is a Doppler Velocity Log (DVL) system in combination with heading from a high performance inertial navigation system (INS). DVL velocities are integrated to estimate dead reckoned position using software developed by the Dynamical Systems and Control Laboratory (DSCL) at Johns Hopkins University (JHU/DSCL) [2]. These estimates are augmented by georeferenced information from ultra short baseline (USBL) and/or long baseline (LBL) acoustic systems [3].

To take better advantage of our new multibeam systems, *Alvin* and *Jason* have added lower frequency Doppler Velocity Log (DVL) systems to their inventories to increase the altitudes at which the DVLs can maintain bottom lock. *Alvin* and *Jason* have historically carried DVL units that operate at 1200 kHz, which maintain bottom lock to an altitude of about 25 meters. *Alvin*'s addition of a 600 kHz unit increases its maximum lock altitude to about 110 meters. *Jason*'s 300 kHz DVL maintains lock up to about 200 meters altitude. *Sentry* also uses a 300 kHz unit and routinely performs bathymetric surveys at 80 meters altitude.

Long baseline positioning was recommended by NDSF to scientific users for more than a decade for precise acoustic navigation and survey work. In 2009 a WHOI-developed LBL system, dubbed N456 [4], replaced the Benthos 455 system that had been used for many years, improving the reliability and flexibility of our LBL handling.

Also in 2009 we introduced into our operations Sonardyne Ranger USBL positioning systems for each vehicle, which can work along with or in place of LBL. In most circumstances, we now recommend use of USBL. Among the advantages offered by USBL is a potentially significant savings in setup time. LBL requires the deployment, positional survey, and recovery of two to six transponders at each work site, using roughly two hours per unit. In comparison, a Sonardyne-specified calibration procedure, which is expected to apply for the duration of a cruise, typically requires five hours total. When results from this calibration have been applied to a Ranger USBL system, precision and accuracy are comparable to N456 LBL. We continue to use LBL when a preset transponder net exists at a work site. We have also used LBL to navigate *Sentry* when a dive plan calls for *Sentry* to perform its survey while *Alvin*, *Jason*, or towed camera operations take the ship out of USBL range.

Figure 2: USBL pole system used by *Jason* and *Sentry* on ships of opportunity. In this case, *Sentry* was aboard *Endeavor* at the Deepwater Horizon site, June 2010.



The transceiver portion of the USBL system for *Alvin*, which is permanently attached to RV *Atlantis*, is integrated with the ship and offers the most consistent performance. Transceiver motion is compensated through use of *Atlantis*'s INS. Because *Jason* and *Sentry* deploy from vessels of opportunity, the transceiver portions of their USBL systems are mounted to side-rail systems that are extended when the vehicles are in the water, or we use the vessel's moon pool if available. In these configurations, an Ixsea Octans INS or Sonardyne Lodestar is mounted with the transceiver to compensate for ship and pole motion.

Multibeam and SubProfiling Sonar Systems

Sentry, *Alvin*, and *Jason* now carry Reson Seabat 7125 multibeam sonars, which operate at 400 kHz/512 beams. *Sentry* also carries an Edgetech 4-24 kHz chirp for measuring sedimentary profiles.

Designed as a mapping vehicle, *Sentry*'s speed (2 knots) and stability make it the preferred platform for multibeam usage and it is proffered as such by NDSF. Depending on instrumentation power needs, *Sentry*'s battery duration allows it to travel up to 85 kilometers in a dive. By contrast, *Alvin* and *Jason* travel at about one-quarter *Sentry*'s rate and are "rockier" platforms for a multibeam sonar. Nevertheless, there are frequent opportunities in the schedules of *Alvin* and *Jason* for scientists to use a high quality multibeam system. *Jason*'s Seabat 7125 system was used for the first time in August 2010, while development of *Alvin*'s system is a work in progress, performed on dives of opportunity. Scientists have used NDSF multibeam systems to observe near-bottom thermal and bubble plumes (Figure 3).

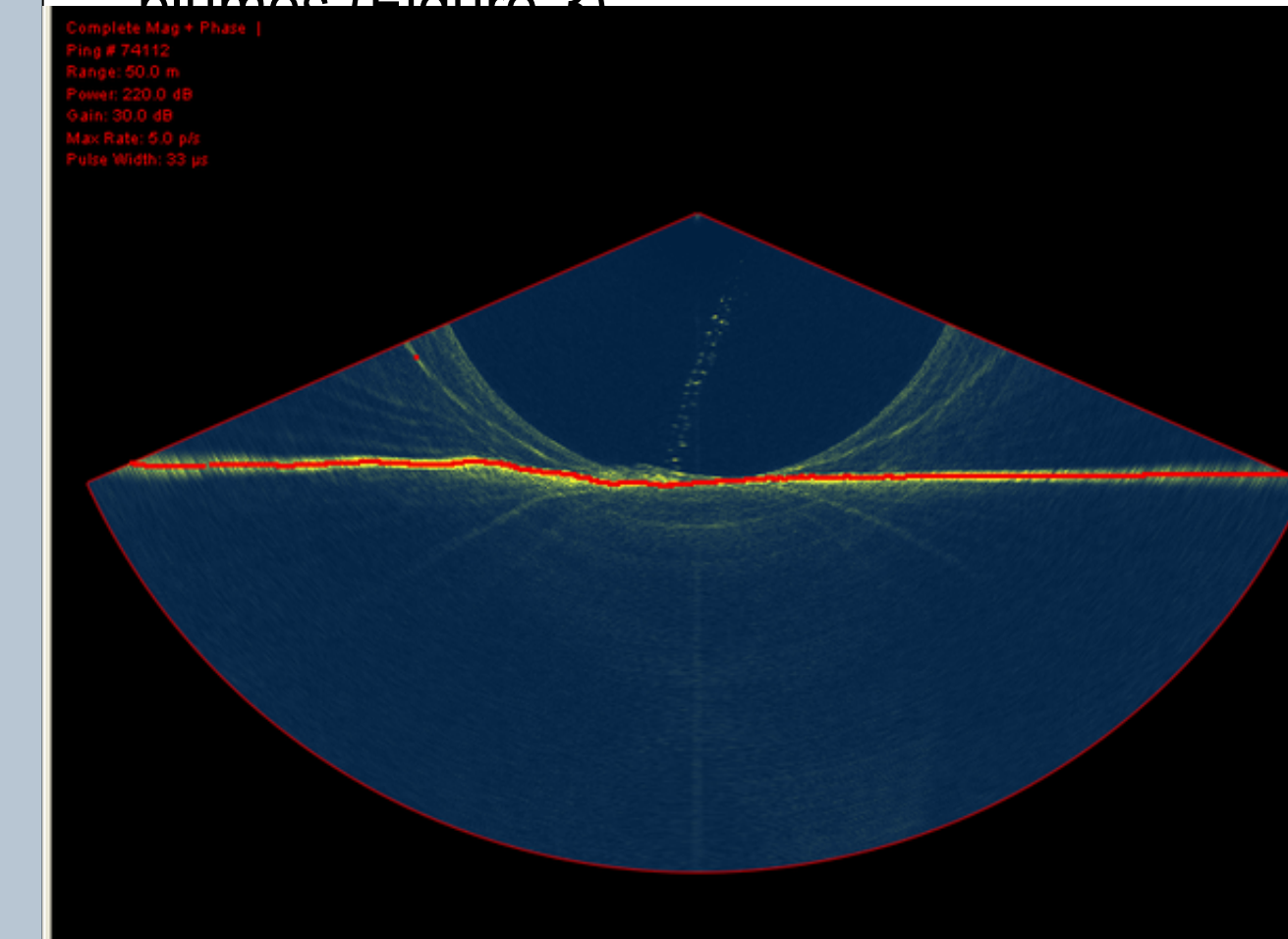


Figure 3: CO₂ bubble plume captured by *Sentry*, Sept 2010 near the Haaken Mosby mud volcano. The figure is a frame extracted from playback of the real time magnitude and phase measurements made by a Reson Seabat 7125 multibeam sonar system.

Multibeam Post-processing

The essential purpose of our bathymetry post-processing is to produce a map which indicates that the raw data was collected properly. Additional goals are to produce a map that can inform follow-on cruise operations. We describe it as a preliminary product, one that our clients should expect to improve themselves for publication or for rigorous analysis. Because of our personnel constraints, we have made it a priority to develop a bathymetry map post-processing pipeline that requires minimal interaction with the data. This pipeline includes two processing flows, both of which we are now working to automate. The first is renavigation of the real time track history, in which an improved estimate for the vehicle track is produced. The second is the treatment of the Seabat 7125 ping history, during which vehicle attitude and biases are compensated, beam anomalies are removed, and adjoining swaths are trimmed or merged as appropriate. We perform renavigation post-processing using software developed within the WHOI Deep Submergence Laboratory, or collegially with the JHU/DSCL. This renavigation software is predominantly written as Matlab scripts. For processing of the raw multibeam record we use a version of MB-system [5] that we have modified to better support our automated pipeline.

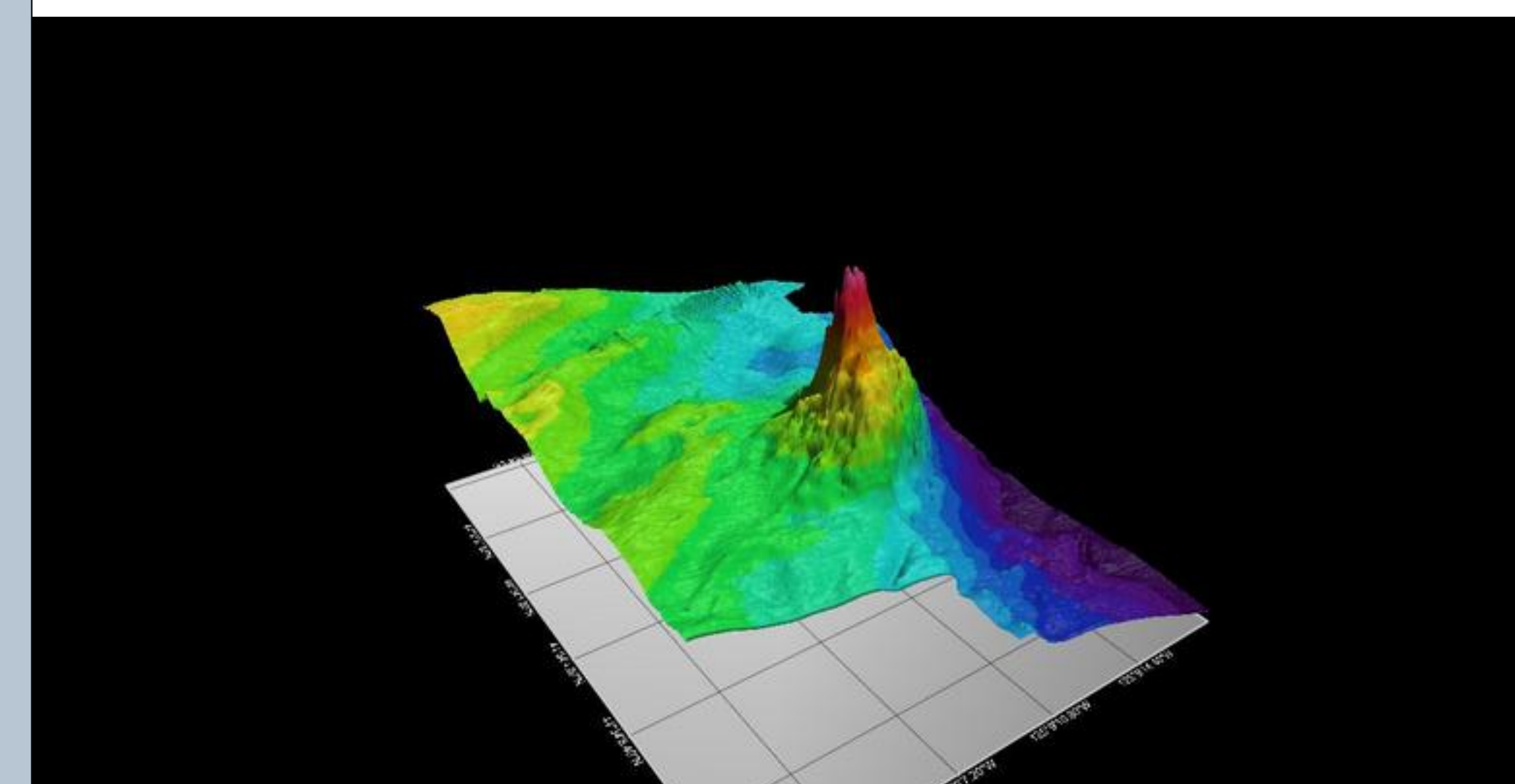


Figure 4: Bathymetry map of "the Pinnacle", Hydrate Ridge, Juan de Fuca Ridge, *Jason* dive 513, August 2010.

High Definition Camera Systems

The National Science Foundation funded a program to specify, design, and install high definition imaging for *Jason* and *Alvin*. This program is now in its final phases.

Jason now carries a high definition camera that acquires high quality imagery in both video and still forms. *Alvin* currently carries an interim design and will have a system similar to *Jason*'s after *Alvin* undergoes a comprehensive upgrade, to be completed around the second quarter of 2012.

Video output from the camera system is 1080i, HD-SDI. Still imagery is acquired at 1920x1080x12 bits resolution, with asynchronous or automatic timing. The quality of these stills makes it likely that the vehicles will no longer carry dedicated external still cameras.

There are a variety of candidate recording methods under consideration. The current system records the entirety of *Jason*'s HD camera video to DVD in a lower bandwidth version on low-cost media. "Highlights" are captured to hard drive by an HD-SDI recorder (Aja KiPro). The resulting computer files are compressed using the Apple ProRes codec [6]. These can be played using QuickTime software (MacOS or Windows) and edited with a non-linear editor such as Final Cut. Stills can be edited with software such as Photoshop.

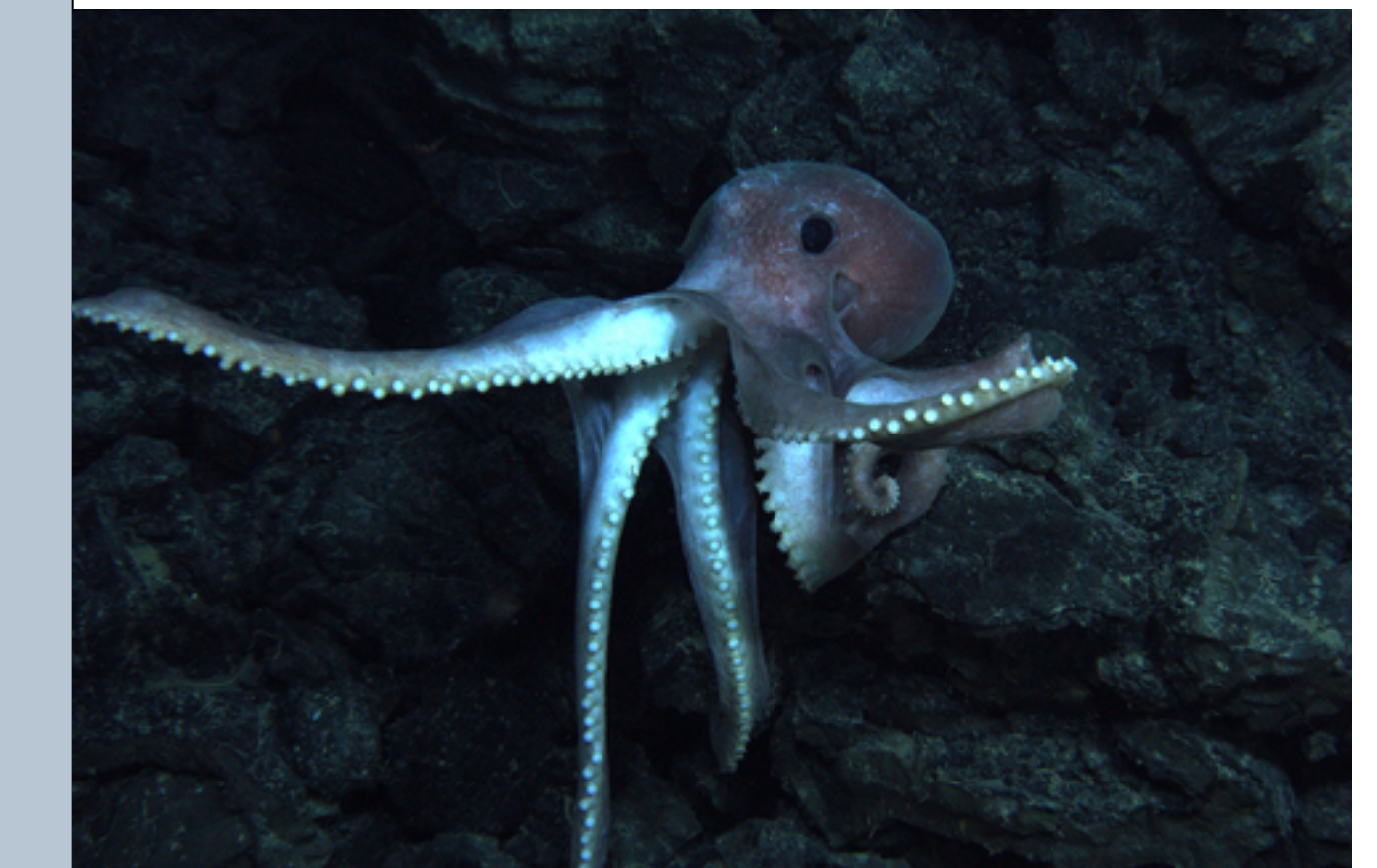


Figure 5: Test shot, *Jason* dive #519, Juan de Fuca Ridge, Aug 2010. Stills are captured by the single-chip NDSF camera as a Bayer-encoded file. We then 'demosaic' the file to a human-viewable color image. This image was otherwise uncorrected, and can be improved by affecting color balance and sharpness.

References

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