MARINE TECHNOLOGY REPORTER

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White Papers

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Unmanned Marine and Subsea Vehicles edition


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Pictured: SeaBotix vLBV300

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Teledyne Marine Offers a Wide Variety of Proven Solutions for Subsea Vehicle Applications

Since 2005, Teledyne Marine has grown in size and scope, adding technology and capabilities through organic growth and acquisition. Now twenty three brands strong, Teledyne Marine is recognized as a preeminent leader in marine technology, delivering a vast spectrum of product solutions and technologies to resolve challenges in some of the most demanding scenarios and environments imaginable.

As Teledyne Marine has continued to grow, so has the need for increased focus and communications throughout the organization to better serve our customers. To meet those needs, Teledyne Marine has restructured to align the company's collective business development, sales, and marketing resources. By providing a more streamlined structure to the organization, Teledyne Marine now offers customers an enhanced level of technical collaboration, customer service and support that leverages the vast resources of the 23 brands that currently

Sydney Kormoran Expedition 2015 - HMAS Sydney (II) portside shell hole
Image courtesy of WA Museum and Curtin University. Copyright WA Museum.

constitute the Teledyne Marine group. Teledyne's customers can access the full range of Teledyne Marine's products from a single point of contact, restoring the small company feel by allowing each Teledyne sales rep to service their local customers for all products. For complex or challenging projects local sales representatives can leverage technology experts, giving customers the peace of mind that their projects are backed by the vast resources made possible through the Teledyne organization.

Teledyne Marine's technologies are grouped in five main categories: Imaging, Instruments, Interconnect, Vehicles, and Seismic. Many of these technologies have applications on unmanned vehicles and bring distinct technical advantages to the integration. From Bowtech cameras and lights to RD Instruments Doppler Velocity Logs, Teledyne products can be found on the worlds most advanced undersea vehicles.

Imaging Solutions

Shedding Light on an Historical Shipwreck

On the 19th of November 1941 the HMAS Sydney slipped beneath the dark waters off the coast of Australia settling on the seafloor in 2,468 meters (8,097 ft.) after engaging with the German auxiliary cruiser the Kormoran.The Sydney and the Kormoran were destroyed in that battle. For many years the fate of the Sydney and her 645 crew was a mystery until both wrecks were found in 2008.

Teledyne Bowtech, a global market leader in subsea vision systems, recently supplied LED-V-20K lamps, a Surveyor-HD-Pro camera and a 3D-HD system to Curtin University and the Western Australian Museum to survey the shipwrecks of Australian warship HMAS Sydney II and the German raider HSK Kormoran in the Indian Ocean 200 km west of Shark Bay, Western Australia.

An array of 10 LED-V-20K lamps, emitting up to 20,000 lumens each, were used on each of two ROVs to illuminate the wreckage which was filmed using a Surveyor-HD-Pro camera and a 3D-HD camera system all supplied by Teledyne Bowtech as part of a suite of equipment used on the project.

Dr Andrew Woods, Research Engineer at the Centre for Marine Science & Technology at Curtin University reported "The lights performed really well providing some rich colours and wonderful lighting effects. The Surveyor-HD-Pro camera operated flawlessly. We've captured some amazing footage". He hailed the expedition "a raging success" due in part to good weather, reliable equipment and very careful planning. "All of our goals were met, including many of our stretch goals. There have been comments that we've set a new benchmark in maritime archaeology – which is what we set out to do". The research team now has the task of reviewing the 50TB of data, around 700,000 still images and some 300 hours of HD video collected during the week long survey.

Photographs taken in 2008, when the wrecks were first discovered, did not explain how Sydney could have been so comprehensively disabled, however, new images taken by Dr Woods and his team using the Bowtech equipment clearly show damage which supports the theory that the bridge was destroyed and the ship's command structure lost early in the battle, as reported by a survivor from the Kormoran.

Imaging Sonar Plays a Key Role in Underwater Forensics

In a cold case investigation near Lake George in Warren, New York, the Sherriff's department employed a Teledyne BlueView2D imaging sonar mounted on a Teledyne SeaBotix Remotely Operated Vehicle (ROV) to look for evidence in the case. The BlueView sonar was crucial to the mission. The lake was extremely dark and the bottom composition made identification of potential targets impossible. In dark or murky waters, the imaging sonar is the only way to locate targets.

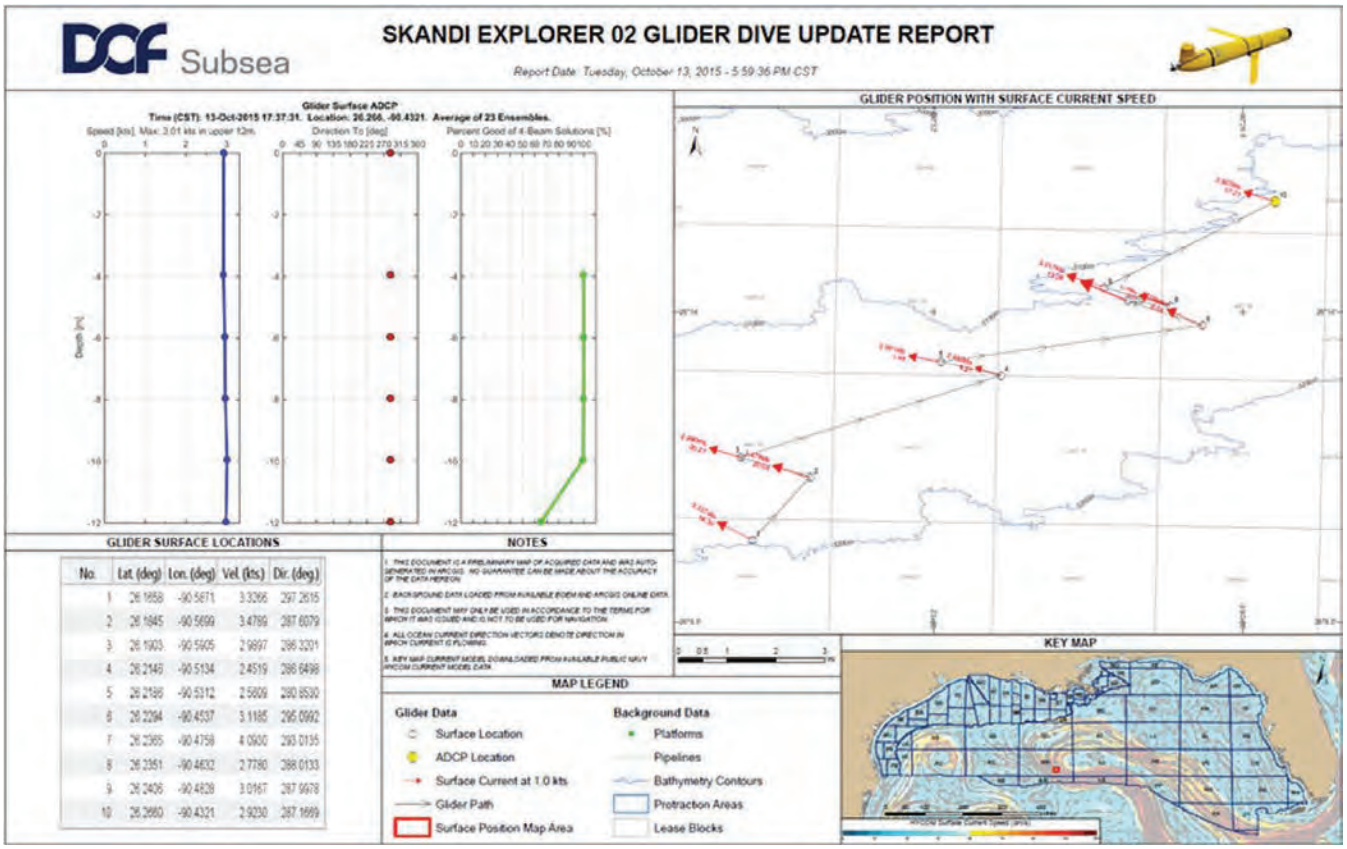
The Teledyne BlueView sonar operates while in motion or from a stationary position. 2D imaging sonar, sometimes referred to as "acoustic cameras" operates differently and provides distinct advantages. Able to operate from both moving and stationary positions, 2D imaging sonar captures data within a defined field-of-view (like a slice of pie), while the "top-side" software processes the data rapidly to generate a real-time sonar "movie" viewable from a laptop or PC. Moving objects can now be seen clearly as they move into, through, and out of the field-of-view.

Unlike traditional sonars that must be stationary while scanning to provide clear imagery, the BlueView's ability to scan while in motion significantly decreases mission times. BlueView delivers mission critical instruments for underwater navigation, monitoring, survey, and detection. Teledyne BlueView' s advanced sonar systems are currently deployed on AUVs, ROVs,surface vessels, fixed positions, and portable platforms, and have been adopted by leading manufacturers and service providers to support mission critical operations. To date the cold case remains a mystery, but a greater search area was covered in a shorter amount of time enabling the team to eliminate areas of probability.

Instrument Integrations

Current Profiling from an Autonomous Underwater Glider

DOF Subsea recently used Teledyne RD Instrument's AD-CP's to study loop currents in the Gulf of Mexico. A loop current is a current of warm water that travels from the Caribbean into the Gulf of Mexico. This current flows through the Florida Strait and then heads north to the eastern coast of the United States. In September 2015, DOF Subsea began glider-based, real-time environmental monitoring of the Gulf of Mexico as a new subscription-based data service. Teledyne Webb Research Slocum gliders equipped with Teledyne RD



DOF- subsea

Instrument's ADCP sare used in the monitoring, which represents a novel approach to collecting current profiles compared with traditional vessel mounted ADCPs. The main objective of this service is to aid operational decision making with observational data. The glider collected data along the Gulf of Mexico Loop Current including surface current velocity profiles and salinity and temperature profiles to 1000m depth. Currently, there exists no other glider-based solution to monitor the Gulf of Mexico Loop Current velocities. The competing solution is to run a vessel-mounted ADCP in the area of interest. The glider-based solution is dramatically less expensive and has the potential for customized mission design such as a multi-glider deployment.

DVL Aided Navigation for ROVs

Teledyne RD Instruments supplied an Explorer Doppler velocity log (DVL) to Oregon State University's School of Mechanical, Industrial, and Manufacturing Engineering for a renewable energy project in partnership with the Northwest National Marine Renewable Energy Center. The Explorer DVL was integrated on a Teledyne SeaBotix vLBV300 ROV for a project that aims to minimize downtime during AUV deployments.

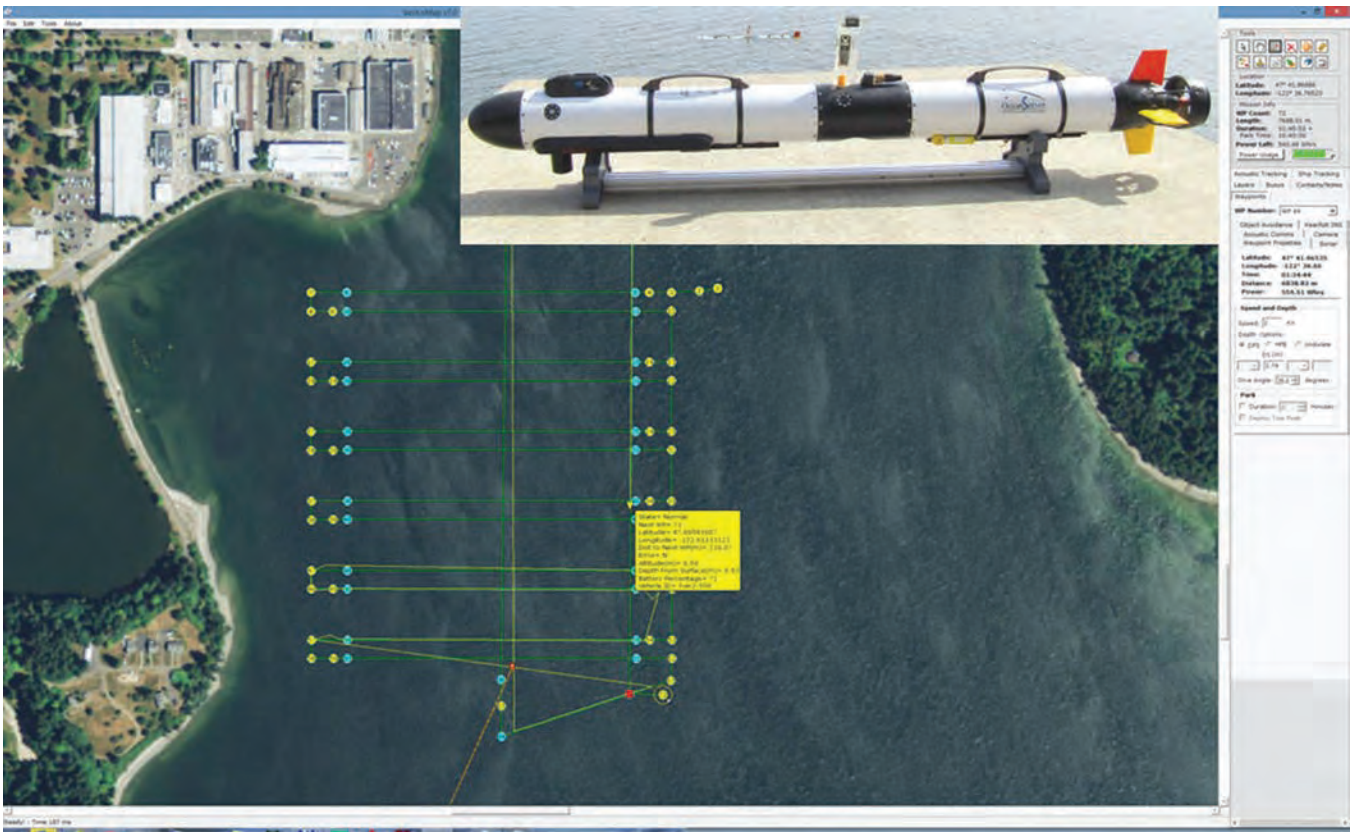
"Teledyne RDI's Explorer DVL is a key component of the navigation system used on the SeaBotix vLBV300 during operation in offshore marine renewable energy arrays," said Geoff Hollinger, Ph.D., the project's co-principal investigator and assistant professor of mechanical engineering at Oregon State University.

"Finding ways to reduce the cost of operations and maintenance for marine energy arrays will contribute to a lower overall cost of energy for this new technology sector," said Belinda Batten, Ph.D., director of the Northwest National Marine Renewable Energy Center.

The goal of the project is to decrease maintenance and intervention time in marine renewable energy arrays. Researchers are focusing on reducing deployment, operator, and shipboard operations times by 30 percent.

Underwater Communication with Person Deployable AUVs

Person deployable Autonomous Underwater Vehicles (AUVs) are used for a variety of tasks from search and recovery to the identification and monitoring of dumped munitions. Oceanserver Ivers 3 AUVs can be outfitted with a variety of side scan sonars and other sensors, depending on mission



IVES 3 AUV

requirements. The Ivers3 AUVs are also routinely outfitted with some important Teledyne Marine instruments including Teledyne Benthos ATM-900 Band C modems and Teledyne RD Instruments Phased Array DVLs. The Teledyne RD Instruments Phased Array DVL provides positional accuracy for x and y speed over ground once the AUV leaves the surface and can no longer access GPS. The Teledyne Benthos modems are specially designed to fully integrate with the Ivers AUVs, providing regular updates on the status and position of the systems while they are underwater and underway. Communication with the AUVs while underwater is safer and more energy efficient. The modems provide waypoint, battery status, position, error messages, and other mission status information, giving the operator vital information about the AUV and allowing the AUVs to be easily re-tasked in situ. Teledyne Benthos worked closely with the customer to custom manufacture a transducer that would fully integrate with the AUV's sensor ports and would be suitably sized for the small AUV.

Tracking Undersea Cables

Bibby HydroMap (formerly Osiris Projects) currently own and operate a fleet of 5 specialist vessels and are experienced in a range of disciplines including tracked ROV survey and inspection. One area in which Bibby HydroMap works is submarine cabling procurement and installation for offshore wind development. Following installation, Bibby HydroMap conducts cable surveys to assess horizontal positioning, areas of exposure or movement and depth of burial. Bibby's Surgeon Tracked Inspection ROV is capable of performing such sur-

TSS pipe tracker installed on a work class ROV

veys. With a weight in air of three tons, the system can reach sea water depths of 100m. The track-driven ROV is mobilized with a Teledyne TSS 350 for cable tracking, which utilizes advanced pulse induction and digital signal processing technology to accurately determine ranges of buried cables. Resultant data is supplied to the support vessel via the ROV's umbilical where all navigation and depth of burial data is logged by the survey computer. These results are logged and displayed in real time, with an option to be overlaid on the ROV video footage.

DeepOcean, UK, owns and operates two TSS 440 and TSS 350 pipe/cable tracking systems. DeepOcean UK undertakes a wide range of subsea services that include survey and seabed mapping, subsea installation and intervention, inspection, maintenance, repair and decommissioning. The TSS pipe/ cable tracking systems perform an essential role in DeepOcean's equipment inventory. A new-build cable-lay vessel was chartered by DeepOcean from Maersk Supply Services and the cable trackers are expected to be used to support its work. The new ship is involved with Interconnector projects as well as work in the oil, gas and renewable sectors. The versatile vessel is suited for installation and burial projects using its 7,000 ton carousel from land-fall to deepwater and also in remote geographical locations.

Interconnect Solutions

Making Connections in Harsh Environments

Bluefin Robotics makes a suite of autonomous underwater vehicles for a variety of markets. Some of their vehicles are rated to depths of 4,500 meters, requiring harsh environment interconnect solutions. Bluefin Robotics met with Teledyne

Liquid Robotics Wave Glider

Impulse to discuss a specific solution for an electrical power and signal requirement. Bluefin sought an improvement over their current solution and Impulse designed a new connector that was able to mate in a wet environment, was blind mateable(with key) for hard to reach spaces, could be mated and de-mated multiple times for longevity of the connector and contained connections to carry both power and data. Teledyne Impulse designed the MKS(W)-412 connector as a custom solution for Bluefin's specific requirements.

Oceaneering in Morgan City, Louisiana, is a major manufacturer of workclass Remotely Operated Vehicles (ROVs) that operate at depths to 10,000 fsw. The ROVs are often required to ascend or descend quickly in the water column. The rapid ascent/descent led to performance issues with their existing cable solution. Repairing these cables in the field was challenging so a new solution was needed. Teledyne Impulse designed an oil filled connector for Oceaneering that was purpose-built to meet the rapid ascent/descent requirement of these heavy workclass ROVs. The new oil filled hose does not require an overmold, eliminating that failure point. The new design also allows the customer to easily repair the assembly in the field, if required. Both design features improved operational up-time for the customer.

Liquid Robotics, manufacturers of the Wave Glider, needed a high power connector solution for their SV3 glider. Limited space, large scale manufacturing, and a higher power requirement, led to a redesign of the connector and the electronics housing.

Teledyne Impulse worked closely with the customer to develop a new custom right angle connector with four different contact configurations and PEEK bodies.The connectors were designed to make assembly of the electronic boxes as simple as possible. Teledyne Impulse supplies these connectors complete with ready-to-assemble inboard PCB connectors.

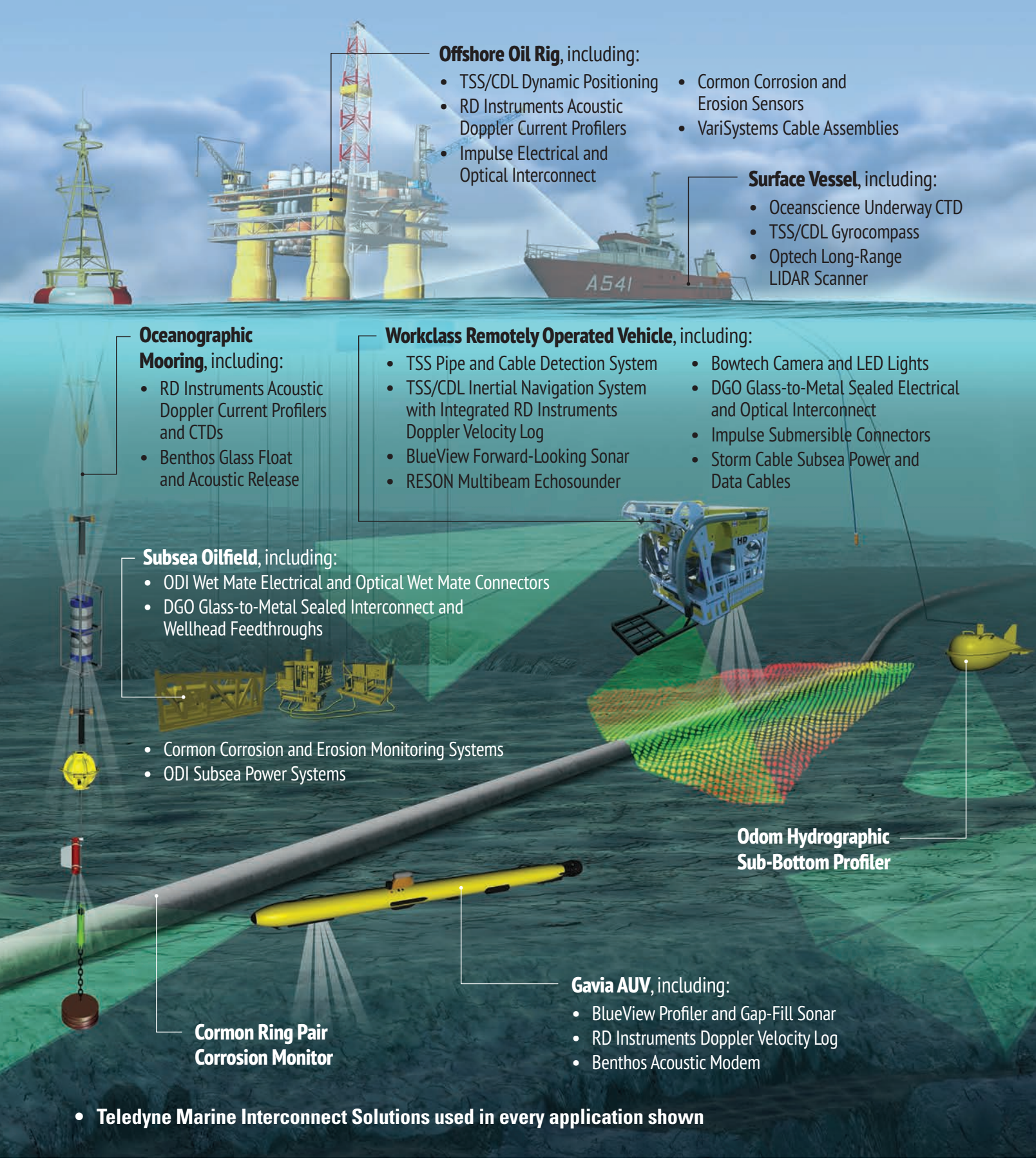
A custom, high power configuration was also adapted for use on the battery housings to manage power from the solar panels and distribution throughout the vehicle. Custom octopus cables facilitate connectivity with a number of sensors in a very tight space. In addition, the breakout molds have mounting features integrated into them.

Oceaneering Millennium Plus ROV

Teledyne Impulse's willingness to work with Liquid Robotic's engineers to find the optimal solution to their connectivity challenge rather than adapt a solution to the current connectors made them a key solution provider.

Teledyne Marine Integrated Solutions

Teledyne Marine is a leading provider of instruments, imaging, and interconnect solutions for unmanned underwater and surface vehicles. In addition to its broad array of innovative products and technologies, Teledyne Marine also has direct access to highly focused and unique resources that are available through the expanded Teledyne family and its world renowned Teledyne Scientific research center and engineered solutions group. Teledyne Marine offers the industry knowledge, technical expertise, and ocean experience to make your products and projects a success.



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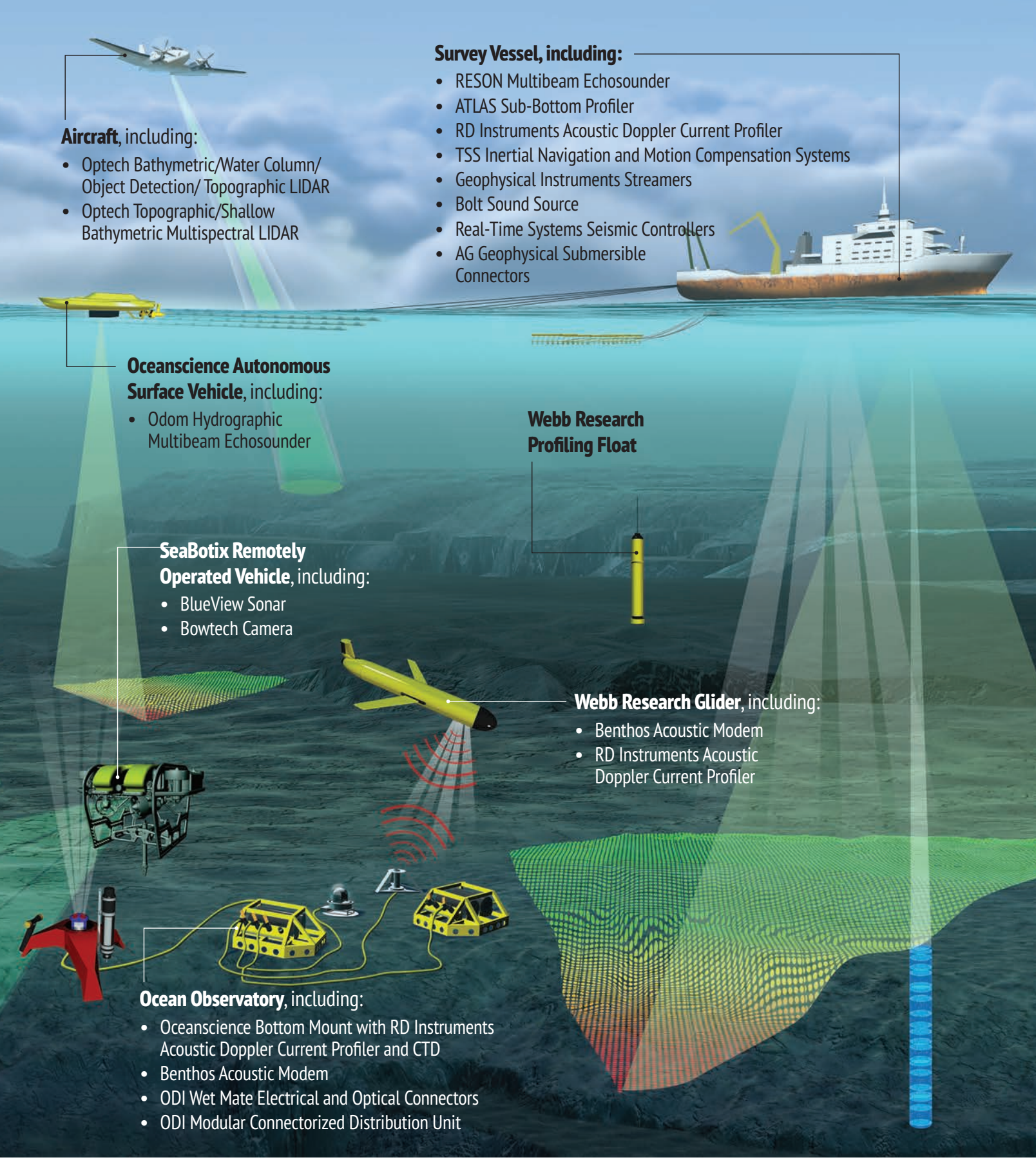

TELEDYNE MARINE

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AUVs are on track with BroadBand DVLs

Teledyne RD Instruments celebrates two decades of navigating unmanned vehicles

By Dr. Peter Spain

Do you remember navigating with a street atlas? What a difference GPS makes. And now it seems every other new gadget includes a GPS chip for supplementary input. Similarly, better navigation tools optimized operations that use unmanned underwater vehicles (UUVs). Plus better navigation permitted expanded capabilities and greater cost-effectiveness. Together these advantages delivered a major gain for users of tethered and untethered UUVs. These are Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs).

During the last decade, AUVs have rapidly advanced from experimental prototypes. They are now considered reliable tools that have operated in diverse undersea activities. AUVs can complete a mission independent of topside support and then return home reliably.

An essential springboard for this new-found autonomy has been much improved navigational systems. A key part of better navigation came from using BroadBand Doppler Velocity Logs (DVLs). In this article we review how they have contributed to the groundswell in using AUVs.

Increased Value to Users

AUVs see action in varied marine industries: offshore engineering, defense, and research. Low-noise Doppler velocity logs (DVLs) enable improved control of these AUVs - motion and positioning. Due to this improved control, other onboard sensors can now realize their true effectiveness.

Direct improvements affect productivity. These include better vehicle position, control, and stability. One example is long-term station keeping and the associated hover footprint. Others are better cruise control and more efficient and exact tracking and surveys.

Indirect improvements include superior output products, like mapping and visualization. One upside is more and higher-quality data during inspections and surveys. Another is making full use of high-resolution imaging sensors and cameras. Examples range from detecting and identifying submerged mines to inspection of structures and pipeline, as well as scientific exploration of fields of hydrothermal vents.

Any external control of a submerged AUV or the setup of its sensors relies on acoustic communication. For the user, this link affects both the productivity of the AUV and its output products. Teledyne Benthos provides a reliable acoustic link with an AUV across a mile underwater.

Productivity improves when the AUV does not need to surface routinely and send data through the air. Output products are better if sensors can be reconfigured while still on the job. For example, an AUV can repeat one survey line with different settings of the sensors. On seeing results, operators can send the optimal setup for the survey.

Doppler Velocity Logs

The motion and position of AUVs can change in horizontal and vertical directions. Doppler Velocity Logs (DVLs) are sonar systems that use sound to measure these changes.

Key advantages stem from using sound. Most important, it can measure speed-over-ground from a remote distance. Plus there are no rotating parts or electromagnetic sensors to foul. And sound changes predictably with ocean conditions. If the seabed is too far, the DVL can still provide measurements of speed-through-water.

Like the radar gun used to catch speeding cars, DVLs use the Doppler Effect to measure motion. This is the change in pitch of returning echoes compared to the transmitted sound. Echoes are measured along several beams. Combining data from these echoes tells how fast the vehicle is moving and in what direction.

These velocity measurements can be used to navigate the AUV. Integrating them over time shows the trajectory or path followed by the vehicle. Conversely, if an AUV is hovering, the motion data can aid the control system to hold position.

As a navigation system, the DVL can be stand-alone or part of an integrated system. The latter delivers even better performance. The DVL's data stream includes velocity, altitude, depth, heading, pitch and roll, and temperature.

Teledyne RD Instruments (TRDI)

Teledyne RDI's DVLs are the industry standard for Doppler-aided undersea navigation. They operate on most of the world's scientific, commercial, and military AUVs. TRDI has a unique, 25-year track-record in using BroadBand Doppler processing. This signal processing opened a new era in low-noise and accurate Doppler velocity data. Real-time naviga-

tion and control systems benefited from improved update rates and precise positions. So too did users of onboard imaging sensors that operate with high resolution in time.

As well as their superior data quality, these DVLs are reliable, even in rough terrain. TRDI's transducer configuration (4-beam Janus) includes a redundant beam. This permits not only more robust operation but data QC on a ping-by-ping basis. Plus the bottom-tracking algorithms have a 30-year legacy of refinement.

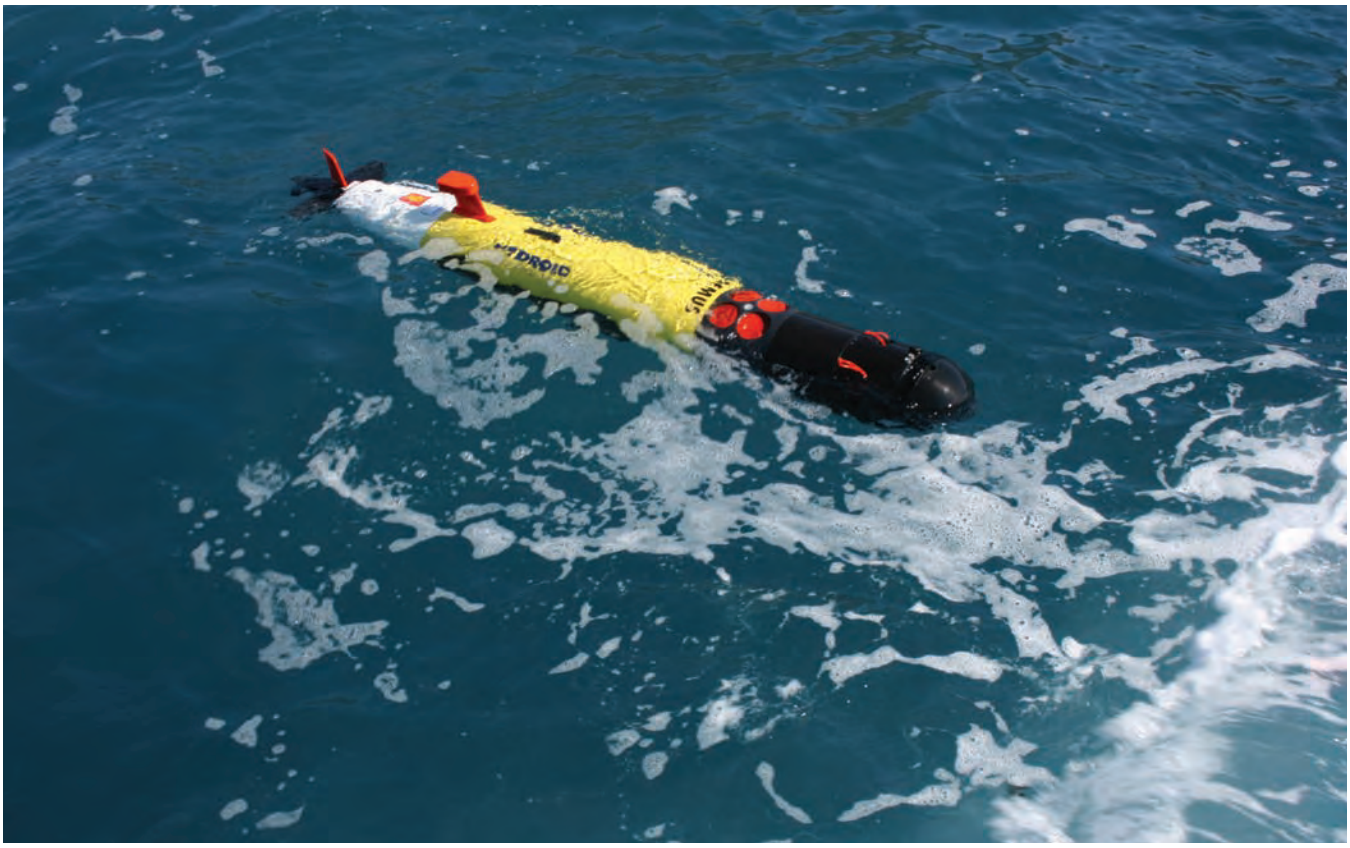
DVL products from TRDI are available in two styles of transducer: Phased Array and Piston. Explorer DVLs that operate at 600 kHz are available in either style. See Figure 1. This flexible design was developed for customized products.

Navigator DVLs are piston only; they come in higher frequencies from 1200 to 300 kHz. The piston design came first and measures lower-noise velocity data.

Pioneer and PAVS products are supplied in phased array configuration. There are several high (Pioneer) and low (PAVS) frequency models. They have greater range to bottom for any given transducer size. Plus this style has some size & weight advantages. They can be compelling for smaller vehicles and for achieving maximal range.

Fig. 1. Teledyne RDI's Explorer DVL. This 600 kHz sonar provides navigation for small underwater platforms that require reduced size and weight. Explorer has been used on AUVs, gliders, ROVs, and diver platforms.

Fig. 2. Hydroid's REMUS 100. This portable AUV carries a range of sensors. Operating to 100 m depth, this vehicle has seen action in a diverse range of surveys. Other Hydroid AUVs can reach much greater depths.



Recent projects

Deep-Sea Science

It seems much of the AUV industry stems from the Woods Hole Oceanographic Institution. Among their supply of vehicles is the AUV Sentry. Sentry's navigation system includes a TRDI DVL. Using its science payload, the AUV explores both mid-water and near-seabed depths to 6000 m depth. Equipped with several acoustic imaging systems and cameras, Sentry has captured unique deep-sea terrains. Even while on the bottom, this AUV can be retasked using acoustic communications. These deep-sea scientists have been enthusiastic about improved navigation tools. They cite the precise positioning and reliable operation provided by the BroadBand DVL as key elements of better surveys.

Environmental Assessment

2-D horizontal coverage of subsurface oceanographic data has not been common. AUVs have been widely perceived as a means to address this shortcoming. One example is a recent study in the northern Adriatic Sea by the Institute of Marine Sciences in Italy. They used a Hydroid REMUS-100 (Fig. 2) to examine spatial changes in coastal waters during floods.

Off one flooding river, the AUV ran a survey pattern that included several sections across the outflow's edge. The researchers examined the dispersal patterns of suspended sediments and fresh water. They found an unexpected result across the visible edge of the river plume. Suspended sediments showed marked decline whereas the deviation in salinity remained unchanged. It seems different mixing models will apply for the dispersion of different river properties.

Resource Mapping

One invasive species of long-spine sea urchin strips reefs bare of living forms. Via this environmental destruction, these urchins can undermine important fisheries. The pest is extending its range along Tasmania's east and south coast. A response strategy to the urchin spread requires a detailed map of their existing habitat.

A Teledyne Gavia AUV (Fig. 3) performed an exploratory mission using bathymetric mapping sonar. The AUV was deployed by scientists of the Australian Maritime College and Institute for Marine and Antarctic Studies. Their goal was to map urchin barrens and classify bottom types. They also identified where vegetation was reduced. Using the AUV permitted 100 times greater areal coverage than prior methods. At the same time, the mapping resolution is 10 times finer due in part to the precise navigation provided by the TRDI DVL.

A different use for the Teledyne Gavia AUV was to survey and picture sub-bottom conditions in Narragansett Bay USA. The AUV carried a sub-bottom profiler (SBP) from Teledyne Benthos. This SBP operates at high frequency and uses chirp

Fig. 3. Teledyne Gavia's AUV. This vehicle is made up of interchangeable modules that can be configured in the field. This AUV is intended for various types of survey work to 1000 m depth.

Mission-ready?

130 hours spent grant writing
3 man-months spent qualifying your vendors
2 man-years spent designing your underwater vehicle
3 man-years spent building your underwater vehicle
1,187 hours spent testing your underwater vehicle
24 hours spent in silent prayer
6 hours spent steaming to your first deployment

Now is no time to be second-guessing your vehicle's navigation system.

Be fearless with Teledyne RDI!

When it comes to safely navigating the underwater environment, there's simply no substitute for experience. Since 1993, Teledyne RD Instruments has been the industry's leading manufacturer of **Doppler Velocity Logs** (DVLs) for precision navigation on board AUVs, ROVs, and surface vessels around the world.

With over 3000 DVLs delivered to date, and tens of thousands of hours of flawless operation, it's no wonder that Teledyne RDI's DVLs have been specified on over 95% of the world's AUVs that require navigation assistance.

Learn why "The DVL is in the Details" at:
www.rdinstruments.com/dvl-stats

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technology. During the mission, the SBP setup and status of the Gavia AUV were controlled using an acoustic modem from Benthos.

These surveys revealed unseen details in near-surface sedimentation. Vertical resolution of the images was 20 cm. These results required a stable low-noise platform that can fly at low and constant altitude above the bed. This capability resulted in part from the BroadBand DVL-based navigation of the AUV

Search Missions

Until recently, searching for lost vessels has been the preserve of ROVs. Now AUVs have become active wreck hunters. Earlier this year, a Bluefin 12 AUV was used to find a sunken Japanese battleship from World War II. The wreck was at 1000 m depth off the Philippines. In the Indian Ocean, a Bluefin 21 AUV had searched for the missing Malaysia Airlines MH370 plane.

Last year, a Hydroid REMUS 100 surveyed off southern UK where two U.S. Landing Ship Tanks (LSTs) were lost. They had been sunk during a training exercise before D-Day. The AUV captured high-resolution imagery of the two LST wreck sites, located in 50 m depth. The low-noise Doppler velocity data enabled the steady navigation and control of these AUVs during the imaging surveys.

Looking Ahead

Trends in the industry point to increasing demand for smaller size, longer tracking range, improved power consumption, and more integrated technologies. Delivering on these challenges will no doubt add to the bright future of AUVs. Partnered with other Teledyne Marine companies, TRDI will continue to expand its product offerings for better navigation tools to optimize AUV operations. Recent additions include lower frequency DVLs to achieve longer range.

Fig. 4. Teledyne RDI's full family of DVL products

Teledyne

CDL Technology

Teledyne CDL – Specialists in subsea marine systems

Micro Electro-Mechanical System (MEMS) technology is at the heart of Teledyne CDL's extensive range of motion sensors that includes a variety of specifications, accuracies and external aiding capabilities. Also available is a complete range of fibre optic gyro (FOG) and ring laser gyro (RLG) gyrocompasses, built for marine vehicle navigation. This wide range of commercially available products is mainly for use in subsea marine and in particular, remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). CDL products are also suitable for subsea gliders, offering combined motion and navigation requirements for all subsea vehicles.

CDL's MEMS based systems include:

- ***MiniSense 2, a 2nd generation motion and magnetic heading sensor***
- ***MiniSense 3, a 3rd generation highly accurate motion and magnetic heading sensor***
- ***MiniSense 2-IPS, a 2nd generation motion, magnetic heading sensor with an integrated IPS depth sensor***
- ***MiniTilt, a static roll and pitch sensor***
- ***MicroTilt, a single axis roll and pitch sensor***

Full navigation systems offering complete attitude and head-

Teledyne CDL – MEMS Technology

TOGS Fibre Optic Gyrocompass – build and manufacture

ing reference solutions (AHRS) include the following products:

- ***TOGS, a tiny optical gyro system that is also available as an IMO approved surface gyrocompass***
- ***TOGSNAV, a tiny optical gyro system fitted with a DVL and options for integrated depth and sound velocity sensors.***
- ***MiniRLG2, an extremely high accuracy ring laser gyrocompass.***

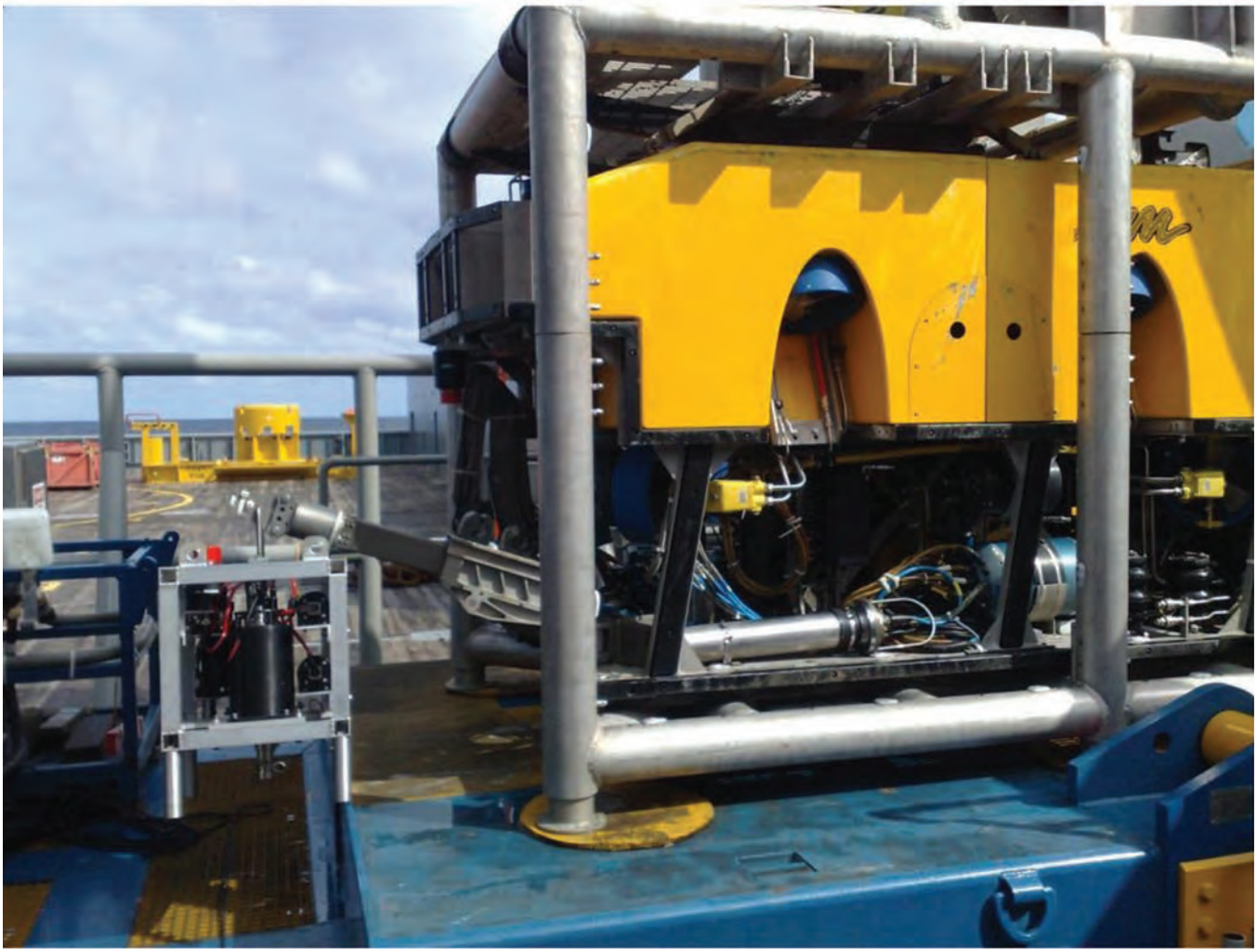
CDL's full inertial products provide positioning systems highly suited to subsea vehicle requirements and survey solutions. Built upon RLG technology, these offer unbeatable heading, roll and pitch accuracies as well as highly accurate position, velocity and heave outputs. These products come either fitted with a Kearfott T-16 or T-24 IMU.

- ***MiniPOS3, a compact and highly accurate INS solution***
- ***MiniPOSNAV3, an inertial navigation system fitted with a DVL and options for integrated depth sensors***

MEMS Motion Sensors for ROV and AUV

The MiniSense range of motion and magnetic heading sensors, the MiniTilt and the MicroTilt all utilise the latest generation of high accuracy 6 Degrees of Freedom (DOF) MEMS

TOGS – fitted to ROV and the DATUM system integrated onto separate frame



WORLD LEADERS IN MARINE INSTRUMENTATION

Individually we are world leaders, **together** we are world class.

Today, the faster a company can develop new technology and deliver new products to the market, the better. By combining our sales teams, Teledyne TSS and Teledyne CDL aim to do just that.

Teledyne TSS has more than a century of experience in marine navigation and survey. Teledyne CDL has earned a reputation for innovative subsea instrumentations and systems – now two world leading companies share sales experience and knowledge to offer world class product ranges that meet all the needs of our customers.

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technology. The advantage of MEMS technology is first and foremost the size. Furthermore, MEMS systems exhibit low power consumption and due to the nature of the solid state design, they have high MTBF and are very robust.

The MiniSense range is CDL's most versatile MEMS based system. Both the MiniSense 2 and MiniSense 3 systems utilise the same magnetic heading sensor achieving 2° heading accuracy. A 2D magnetic calibration algorithm enables these products to be used on a variety of systems where a 3D calibration is not feasible.

Once this calibration has been performed the highly advanced algorithm combined with very accurate gyroscopes results in products that are not susceptible to magnetic disturbances over short time periods. This means that the MiniSense systems can be used close to magnetic disturbances like subsea metal structures and still provide a stable magnetic heading.

The MiniSense 2 achieves 0.2° pitch/roll accuracy where as the MiniSense 3 achieves 0.04° or an unbeatable 0.03° over +/- 5°. With various accuracy options and with depth ratings from a surface version to 6000m, as well as a model with an integrated depth sensor, there is a solution for most customer and user requirements.

This is reflected in the fact that the MiniSense products have been used in a variety of systems ranging from smaller ROVs, subsea structures for motion monitoring and racing sail boats.

FOG & RLG gyrocompasses for ROV and AUV

The TOGS gyrocompass has had endless success since its inception in 2007.As pioneers of the small form factor Fibre Optic Gyro system, CDL engineers have worked to continually develop the TOGS gyrocompass. Due to its very small size, a huge defining factor is that the TOGS provides the essential space saving element crucial to ROV and AUV manufacture that many other subsea navigation systems cannot offer. A combination of the TOGS' exceptional specifications and unmatched cost has meant that it is rapidly becoming standard fit on a large percentage of the world's work class ROV systems. Providing one shipment of 52 TOGS units to a world-renowned ROV manufacturer for new ROV builds in 2014 not only highlights success but also indicates the confidence that industry subsea vehicle designers and manufacturers have in the system. Development of the TOGS led to the TOGSNAV that provides the exact same 0.5° (secant latitude RMS) heading and 0.1° (RMS) roll and pitch performance. Coupled with an integrated DVL supplied by our fellow Teledyne Marine company, Teledyne RD Instruments, TOGSNAV also integrates a depth and sound velocity sensor making it the most integrated CDL system commercially available. The TOGS-S, a surface version of the TOGS unit, was granted full IMO (International Maritime Organisation) Approval in 2012. This operates with the exact same capabilities, flexibility and reliability as the TOGS but it is designed solely for surface vessel navigation. It can operate in conjunction with GPS to provide a robust heading solution that also delivers pitch and roll outputs to accurately track the vehicle's motion. With the TOGS-S certified for the high speed IMO certification (up to 70 kn) it is suitable for any surface vehicle ranging from large displacement ships to small high speed vessels. As well as the FOG technology, CDL also utilises RLG technology in its portfolio of products by building the MiniRLG2 gyrocompass, the MiniPOS3 fully inertial navigation system, and the MiniPOSNAV3 fully inertial navigation system with DVL. These inertial, highly ruggedized solutions supply ROVs and AUVs with a complete navigation package. These systems can also form an integral part of a Mid Water Station Keeping System by fusing the INS, DVL and USBL; they can produce highly stable INS solutions feeding precise position, acceleration and rotation information directly to the control system on the ROV/AUV at updates rates of 100Hz.

In-service Life

All CDL products are subsea rated to 3000m, with options of 4,000m and 6000m, ensuring compatibility with all work class ROV, and most ROV and AUV applications. Housed in black anodized aluminium (and utilising titanium for the 6000m options), these products are purpose-built for the subsea vehicle market and consider every parameter of ROV and AUV manufacture, development and operation in performance, durability and reliability across the whole product life.

All products developed and built by CDL have ease of use and space saving in mind. This design philosophy is clear when looking at the TOGS, MiniRLG, MiniPOS and MiniSense products.With a vast amount of options within these products categories it's clear to see the importance of product integration with ROVs and AUVs and how this is ultimately the defining factor between a well-engineered product and a good product idea. This is fundamental to Teledyne CDL and the way in which CDL solutions are designed, built and most importantly, how they perform and operate in the field.

VideoRay Debuts New Underwater Products

Over the last few months, VideoRay LLC has rolled out two new additions to their product line – the VideoRay Voyager, an economy ROV system, and a brand new line of customized ROV systems called the Mission Specialist Series.

Mission Specialist Series ROV Systems

Beginning in 2016, VideoRay will offer the Mission Specialist ROV Series, a highly customizable and flexible platform that relies on a system of interchangeable, modular components residing on a single, intelligent network. The Mission Specialist ROV Series will consist of ROV systems customized to each customer's specific job task needs. The philosophy behind the Mission Specialist ROV Series is building each system around the capabilities needed for the job at hand, rather than retrofit accessories to a standard ROV.

VideoRay Mission Specialist ROVs will be configured from a range of modular components. Available Mission Specialist components include cameras with a wide range of resolutions, LED lighting modules, powerful thrusters capable of up to one horsepower operation, power systems ranging from 75 Volts to 1600 Volts as well as an on-board battery option, and a purpose-built frame customized around the payload requirements of the operator's chosen sensor package. As with exist-

ing VideoRay Pro 4 systems, the Mission Specialist ROV Series will offer a wide range of the best underwater sensors and tools available on the market, including sonars, positioning systems, cavitation cleaners, manipulators, Doppler Velocity Logs (DVLs), autonomous control, and water parameter sensors.

The topside control panel and user interface will continue to adhere to the user-friendly principles that informed the VideoRay Pro 4 design, while improving upon the technology and adding an optional IP65 ingress rating. Mission Specialist ROV Systems can be controlled over the Internet or through whichever USB controller option preferred by the ROV pilot.

The initial depth rating for the Mission Specialist ROV Series will be 4000 m (13,123 ft), a huge leap from the Pro 4's 300 m (1,000 ft) limitation. Eventually, VideoRay plans to offer systems operable to full ocean depth – over 11,000 m (36,200 ft). All VideoRay Missions Specialist ROVs will use high quality, durable VideoRay plug and play tether, and can accommodate tether configurations up to 2000 m (6,561 ft).

The first VideoRay Mission Specialist ROV system was officially deployed for the first time in September during the VIPS 2015 conference. The Cavitation Cleaner hit the water in Dutch Springs during a demonstration for VIPS attendees, where the VideoRay engineering staff was on hand to explain how the new modular system works and demonstrate the new interface. The Cavitation Cleaner ROV attaches a CaviBlaster probe to the front of the ROV to clean underwater surfaces such as ship hulls, sea chests and cooling water intakes, and other surfaces that collect marine debris.

The Cavitation Cleaner is the first of many different customized ROV system configurations in VideoRay's Mission Specialist Series. Other task-specific ROVs will be configured and introduced as VideoRay determines customers' needs and desires. Currently, plans are underway for systems for 3D surveys, tunnel penetration, mine countermeasures (MCM), as well as a fly-out system for a long-term or permanent deployment.

Voyager ROV System

The Voyager, part of VideoRay's economy series, is designed to bridge the power gap between the economy and professional ROV lines, while retaining the simplicity, portability, and affordability of the economy series ROVs.

The Voyager is at the top of VideoRay's economy line, with

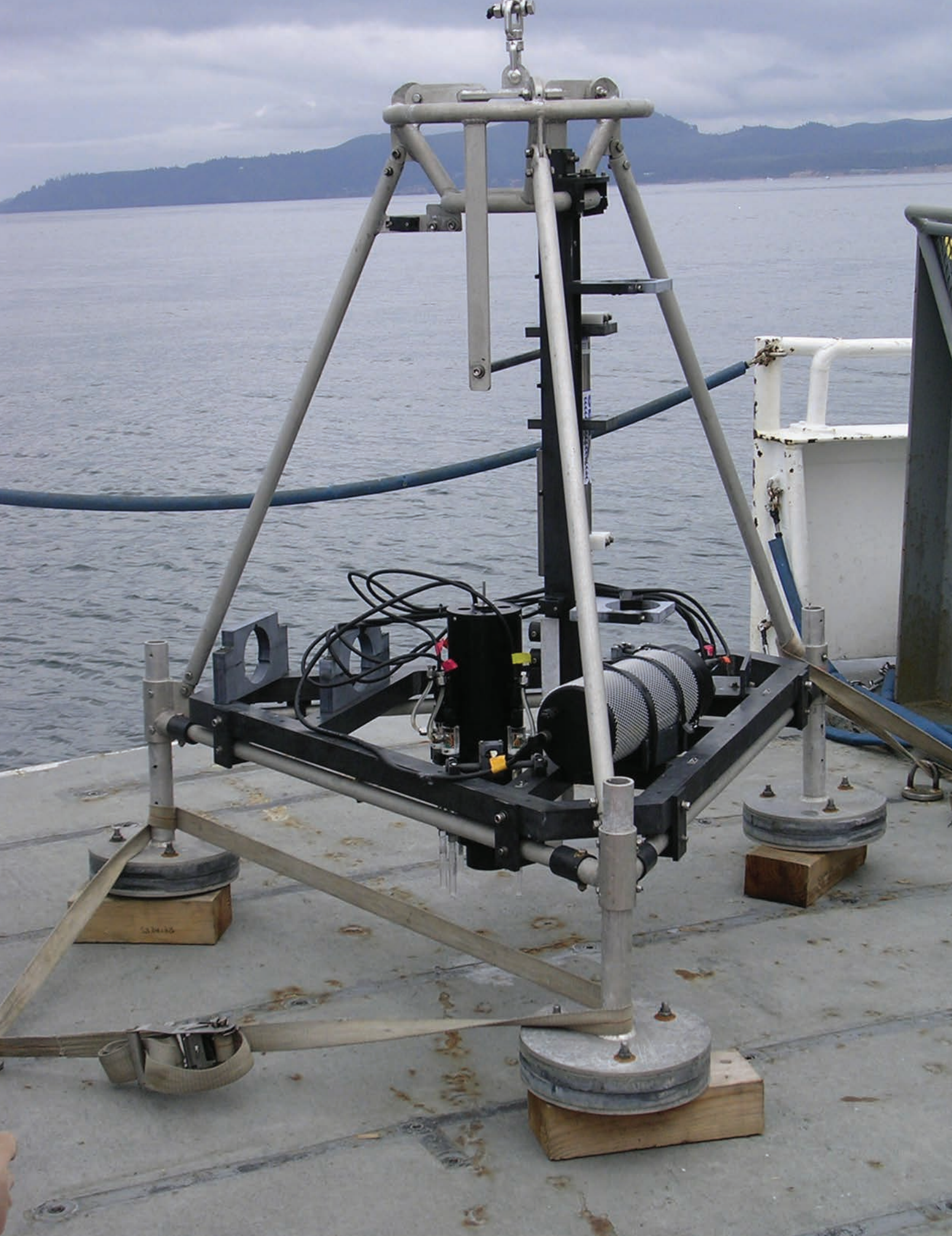
enhanced horizontal and vertical thrusters that increase the submersible's maximum speed to 2.9 knots. The Voyager provides a live video feed from a submerged robotic camera to a topside control panel. The Voyager is depth rated to 250 ft (76 m) and designed for basic underwater visual operations in a low current environment.

The lightweight Voyager ROV system is completely portable, relying on a standard power source (100-240 VAC) rather than heavy batteries that need to be recharged after only a few hours. Weighing in at only 75 lb (34 kg), the complete Voyager system can be transported by hand, on small inflatable boats, or even as checked luggage on any commercial airline. The Voyager maintains the user-friendly nature of all VideoRay ROV systems. Maneuvering techniques can be mastered after just a few hours of training, and operations can continue for as long as the operator is willing.

The Voyager ROV system includes the submersible, the control panel, and 130 ft (40 m) of professional performance tether. The Voyager also features a high resolution, 160° vertical tilt color camera, water depth readout, auto depth feature, compass heading readout, and run time meter. The control panel has a 7-inch color LCD display and control knobs for the horizontal and vertical thrust, as well as the variable intensity halogen lights.

Lost At Sea: Recovering Lost Scientific Packages with VideoRay ROVs

When conducting underwater experiments and research, the safety and accessibility of the equipment and devices is absolutely imperative to the success of the operation. In the unfortunate case that a device goes missing, the operation must be halted until the device can be located and recovered either to its previous location or to the surface for inspection. Searching for lost equipment can cost research organizations precious time and resources, as well as valuable and irreplaceable data. Even if the location is known, deploying divers to

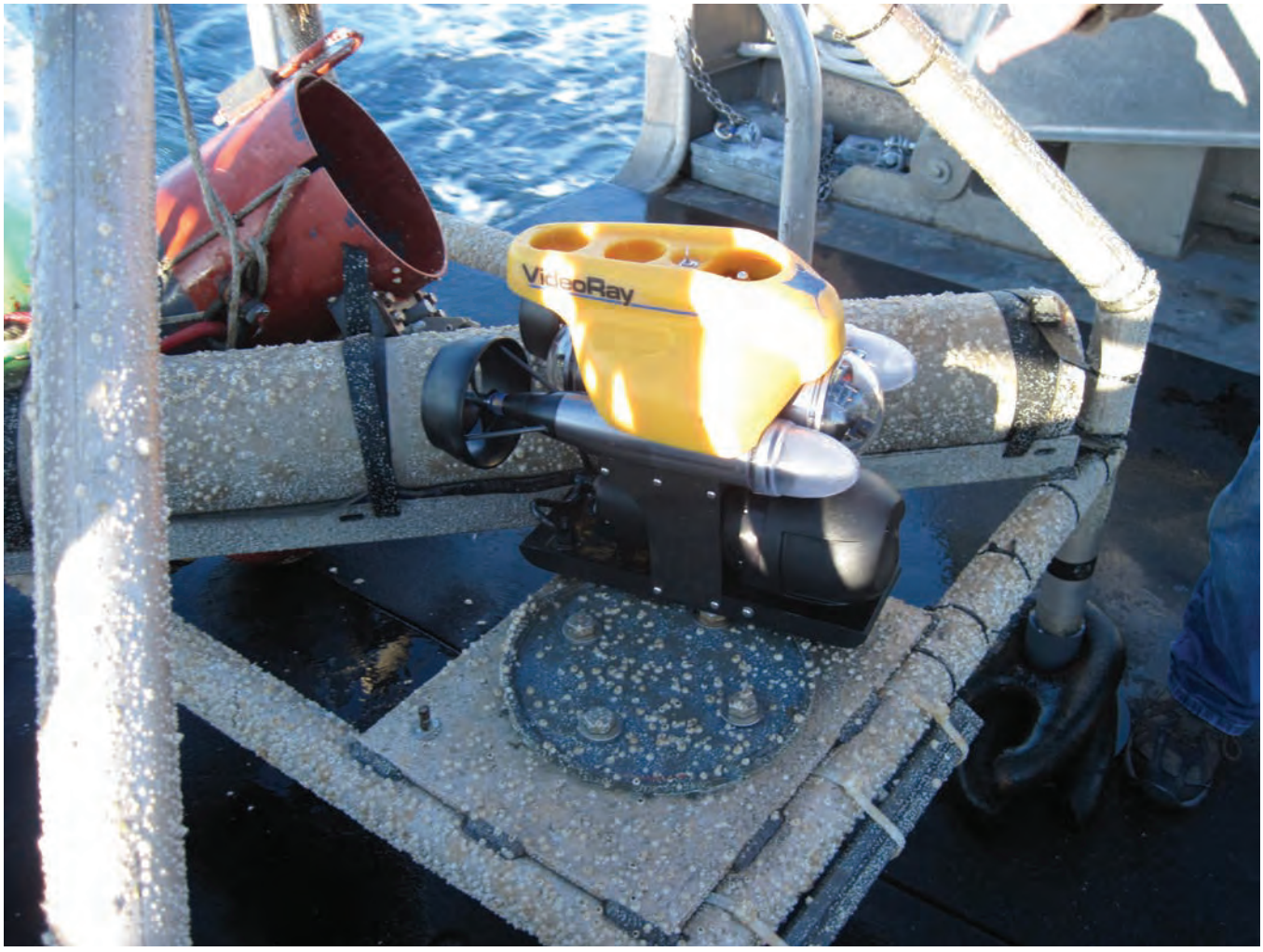


recover it can be expensive and extremely dangerous. If the device cannot be recovered, the entire expedition usually must start from the beginning.

Inspection class or mini Remotely Operated Vehicles (ROVs), such as the VideoRay Pro 4, are an alternative method to locating and retrieving lost scientific packages. ROVs can conduct safer and more efficient searches at a fraction of the cost of a diver deployment. Unencumbered by the limits of physical exhaustion or oxygen tanks, an ROV can search longer and deeper than a diver could. The addition of sonars and positioning systems allows the ROV to "see" in low visibility conditions and keeps track of its location, and ultimately the device.

After a package is located, the ROV can be used to recover the equipment to the surface. Equipped with a manipulator arm, the VideoRay Pro 4 ROV can lift objects up to 10 times its weight underwater using the tether and the manipulator, once a good grip is established. Heavier objects, even up to several hundred pounds, can be lifted using specialized techniques to attach recovery lines. If the package is still too heavy or delicate, divers can follow the Pro 4's tether to the specific target location, minimizing their dive time.

Since 2009, Submerged Recovery & Inspection Services, led by Craig Thorngren, has recovered 12 scientific lander packages for Oregon State University (OSU), Woods Hole Oceanographic Institute (WHOI) and the National Science Foun-



dation (NSF), as well as verified the condition of scientific devices for the Ocean Observatories Initiative (OOI) using VideoRay Pro 4 ROVs. The total value of the gear recovered is more than $1 million U.S. dollars, while the data itself is almost priceless.

Thorngren and Submerged Recovery & Inspection Services were first contacted about recovering a lost scientific package in September 2010. A 300-lb acoustic hydrophone array owned by Oregon State University's Hatfield Marine Science Center had malfunctioned, and needed to be recovered from 175 feet underwater and six miles offshore. The array contained critical data for the Northwest Marine Renewable Energy Center for an environmental impact study of wave energy conversion devices, research sponsored by the US Department of Energy, the Oregon Wave Energy Trust, and Oregon State University. Even though the crew knew the location, sending down divers would be cost-prohibitive and far too dangerous. Fortunately, Joe Haxel from Oregon State was familiar with an alternative method: VideoRay ROVs.

When Submerged Recovery & Inspection Services arrived on the scene, there were only three hours – including travel time – for the crew to locate and assess the condition of the equipment, develop a plan for recovery, and execute the plan successfully. They planned an initial dive to locate and assess the array and its recovery lines to help them develop the best plan for retrieval. A VideoRay Pro 4 ROV equipped with BlueView P900-130 imaging sonar and LYYN real-time video enhancement quickly located and imaged the equipment, and recognized that the buoys that were meant to bring the array to the surface were entangled in the recovery line, damaging the buoy.

The ultimate plan was to attach a carabineer to a recovery line, fly a second VideoRay Pro 4 ROV down to the array, attach the carabineer to the retrieval line at around 90 feet, and then pull the array to the surface. Most of the scientists were unsure that a mini ROV like the VideoRay would be able to accomplish the complex task of attaching a carabineer with line attached to it; however it was a technique Thorngren was familiar with from conducting several similar recoveries. The method was successful, and the array – and its data – were quickly recovered.

The minimal size and power requirements of a VideoRay ROV make it an ideal solution for deployments on the water. The entire system can be transported and deployed by one person from a small vessel. The Pro 4 ROV can be mobilized in a matter of minutes from a standard power source and can be operated by one person for as long as the operator is willing. The cost of an ROV recovery is significantly lower than the replacement cost of lost equipment and most importantly, the lost data.

For more information about VideoRay ROV solutions, contact VideoRay at sales@videoray.com or +1 610 458 3000.

www.videoray.com

Photo Credit: Alex Messenger Photography

VideoRay

Your success drives everything we do. That's why we've engineered every aspect of our ROV systems with you in mind. VideoRay offers affordable, reliable, and robust ROV systems that get the job done right the first time. There's a reason why more customers have chosen VideoRay inspection class ROVs than any other ROV solution on the market. From our unparalleled customer service to our innovative training programs, VideoRay gives you confidence underwater.

From Surface to Seafloor, Teledyne Delivers Subsea Vehicles with Proven Performance for Diverse Market Applications

Autonomous, tethered, and towed vehicles are doing important work in defense and security, oceanographic research, offshore and onshore energy, and water resource markets. In fact, unmanned underwater vehicles have become an essential tool for a variety of tasks across all these markets, which is a testament to the evolution of robotics technology. Underwater unmanned vehicles are doing work that is impossible, expensive, or clearly too dangerous to humans.

Many manufacturers build equipment for the ocean environment, however, manufacturers of air and ground solutions are still greater in number. The difficulties associated with engineering vehicle solutions for the ocean environment is not insignificant. Strong currents, incredible pressure, corrosive conditions, and the inability to communicate with GPS require highly engineered solutions to properly design and build vehicles that operate efficiently, communicate effectively with the surface and underwater targets, and navigate accurately in the context of the environment.

Teledyne Marine manufactures a wide selection of unmanned underwater vehicles operating throughout the water column from the surface to the seafloor. The Teledyne brands that operate in this space are industry and technology leaders. The Teledyne Webb Research Slocum glider, originally developed by Doug Webb, has earned its reputation at sea and continues to be the most reliable and versatile underwater glider with over 550 units delivered since 2002. The Gavia Offshore Surveyor AUV has become the low logistics vehicle of choice for the offshore survey market. Gavia's modular design and small footprint make it easily deployable from a vessel of opportunity and quickly reconfigurable to meet changing mission requirements. These and other Teledyne brands continue to develop and manufacture highly engineered, proven solutions for harsh environments across a broad range of markets and applications.

Defense/Security

Littoral Battlespace Sensing: The US Navy awarded the Littoral Battlespace Sensing Glider or (LBS-G) as a program of record in 2009. The gliders have been used operationally since 2012. NAVOCEANO provides the fleet with important information about the ocean to produce regular forecasts, hindcasts, and nowcasts of ocean conditions. In addition to weather applications, various sensors provide detection of

photo courtesy Al Good SSC Pacific Code 56440

LBSG

systems, assets and people. NAVOCEANO also uses glider data to create models of ocean properties where real world data would otherwise not exist. The gliders provide temperature, salinity, water clarity, and depth information. Gliders provide a more cost effective data collection tool than ship based information. More data can be collected over long periods of time without the need for a supporting vessel, allowing ships to perform other functions. (NAVOCEANO, 2015) Teledyne Webb Research has supplied 142 gliders to the LBS-G program and will provide up to 150 additional gliders for the program through a new sole source contract.

Ordnance Identification and Removal: Remotely operated vehicles (ROVs) are also routinely used for a variety of defense and security tasks. Teledyne SeaBotix MiniROVs are widely used by the United States Navy Explosive Ordnance Disposal (EOD) teams. Specially outfitted SeaBotix vLBV 300s are deployed by the Navy EOD to identify and disable or destroy underwater unsafe ordnance. SeaBotix' collaboration with the Navy EOD resulted in a highly specialized tool for the military and limits or removes humans from potentially harmful situations.

Ocean Research

Understanding Storms: The Cooperative Institute for the

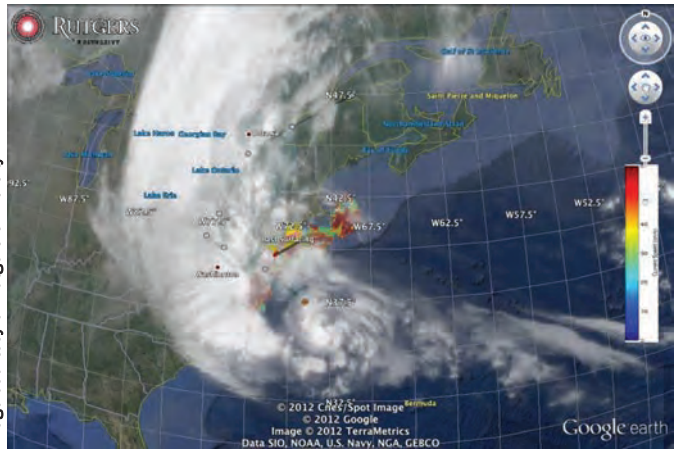


Image courtesy of Rutgers University

Hurricane Sandy

North Atlantic Region (CINAR) Storm project is a joint effort to improve forecasting on the intensity of hurricanes and winter storm events in the Middle Atlantic Bight and Gulf of Maine. CINAR leverages the extensive network of observation and modeling capabilities of the region using information from a variety of sources including the National Science Foundation's Ocean Observatories Initiative Pioneer array. The project includes the use of four dedicated Slocum Storm gliders manufactured by Teledyne Webb Research that perform transects covering the mid to outer shelf for each storm. In addition to the gliders, the project employs profiling floats and portable buoys to gather significant data on approaching storms. The sensor suites on the gliders are customized and include CTD, optical sensors, accelerometers and a current profiler. The vehicles are designed to sample the conditions that control mixing on continental shelves during storms. (Riley Young Morse, 2013) Storm gliders are designed to be deployed into the worst storms to collect data that will help researchers better understand and predict weather events that can have negative impacts on coastal areas and can threaten both lives and infrastructure.

Investigating Natural Oil Seeps: In September 2014, scientists from The Lamont-Doherty Earth Observatory of Columbia University, New York, along with other marine scientists, embarked on the second leg of a multi-day ECOGIG (Ecosystem Impacts of Oil and Gas Inputs to the Gulf of Mexico) cruise. One objective of the ECOGIG consortium is to understand the impact of natural oil seepage into the Gulf of Mexico. When catastrophic oil spills occur, they can release more oil than all other sources would collectively release in an entire year. However, in the absence of such spills, nearly half of all oil released into the ocean is from natural seeps. The team from Columbia University needed a cost effective platform for measuring water column properties with a high degree of spatial and temporal resolution. The new BIOGEOCHEM APEX float from Teledyne Webb Research provided the perfect vehicle solution. The float used for this experiment housed several sensors measuring properties such as chlorophyll fluorescence, dissolved oxygen, particulate backscattering, irradiance, and the usual CTD pressure, temperature, and salinity. Measurement of chlorophyll fluorescence can be used as a proxy for phytoplankton abundance, which was one of the primary areas of study. With these sensors installed, one of the goals for this float was to confirm the elevated levels of subsurface chlorophyll seen near oil seep site GC600.

The APEX float was programmed to execute three profiles, varying between 1200 & 600 dbar, followed by a transition to 'recovery' mode during which it remained on the surface, transmitting its location every fifteen minutes. The float was deployed directly over the target oil seep GC600, the position of which was previously known due to satellite-detected oil on the surface. Data from the deployment will undoubtedly increase understanding of how the water column is affected above natural oil seeps, with potential implications for bacterial and phytoplankton communities in the region.

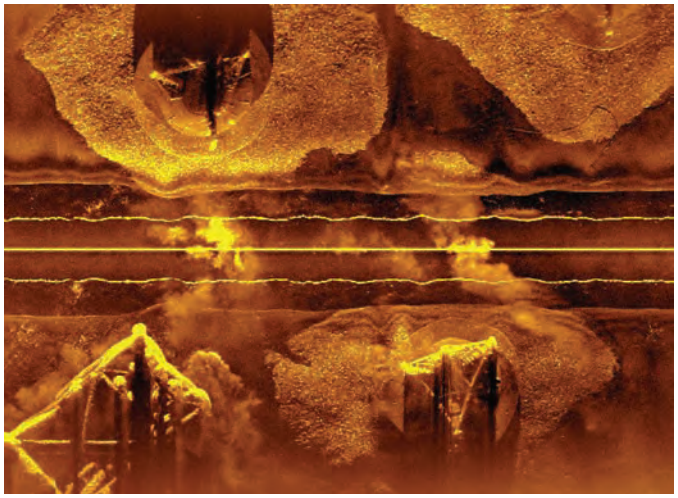
Investigating Natural Oil Seeps deploying the APEX float

Wreck Identification and Salvage: Teledyne Benthos in cooperation with Teledyne Reson recently built and outfitted a Benthos Deep Tow for Odyssey Marine Exploration. Odyssey Marine is a search and recovery company that recovers interesting assets from the deep-ocean through the identification and salvage of lost shipwrecks. Odyssey Marine has surveyed and mapped more than 26,000 square miles of seabed and spent more than 14,000 hours diving on sites using advanced robotic technology. Odyssey's mission for the Benthos Deep Tow was to positively identify the exact location of wrecks

by using the Deep Tow's acoustic imaging equipment to accurately map large expanses of the ocean floor efficiently and perform searches at depths greater than 3000m. Targets under investigation using the Deep Tow are the SS Bloody Marsh, a turbine tanker carrying thousands of barrels of Navy fuel oil that was torpedoed by a German submarine on July 2, 1943 on a route from Houston to New York, and the SS Central America, a sidewheel steamer laden with gold from the California Gold Rush, lost in a hurricane off the coast of the Carolinas in 1857. The Deep Tow Vehicle with Teledyne Reson 7125 SeaBat multi-beam sonar systems returned fantastic 3D images of the wrecks. Odyssey Marine Exploration will continue to use the Teledyne Deep Tow to search for, and map, existing and new wrecks.

Energy

Pipeline Inspection: Regular safety inspections are required of the pipes carrying oil and gas from rigs and subsea installations. These inspections typically employ high frequency sonars and cameras, both of which require close proximity to the pipe. The inspections need to be conducted end to end and are especially challenging around offshore rigs and subsea installations. Safety is a priority, so a survey solution is required that allows production to continue without additional risk. Operating boat-mounted or towed sonars near offshore installations involves collision risk, requiring production to be halted during inspections.The project team of a major oil company required a solution that would enable engineering-quality surveys from outside the safety exclusion zone. The Gavia Offshore Surveyor is a man-portable low logistics Autonomous Underwater Vehicle (AUV) that can carry a suite of survey-grade sensors. Its small size and highly accurate navigation allows it to follow pipe routes right up to the rigs without risk to the installations. The solution was to launch the Gavia AUV from a vessel well outside the exclusion zone, programmed to carry out the survey autonomously using the AUV's side scan, multibeam and camera systems. Low logistics AUVs offer many benefits including safety of operations, ease of deployment, and cost when compared to dedicated survey vessels or ROV operations. A small team can carry out a full inspection from a vessel of opportunity, moored safely away from the rig, without stopping production.



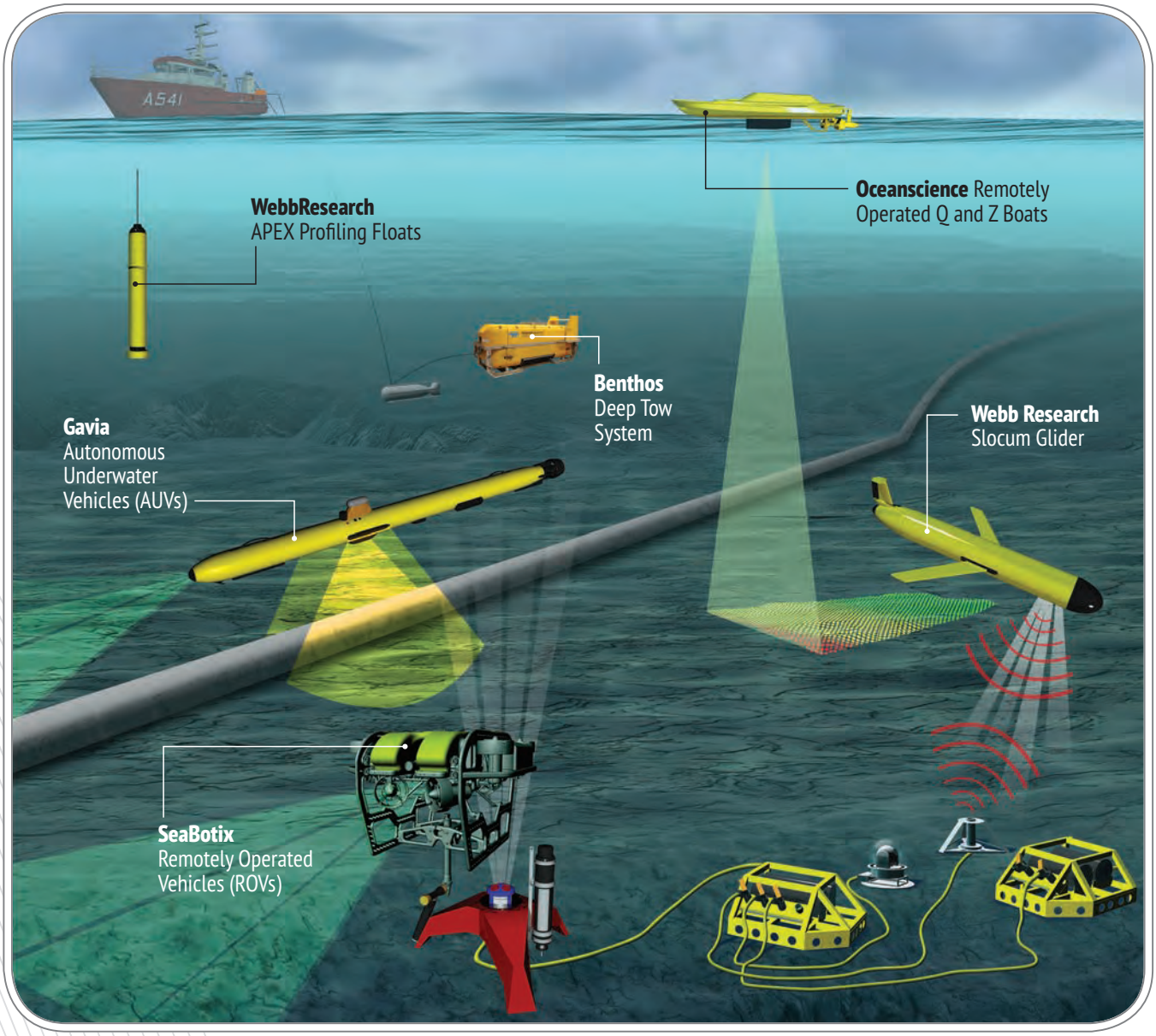
Between the legs of a jack up rig Gavia AUV

Nuclear Waste Inspection: In nuclear energy, storage ponds are sometimes employed to store nuclear products. The contents of the ponds must be routinely inspected and maintained. Recently James Fisher Nuclear Ltd (JFN) worked on a project with Sellafield Ltd, in Northern England using a Teledyne SeaBotix SeaLift vLBV-10 Remotely Operated Vehicle system. Work was required in First Generation Magnox Storage Ponds (FGMSP). The ponds were constructed in the 1950s and 1960s to receive and store irradiated fuel. The ponds are 5 meters in depth and contain 1200 storage skips of irradiated fuel and other items. The ROV's task is to grasp, lift, and move cobalt 60 cartridges, weighing approximately 5Kg each. The cartridges are inspected and then transferred to a new location.The SeaLift and a fleet of vLBV300 are fitted with an articulating single function grabber arm to handle the heavy lifting. In standard configuration the grabber arm is pointed forward for easy viewing by the primary camera. Once the object of interest is grasped, the grabber arm is rotated down and centered under the ROV for stable lifting. This technique is employed to ensure the vehicle remains stable and fully maneuverable while transporting heavy loads. Since May of this year, over 4500 Kg of waste material has been inspected and repositioned within storage ponds at Sellafield in over 200 hours of operations using Teledyne SeaBotix ROVs.

Water Resources

Shallow Water Survey: Shallow water survey can cause safety concerns prohibiting the use of ships or launches. Oftentimes, the water is too murky to be mapped with the airborne lidar systems used in clear waters. Teledyne Oceanscience supplied a Z-Boat autonomous surface vehicle to the National Oceanic and Atmospheric Administration (NOAA) for use on its Thomas Jefferson survey vessel. With the new Z-Boat (using a single beam echo sounder), Thomas Jefferson can measure depths in areas as shallow as one foot, and get that data into processing almost immediately. The boats are highly maneuverable, have a very shallow draft, and turn in their own 5.5-foot length, meaning they can get much closer to piers, pilings, and the shoreline than a full-sized launch. One of the benefits of using off-the-shelf vehicles like Z-Boats is that hydrographers are able to calibrate the boats and put them into use quickly, without the need for additional installation and integration of a survey system. Thomas Jefferson took delivery of the boats in August 2015. NOAA have now qualified the system for hydrographic use, developed first-generation deployment and retrieval systems, and trained a small group

Proven Performance and Reliability from Surface to Seafloor



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Shallow Water Survey NOAA Z boat

of Z-Boat operators.

"Deploying the Z-Boat from the Thomas Jefferson is a significant milestone for the NOAA fleet," said Rear Admiral David Score, director of the Office of Marine and Aviation Operations. "In the coming decade, these types of unmanned systems will become the norm. We will be able to build on Thomas Jefferson's experience in unmanned systems as we expand these programs into the broad range of scientific observations that the NOAA fleet provides."

"Two weeks from delivery to a calibrated system with trained operators is a significant achievement," said Capt. Shepard Smith, Thomas Jefferson's commanding officer. "We have already used them to conduct a small survey in Newport, Rhode Island, and we are thrilled with the new capability this boat will give us in our coastal projects."

A Look Toward Tomorrow

Technology in ocean autonomy continues to evolve. Equipment thought experimental just a few years ago is now considered robust and reliable for routine operations on and under the water. Unmanned operations benefit from reduced risk to human life, reduced cost of operations compared to traditional methods, and remote mission completion. Unmanned vehicles can also provide extended length missions or persistent monitoring, offering the user a larger set of collected data.

Through acquisition, collaboration, and research and development, Teledyne Marine is focused on the growth and advancement of its portfolio of surface and underwater vehicles as ideal tools for tasks in a variety of marine markets. Customers can be confident that they are purchasing the technology of today and tomorrow when they invest in Teledyne solutions. Whether customers are discovering the past, gathering information to predict future events, or protecting the environment, sensitive infrastructure, or human life, Teledyne Marine is a dedicated partner in the success of each mission.

(Image courtesy of Defense Video and Imagery Distribution System)

Teledyne SeaBotix vLBV300

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Teledyne BlueView Helps Ocean X Team Find a 100-year-old Submarine in the Baltic Sea

Ocean X Team's main focus is to search for hidden treasures such as antique high-end alcoholic beverages and historic artifacts. They started their wreck career by finding an American B-17 bomber in 1992 off the Swedish east coast.

In 1994 Peter Lindberg found information about a ship wreck loaded with champagne and cognac in local court archives. This information led to the great find of the small schooner "Jönköping" in 1997 and salvage in 1998. 2400 bottles of Heidsieck & Co MONOPOLE Gôut Americain 1907 champagne where recovered from the wreck and raised world record prices when sold at Christie's auction house in London. Ocean X Team has participated in many wreck projects and salvages since 1992, one of which is the newly found 20-meter long, 3.5 meter wide Russian mini-submarine from World War One.

The dimensions described by Ocean X Team are similar to that of the Som (Catfish), a Russian submarine lost in 1916 after colliding with a Swedish steamer in the Baltic Sea. The submarine was built in the United States in 1901 before being handed over to the Russian Navy in Vladivostok in 1904 and was then integrated into the Baltic Sea Fleet. The Som class submarine was designed to be easily transported by railroad train cars. Seven submarines of the Som class were delivered to the Imperial Russian Navy between 1904 and 1907. The located submarine is allegedly the last of the fleet of seven located and is the only one not scuttled.

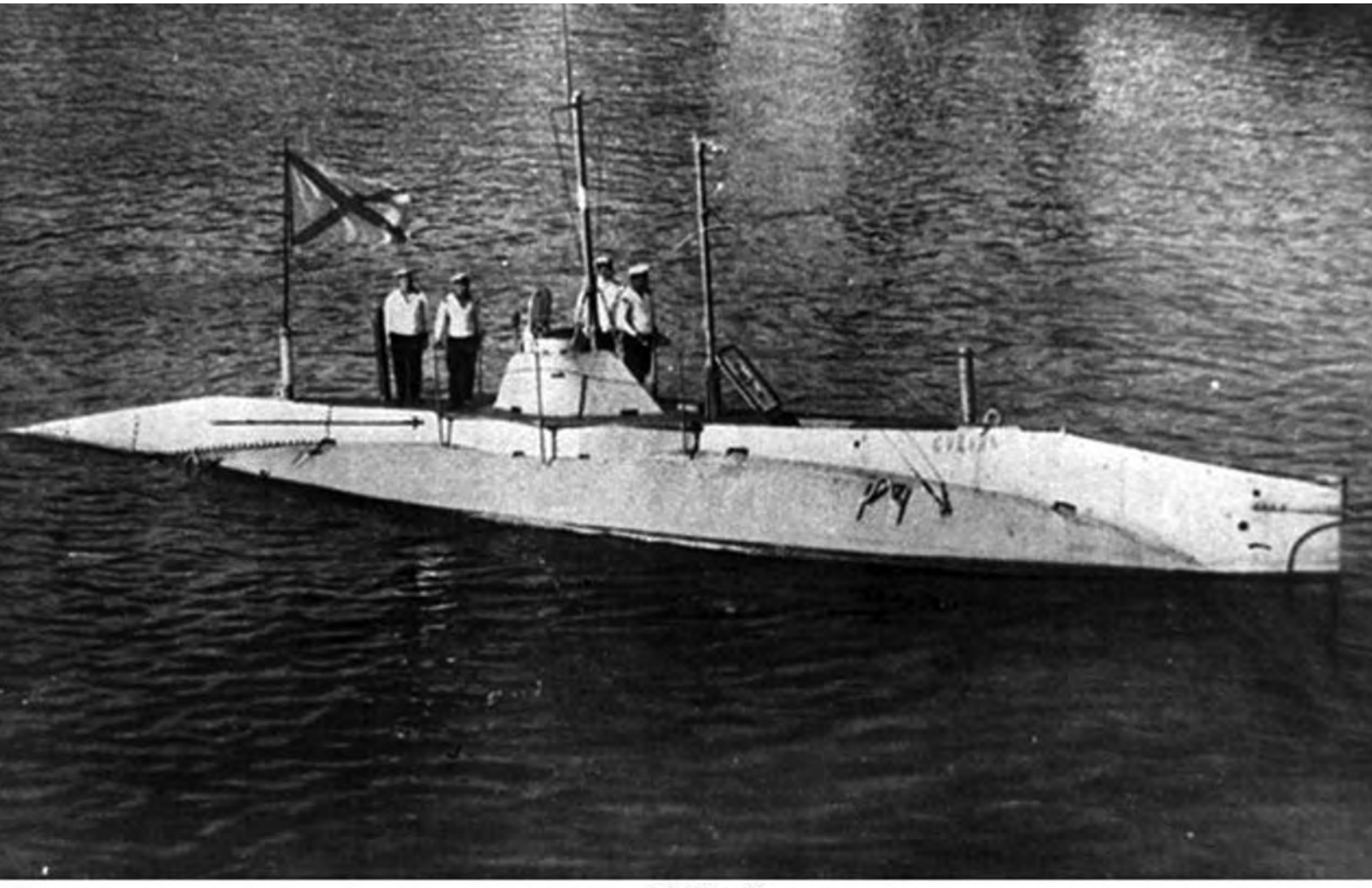
"The submarine is completely intact, has no visible damage to the hull and the hatches are closed. Therefore we fear that the crew have not been able to save themselves when the sub went down," says Stefan Hogeborn, a diver with Ocean X Team.

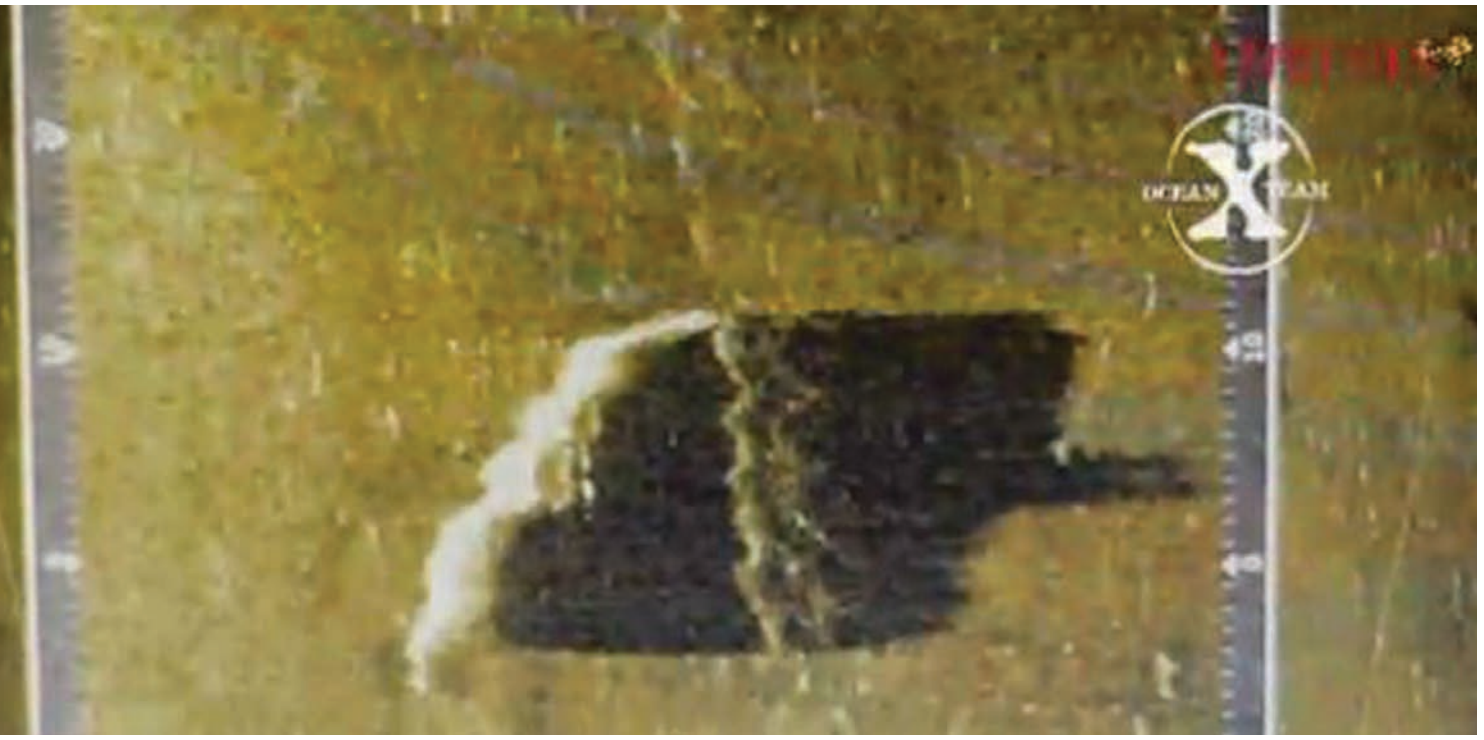
How did Ocean X Team find it?

The submarine was found on the bottom of the Baltic Sea, 2,750 meters outside the Swedish coast in July 2015 during a large area search using side scan sonar to locate any out of the ordinary targets in the area. When the submarine was located, the Ocean X team launched a remotely operated vehicle (ROV) to investigate the target.

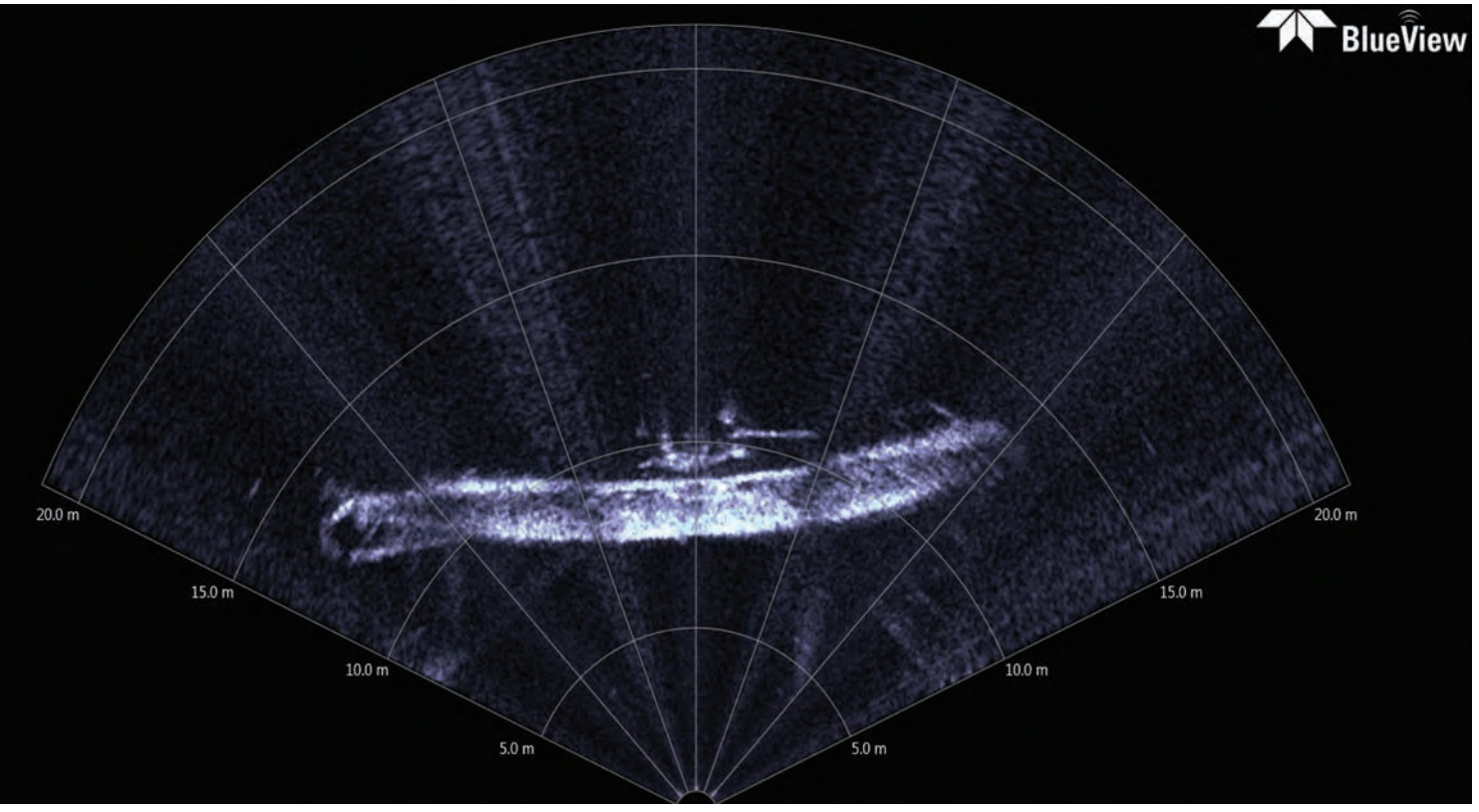
Ocean X Team used equipment from one of the world's leading manufacturer of 2D forward looking sonar technology, Teledyne BlueView. Due to its dual frequency technology the pilot was able to navigate thesonar installed on anROVefficiently to the target while collecting sonar recordings, taking accurate measurements and keeping aware of the surroundings. In very low visibility conditions the ROV has difficulty searching for targets and navigating to the targets of interest without sonar technology. The 2D forward looking sonar pro-

The Ocean X Team, using Teledyne BlueView technology, found a 20-meter long, 3.5 meter wide Russian mini-submarine from World War One.





The next phase of the salvation program includes Ocean X Team divers to examine the boat in detail.



Teledyne Marine

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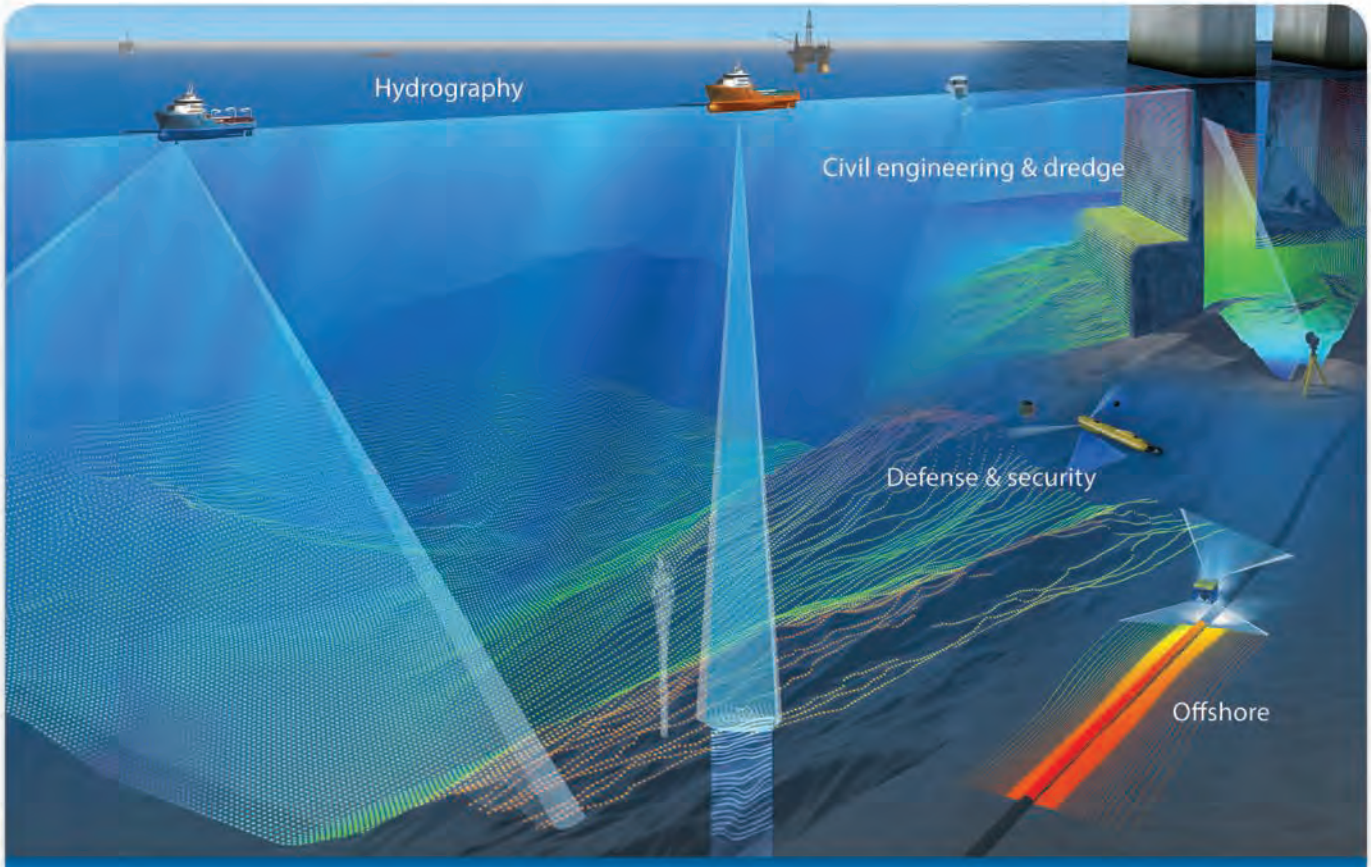

Hydrography
Seafloor mapping
Sub bottom profiling
Marine research

Defense & security
Terrain mapping
MCM and Obstacle Avoidance
Diver detection

Civil engineering & dredge
Dredge guidance
Construction support
Bridge, Dam and Harbor inspection

Offshore
Pipeline surveying
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Photo taken from ROV showing the submarine is intact.

vides real time navigational imagery increasing the usability, efficiency and capability of the ROV when searching for targets of interest.

After identifying the location of the wreck and inspecting the wreck with the ROV and sonar, the Ocean X dive team went in to conduct a hands-on inspection of the submarine. Using a diver handheld imaging sonar device that contains a 2D forward looking sonar, the divers were able to locate the submarine quickly after descending the 87 meters to the bottom.

Efficiently locating the wreck is crucial because of the limited bottom time at these extreme depths. By quickly locating the wreck once on bottom, the dive team has more time investigate the submarine for identifying markings and evidence of damage that lead to the sub's sinking. Divers with increased awareness of their surroundings can make decisions that increase safety and improve their capabilities at dive locations.

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Copenhagen Subsea A/S and the Rim Driven Thruster

Copenhagen Subsea A/S is a newly created company with the purpose of bringing a range of innovative products to the subsea industry. The products are based on many years of experience with building products for the demanding subsea industry.

The first product series presented by Copenhagen Subsea is the rim driven thruster. Due to its simplicity, the rim driven thruster has for years been seen as the ideal thruster concept, but it has proved to be difficult to implement. Several attempts of implementing the rim driven thruster concept has failed

Innovative: The development team behind the thruster has many years of experience with subsea equipment but had to look at other industries in order to find the right combinations of materials and production techniques

Technological advances in materials science and production techniques, has allowed Copenhagen Subsea A/S to succeed in creating an ultra-reliable rim driven thruster with unique features.

over the years, but due to technological advances in materials science and production techniques, Copenhagen Subsea A/S has succeeded in implementing the concept resulting in an ultra-reliable thruster with unique features.

Due to the extreme harsh environment to which a subsea thruster is exposed – the realization of the rim driven concept has involved the utilization of materials with very specific characteristics. The development team behind the thruster has many years of experience with subsea equipment but had to look at other industries in order to find the right combinations

Low acoustic noise signature; High reliability & Increased maneuverability are just a few of the featurs of the Rim driven ROV Thruster from Copenhagen Subsea A/S

The power of silence

NEW class of ROV Propulsion

Powerful and silent subsea thrusters from Copenhagen Subsea A/S have been developed with reliability as the highest design priority.

The ROV thrusters are responsive, powerful and easy to integrate – and will provide vehicles with a unique combination of silent power and high maneuverability.

Reliability first

The revolutionary range of powerful and silent subsea thrusters from Copenhagen Subsea A/S have been developed with reliability as the highest design priority. This goal to produce reliable thrusters has been verified with intensive testing – additionally the technology has proven its validity through key customers´ intensive use over long time periods.

The thrusters are responsive, powerful and easy to integrate – and will provide vehicles with a unique combination of silent power and high maneuverability.

Unique features

- The unique rim drive design will provide vehicles with an unprecedented low acoustic noise signature.
- The thrusters are responsive, powerful and easy to integrate and will provide vehicles with a unique combination of silent power and high maneuverability.
- High torque at low RPM
- Only one moving part – no gear
- Two solid molded parts - No sealing needed, no oil inside, no air inside.
- Ultra high reliability
- Low friction Seawater lubricated bearings providing high efficiency
- Hub less propeller - low risk of entanglement
- Easy exchangeable propeller
- Equal forward and reverse thrust
- Low weight
- Compact format – unprecedented power/size ratio

					
		Version Medium (VM) Standalone	**Version Large (VM) Standalone**	**Version Medium (VM) Compact**	**Version Large (VM) Compact**
Propeller diameter	mm	140	168	140	168
Outer diameter	mm	195	245	195	245
Length	mm	237	274	130	130
Maximum bollard pull thrust/power*	N/kW	~900/7	~1400/10.5	~800/7	~1300/10.5
Weight in air	Kg	7.7	12.8	6.3	10.3
Weight in water	Kg	4.4	7.0	2.9	4.4
Maximum Rotational speed	1/min	2500	1600	2500	1600
Pressure rating	Bar	70	70	70	70

*The motor controller can be customized to voltage- and communication requirement.

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of materials and production techniques, which could give the right compromise between reliability and performance required in the subsea industry.

Today one of the limiting factors in the utilization of ROV and AUV is the reliability of the thrusters. The thrusters are equally critical to the ROV operation as the rest of the sub-components - but due to the complexity of the thruster coming from moving parts; it is harder to achieve the same level of reliability as can be achieved in the non-moving parts of the system. The reliability of thrusters used in the ROV industry today is also a result of the small batch sizes in which they are produced. Copenhagen Subsea has successfully developed a series of industrialized thrusters with a significantly higher level of reliability.

Features of the Rim driven ROV thruster include:

• *Low Acoustic Noise Signature:*

Due to the fact that the rim driven propeller has a low tip speed of the propeller blades the noise emission from the propeller is significant lower than a normal propeller. Beside the propeller, the motor has no gears or other mechanical moving parts.

• *High Reliability:*

The low number of components in the thruster means that the reliability of the thruster is high.

• *Increased Maneuverability:*

The thrusters are responsive, powerful and easy to integrate and will provide vehicles with a unique combination of silent power and high maneuverability.

• *Compact Form:*

The thruster is easy to integrate the thrusters can be orderen in two versions either as a stand alone thruster for easy integration or in the compact form where the thruster can be closely integrated into the vehicle

• *Symmetrical Thrust:*

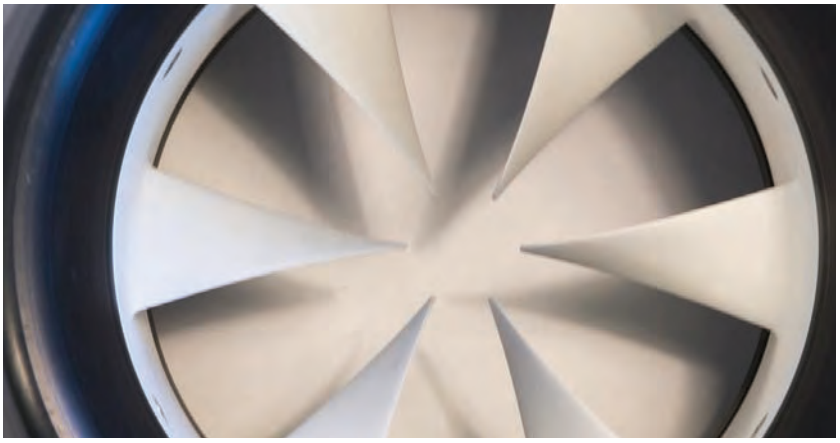
A unique feature or the rim driven thruster is the symmetrical construction - which means that there is no preferred front or back - the thruster will deliver the same thrust going forward as it will when going backwards

• *Fluid Free:*

There is no oil or other fluid inside the thruster, which can leak and pollute the surroundings.

• *Hub-less Propeller:*

The hub-less propeller is open in the middle, which gives the advantage that seaweed and pieces of rope can pass right through the thruster with a low risk of entanglement.



EDITORIAL CALENDAR

Month/Edition	Features		Bonus Distribution
January/February Underwater Vehicle Annual: ROV, AUV & UUVs Ad Close: 01/21	Market: Technical: Product: Special Report:	HD Cameras and Sonar for Vehicles Underwater Navigation Scientific Deck Machinery US Navy	
MTR Special Reports: Oceanographic February 2016 Bonus Electronic Edition Publication Date: February 27, 2016			
March Oceanographic Instrumentation: Measurement, Process & Analysis Ad Close: 02/22	Market: Technical: Product:	Subsea Engineering: Complexity of Subsea Field Architecture Oceanology International 2016 Technology Spotlight Sonar Systems & Seafloor Mapping	Oceanology International March 15-17, London Subsea Tieback March 22-24, San Antonio
April Offshore Energy Annual Ad Close: 03/21	Market: Technical: Product:	Seismic Vessels: Streamers & Magnetometers Deepwater Positioning, Mooring & Anchoring Subsea Vehicles and Systems for Pipeline Survey & Inspection	AUVSI May 2-5, Arlington OTC May 2-5, Houston
May Underwater Defense Ad Close: 04/21	Market: Technical: Product:	Offshore Renewable Energy: Wind, Wave & Tide International Naval Technologies Subsea Housings	Sea-Air-Space May 16-18, National Harbor Mast Europe May 24-26, Amsterdam UDT June 1-3, Oslo
June Hydrographic Survey Ad Close: 05/20	Market: Technical: Product:	Comms, Telemetry & Data Processing GPS, Gyro Compasses & MEMS Motion Tracking Interconnect: Underwater Cables & Connectors	
MTR Special Reports: Hydrographic July 2016 Bonus Electronic Edition Publication Date: July 15, 2016			
July/ August **MTR 100** Ad Close: 07/22	The 11th Annual Listing of 100 Leading Subsea Companies Market:	The Norwegian Subsea Market	Offshore North Sea August 29-September 1 Oslo
September Ocean Observation: Gliders, Buoys & Sub-Surface Networks Ad Close: 08/22	Market: Technical: Product:	Research Vessels Seafloor Engineering & Remote Operations Geospatial Software Systems for Hydrography	Oceans 2016 September 18-22, Monterrey
October AUV Operations Ad Close: 09/21	Market: Technical: Product:	Harsh Environment Systems for Arctic Ops ROV Technology: Workclass to Micro Systems Underwater Tools & Manipulators	Arctic Technology Conference October 24-26, St. John's
November/ December Subsea Engineering & Construction Ad Close: 11/23	Market: Technical: Product:	Fresh Water Monitoring & Sensors Offshore Inspection, Maintenance & Repair (IMR) Underwater Imaging: Lights, Cameras & Sonars	Underwater Intervention 2017
MTR Special Reports: Unmanned Marine & Subsea Vehicles November 2016 Bonus Electronic Edition Publication Date: November 7, 2016			

NOAA Ship Thomas Jefferson Deploys Innovative "Z-Boat" Unmanned Survey Vessel

If you look closely at any U.S. coastal nautical chart, you'll likely find that the areas closest to the shore, shoals, and rocks do not have updated depth measurements. In many areas, safety concerns prohibit the use of NOAA ships or launches to survey shallow depths. In many areas, the water is too murky to be mapped with the airborne lidar systems used in clear waters. Now, however, charting those shallow areas is about to get safer, thanks to recent purchases of small, commercial off-the-shelf, unmanned survey vessels.

This summer, **NOAA ship Thomas Jefferson** deployed a "**Z-Boat**," offered by **Teledyne Oceanscience** out of Carlsbad, California.

The Z-Boat complements the ship's existing hydrographic toolkit.

- ***Thomas Jefferson uses its multibeam echo sounder to measure depths from 45 to 1000 feet.***

Doug Wood, physical scientist on NOAA Ship Thomas Jefferson, deploys a Z-Boat from the ship's fantail.

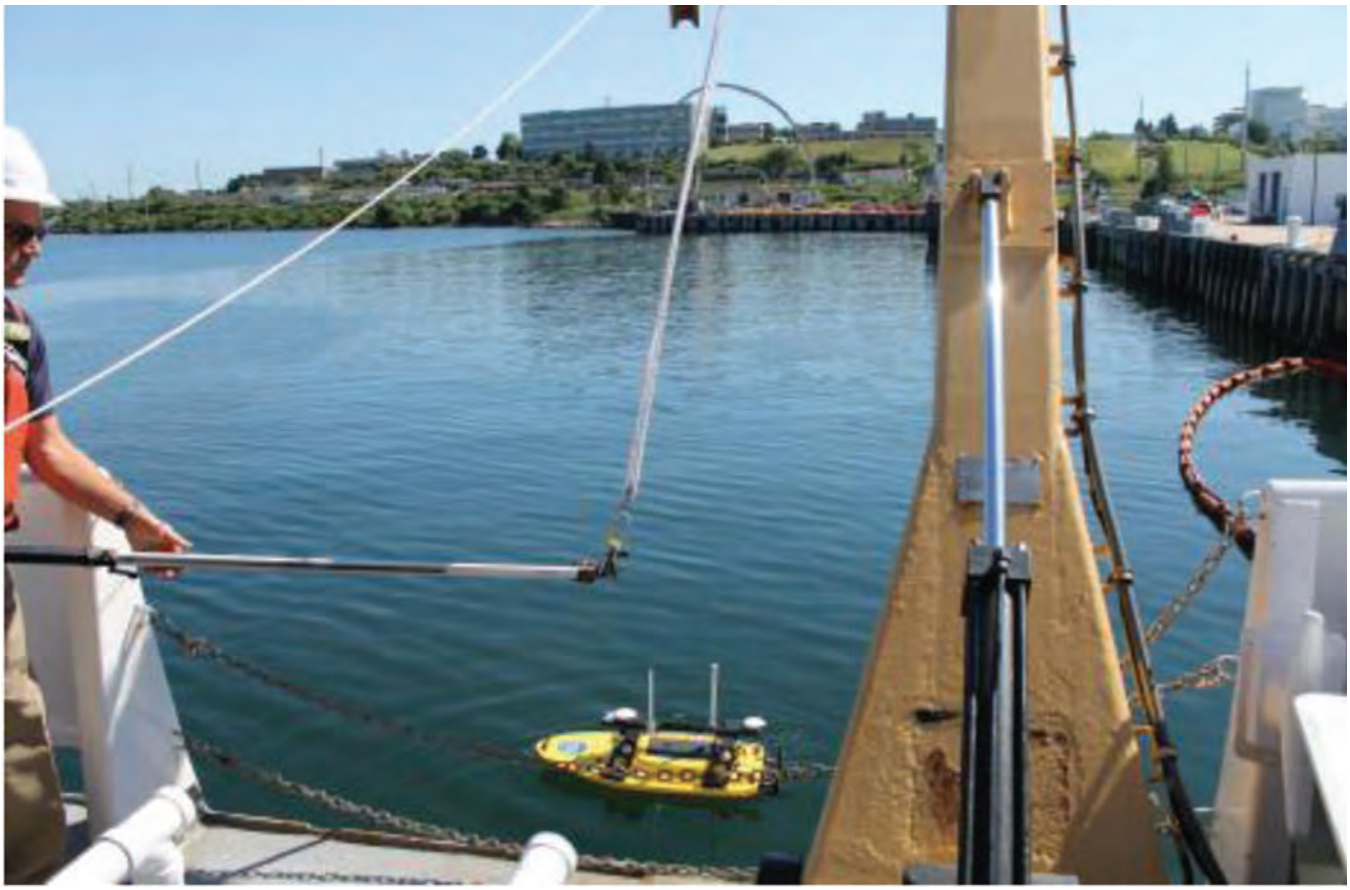


Image courtesy of the NOAA Office of Coast Survey.

"Deploying the Z-Boat from the Thomas Jefferson is a significant milestone for the NOAA fleet. ...In the coming decade, these types of unmanned systems will become the norm. We will be able to build on Thomas Jefferson's experience in unmanned systems as we expand these programs into the broad range of scientific observations that the NOAA fleet provides."

Rear Admiral David Score
Director of the Office of Marine and Aviation Operations

- ***For shallower and more constricted waters, the ship's two hydrographic survey launches with multibeam echo sounders efficiently and safely survey areas from 12 to 200 feet deep.***

- ***With the new Z-Boat (using a single beam echo sounder), Thomas Jefferson can measure depths in areas as shallow as one foot, and get that data into processing almost immediately. The boats are highly maneuverable, turning in their own 5.5-foot length, meaning they can get much closer to piers, pilings, and the shoreline than a full-sized launch.***

This new capability is important to improving charts for smaller vessels operating near the coast, and in the inlets, bays, and harbors so critical to many small coastal towns. In the 1930s, the Roosevelt Administration – through its massive Depression-era public works program – hired hundreds of men to survey shallow Intracoastal Waterway areas. However, NOAA has done very little survey work in shallow water in the 80 years since then. Not surprisingly, there is a backlog of reported shoals, rocks, wrecks, and obstructions in shallow water, leading to an increased risk of grounding for those smaller vessels. Knowing the depth in these inlets is also important to accurately predicting coastal inundation during storms.

Thomas Jefferson, with the support of NOAA's Office of Marine and Aviation Operations' innovative platform program, plans to use two Z-Boats this summer in Massachusetts to investigate shoals and rocks in Buzzard's Bay and Vineyard Sound. This December, they will use them in a project near Chesapeake Bay.

Coast Survey has been exploring the use of autonomous underwater vehicles – AUVs – to support nautical charting for over a decade," explains Rear Admiral GerdGlang, Coast Survey director. "Autonomous surface vehicle – ASV – technologies have advanced in recent years, and NOAA is now also exploring these for our hydrographic operations. The Z-Boat is one of several autonomous surface vehicles that we are experimenting with."

Through a hydrographic survey contract with NOAA, TerraSond (Palmer, Alaska) is using an ASV in addition to their traditional manned boats. (See this article in Marine Technology News.)

One of the benefits of using off-the-shelf vehicles like Z-Boats is that hydrographers are able to calibrate the boats and put them into use quickly, without the need for additional installation and integration of a survey system. Thomas Jefferson took delivery of the boats on August 13. They now have qualified the system for hydrographic use, developed first-generation deployment and retrieval systems, and trained a cadre of Z-Boat "pilots."

"Two weeks from delivery to a calibrated system with trained operators is a significant achievement," said Capt. Shepard Smith, Thomas Jefferson's commanding officer. "We have already used them to conduct a small survey in Newport, Rhode

Island, and we are thrilled with the new capability this boat will give us in our coastal projects."

Thomas Jefferson will operate the boats from a control station on the ship or one of their launches. Depending on the circumstances, technicians have several options to control the boats, by using: 1) a handheld remote control; 2) a networked radio link with one-mile range; or 3) an onboard autonomy module. NOAA is working with Teledyne and with researchers at the University of New Hampshire-NOAA Joint Hydrography Center to develop improvements to the boat's autonomy system that will permit it to gradually work more independently of the operator. With more Z-Boat autonomy, survey ships can operate a larger fleet of boats without adding additional operators.

Capt. Richard T. Brennan, chief of the Coast Survey Development Laboratory, puts this move into a strategic technology context.

"NOAA envisions unmanned and autonomous systems working in conjunction with our manned systems, deployed and controlled from our hydrographic survey ships," Brennan explained. "The Z-Boats are the first step towards unmanned surface vessels. We are looking forward to the lessons learned to drive further innovation in communications and automation technology."

Thomas Jefferson will be exploring other options for the boats. For instance, Z-Boats have an onboard streaming video camera, so the operator can see what the boat "sees" in real-time, raising the possibility of additional uses beyond depth measurements. And although these Z-Boats are fitted with single beam echo sounders appropriate to very shallow water,

Teledyne Oceanscience new ruggedized Z-Boat

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there is an option to fit them with side scan sonar, or a multi-beam system, for other applications.

"Deploying the Z-Boat from the Thomas Jefferson is a significant milestone for the NOAA fleet," said Rear Admiral David Score, director of the Office of Marine and Aviation Operations. "In the coming decade, these types of unmanned systems will become the norm. We will be able to build on Thomas Jefferson's experience in unmanned systems as we expand these programs into the broad range of scientific observations that the NOAA fleet provides."

To learn more about Teledyne Oceanscience's Z-Boat, visit **www.oceanscience.com/z-boat.html.** ***To read more about the Thomas Jefferson NOAA research vessel and the NOAA Office of Coast Survey, visit*** **noaacoastsurvey.wordpress.com.**

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