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Newfoundland & Labrador

The Final Word

Exploring Vast Opportunities

With the Newfoundland and Labrador Oil and Gas Industries Association (Noia)

Newfoundland and Labrador's first oil and gas well was drilled in 1966 and within a decade came a flurry of oil and gas exploration that lasted into the mid-1980s. It was during this period of high activity, in 1977, that the Newfoundland and Labrador Oil and Gas Industries Association (Noia) was founded to connect local businesses with emerging opportunities in the industry. Today, Noia is the largest offshore petroleum association in Canada – over 620 members strong – with a mission to promote development of East Coast Canada's hydrocarbon resources and to facilitate its membership's participation in global oil and gas industries. Members include local companies, many companies from other parts of Canada, and a significant international membership, signifying the global scope of the province's oil and gas industry.

Noia provides a range of invaluable services to its members, from advocacy and industry promotion to business information and networking opportunities and events, such as its widely-attended annual conference. Included in its valuable services is the distribution of timely industry updates through The Daily Barrel, an email bulletin issued directly to members each day, detailing local, national and international industry news, expressions of interest, and a host of other relevant information.

Noia also facilitates information sessions between oil and gas operators and local suppliers and service providers, as well as hosts its Play on the Edge conference every June in St. John's, Newfoundland and Labrador's capital city. The event, which has been running for over thirty years, is the premium oil and gas conference in Canada and regularly attracts around 1,200 participants, including delegates from oil and gas jurisdictions all over the world.

"We look at topics related to harsh environments, we look at broader social issues like social license, and we take a broad

Boa Galatea – Research/Survey Vessel (Photos courtesy of NOIA)

look at the industry from a geopolitical perspective," says Bob Cadigan, Noia's President & CEO. "All the things you need to know as a business leader in order to operate in what truly is an international business."

Legislative issues have never been far from the conversation and Noia has played a key role in lobbying Government for change where it is deemed necessary. One such matter was that of legislative impediments to oil and gas exploration in Canadian waters. Due to legislation limiting access for seismic vessels, these waters were vastly underexplored, particularly off the shores of Newfoundland and Labrador.

Seismic data is critical for oil and gas companies interested in looking at the potential of an area for development; however, legislation meant that operators of these vessels were unable to collect the data, which is captured and then made available for sale to interested parties. This meant that in the critical period of the mid-1980s up until recent years, no multi-company seismic data was collected in Canadian, and Newfoundland and Labrador waters.

"This has really held back the Newfoundland and Labrador offshore and the Canadian offshore industry in general for the last fifteen to twenty years," says Cadigan. "Noia, the Province and others have lobbied hard."

The hard work paid off as, in 2010, the Government of Canada made a change to allow seismic vessels practically unfettered access to Canadian waters, ushering in a period that is seeing some very large seismic programs getting underway to finally collect this much needed data.

One such initiative, started three years ago, is a joint venture between Newfoundland and Labrador's power company, Nalcor Energy; Petroleum Geo-Services (PGS), an operator of seismic vessels; and TGS, a company that deals with the sale of the data to interested oil and gas operators. This initiative garnered international attention as the largest discovery of its

kind in 2013 and has opened up a whole new area for further exploration and development.

"We will have a library of data available that will run from the northern tip of Labrador, right down to the Grand Banks and across the boundary with Nova Scotia, the boundary with Quebec and the Gulf of St. Lawrence," says Cadigan. "So we'll have one of the largest, most modern pools of seismic data available and that is a critical ingredient."

"We are now an area that international operators are looking at investing in. They will invest and we will see a renaissance of exploration in Newfoundland and Labrador."

In a recent land sale, include price one of the existing operators in the Newfoundland and Labrador offshore, ExxonMobil, bid on a parcel of exploration land in the Carson Basin,

one of the previously unexplored areas that this new legislation has opened up. Noia sees this as a leading edge indicator of the kind of global attention that is beginning to be seen in the province.

Attention is also being cast even further north, to unexplored and potentially lucrative regions in the Arctic, and Newfoundland and Labrador's rich heritage of oil and gas experience in harsh conditions positions the province as an ideal Path to the ArcticTM. The province already has three major projects under its belt in the form of Hibernia (first oil 1997), Terra Nova (first oil 2002), and White Rose (first oil 2005), with Hebron (first oil planned for 2017) set to soon make it four. These operations have helped to grow Newfoundland and Labrador's capabilities significantly over the past twenty-plus years, par-

West Aquarius Rig 8. (Photos courtesy of NOIA)

ticularly as it relates to operating in cold, harsh and ice-prone environments.

"When Hibernia was built, or when the project was envisaged, there were skeptics as to whether you could produce oil in an environment that had seasonal sea ice, the fog, the sea states," says Cadigan. "We were a frontier, at the absolute edge of what's possible in terms of producing oil and gas in a harsh environment.

"It has led to us being, really, thirty years ahead of the rest of the world in terms of producing oil in a harsh environment that has many similar conditions to those that exist in the Arctic."

The 2008 findings of the United States Geological Survey (USGS) greatly ramped up interest in the Arctic, identifying 1670 trillion cubic feet of natural gas, 44 billion barrels of natural gas liquids and 90 billion barrels of oil yet to be discovered in Arctic waters.

"This is where about 25 per cent of the world's remaining oil and gas resources are located," explains Cadigan. "So, I think we were lucky in that with the discovery of Hibernia in 1979, and first oil in 1997, we were substantially earlier than rest of world in terms of dealing with Arctic-like conditions. We have a head start and that's a positive thing."

The Hibernia platform was the first of its kind, designed to withstand the impact of a one million tonne iceberg and the considerable forces of pack ice. Terra Nova brought about innovations such as a disconnectable turret that could be moved out of the way of incoming sea ice, and subsea excavations that protect subsea equipment from iceberg scour.

Meanwhile, the soon-to-be operational Hebron platform will become one of the world's biggest float-over operations. These are all examples of innovations made directly because of the Arctic-like conditions found in Newfoundland and Labrador's offshore.

"We were the innovators, we have a lead in terms of the thinking, we've done a lot of research, and we have a lot of companies that have figured out how to deal with these issues," says Cadigan. "They are world leading, world class, and will be called upon for many of the challenges as oil and gas companies start to move in."

Newfoundland and Labrador is the World's Cold Ocean Laboratory™. During the winter season (December to March), winds can reach 90 to 100 knots offshore – hurricane force. Sea ice, up to 100 centimetres thick, may reach the area from February to April, two to three years out of every ten. Icebergs pass through the area from March to July. Fog from April to August can reduce visibility and impact crew changes by helicopter. Air temperatures can dip to minus-18.5°C.

Living and working for generations in these challenging conditions has given rise to a great amount of expertise and innovation. Newfoundland and Labrador is known worldwide for its expertise in ice engineering, surveillance and management. Its capabilities have evolved to include remote logistics; geotechnical, ocean and environmental engineering; marine meteorological services; safety and training; and many more.

St. John's is home to a cluster of private sector ocean technology companies, public institutions, and R&D infrastructure. Applied research and development in ocean mapping, ocean observation systems, ocean instrumentation, and ocean intervention is ongoing and the province's Marine Institute is home to the most comprehensive suite of marine simulation capabilities in North America, and possibly the world.

2014 was a typically active year for Newfoundland and Labrador in the oil and gas sector. Nalcor began working with Airbus Defence and Space to map oil slicks originating from the seabed on the surface of the ocean using satellite imagery.

Nalcor also partnered with Ikon Science Canada to release a comprehensive regional pore pressure study for offshore Newfoundland and Labrador to the global oil and gas industry. The first large-scale study of its kind for offshore Newfoundland and Labrador, it is a comprehensive evaluation of the subsurface pressure systems in the province's eastern frontier slope and deep-water basins.

The study region spans an offshore area from northern Labrador to the Flemish Pass in the south, including the newly discovered Chidley, Henley and Holten basins in the Labrador Sea.

Meanwhile, EMGS (Electromagnetic GeoServices) Canada embarked upon a non-exclusive, four-year electromagnetic data acquisition campaign covering a 41,000 sq. km area from northeast Newfoundland to the Southern Grand Banks.

This activity is in addition to the continuous work being carried out on a daily basis in the province, which involves some truly world-leading companies that are counted among Noia's membership.

- **Provincial Aerospace (PAL)** is a world leader in maritime surveillance with over 165,000 hours of airborne operations, working on projects in thirty countries globally, specializing in ice management support, iceberg detection and reconnaissance, environmental observation and reporting, oceanographic measurements, and weather forecasting.

- **Virtual Marine Technologies (VMT)** was incorporated in 2004 and emerged from collaboration between the oil and gas industry, Memorial University and the National Research Council, in recognition of the importance of safety and surviv-

al training, and emergency preparedness to support the growth of the oil and gas industry. VMT's roots remain tied to the Newfoundland and Labrador offshore, but it has broadened its focus to apply its maritime simulation expertise to meet the needs of a growing number of other global industries.

- **Rutter Inc.** has evolved from being the world's largest supplier of voyage data recorders to now supplying fully integrated radar-based systems for oil and gas exploration and production, as well as security and surveillance applications.

- **GRI Simulations** was established in 1986 to provide support for ROV (Remote Operated Vehicle) system development. Since 1997, the company has focused on supporting subsea ROV operations by providing simulation technology to enhance pilot training, mission planning, and rehearsal for offshore oil construction and production operations.

- **Northern Radar**, much like **PAL**, focuses on maritime surveillance, including search and navigation equipment for tracking ships, icebergs, sea ice and low-flying aircraft.

- **Oceans Limited** was incorporated in 1981 to carry out applied research in oceanography. The company has conducted a variety of research activities, including search and rescue field trials, detection of objects at sea, oceanographic data collection, and analysis of waves, currents and ocean circulation.

This is just the tip of the iceberg in terms of the variety of skills and knowledge that has both paved the way for, and evolved thanks to, the great success of Newfoundland and Labrador's offshore petroleum industry, which is the largest contributor to the provincial GDP, at around 33 per cent.

With oil production value of over $8 billion, the royalty revenues for 2012 alone amounted to $2 billion, and three new basins were announced last year, covering an area the size of the Gulf of Mexico, along with significant finds beyond the northern tip of Greenland and in Statoil's Bay du Nord prospect.

Nalcor continues to conduct seismic work in northern waters, with more than 50,000 line km completed since 2011, and a 2014 extension to acquire an additional 30,000 line km of data in the Labrador Sea, Northeast Newfoundland Shelf, Flemish Pass and the southeast Grand Banks. Surveys could continue until 2018.

Put simply, the province has had great success in operating offshore in cold, harsh and ice-prone environments and is ideally equipped to assist in a new era of oil and gas exploration and operations.

"The environment we have here has a lot of the same characteristics as the Arctic, and we're a perfect incubator and proving ground for the technologies that will be necessary to move oil and gas exploration and development into the Arctic," says Cadigan.

While exploration and development in the Arctic is not something we are likely to see for some time, the signs are that it is a case of not 'if', but 'when'.

"I think we're in a world where there are a number of pieces that have to be sorted out before exploration and development begin in the Arctic," says Cadigan. "Social license, the people adjacent to the resources, particularly indigenous peoples in the north, particularly the Inuit, they need to decide when they are ready to see exploration and activity in the lands they have used for centuries, so certainly social license in as an issue that needs to be addressed.

"We believe that, over time, the opportunities for well-paying jobs and opportunities for indigenous businesses will help and we'll see the social license evolve in the Arctic."

For all the challenges that come with exploration and development in the Arctic, Newfoundland and Labrador is poised and ready to provide the solutions.

Its strong ocean technology cluster, composed of public R&D facilities and private sector companies, is a natural evolution for a people that has traditionally derived its living from the sea and possesses skill sets that transcend generations and ocean sectors.

Add to this the province's deep cultural connections with Aboriginal peoples, its cold ocean and near-Arctic conditions, and its strategic location along international shipping lanes and northern sea routes, and you have the ideal cold ocean laboratory and Path to the ArcticTM.

"We are uniquely positioned because we're far enough south and some of the conditions are sporadic, whereas in the Arctic they are continuous, so it makes us an absolutely perfect proving ground," says Cadigan.

"The other thing we see is the investment the oil companies are making here to take advantage of the bright minds; the core base of knowledge and the facilities we have.

"We have not only the heritage and a part in developing some unique technology; we have the core knowledge, we have continuous research, and we've demonstrated that we have the entrepreneurs that are needed to take an idea that might help to commercialization. We have enablers like the Atlantic Canada Opportunities Agency (ACOA) and the Government of Newfoundland and Labrador…We've got a lot of things going for us."

Teledyne Marine –

Offering you a Sea of Oceanographic Solutions

By Margo Newcombe, Director of Marketing, Teledyne Marine Sensors & Systems

Introduction

Teledyne Technologies' growth in the marine industry began with the acquisition of RD Instruments in 2005, quickly followed by Benthos in 2006. These two entities joined Teledyne Geophysical Instruments, which was already a long-standing Teledyne company. With the cooperation and foresight of these three companies, Teledyne Marine was formed. Since those initial acquisitions, Teledyne has gone on to acquire twenty-oneadditional marine organizations, as well as several product lines and technology partnerships, propelling Teledyne into one of the leading brands within the marine industry.

Teledyne Technologies Incorporated is a publicly-held company that provides a wide array of sophisticated electronic components, instruments and communications products for defense, industrial, aeronautical and environmental applications. The company is structured to serve niche market segments where performance, precision and reliability are crucial. Thus, it's really no surprise that Teledyne set its sights on the marine industry back in 2005. Thisindustry's unique technology, proven products, and innovative, talented individuals are exactly what Teledyne aspires to add to its team. Teledyne's philosophy is to select and acquire key companies that are highly successful in their own right, with core technologies and capabilities that lend themselves to co-operative development and shared, consistent growth and technology based, "solution" advancement.

Each company, while retaining the attributes of its successful business, is able to leverage the expanded science, technology, distribution channels, and manufacturing capabilities of the collective Teledyne entity; thus making each organization more relevant and valuable to their customer base.

The Teledyne Marine companies service a wide array of markets and applications, with the oceanographic marketing being a common focus. Virtually every Teledyne Marine company provides an innovative product or technology that's used to enhance this critical field of study.

With hundreds of products available to serve oceanographic applications, Teledyne Marine's offerings canbest be organized into four categories:

1. **Sensors** – oceanographic data collection devices
2. **Systems** – oceanographic data platforms
3. **Navigation** – oceanographic platform tracking
4. **Communication and Infrastructure** – oceanographic interconnect/data/powertransmission

Sensors: Oceanographic Data Collection

Teledyne Marine offers a wide array of highly innovative, field proven sensors designed to collect critical data regarding the health and welfare of our world's oceans and its vast resources.

- ***Ocean Current and Wave Measurements***

In 1982, RD Instruments developed and delivered the industry's first self-contained Acoustic Doppler Current Profiler (ADCP),a revolutionary device capable of profiling currents at 128 individual depths in the water column. Prior to this advancement, scientists were only able to calculate the speed and direction of currents at a few depths in the water column where current meters were located. The ADCP is arguably the biggest game-changer to date for oceanographers tasked with studying this highly dynamic physical environment. Over the past 30+years, Teledyne RDI has developed a full line of ADCPs capable of collecting critical ocean current data, as well as wave height and direction for a wide array of oceanographic applications, including: climate change research, current modeling, biological / fisheries studies, ocean observatories, recreational activities, and weather studies and prediction --just to name a few. ADCPs can be used to collect data from environments ranging from less than one meter of water to full ocean depth, and can be deployed on the surface, the seafloor or anywhere in between.

- ***Conductivity Temperature and Depth (CTD) Measurements***

A CTD is used to measure the three parameters necessary to determine salinity, density and speed of sound: conductivity, temperature and depth. CTDs measurements have perhaps the longest history and are the most ubiquitous of all oceanographic sensors.Like ADCPs, CTDs are used throughout the world's oceans for a variety of purposes, including: environmental monitoring, fisheries studies, hydrographic surveys, ocean observatories, climate change research, and ocean modeling. Teledyne RD Instruments offers a full line of Citadel CTD products which can be used alone, or in concert with ADCPs or other oceanographic sensors.

- ***Underway Conductivity, Temperature and Depth Measurements***

Unlike standard CTDs, which are installed on the ocean floor or within vehicle or platform, Underway CTDs / profiling systems are used, as the name suggests, while avessel is underway. This product, offered by Teledyne Oceanscience, eliminates the need to stop the vessel for upper ocean conductivity temperature, depths profiling activities. Data quality similar to stationary casts can now be obtained while fully underway, allowing researchers and surveyors to collect valuable data profiles with no loss of costly ship time.

- ***Seafloor / Object Imaging***

Underwater imaging systems can be used for a number of oceanographic applications, including: investigating ship wrecks, monitoring pollution, tracking whales and dolphins,and studying fish stock. The Teledyne Marine Acoustic Imaging companies offer a wide array of products for multi-beam surveysand sub-bottom profiling while operating from surface, towed or remotely operated, or autonomous vehicles.

- ***Seafloor Mapping***

Multibeam and single beam echosounders manufactured by Teledyne RESON, Atlas Hydrographic and Odom Hydrographic are used to map the seafloor in water depths from 0.05 meter down to full ocean water depths. These charts are used to support a variety of applications.

- ***Object imaging***

Imaging sonars are used to monitor infrastructure below the water line and is crucial to ensuring it is well maintained. RESON and BlueView manufacture sonars, which can be deployed from a fixed or moving platform to provide a high detail view of the condition of these structures.

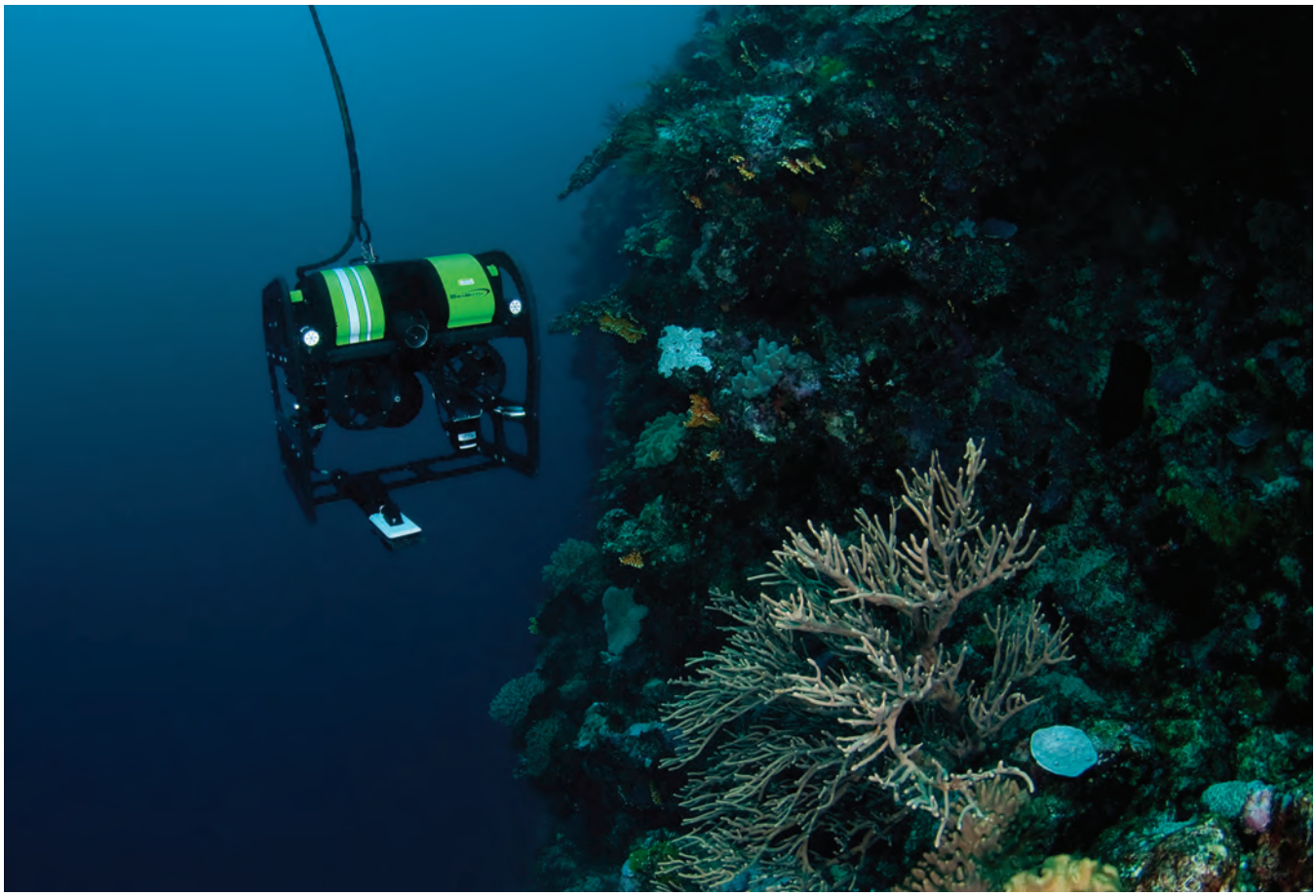
- ***Underwater Forward looking***

AUVs and ROVs use forward looking sonars for obstacle avoidance and inspection. RESON and BlueView offer a complement of products with a choice of high resolution, short and long range, and low power configurations to meet most applications.

- ***Sub bottom profiling***

Sub-bottom profiling systems are used to identify and characterize layers of sediment or rock under the seafloor. Tele-

Teledyne SeaBotix vLBV300 Remotely Operated Vehicle (ROV) on Coral Reef Research Mission.



Teledyne Marine Interconnect Solutions

dyne Atlas Hydrographic and Odom Hydrographic offer sub-bottom profiling systems that can be installed onboard large research vessels and/or deployed via a towed or autonomous vehicle, depending upon your application.

Systems: Oceanographic Data Platforms

In our first section, we discussed the Teledyne sensors that can be used to collect oceanographic data, but how are those instruments deployed? The Teledyne Marine companies facilitate this need with a full line of systems and platforms that can be utilized to deploy anything from a single sensor to a full suite of sensors, depending upon the data desired.

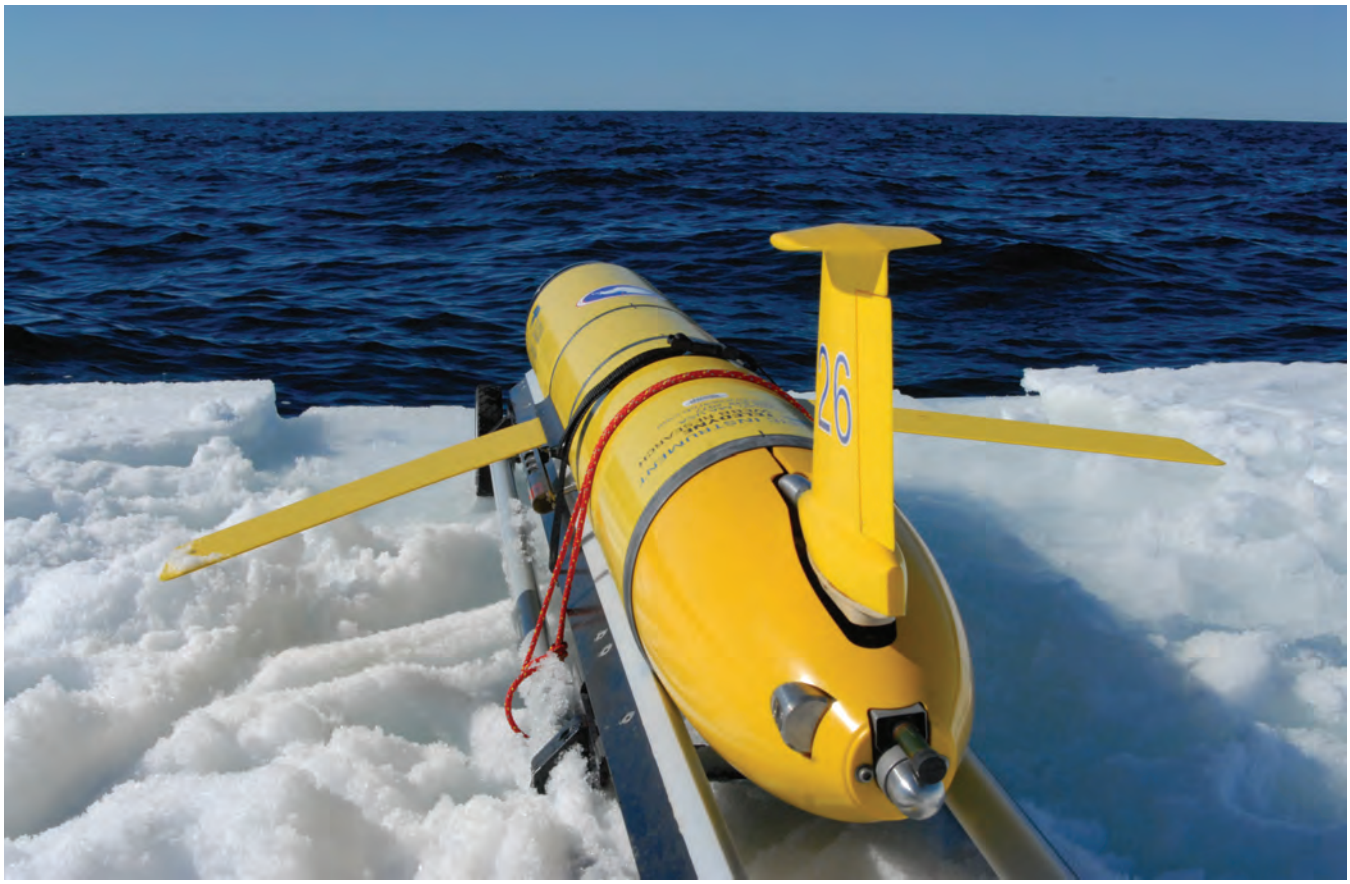
- ***Bottom Mounted Frames***

Bottom mounted frames are used todeploy oceanographic instrumentation on the seafloor. Teledyne Oceanscience manufactures the Sea Spider, which is designed for the deployment of ADCPs, transponders, cameras, CTDs and virtually any other type of compact oceanographic instrumentation package – all within a single structure. The Sea Spidercan also come equipped with a pop-up buoy for diverless recovery.

- ***Moorings***

Oceanographic sensors can also be deployed via surface or sub-surface moorings. Teledyne Benthos offers a wide array of solutions for oceanographic moorings, including glass flotation spheres for buoyancy, acoustic releases for mooring recovery, and acoustic modems for subsea communications. These items can be used independently, or together, for applications

Teledyne Webb Research Slocum glider RU26 deployment from the Ross Sea ice edge, Antarctica



such as the tsunami warning systems, which use glass floats and acoustic releases on a fixed buoy and an undersea bottom pressure recorder (BPR), which records slight variances in ocean pressure. These components are linked via acoustic modems, which provide wireless data transmission to the surface.

- ***Profiling Floats***

Profiling floats are a versatile tool for oceanography. Perhaps best known is Teledyne Webb Research's APEX float, an autonomous drifting profiler used to measure subsurface currents and make profile measurements in the global Argo array. The float descends to drift at an assigned depth for up to nine days, then quickly descends to 2000m and ascends to the surface while collecting data. APEX Argo carries a CTD to collect temperature and salinity profiles; other sensor options are available. While on the surface, the APEX floatcan be geo-located using GPS, and telemetersdata via the Argos or Iridium satellite communication systems. Iridium provides two-way communication to update mission and data collection parameters. APEX floats are frequentlyused as platforms for other purposes,such as measuring currents and biogeochemistry studies. APEX Deep is the only commercial profiling float able to reach 6,000m depth.

- ***Remotely Operated Vehicles (ROVs)***

Remotely Operated Vehicles (ROVs) are well-established tools for ocean science. They allow operations beyond typical diver depths and in hazardous conditions such as under ice. Teledyne Benthos and Teledyne SeaBotix offer a broad range of ROVs that can be used to perform oceanographic tasks including aquaculture monitoring, marine life studies, chemical and biological sampling, and marine archaeological research.

Teledyne's ROVs can be outfitted with any number of industry standard sensors to collect a wide array of data. Some Teledyne family sensors commonly used on ROVs include Bowtech cameras and lights and BlueView imaging sonars.

- ***Gliders***

An underwater glider is an autonomous underwater vehicle that uses small changes in its buoyancyin conjunction with wings to provide a long-endurance ocean monitoring platform with mission lengths measured in months rather than hours. A thruster option ensures the typical "yo-yo" dive pattern can be augmented with other maneuvers as required.Teledyne Webb Research's Slocum G2 glider is a highly versatile remote sensing vehicle used for ocean research and monitoring. The long range and duration capabilities of Slocum gliders make them ideally suited for water column observation at the regional scale. Slocum gliders can operate on preprogrammed routes, surfacing to transmit data while downloading new instructions via the Iridium satellite system, at a substantial cost savings compared to traditional vessels. Modest capital acquisition and operation and maintenance costs enable fleets of gliders to

HCMR Institute of Oceanography deploying Teledyne RD Instruments Long Ranger Acoustic Doppler Current Profiler (ADCP) in the Aegean Sea.

Photo credit: Manolis Ntoumas

Teledyne Benthos flotation and acoustic releases

study and map dynamic (temporal and spatial) ocean features in entirely new ways.

Slocum gliders can support a wide array of Teledyne and third-party ocean sensors. Typical options include CTDs, ADCPs, and optical biological and environmental instruments. Teledyne RD Instruments and Teledyne Webb Research have also collaborated on the development and integration of a new ADCP for the Slocum glider called the Explorer ADCP.

Navigation: Oceanographic Platform Tracking

As noted in the previous section, the Teledyne companies offer a variety of remote platforms designed to house any number of oceanographic sensors, whether they be Teledyne, or other innovative solutions. The challenge then becomes navigating these systems within the depths of the unknown. To be viable, underwater vehicles need to understand where they have been, where they are going, and how to pinpoint an exact location of interest. There are many tools and techniques to address this need, but perhaps the best known methods include Doppler aided navigation.

- ***Doppler Velocity Logs (DVLs)***

A DVL is a multi-function acoustic sensor that provides highly accurate velocity information. In addition to providing speed over ground and speed through water, the instrument uses other sensors to provide position updates for both subsea and surface platforms. The DVL provides information by collecting, compiling, and processing a full range of data parameters which include: velocity, depth, pitch and roll, altitude, heading, and temperature. The DVL can be used as a stand-alone navigation system or incorporated into an existing marine navigation system to significantly enhance system performance. Teledyne RD Instruments designed and manufactured the industry's first BroadBand DVL back in 1994, and has since gone on to provide a full line of DVLs for precision navigation onboard AUVs, ROVs, towed vehicles and surface vessels.

- ***Inertial Navigation Systems***

For operations requiring autonomous and accurate navigation, a DVL can be integrated into an Inertial Navigation System. An inertial navigation system (INS) is a navigation aid that uses a computer, motion sensors (accelerometers) and rotation sensors (gyroscopes) to continuously calculate via heading, orientation, and velocity (direction and speed of movement) of a moving object. Teledyne TSS and Teledyne CDL have many years of experience providing INS solutions to the industry.

Teledyne Oceanscience Underway SV

Photo credit: C&C Technologies

Teledyne RDI Bio-Fouling resistant Citadel CTD

Communication / Infrastructure: Oceanographic Connections and Data/Power Transmission

Thus far, we've addressed the sensors, platforms, and navigation aids that may be required for oceanographic applications, but how does it all come together? That's where Teledyne Marine's interconnect, power and communication solutions come in.

- ***Interconnect and Power Solutions:***

Each of Teledyne Marine's instruments and platforms require a series of highly robust and reliable standard and custom electrical, fiber optic, and/or hybrid electro-optic connector solutions. The Teledyne Marine Interconnect Solutions companies, which are now comprised of AG Geophysical Products, DGO, Impulse, ODI, and Storm Cable, supply many of these mission critical components to the Teledyne companies and to the industry as a whole.

Interconnect solutions include wet-mate, splash mate and dry-mate connectors, differential pressure penetrators, cable assemblies, cable terminations, and custom-engineered encapsulation and molding. Teledyne Marine's Interconnect companies not only provide products, but extensive custom design, engineered solutions, and test capabilities, which are second to none in the industry.

- ***Data Transmission Solutions:***

In addition thehard-wire cable solutions offered by Teledyne Marine Interconnect Solutions, Teledyne Benthos offers oceanographic customers the option of wireless data transmission via theirwide range of acoustic modems.

Wireless data transfer can offer a significant cost savings over underwater cabling. It also offers the option of extending the reach of cabled networks, integrating wireless nodes to transfer data back to cabled networks. Benthos modems are available for operations in shallow or deep water environments and in a variety of frequency ranges. Modem applications include remote monitoring of oceanographic sensors, command of AUVs, and subsea networking.

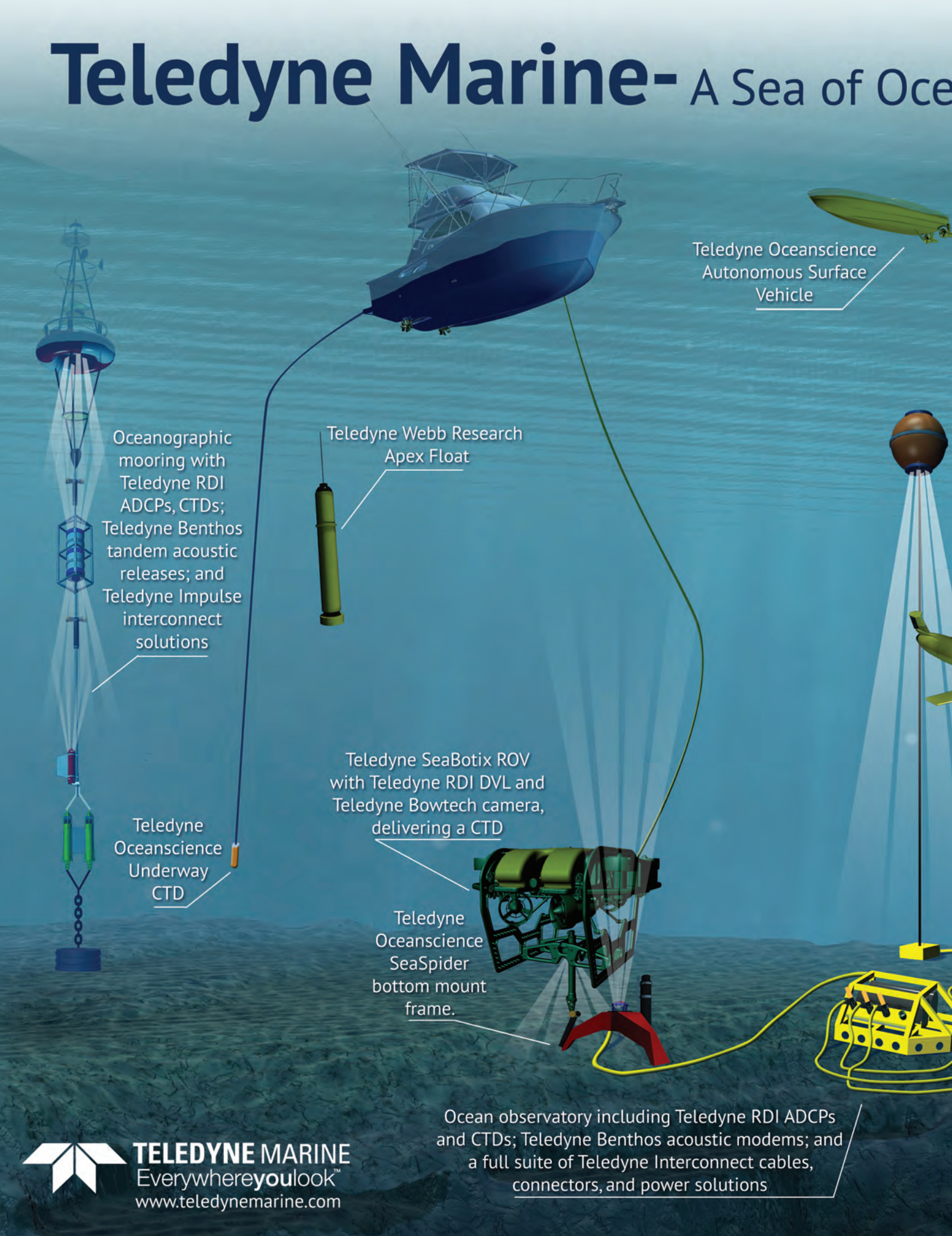
- ***Conclusion***

As the field of oceanographic research continues to expand in importance and scope, Teledyne Marine will continue its quest to deliver the highest value, most innovative products and services available. As new and exciting challenges and questions continue to arise, Teledyne Marine looks forward to partnering with our industry to deliver the tools and technology required to unlock the secrets of our world's oceans.

Teledyne BlueView Sonar mounted on a Teledyne Benthos ROV

Photo credit: Fernando López Mellan

Teledyne Marine- A Sea of Oce



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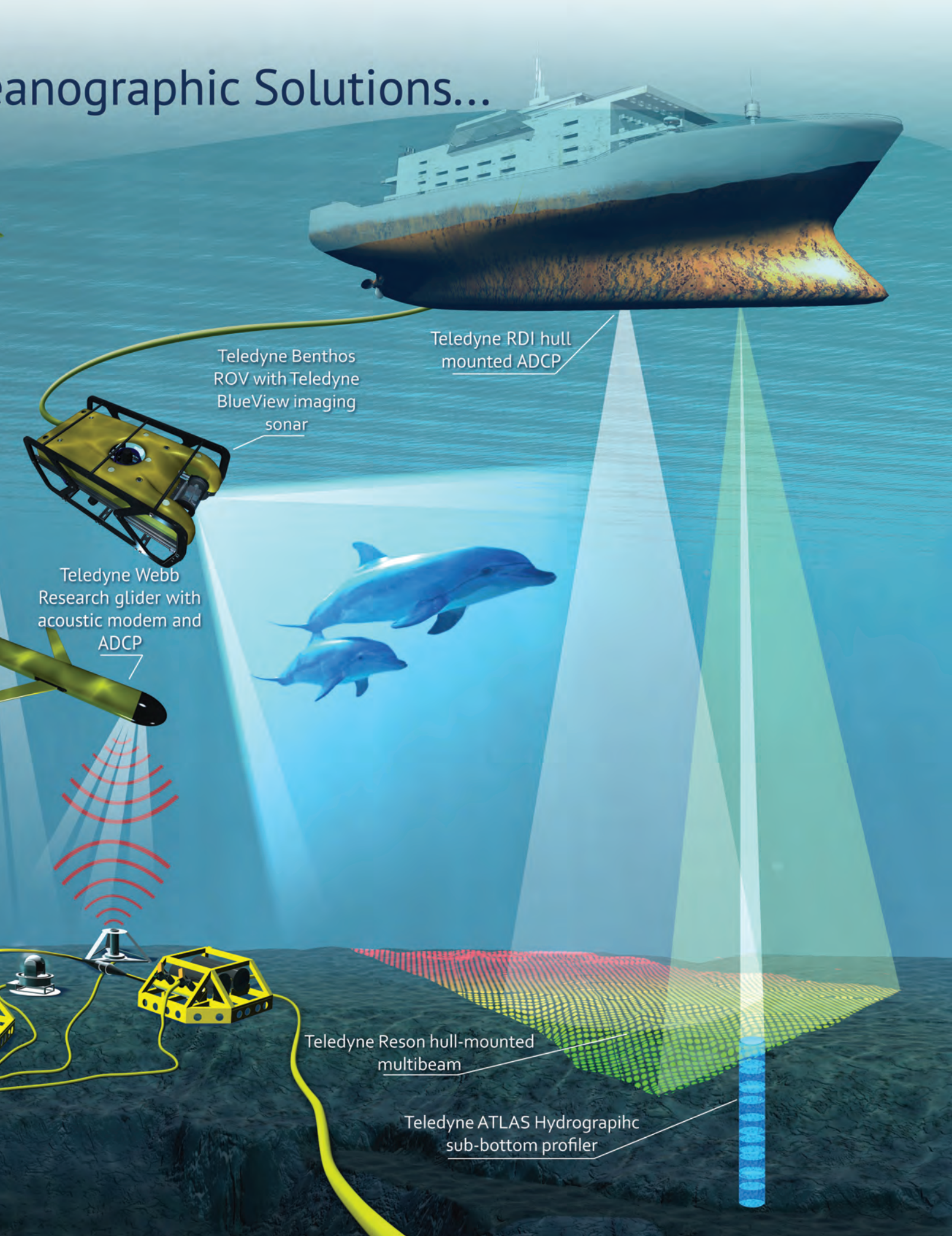


It's Time to Think in ~~Months~~ *Years!*

480 Days and Counting

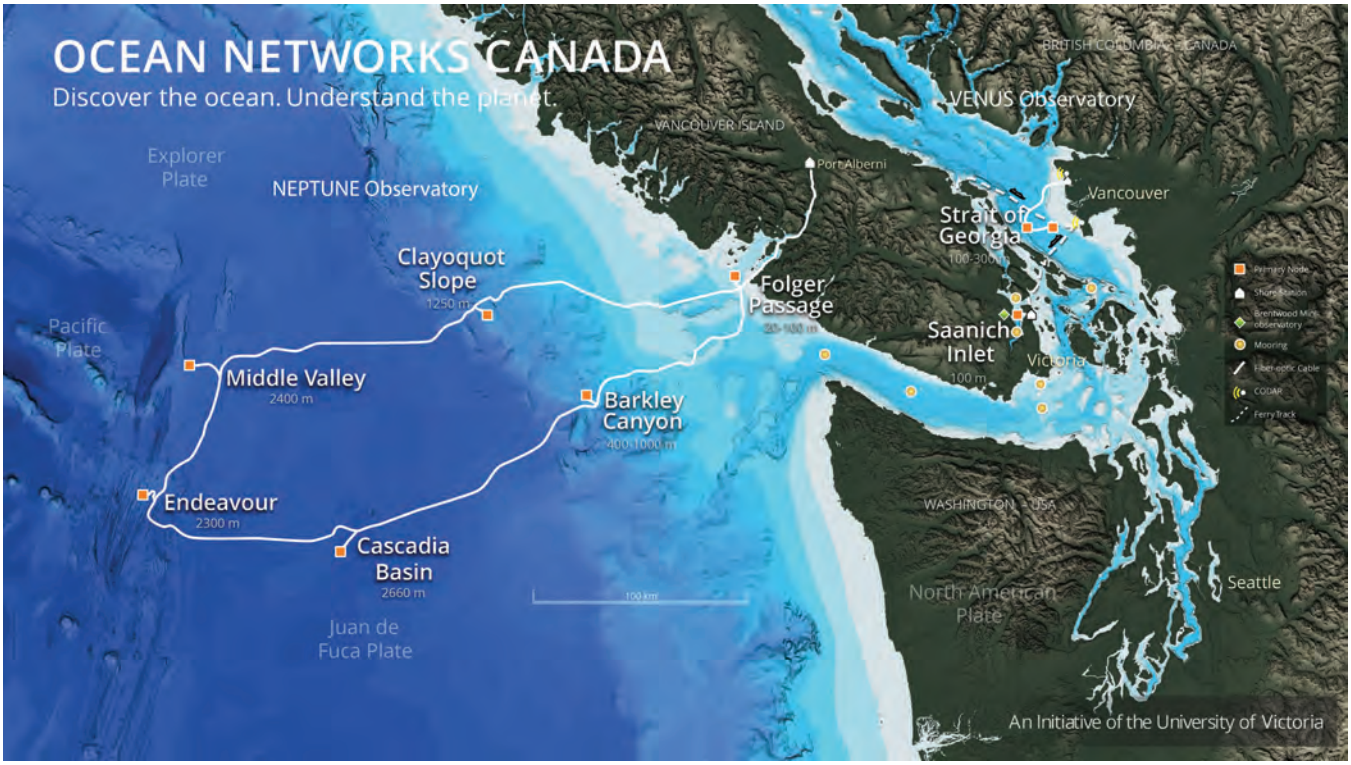
By Pete Reedeker, Director of Sales & Marketing, AML Oceanographic

*For the past 16 months, **AML Oceanographic** has watched their sensors protected by **UV•Xchange** biofouling control technology produce accurate data. AML instruments were originally deployed in October of 2013 at Ocean Networks Canada's Folger Pinnacle site and continue to operate today, suggesting a big step forward for environmental sensing.*

When it came time to put their new UV biofouling control technology to the test, AML approached **Ocean Networks Canada** (ONC) about deploying instrumentation on one of their platforms. Ocean Networks Canada operates the world's most advanced cabled ocean observatories off British Columbia's coast and the Arctic for the advancement of science and the benefit of Canada. These observatories supply continuous power and Internet connectivity to a broad suite of subsea instruments from the coast to the deep sea, allowing researchers to operate instruments remotely and transmit real-time, digital data globally.

To demonstrate the efficacy of UV light as an antifoulant, three **Metrec•X** instruments were deployed at the **Folger Pinnacle** observatory near Folger Passage off the coast of Vancouver Island, Canada **(Figure 1)**. Two instruments were equipped with UV•Xchange to protect them from biofouling,and one was left unprotected as a control. A Sea-Bird SBE-19 PlusV2 was also deployed on the platform. Originally scheduled for a one year trial to finish October 2014, the deployment remains operational today with the AML sensors protected by UV•Xchange continuing to produce consistent data.

Figure 1. Image courtesy: Ocean Networks Canada



Maintenance of Folger Pinnacle platform. Photo courtesy: Ocean Networks Canada

Got Fouling?

Ocean Networks Canada did.

UV•Xchange and Cabled UV prevent biofouling on critical surfaces, reducing maintenance and ensuring accurate sensor data for a long time - **longer than ever thought possible.**

"With the incredible results of the AML Oceanographic CTD and UV anti-biofouling system we are very pleased to be deploying these systems across coastal BC as part of the Smart Oceans™ program. High biofouling areas in the coastal zone create a huge challenge in ongoing operations and maintenance costs for any observatory, especially in remote locations. AML Oceanographic has made a revolutionary advance in anti-biofouling technology with this new product."

Scott McLean
Director, Ocean Networks Canada Innovation Centre

OCEAN NETWORKS CANADA

AML OCEANOGRAPHIC
Xchange your old ideas

conductivity / sound velocity / pressure / temperature / turbidity / biofouling control

1-250-656-0771
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The demonstration has many highlights. Perhaps most spectacular is the longevity of good conductivity data from AML unit #1. The instrument has been running continuously with no maintenance for over 480 days. Only UV antifouling technology has been used; no chemicals or mechanical wipers. Tom Dakin, Sensor Technology Officer at Ocean Networks Canada was impressed:

> ***"I am quite astounded by the results of this test. I expected the UV antifouling system to be a significant improvement, perhaps doubling the time between required maintenance, but I did not expect it to outperform the TBT protected CTD. We operate our CTDs continuously on the Observatory. The pumped CTDs, protected with TBT, last about 7 or 8 months before the TBT is depleted and we also wear through the pumps. Near hydrophones, where we cannot use pumps, the CTDs last 2 months at best. The UV protected CTD at our most challenging site has lasted over 15 months and shows no loss of accuracy yet."***

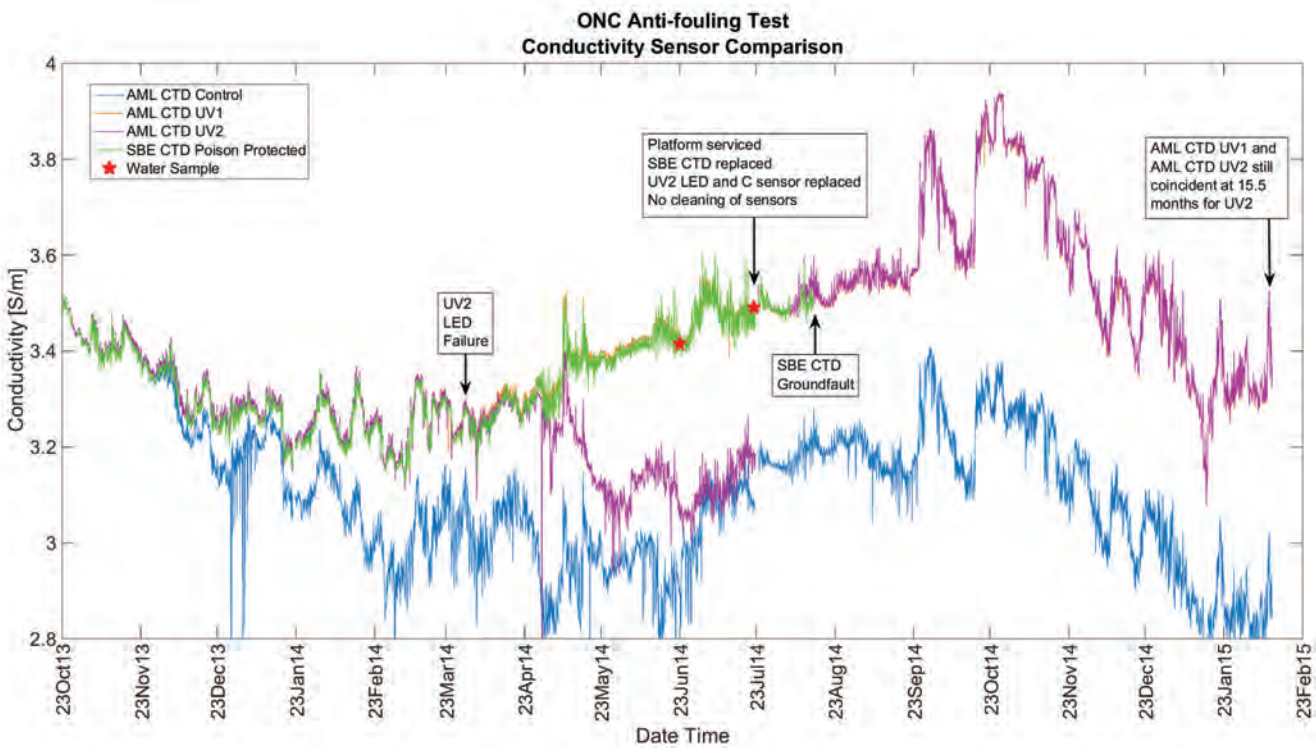
AML's conductivity sensor, **C•Xchange**, is unique to the industry with its 4 electrode transverse design. Originally developed at the Institute of Ocean Sciences (IOS) Canada, this sensor design has been used with AML instruments for high speed profiling for over 15 years. With some recent changes to the electrodes, AML has optimized its performance for in-situ measurements when used with UV•Xchange. The design is conducive to UV biofouling protection due the accessibility of the electrodes and open flow characteristics. Where the electrodes of other conductivity sensors are buried within the walls of a long tube, the electrodes and volumetric regions of C•Xchange are exposed. This allows UV light to reach all of the critical regions of the cell, giving stability to the sensing volume and thus maintaining its performance.

An ONC camera has provided footage of the demonstration since commencement. As can be seen in the time-lapse video to date **(Figure 3)**, UV•Xchange has kept all critical surfaces free of fouling. Note the various cycles of growth, as well as the marine life that inhabits the installation area.

Critical areas of the AML sensors are not the only surfaces still clean at the demonstration site. Areas on various apparatus in and around the platform – up to 47 cm away and at a wide diameter – have remained clean, proving the scope of UV•Xchange and sister product **Cabled UV** to be much greater than first envisioned. This capability suggests the potential for use on a much broader variety of applications than just sensors.

True to AML's collection of **X•Series** instrumentation

A graph of the conductivity data vs time of all four instruments is shown in **Figure 2**, with notations on various events within the test period. **Figure 2.** Image courtesy: Ocean Networks Canada

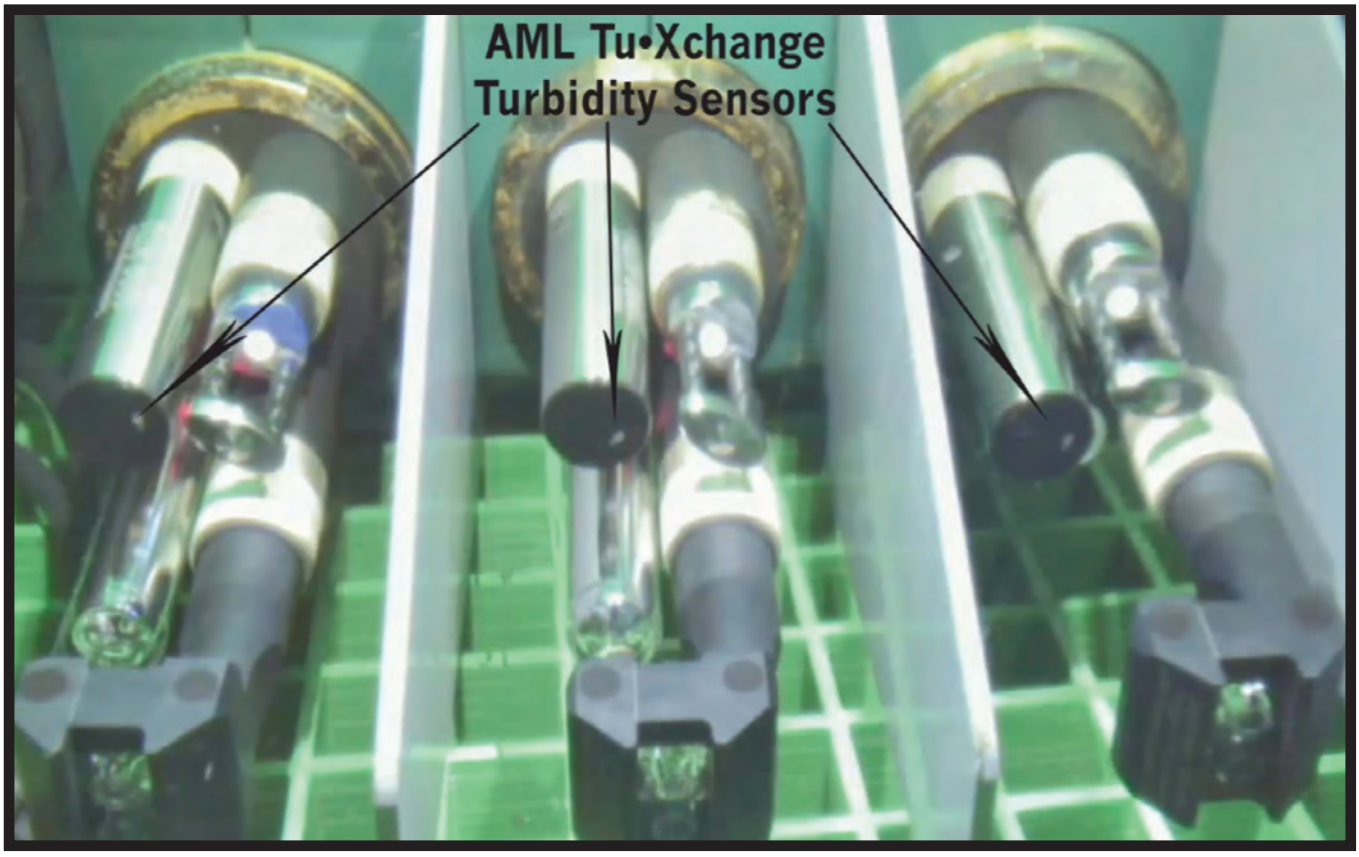


AML Director of Engineering Dustin Olender, PhD, says, "When I saw our sensors come back pristine - after months underwater - I knew we had something. You can completely rethink your deployments: Biofouling typically necessitates monthly maintenance, but with UV, you can start thinking in years."

and field-swappable **Xchange™** sensors, the modularity of UV•Xchange and Cabled UV enables unrivaled adaptability to prevent biofouling on a variety of surfaces and devices. With LEDs that can rotate 360° and be stacked and flipped over to reverse the angle, the UV light can be directed in almost any direction. Coupled with mounting on a flexible cable as with Cabled UV, the applications are boundless. While UV•Xchange is ideal for protecting Xchange™ and third party sensors on X•Series instrumentation, prime candidates for Cabled UV include ADCPs, LISST instruments, SVPs in a vessel's sea chest, cameras, and other peripherals. Being non-contact and non-toxic, UV is an ideal antifoulant for sensitive environmental parameters such as turbidity, chlorophyll, pH, and dissolved oxygen. Another unique advantage is the silence. Noise-making instruments equipped with pumps and wipers interfere with hydrophones, which are becoming more prevalent in mammal tracking, ship fingerprinting, and surveillance.

Servicing in-situ platforms is critical to maintaining accurate data and keeping equipment operational. The cost, however, can be extreme. Thousands of dollars can be spent on a single platform recovery and refit. The costs skyrocket when changing weather and currents cause delays due to safety concerns. By reducing maintenance intervals, system costs can be dramatically reduced. According to Tom Dakin, "The cost of the UV system is about 25% of one maintenance trip to the Folger Pinnacle site, so this technology will have a significant impact on the operations budget, in addition to improving the

Figure 3. A Time-lapse Video.



data quality. "By using UV•Xchange or Cabled UV to prevent fouling, not only can intervals between service be extended, but the time involved in servicing can be condensed due to the reduced the amount of scraping and cleaning!

The success of AML's UV systems and resulting sensor performance has prompted ONC to utilize this technology in upcoming projects, including the **Smart Oceans™** program. Smart Oceans™ is being developed by Ocean Networks Canada, an initiative of the University of Victoria, to harness its data and create data products that will improve marine and public safety, as well as enhance environmental monitoring along the British Columbia coast.

Scott McLean, Director of ONC's Innovation Centre, had this to say:

> ***"With the incredible results of the AML Oceanographic CTD and UV anti-biofouling system in our technology demonstration program we are very pleased to be deploying these systems across coastal BC as part of the Smart Oceans™ program. High biofouling areas in the coastal zone create a huge challenge in ongoing operations and maintenance costs for any observatory, especially in remote locations. After 15 months and still going, at our worst bio-fouling site, the sensors remain clean and operating fine. We are all absolutely amazed. AML Oceanographic has really made a revolutionary advance in anti-biofouling technology with this new product."***

More information on the AML technology development and related products can be found on AML's website at ***http://www.amloceanographic.com/Biofouling***

More information on Ocean Networks Canada's activities, installations and a host of other resources is available at ***www.oceannetworks.ca/***

Figure 4."On the dock at Bamfield, BC, during the July 2014 summer maintenance of Folger Pinnacle platform.

Image courtesy: Ocean Networks Canada

Shipboard ADCP Surveys

Mapping Subsurface Ocean Currents

Dr. Peter Spain, Scientific/Technical Marketing, Teledyne RD Instruments

For two decades, Teledyne RDI's Acoustic Doppler Current Profilers (ADCP) have been an industry standard. They measure the velocity of water currents in oceans and rivers. While fixed at one site, an ADCP offers excellent time coverage of closely-spaced measurements versus depth. Furthermore, ADCPs can be operated from a moving vessel or vehicle to explore the along-track distribution of currents versus depth. This versatility greatly expands the ADCP's scope of applications.

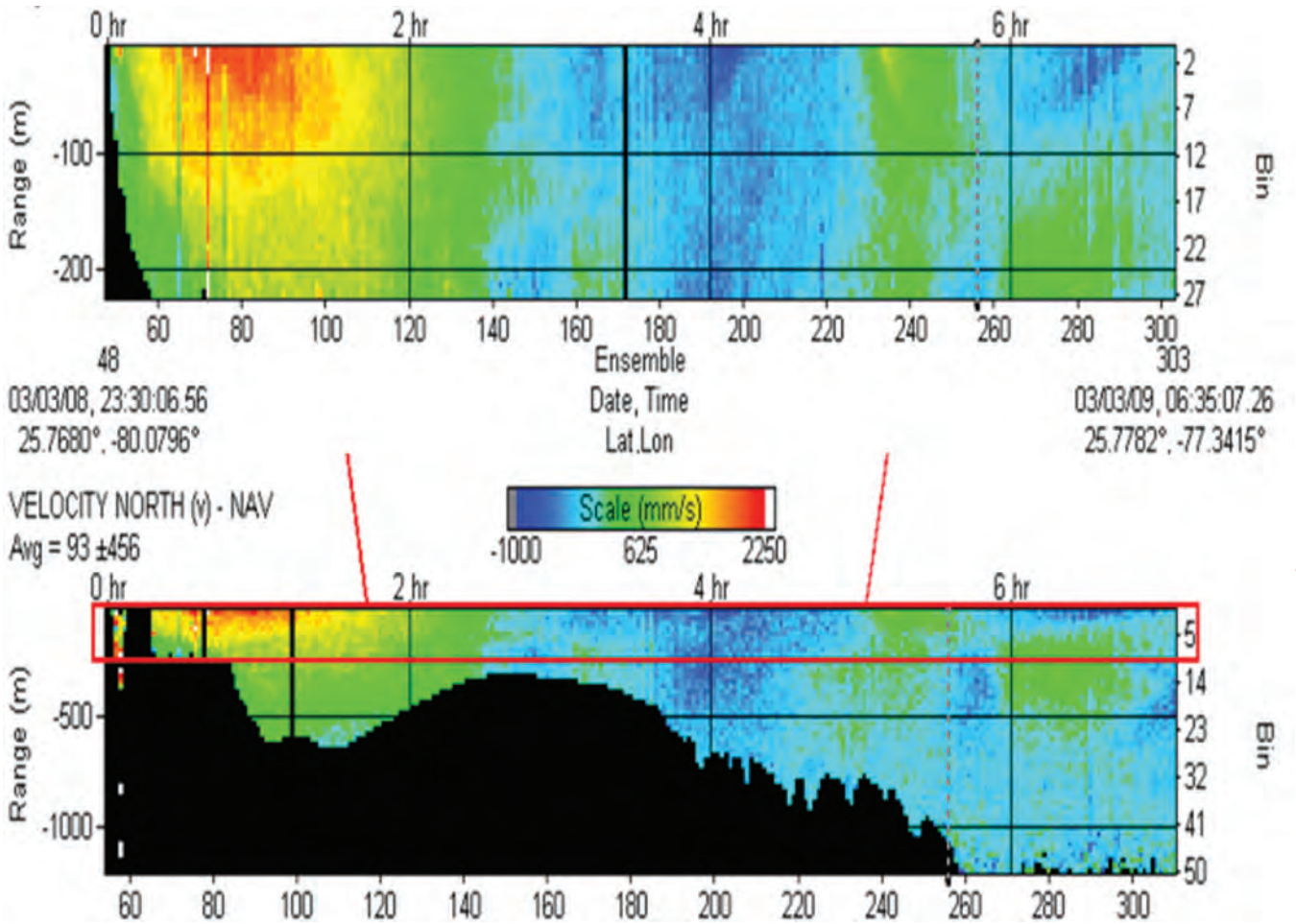
ADCPs mounted on the seabed and moorings are well-known oceanographic tools. They record the history of local fluctuations of currents throughout much of the water column. In this article, we review some oceanographic applications of shipboard ADCPs.

1. Introduction

From a data point of view, the ADCP combines what had been two complementary views of the ocean. From the early 1960's, time series measurements were recorded at several depths. Current meters were deployed on deep-sea moorings and left unattended for long periods. A decade later, vertical profilers provided close measurements of water current velocity versus depth.

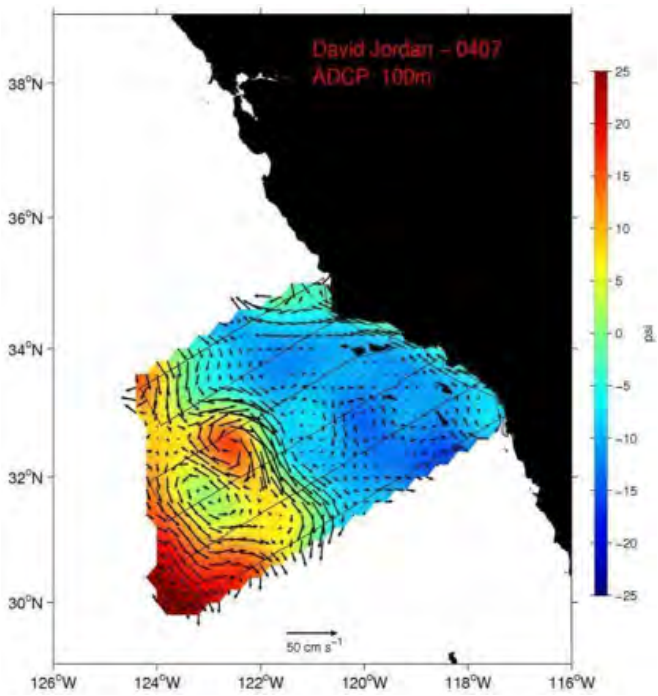
Each of these technologies revealed new, exciting, and different facets of the ocean. Yet their resolution was restricted to one dimension (1-d): time (current meters) or space (profilers). In contrast, the ADCP measured time series of vertical profiles, an inherently 2-d view of water motions.

Ocean currents move things around, transporting them for



ADCP data were key input to processing that output maps of sea-surface height and circulation.

Citation: CalCOFI ADCP Digital Atlas due to T. Chereskin (Scripps Institution of Oceanography).



large distances. And the things being carried affect us. The heat and momentum conveyed by ocean currents affect our living environment. Examples include global climate change (e.g., ice ages) and weather events (e.g., El Nino, hurricanes). Strong currents also affect the choice of routes taken by shipping. Reducing travel time for a voyage can save large amounts of money in the competitive commercial arena.

Water currents carry biological and chemical constituents that affect life in and out of the sea. Currents can cause a global transfer of organisms, ranging from fish larvae to crocodiles. And currents can provide a virtual pipeline for nutrients, pollutants, and sediments.

2. ADCP Technology

The speed and direction of ocean currents can change in several dimensions: with depth, position, and time. ADCPs use sound to measure these changes. There are key advantages to using sound. It can measure remotely (even at great distances), there are no rotating parts to foul, and sound changes predictably with ocean conditions. Like the radar gun used to catch speeding cars, ADCPs use the Doppler Effect to measure motion.

This is the change in pitch of returning echoes compared to the transmitted sound. These echoes tell how fast particles carried by the water currents are moving and in what direction. And the measurements are made at many depths, all at the same time, creating an ocean current profile.

When mounted on ships and boats, ADCPs provide real-time data to aid decision-making at sea and to adapt field operations. But what sets the ADCP apart is the surveying of ocean and coastal currents from moving vessels. Seeing the 2-d distribution of currents -- along-track and through depth -- reveals the details of ocean circulation patterns.

This section shows why the ancients likened the Gulf Stream to a river flowing in the ocean.

In the adjacent graphic, you can see ADCP data from a long transect that crossed the Gulf Stream. At the left hand side, the *hot spot* is the Gulf Stream. The upper panel shows the near-surface region (200 m) of the lower panel. Warm colors signify strong northward currents while cool colors represent moderate flows headed south. The black region shows the sea bed; you can see significant variation in water depth across the panel. At the right hand side, the ADCP's current measurements reach as deep as 1200 m. Current speed and direction change quite a bit from top to bottom and left to right. As well as the spatial variation seen in this snapshot, the flow changes from week to week and over longer time scales.

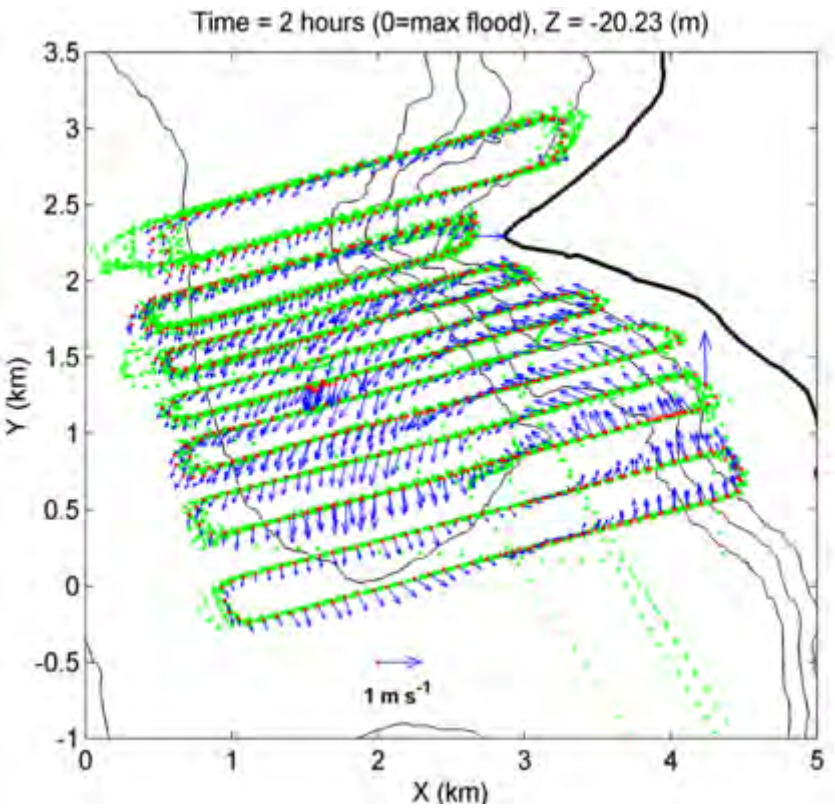
3. Marine Monitoring

A compelling example of scientific surveys that use ADCPs is the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Quarterly cruises are conducted off southern & central California. Researchers collect a suite of hydrographic and biological data on station and underway. Started in 1949, CalCOFI originally studied ecological aspects of the collapse of the sardine population off California.

Now the scope of the study/work is broader. It includes studying the marine environment off California, managing its living resources, and monitoring indicators of El Nino and climate change. The ADCP data are used together with objective mapping routines to create snapshots of the circulation patterns. Later processing yields impressive color-coded maps of sea-surface height. Eddies, which transport biological and chemical properties, are clearly seen. (http://adcp.ucsd.edu/calcofi).

4. Coastal Currents

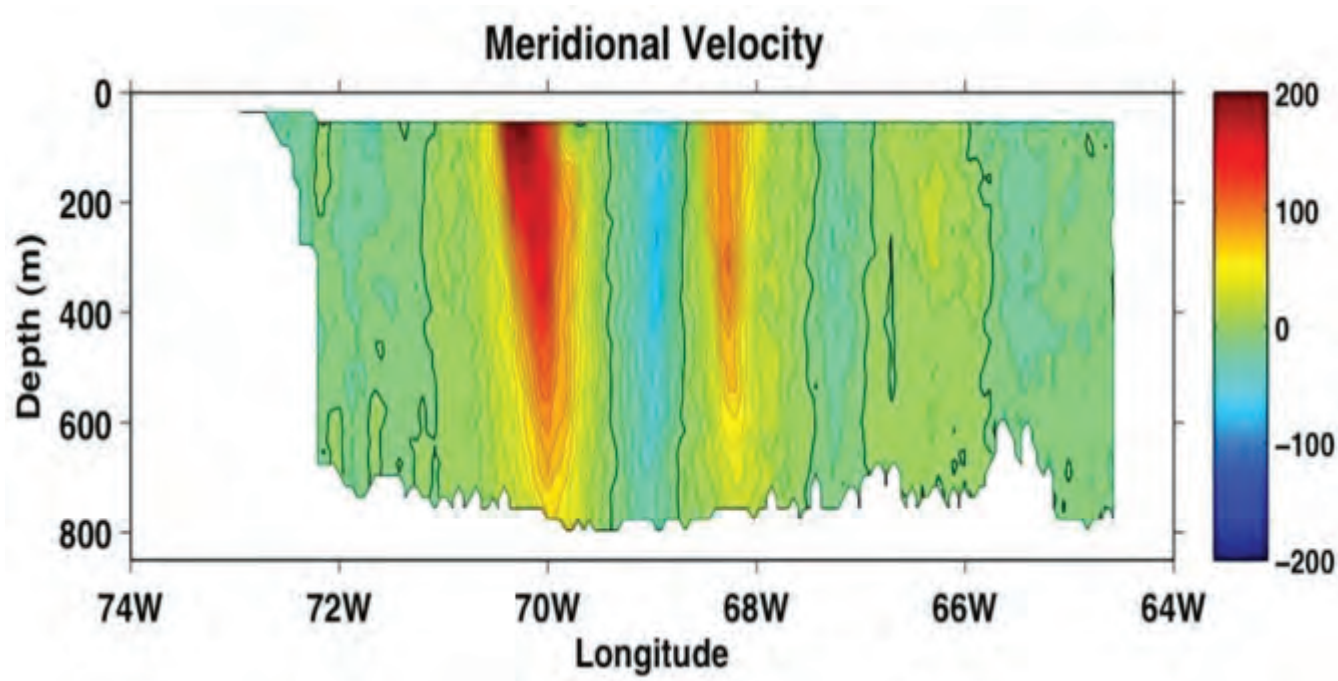
Strong tidal flows around sharp headlands can generate pronounced eddies that span a kilometer or more. Due to their notable lateral shear, these eddies can stir and redistribute local water properties. Moreover, the lifespan and long-term role of these eddies can vary considerably depending on the bottom friction they experience.

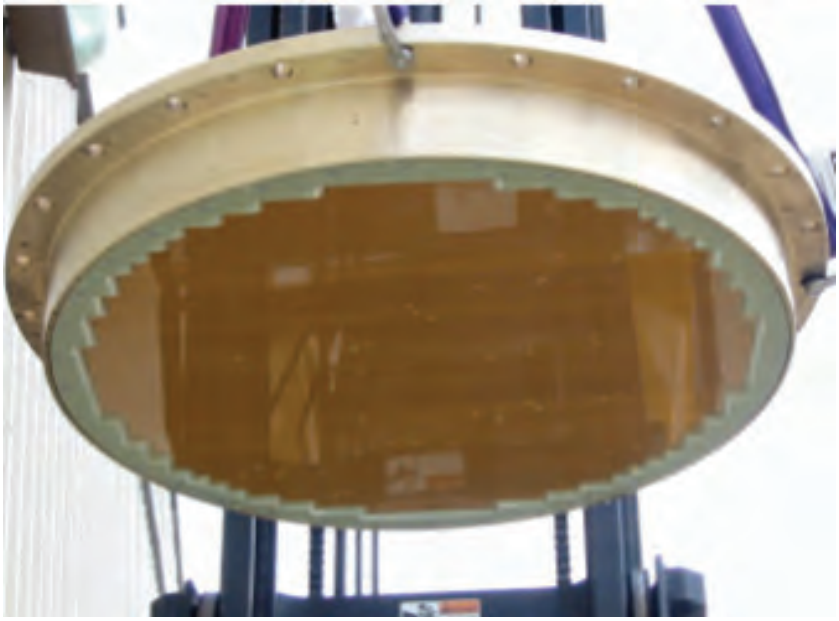


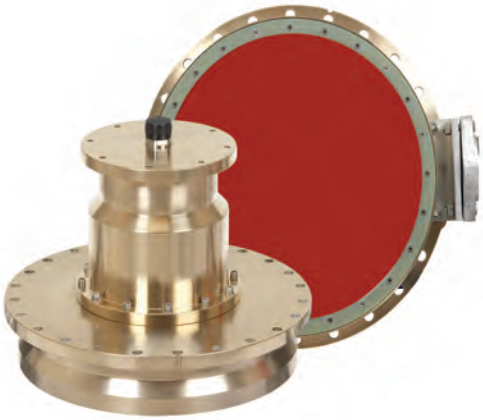
ADCP surveys captured the spatial pattern of a tidally-generated eddy.

Citation: Data section due to G. Pawlak (University of Hawaii) and P. MacCready (University of Washington).

An intriguing example of using ADCP-based surveys in a process study was conducted in Puget Sound, Washington. In conjunction with surface drifters, ADCPs were used to describe the spatial pattern of a tidally-generated eddy and to examine its spin down. Different survey plans were used to study the three-dimensional structure of the currents. For creating a map of the eddy field, the vessel traveled a rectangular circuit about once an hour through much of a tidal cycle. For examining the effects of strong lateral shears, the vessel traveled a bow-tie circuit centered on a drifter.







Teledyne RDI's Phased Array technology pushed back the practical limits for transducer size and frequency.

Interested readers can find an archive for shipboard ADCP data collected for ocean science research at

http://ilikai.soest.hawaii.edu/sadcp/

Results showed a two-layer structure with the surface layer lagging the deep flow by 1-2 hours. Data from the cross-channel transits showed similar time lags with the flow near the headland turning ahead of the mid-channel flow. Regions of strong lateral shear were seen to migrate upward from the bed as the flood tide strengthened.

5. Climate Programs

Due to its strong currents carrying much warm water, the Gulf Stream is a major contributor to the global redistribution of heat from low to high latitudes. Yet measuring accurately the mean transport had been difficult. The Gulf Stream meanders around more than it is wide. Scientists needed a method for repeatedly sampling the horizontal structure of the current in a long-term program. To this end, researchers installed a ship-board ADCP on a container vessel that makes weekly trips between New York and Bermuda. Operating at 75 kHz, the ADCP provided a data set that had close measurements along track and deep into the ocean. As a result, the view showed a large section of ocean in limited amount of time. The red *hot spot* is the Gulf Stream. Warm colors describe the speed of currents headed north whereas cool colors describe currents headed south. (http://www.po.gso.uri.edu/rafos/research/ole/index.html)

These researchers later initiated a similar program to observe the Nordic Seas. For climate monitoring, the goal was to observe the over-turning circulation of the north-south flow. Operating the ADCP on a high-speed ferry proved a persistent challenge for the researchers due to bubble clouds under the hull. Not dissuaded, they repeatedly sampled upper-ocean currents from Denmark to Greenland. Individual transects showed highly variable currents that were dominated by eddy energy. Yet averaging these transects revealed organized mean currents along a dominant topographic ridge.

6. Phased Array Technology

Accurately mapping the velocity of deep ocean currents from a ship moving faster than 3 m/s is challenging. It demands that shipboard ADCPs operate at a low frequency yet keep narrow acoustic beams. To achieve this balance, Teledyne RDI developed a phased array ADCP that emits four narrow beams of sound from a single transducer face.

This permitted longer range current profiling (800-1000 m) at a lower frequency (38 kHz). As a result, detailed spatial surveys of deep currents were accomplished, impossible to achieve any other way.

A shipboard ADCP enabled repeat sampling of the Gulf Stream's structure in a long-term program.

Citation: The Oleander Project (05/02-05/04, 2008) due to T. Rossby (University of Rhode Island) and C. Flagg (State University of New York).

Networked Systems

Enable Ocean Observation

By Justin Manley, Teledyne Marine Systems

RAPIDLY EVOVLING TECHNOLOGIES

The ocean environment challenges the designs of engineers and the skills of sailors and seafarers. Pressure, temperature and corrosion impact mechanical systems and impede most communications and positioning technologies. Until very recently even vessels afloat were removed from the networked world ashore. This is changing as new technologies, and evolutions of old ones, advance techniques for ocean observation.

Unmanned maritime vehicles (UMVs) have been under development for decades. Since the late 1990s several systems have evolved beyond research labs and become commercial realities. Businesses have bloomed and technical advances thought impossible are proving no match for today's UMVs. These tools are now in routine use for scientific, commercial and military applications.

With robust vehicles available, connectivity is becoming a key element of UMV operations. All operators deploy UMVs for a purpose. Awareness of progress toward mission goals is a key requirement for risk mitigation. Timeliness of information is also important to survey, inspection and observation activities, even if complete data sets must await a physical return of the UMV. Connectivity and networked operations are key enablers of undersea operations, especially ocean monitoring.

CONNECTIVITY: TELEMETRY AND POSITIONING SUBSEA

Connectivity

While wireless networks and satellite navigation have revolutionized life ashore, acoustic systems bring similar capabilities to undersea operations. Advances in digital signal processing have seen venerable tones and pings give way to broadband schemes. These systems offer reliable connections between many platforms and can also provide positioning information. Wise application of such technology reduces risk

Figure 1. A Fixed Node Undersea Network

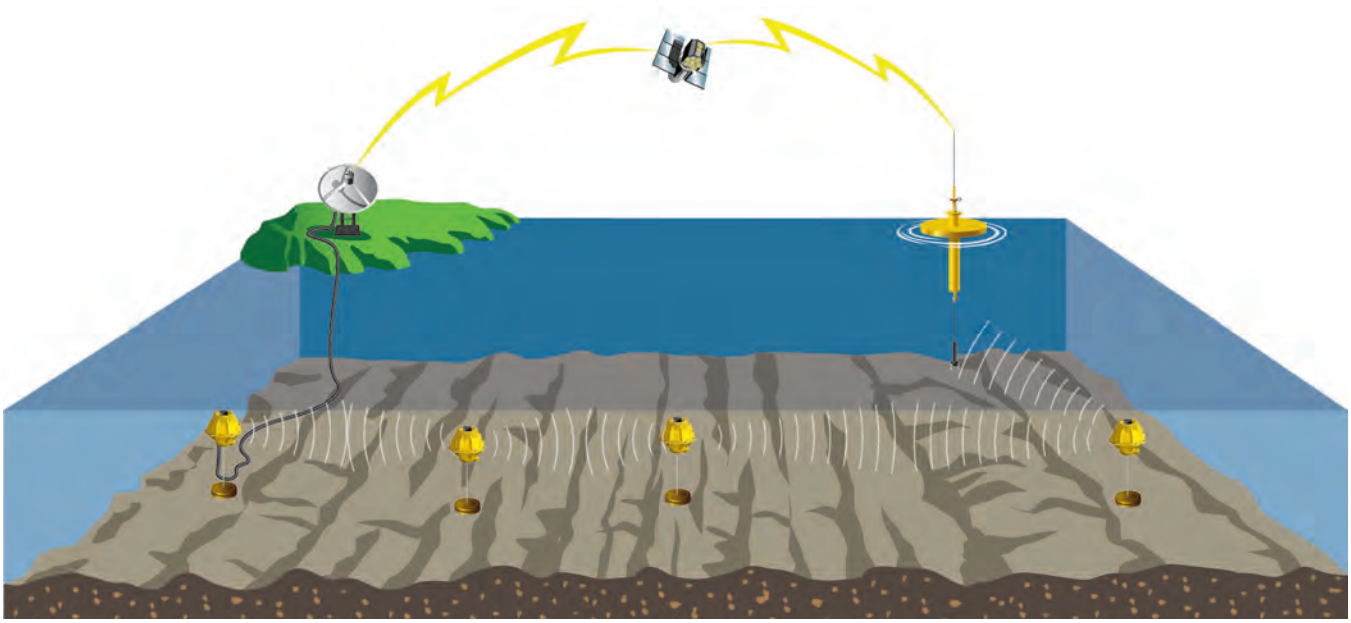
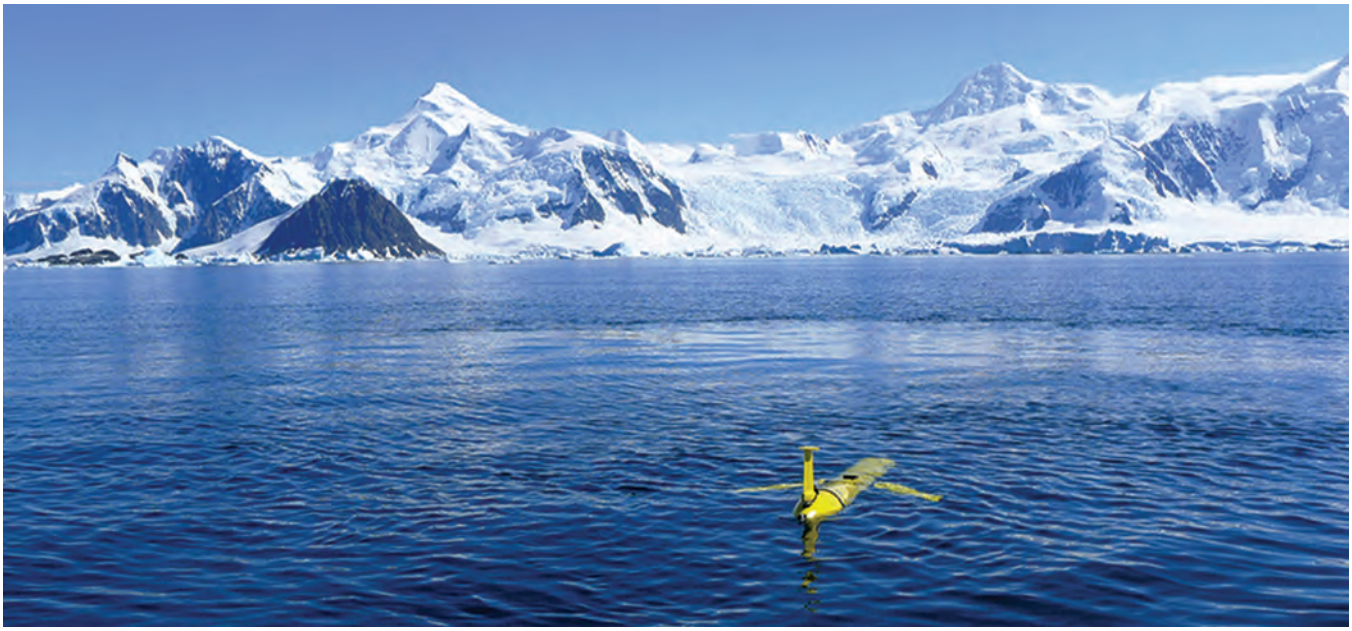


Figure 2. SM-976 Modem Node

and increases productivity. The predominant approach to subsea connectivity is point to point. Adaptive networks have been demonstrated but are not widely deployed. Technologies are mostly closed with operators dependent on single sources or forced to own potentially redundant equipment. Subsea networked connectivity is having an impact, but it still evolving and penetrating the market.

Wireless undersea networking can be fixed (Figure 1) or mobile. One example of an application for a fixed wireless network comes from an experiment in Monterey Bay. In this project two sensors were deployed on the end of a cabled observatory known as the Monterey Accelerated Research System (MARS). These sensors were connected via acoustic telemetry back to the cabled system. By placing a fixed modem on the end of

Figure 3. A long endurance UUV enables ocean observation. (Courtesy Ben Allsup, Teledyne Webb Research)



the cable, new instruments could be employed without complex intervention. The original instruments were Remotely Operated Vehicle (ROV) deployed but the concept of ad hoc network assembly was also demonstrated. During operation it was discovered that one of the nodes, was not communicating well with the hard-wired "hub" some 500 meters away. Strong local noise conditions were suspected to be the root cause. Communications were essentially "faint" and unable to provide reliable connectivity to the main modem. By using another modem, in a self-contained housing (Figure 2) as a repeater, it was possible to restore connectivity and continue the operation of the experiment. A short day trip, enabled by the easy deployment of the modem node, provided a low cost solution to what might have otherwise required an ROV intervention.

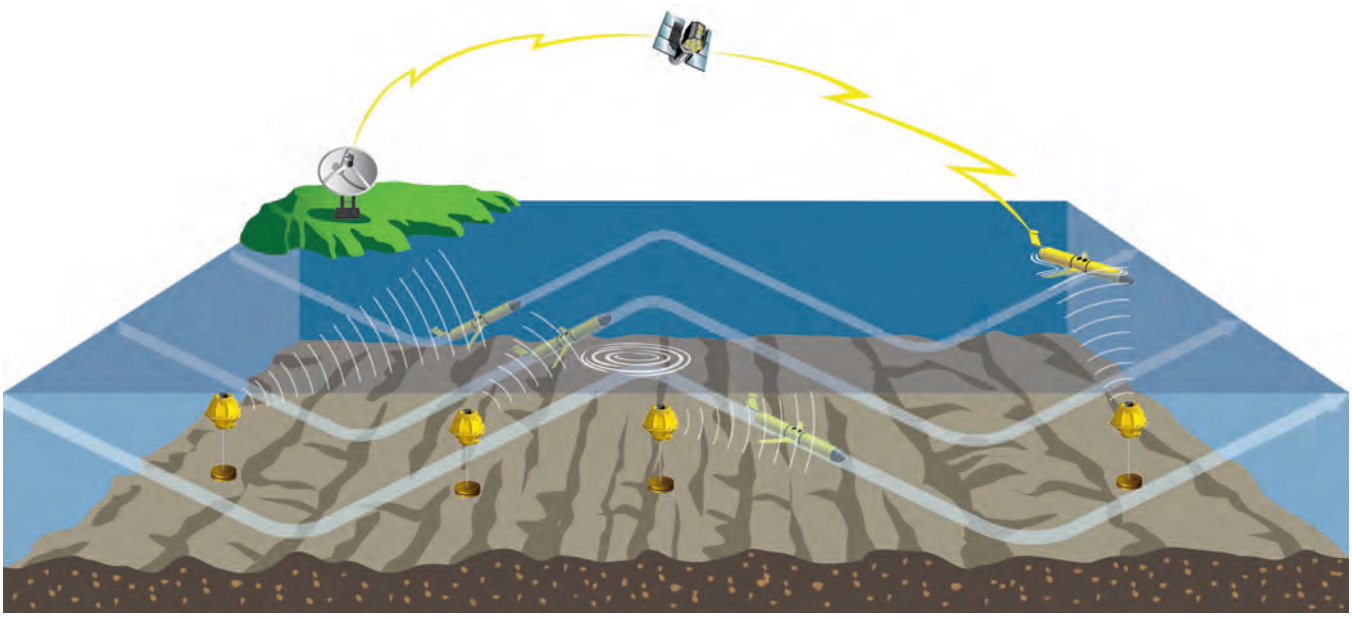
The capabilities of acoustic telemetry are diverse and worthy of significant review in their own right. This example is simply offered as a real world case where the flexibility of an acoustic repeater provided a significant operational benefit to an ongoing research project. Combining acoustic telemetry with mobile undersea systems, especially Unmanned Underwater Vehicles (UUVs), yields additional benefits to subsea operations.

GLIDERS: GROWING FLEETS AND CAPABILITIES

Ocean observing has traditionally relied on vessels and moorings, with significant logistic investments required. Today, extended endurance UMVs (Figure 3) and autonomous profiling floats offer broad spatial and temporal coverage, affordably. Using buoyancy engines, these UMVs can remain at sea for months or years and do not demand large infrastructure to support their operations. These systems have demonstrated endurance to cover large distances or loiter in place for extended periods. Some simply drift with the currents for years. Physical oceanography has most commonly been the focus of these platforms, due to available sensors and limited payload energy budgets. However, new biogeochemical sensors are routinely being demonstrated on long endurance platforms.

The most significant demonstration of the economic impact of UMVs on ocean observing is the US Navy Littoral Battlespace Sensing - Glider (LBS-G) program. This program of record is acquiring and deploying 150 gliders to support Navy operational observations, with another 150 planned for the future. While the low capital and operational costs of these tools is a clear benefit to the economics of ocean observation, there is another, subtle, effect of great value. Academic or government programs can, and do, share data collected by these plat-

Figure 4. Gliders and modes enable expanded options for data telemetry.



forms freely and often online. With hundreds of gliders and thousands of floats in routine operation there is a large user base to advance new scientific concepts and challenge technologies. The sharing of data and wide user community make ocean observing UMVs highly leveraged investments. Further leverage can be obtained by interfacing these stand-alone systems with subsea networks.

The National Science Foundation has embarked upon the operational use of gliders with acoustic telemetry for its Ocean Observatories Initiative (OOI). OOI is a multi-scale observatory designed to utilize a network of sensor systems to collect physical, chemical, geological and biological data from the ocean and the seafloor on coastal, regional and global scales. The data will be made available to anyone with an internet connection. This information will increase understanding of climate change, ocean and coastal ecosystems, environmental health and climate, and biodiversity. While both coastal and open ocean OOI elements will make use of gliders, the high latitude Global Arrays of the OOI will make use of gliders employing acoustic telemetry. These gliders will be used to provide connectivity between subsea mooring systems and satellite communications to shore similar to Figure 4.

As a preliminary step towards the OOI installation, a number of tests were conducted 2012 to quantify communications between a Teledyne Webb Research Slocum glider equipped with a Teledyne Benthos acoustic modem and the Scripps CORC IV mooring located off the coast of southern California at an approximate depth of about 5000 meters. Many of the tests were conducted with the glider sitting at the surface processing manual commands sent over Iridium satellite link. Others were conducted with the glider in an autonomous mode diving to a particular depth. The slant range to the mooring varied from about 2500 meters (with the glider at depth) to over 7000 meters. Data transfer rates were tested between 15360 bps PSK (phase-shift keying) and 300 bps MFSK (multiple frequency-shift keying). Since then, two OOI Open Ocean gliders spent 330 days each at Station Papa transferring data from the moorings. Operationally the combination of acoustic telemetry and gliders is proving effective.

THE FUTURE: UNDERSEA NETWORKS

Considering a comparison to mobile phones, what might UMV operators look forward to in the future? Today a typical smart phone user can carry their device anywhere in the world and make voice calls, read email, surf the web and navigate maps. They can also draw upon a host of specialized “apps” for advanced tasks such as making hotel reservations or currency calculations. This capability is built upon enabling developments in hardware, especially compact processors and power sources, and accepted standards for connectivity. Such a reality is coming to the undersea realm.

UMVs in coming years will draw upon acoustic telemetry to “network” into ever more productive roles. Drifting and energy harvesting surface platforms will provide overhead coverage for acoustic telemetry and positioning to heterogeneous undersea systems. Integrated networks of undersea wireless technologies will provide low bandwidth but reliable coverage much like first generation cellular networks. Full data sets may reside on local UMV solid state drives but status information and key data identified through onboard analytics will be exchanged across the network, ensuring operators are informed and support assets are deployed for maximum efficiency. It will be possible to create the equivalent of “tweets” between systems and across the undersea domain.

CONCLUSION

UMVs are currently capable systems offering significant value to marine operations. When viewed through the lens of connectivity the potential value of UMVs is just beginning to be revealed. Just as smartphones changed daily life, networked UMVs will bring more capability to ocean observing. There are challenges to this vision, some are technical and others tied to policy questions. But none are insurmountable. New technology developments can be counted on to appear, probably sooner than anyone expects. To harness those developments the UMV community will need to collaborate effectively to create the networks. Engineers and business leaders will need to see the value in standards, potentially open protocols and interoperability across platform types and businesses. Regulators also will need to understand the technology, appreciating the benefits and rapid pace of technical evolution. A future UMV ecosystem is exciting to consider, the path forward is apparent, if not clear, and the value to ocean observing will be substantial.

Seaformatics

Empowering the Seafloor

The Seaformatics project is led by a team of researchers and engineers based out of the St. John's, NL campus of Memorial University (MUN). Seaformatics began life as a project targeted at applications such as subsea geological imaging and earthquake detection, but its evolution has seen a greater emphasis placed on subsea power harvesting technology, a key area of interest to those seeking to pursue ventures in cold ocean conditions, particularly in the Arctic. This focus has resulted in the creation of an innovative seabed instrumentation platform with unique power harvesting capabilities and diverse potential commercial and research applications.

Seaformatics began in 2007as an Atlantic Canada Opportunities Agency (ACOA) Atlantic Innovation Fund (AIF) project, and was led by Dr. Vlastimil Masek of the Faculty of Engineering and Applied Science.

The power-harvesting Seaformatics 'Pod' is the group's crowning achievement and is rapidly approaching the stage of real-world commercial application. The Pod utilizes a patented 1.5m diameter floating horizontal-axis turbine and flexible attachment which harvests energy from ocean currents and stores the energy in an attached battery pack. The flexible attachment mechanism not only tethers the turbine to a 600kg base which sits on the seabed, but also allows it to orient with water flow while resisting twist.

"So it's able to harvest power from low speed flows in basically any direction," explains Seaformatics Project Manager and Co-founder, Andrew Cook, who adds that they are targeting up to two-year deployments for the pods, which are retrievable thanks to an acoustically-activated release system that allows the floating turbine to rise back to the surface.

It is a versatile instrumentation platform designed to monitor the subsea and seabed environment, and can support a variety of sensors. In addition to the original targeted applications such as geological imaging and earthquake detection, the system can also be utilized in other marine science, environmental monitoring and security/defense applications.

When deployed as an array, the Pods are able to communicate with each other and to the surface via an acoustic network, facilitating ocean monitoring from the shore.

"The advantage of an array is that you can cover a wide area with a number of sensors," explains Cook. "Also, some wide area systems now are cabled, but the cost is extremely high, so this is a kind of middle ground that spans the gap between battery-only powered systems and cabled systems in terms of the power and communications bandwidth available." The team has also developed a novel fibre-optic-based 3D seismometer, but it is the power-harvesting Pod that is currently the group's main focus.

"Early on we also focused on sensors, but as time went on we saw the really high value part was the idea of not having to go offshore and change batteries, or in harsh environments where battery changes are difficult," says Cook. "Now we are really focused on power harvesting technologies, and that's the technology that we're going to take and spin out of the university."

Seaformatics is currently engaged in advanced discussions about bringing this unique technology to market, and is an example of the kind of innovative, world-leading cold ocean research and development, with a focus on practical applications, that is prevalent throughout the province of Newfoundland and Labrador.

Seaformatics "Pod" harvests energy from ocean currents and stores the energy in an attached battery pack.

Editorial Calendar

MARINE TECHNOLOGY REPORTER

Issue	Editorial	Bonus Distribution	Ad Close
January/ February	**Underwater Vehicle Annual: ROV, AUV, and UUVs** **Market:** Subsea Engineering: Oil & Gas **Tech:** Harsh Environment Systems for Arctic Ops **Product:** Scientific Deck Machinery	**Arctic Technology Conference** March 23-25, Copenhagen, Denmark **Subsea Tieback** March 3-5, New Orleans, LA	January 21
March	**Oceanographic Instrumentation: Measurement, Process & Analysis** **Market:** U.S. Navy Strategic Initiatives **Tech:** Ocean Business 2015 Technology Spotlight **Product:** Sonar Systems & Seafloor Mapping	**Ocean Business** April 14-16, Southampton, UK **Sea-Air-Space** April 13 - 15 National Harbor, MD	February 18
April	**Offshore Energy Annual** **Market:** Seismic Vessels & Systems **Tech:** Deepwater Positioning, Mooring & Anchoring **Product:** Subsea Vehicles and Systems for Pipeline Survey & Inspection	**Offshore Technology Conference** May 4-7, Houston, TX **AUVSI 2015** May 5-7, Atlanta, GA	March 27
May	**Underwater Defense** **Market:** Offshore Renewable Energy: Wind, Wave & Tide **Tech:** International Naval Technologies **Product:** Remote Sensing & Environmental Monitoring	**MAST Asia** May 13-15, Yokohama, Japan **UDT** June 3-5, Rotterdam, NL	April 24
June	**Hydrographic Survey** **Market:** Comms, Telemetry & Data Processing **Tech:** GPS, Gyro Compasses & MEMS Motion Tracking **Product:** Interconnect: Underwater Cables and Connectors		May 27
July/ August	**MTR100** **The 10th Annual Listing of 100 Leading Subsea Companies** **Market:** Offshore Europe Tech & Trends	**Offshore Europe** September 8-11, Aberdeen, UK	July 21
September	**Ocean Observation: Gliders, Buoys & Sub-Surface Networks** **Market:** Oil Spill Monitoring & Tracking Systems **Tech:** Seafloor Engineering & Remote Operations **Product:** Geospatial Software Systems for Hydrography	**OTC Brazil** October 26-29, Rio de Janeiro, Brazil **SeaTech Week** October, Brest, France	August 21
October	**AUV Operations** **Market:** Research Vessels **Tech:** ROV Technology: Workclass to Micro Systems **Product:** Underwater Tools and Manipulators	**Oceans 2015** October 19-22, Washington DC **SNAME** November 4-6 Providence, RI	September 25
November/ December	**Subsea Engineering & Construction** **Market:** Fresh Water Monitoring & Sensors **Tech:** Offshore Inspection, Maintenance & Repair (IMR) **Product:** Underwater Imaging: Lights, Cameras & Sonars	**Underwater Intervention 2016** New Orleans	November 26

Mapping the Channel of the Colorado River in Grand Canyon

By Matt Kaplinski, Northern Arizona University, matt.kaplinski@nau.edu

Situation

Researchers from Northern Arizona University and the U.S. Geological Survey's Grand Canyon Monitoring and Research Center are conducting survey operations to map the channel of the Colorado River in Grand Canyon National Park. The channel mapping project is part of a large federal effort, called the Glen Canyon Adaptive Management Program, to investigate and mitigate the effects of flows from the Glen Canyon Dam on the downstream environment. The completion of Glen Canyon Dam in 1963 caused a 95% reduction in the delivery of fine-sediment (that is, sand-sized and finer material) to the modern river, reduced the magnitude and frequency of floods, and changed the seasonal flow pattern to regime of daily fluctuations. These changes have had a significant effect on the fine-sediment resources, resulting in smaller and coarser grained deposits throughout the ecosystem. Sandbars are of particular interest because sandbars form the foundation of the riparian ecosystem and are a fundamental element of the river's geomorphic framework and the landscape of the Grand Canyon. Sediment laden flows that have the most potential to replenish sandbars are now rare and sandbar erosion has generally outpaced deposition. Throughout Grand Canyon, sandbars create habitat for native plants and animals, camping beaches for river runners and hikers, and provide sediment needed to protect archaeological resources from weathering and erosion. The channel mapping is part of an effort to determine magnitudes and trend of fine sediment storage within the Colorado River in Grand Canyon. The channel mapping data will also provide a complete bathymetric map of the river channel and be used to support improved flow models, sediment transport models, aquatic habitat classifications complete a bathymetric map of the entire river from Lees Ferry to Diamond creek.

Goal of the channel mapping program

The goal of the channel mapping program is to survey approximately 30 miles of the river each year, and repeat the surveys for each reach every 3 to 10 years. Surveys were conducted in 2009, 2011, 2012, and 2013 (Figure 1). Surveys of each reach were conducted using three methods: (1) multibeam bathymetric surveying, (2) single-beam bathymetric surveying, (3) conventional topographic surveying (Figure 2a next page). The majority of the survey area is surveyed with the multibeam sonar, while the singlebeam system is utilized for coverage in shallower areas along rocky shorelines and sand bar deposits. Total station surveys cover the above-water portions of sand bars and shallow portions (less than 1 m) of sand bar deposits. The three datsasets are combined together to create hybrid, 1 meter DEMs of the study reach (Figure 2b next page).

No going back to "clean up"

Surveying in one of most spectacular landscapes on the planet is extremely rewarding, but comes with a unique set of challenges. The surveys are conducted on self-contained, 18 to 20 day wilderness river trips through Grand Canyon National Park – a 270 mile journey regarded as one of the world's premier wild river experiences. This requires that our survey systems are built to navigate some of the largest whitewater rapids in North America and once a survey is completed, there is no going back to "clean up" a survey after the fact.

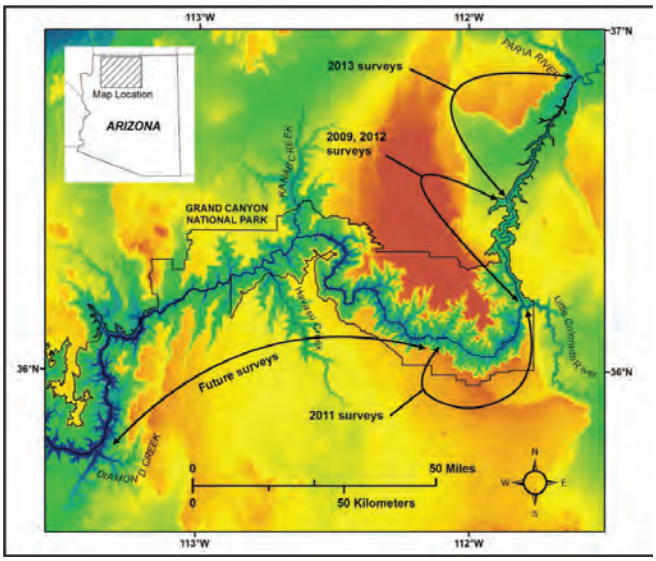


Figure 1. Location map of Survey Area.

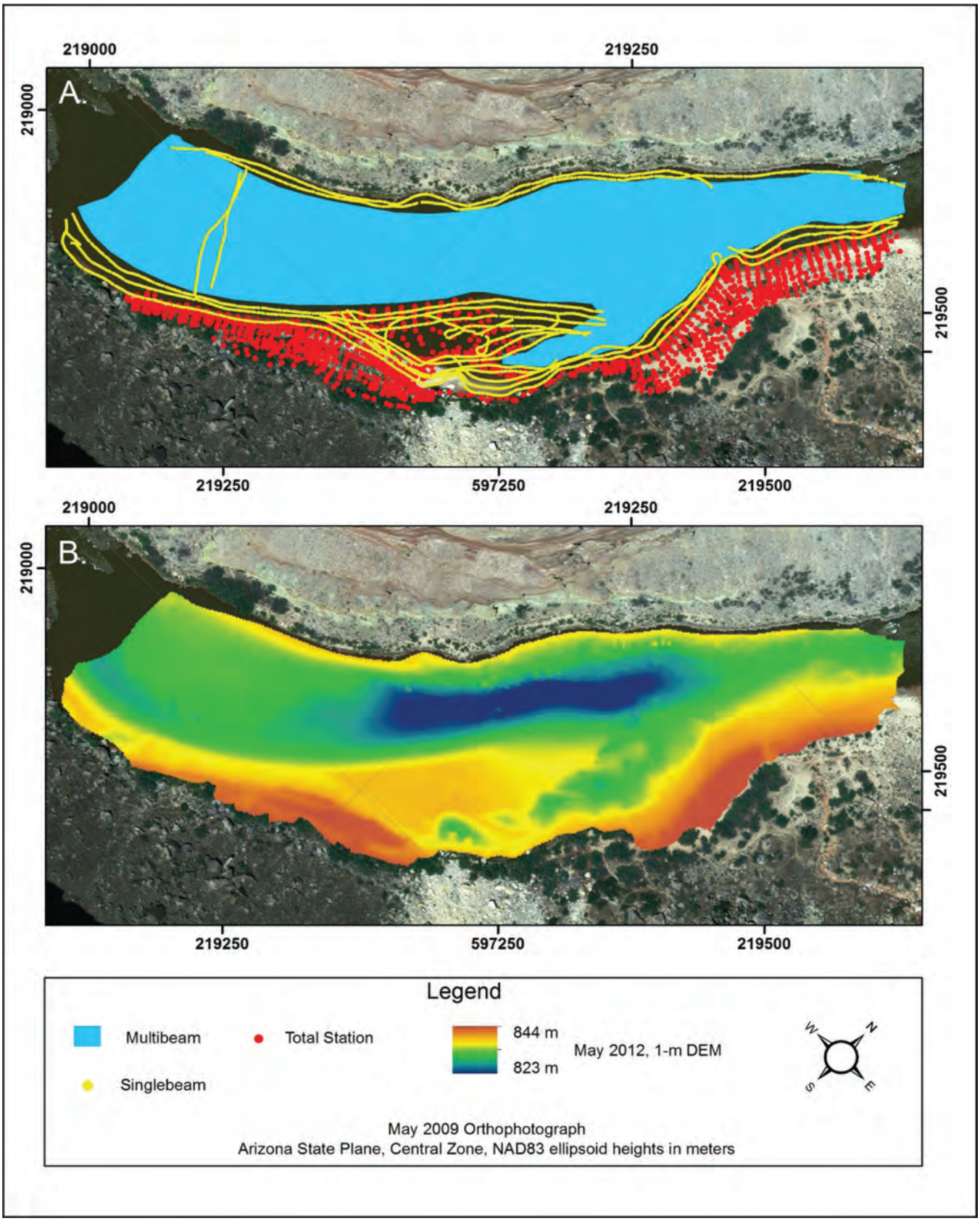


Figure 2. Maps showing (A) spatial coverage of mulibeam, singlebeam, and total station data collected at one site; and (B) 1 meter DEM constructed by combining data from the three surveys.

Equipment

The bathymetric survey systems employ a unique set of components. Primary systems (AC/DC power, computer, dryend sonar, IMU, heading, etc.) are housed in a waterproof aluminum dry box on a 7m and 5m inflatable pontoon (snout) raft powered by a 50 horsepower outboard motor (Figure 3).

The sonar heads are mounted on a swivel-mast assembly and all components are easily broken down and secured for running the rapids (Figure 4). We use a Reson 7125 system for multibeam surveying and a 200 kHz sonar for singlebeam operations. Heading and motion data are collected using an Inertial Navigation System. Poor GPS reception within the deep canyon walls renders kinematic GPS positioning practically impossible and we use the 1pps signal from a GNSS receiver for system timing only. A line-of sight, robotic total station is used for positioning and elevation control for all surveys. The robotic total station is set on benchmarks along the shoreline, transmits positioning information to the survey vessel via radio modem with a 20 Hz update rate, and has a maximum range of about 500m, depending on environmental conditions. Surveys are processed in elevations, and the 20 Hz elevation track of the vessel is used to compensate for heave. Reference surface calibrations using this system show depth differences (between the reference surface and one full sweep) of 0.03 m to 0.05 m across all beam angles at the 95% confidence level (figure 5).

Results

Figure 6 (next page) shows results from a multibeam survey for an approximately 400m long pool directly below Cave Springs rapids that highlights the capabilities of the

Figure 3

Figure 4

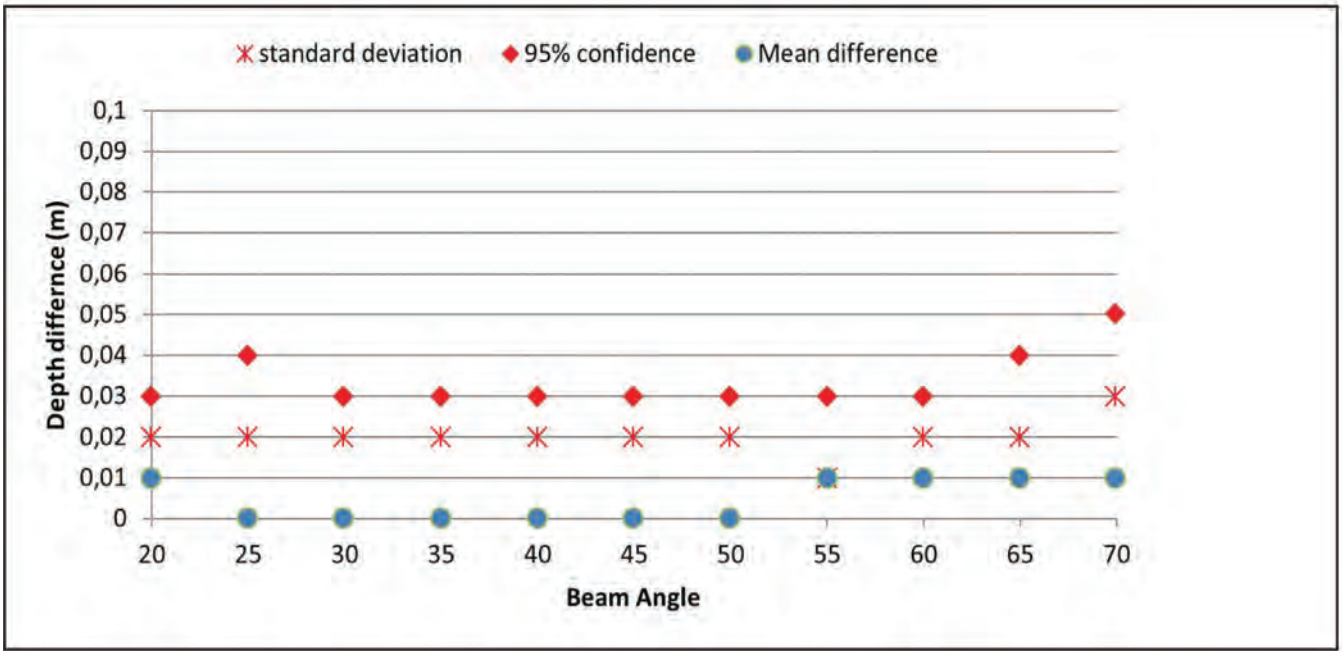


Figure 5. Reference Surface calibration results.

system. This pool is fairly challenging with high current velocity gradients, aeration below the rapids, and steep slopes. Depths in this pool range from 0 to 23m. The maximum depth measured in all our surveys is 28m. Surveys are collected "on-the-fly" without pre-planned line files (figure 6a). The 1m DEM also shows overhanging bedrock ledges, large boulders, a small sandbar, and a shallower area at the downstream end of the coverage (figure 6b). A map of cell standard deviation shows the combination of the natural variability of the river bed topography and sonar uncertainty (figure 6c). The majorities of cells have standard deviations at the 0.1 m level (and below), which gives a good indication of overall survey quality (figure 7). Efforts to provide a better quantification of the survey uncertainties are ongoing and necessary to help quantify the uncertainty in sediment budgets derived by differencing the channel mapping datasets once repeat surveys are conducted. Sediment budgets calculated from repeat channel mapping surveys will determine whether or not experimental dam operations are conserving sediment within the Colorado River through Grand Canyon.

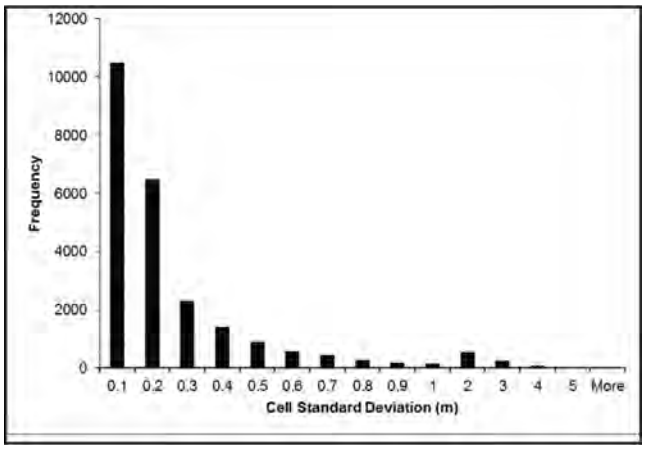
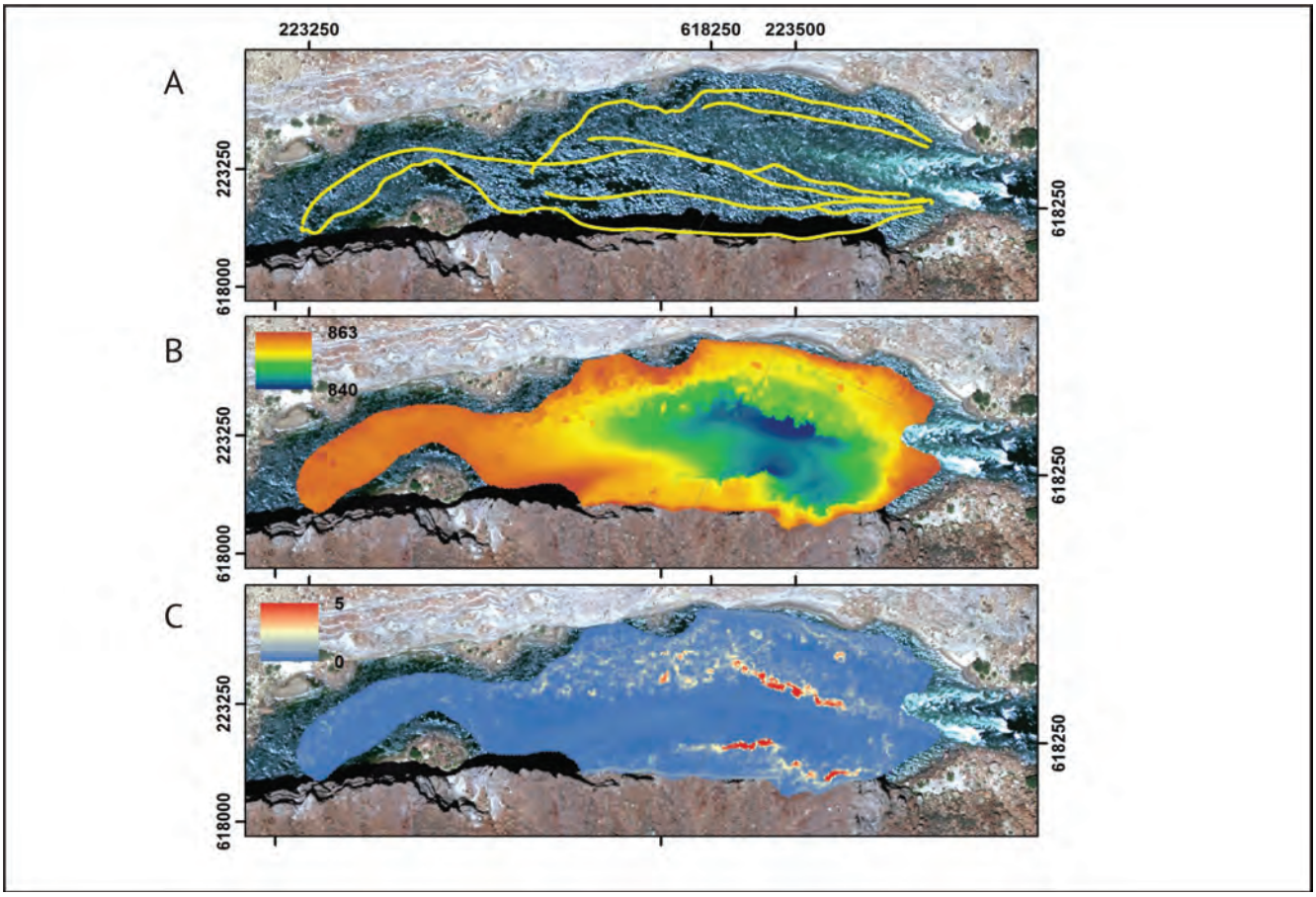


Figure 7. Histogram of cell standard deviation from survey shown in figure 6. Note that standard deviation scale changes at the 1m level.

Figure 6. Maps of a multibeam survey showing, (A) survey tracklines; (B) 1m DEM; and (C) 1m cell standard deviation.



Kraken

Seeing With Sound

Kraken Sonar Systems Inc. is a developer of high performance sonars for acoustic and military applications, and is a world leader in the development of Synthetic Aperture Sonar (SAS), an advanced sonar technology that produces ultra-high resolution seabed imaging. Kraken is based in scenic Conception Bay South, Newfoundland and Labrador.

Founded in October of 2012, Kraken employs over a dozen experts and has made waves in ocean technology circles with its Aquapix® system, the world's most technologically-advanced and competitively-priced interferometric Synthetic Aperture Sonar. Kraken's practical realization of Synthetic Aperture Sonar is recognized as one of the most significant advances in ocean systems engineering in recent times.

"We developed our own synthetic aperture beam-forming software and that's one of the key IP (Intellectual Properties) that we have here," says Engineering Manager, David Shea. "When we were developing this, we were provided access to a code base from NATO. We were able to use their code as kind of a ground truth for our own beam-forming codes."

This represented an incredible opportunity for Kraken, who set about speeding up the NATO codes so they could view the underwater images as quickly as possible.

"It was taking four hours to process an hour of data," says Shea. "We wanted to speed up that process and be able to do that processing onboard the vehicle. We can now process the data three to four times faster than real-time, so if you have 10 hours of data, it means we can process that data in 2.5 hours, using a standard laptop computer. We can also process that data in real-time, at full-resolution, directly onboard the vehicle."

In many applications, SAS provides over 25-times greater image resolution with a 300 per cent increase in area coverage compared to conventional sidescan sonars. Kraken has also developed a removable data storage pod utilizing the latest solid-state disk drive technology to provide a high-density, removable data storage solution in a compact and robust unit.

Kraken's small size and strong background in systems integration makes it an especially agile presence in the global sonar arena, able to provide custom solutions to its clients.

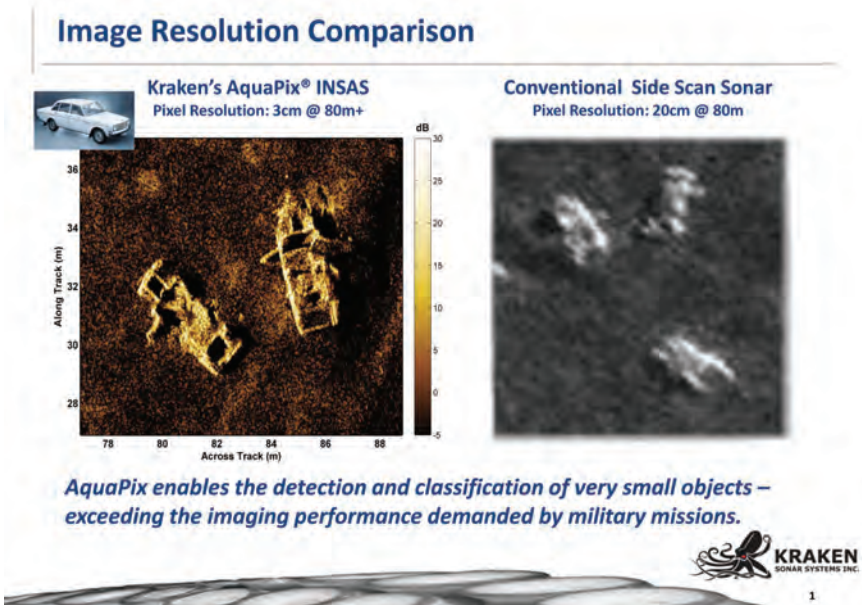
"As a sonar company, (that gives us) a unique value proposition in the international market," explains Shea. "A lot of sonar companies, big or small, are very good at building sonars, but they don't necessarily understand the customer's end application. We want to make sure our customers are using their sonar the right way to get the best images possible on their platform."

Shea was recently invited to take Kraken's technology on a successful Arctic mission to locate the HMS Erebus, one of the long-lost vessels of the ill-fated Franklin expedition, but major applications also lie in offshore exploration, ocean science, seabed surveying, environmental surveillance, and military missions. Arctic applications are nonetheless very much a part of the future for Kraken's technology. Its flexibility (AquaPix® is primarily designed for use onboard Autonomous Underwater Vehicles (AUVs), Remotely Operated Tow Vehicles (ROTVs), Remotely Operated Vehicles (ROVs) and Tow Bodies) aligns well with the challenges of charting in the Arctic, which could help to produce safer and shorter shipping routes.

Kraken is a true Newfoundland and Labrador company that has grown out of the rich ocean technology environment in the province. "Positioning ourselves in Newfoundland is really ideal because we have that government support, we have the facilities, and there are world-class researchers here at the university that we collaborate with," says Shea.

It is the winning combination of location, facilities and support that provides young companies like Kraken with the conditions they need to thrive and flourish, and that support Newfoundland and Labrador's position as the Path to the Arctic™.

Kraken's AquaPix enables the detection and classification of very small objects – exceeding the imaging performance demanded by military missions.



SubC Imaging

Vision Underwater

Clarenville, NL-based SubC Imaging is a world leader in revolutionary and reliable solutions for video, imaging, and lighting requirements in the offshore and subsea markets. Founded in 2010, the company has enjoyed over 100 per cent growth each year and attributes its success to a commitment to quality and the passion of its people.

SubC made a big splash with its first camera, which enabled Remote Operated Vehicle (ROV) pilots to upload standard definition (SD) footage through existing cables while high definition (HD) footage was recorded to the camera itself, to be uploaded once the ROV was on the surface. This technology proved to be an industry game-changer, allowing offshore suppliers to bid on projects that may have previously been out of scope due to HD requirements.

It is through this kind of insightful thinking and relevant innovation that SubC has become a renowned ocean-imaging innovator with an increasingly global reach and reputation.

The company was the brainchild of Chance Cove, NL native, Chad Collett. Collett, SubC's Co-owner and CEO, was an offshore project engineer who felt he could improve upon the quality and efficiency of the underwater cameras he saw being used in the industry. It was this motivation that saw him enlist the help of longtime friend and fellow engineer, Adam Rowe, now SubC's Co-owner and VP. Both Collett and Rowe are graduates of NL-based College of the North Atlantic (CNA).

Since its inception, SubC has placed great emphasis on the development of not only groundbreaking hardware, but also intuitive, custom-made software, enabling the company to provide clients with robust and comprehensive systems, right out of the box.

"We have a 4k camera in development," says Rowe, regarding one of SubC's latest projects, a camera that, when released, will be the highest resolution subsea camera on the market, trumping the current best, also a SubC product. "But what's different about what we do is that, instead of just releasing a 4k camera, we'll have an entire package. We'll have the 4k camera, we'll have the 4k DVR, and we'll have integrated software to control it all."

SubC is exploring new technological depths for harsh, subzero, ice-infested environments, with an eye on future demand for Arctic applications.

"We've put temperature monitoring into all of our equipment," says Collett. "In the Arctic, where it can get to minus-50, that's kind of important.

"There's definitely going to be more demand for technology with an Arctic focus. As things develop, we're already going to be there. We're going to be ready for it instead of trying to catch up."

Ron Collier, SubC's VP of Business Development, echoes the sentiment, and says that there is no better place than Newfoundland and Labrador to conduct this kind of research and development.

"We call it our 'Cold Ocean Laboratory' because we can do a lot of testing here that's hard to do anywhere else in the world," says Collier. "The Arctic is just that next step."

The favourable environment also extends to the infrastructure and support for ocean technology that is so abundant in the province.

"Provincial and Federal programs have been really helpful, such as the Provincial Government's Innovate and Demonstrate program," says Collier. This program allows technology developers to partner with established offshore and subsea operators to conduct trials of their products in the field, with funding awarded based on this real-world application of the technology.

Currently seeking to add to its approximately 12-strong team of highly-skilled employees, success and growth seems set to continue for SubC Imaging, a Newfoundland and Labrador company with a clear vision for the future of underwater video, imaging and lighting technology.

Arctic Air

ADIANL is helping Newfoundland and Labrador's aerospace, defence and security (ADS) industry soar

The Aerospace and Defense Industry Association of Newfoundland and Labrador (ADIANL) was established in 2001. The association is mostly involved in defence and security, but has seen increasing ties to offshore oil and gas operations in the province, largely through the aerospace industry's considerable surveillance capabilities.

ADIANL is drawing international attention to the impressive ADS technology, infrastructure and expertise in the province, particularly in relation to harsh environments and emerging Arctic requirements. Central to this are a number of world-leading aerospace, sonar, communications, and surveillance companies resident in the province.

The association's membership has doubled in the last two years, now standing at approximately forty. Members benefit from advocacy and closer ties to Provincial Government to promote their industry, while ADIANL is very active in engaging the ADS community in the province. For example, it is currently heavily involved with the Town of Goose Bay, NL to help them bring to market their considerable experience and capabilities.

Goose Bay, along with Gander, NL, was a very strategic location during World War 2, and remains so today for the emerging Arctic requirement. Location is key, and ADIANL has been working to create leadership in such strategic locations in the province.

ADIANL also forms part of a wider association, the Atlantic Alliance of Aerospace and Defence Associations (AAADA), which encompasses all four Atlantic Provinces. ADIANL members are automatically AAADA members too, with the opportunity to participate in a number of tradeshows and industry events in Canada, the U.S. and even into Europe.

The MASS (Maritime and Arctic Security and Safety) Conference is organized each year by ADIANL, aimed at engaging the international community around environmental, geopolitical, strategic, and security issues in the Arctic. Most notably, topics focus on the pursuance of offshore resources and the opening of northern shipping routes, which highlight the Arctic as an emerging hub of technology and economic activity. MASS 2014 attracted about 260 attendees from several countries. MASS 2015 will be held in St. John's, October 13 – 15, 2015 with the theme "Collaboration for Effect."

ADIANL works with leading academic, and research and development institutions such as Memorial University of Newfoundland (MUN), National Research Council Canada (NRC), Research and Development Corporation (RDC), Petroleum Research Newfoundland and Labrador (PRNL) and other local and national industry associations to further the province's capabilities and enhance ties with the offshore oil and gas industry.

The technologies that aerospace has for many years utilized and developed for Maritime security and safety purposes are the same technologies that will be required for oil and gas exploration and development in the Arctic. These include surveillance (radar and sonar), ice management, remote communications, physical security, asset management, and tracking.

Geography also plays an important role, as Newfoundland and Labrador is the eastern North American Path to the Arctictm for all shipping activity. From an aerospace perspective, most of the traffic into the Arctic flies over Newfoundland and Labrador and the province is also very strong in simulation. Central to this capability is the world-leading simulation suite located at the St. John's-based Fisheries and Marine Institute of Memorial University, and many of the high-end simulators that are used for marine simulation and training have crossovers into aerospace, defence and security and oil and gas simulation.

The Newfoundland and Labrador companies among ADIANL's membership are recognized all over the world and are developing a variety of innovative products and services for markets in Canada and as far afield as the Middle East, Central and South America, the United States, Europe and the Arctic. As operations in the Arctic increase, ADIANL will continue to push to bring international companies to the province to demonstrate the many virtues of its strategic location and its vibrant ADS and related industries.

Provincial Aerospace Ltd. (PAL) is an example of a company that has an international reputation for its surveillance capabilities. Recently, PAL teamed up with Airbus Defence and Space to be part of a bid for the fixed-wing search and rescue aircraft to serve the whole of Canada, indicative of the level of confidence and respect the global community has in PAL's capabilities.

It is this sort of international acknowledgement of Newfoundland and Labrador's aerospace capabilities that ADIANL strives to build upon, ensuring that the province's ADS industry is high on the agenda when it comes to future Arctic development.

Canatec

Leading-edge technology to the rescue

A relatively new addition to the Newfoundland and Labrador ocean technology cluster, Canatec has a deep history of cold-ocean and arctic research and development, having been in business for twenty-two years. Headquartered in Calgary, Alberta, Canada, Canatec's primary business has been in the safe design of ocean structures and vessels that will be constructed and deployed in harsh environments. Their St. John's, NL office was founded with another focus in mind: repurposing their existing iceberg monitoring technology for use in search and rescue (SAR) operations.

Canatec also has an office in The Hague and has extensive experience working off the east coast of Russia, in the Caspian Sea, as well as off Greenland and Newfoundland and Labrador. Their work is largely for the offshore petroleum industry, utilizing robotics and specialized software.

"We have developed instrumentation with the potential for much broader spinoffs for global markets," says Dr. Scott Tiffin, Partner and Project Manager of Canatec's St. John's Operation. "This is the project I'm leading here, making decision support systems for maritime search and rescue operations."

The St. John's Canatec team is a highly qualified research and development arm of the core company, some thirteen people strong, comprising three PhDs and ten Masters. The team is engaged in a number of iceberg monitoring- and management-focused projects, but it is the search and rescue application of their technology that is top of their agenda.

The technology gives operators real-time data, improving the safety and survivability of both offshore workers and search and rescue personnel. Such data can also widen the windows of operations, allowing helicopters to fly in areas and conditions that were not previously considered viable due to safety concerns.

In creating their highly qualified St. John's team, Canatec has pulled from nearby Memorial University, one among the many advantages of being stationed in Newfoundland and Labrador, says Tiffin.

"This is a place where not only is there production offshore, which drives a lot of activity…but it is a place where there is a consensus between Government, the population at large and industry to work together to invest in research and development, and innovation. This is the best place we could possibly be in Canada to do this very large innovation project."

Canatec is one among many ocean technology companies finding a home in Newfoundland and Labrador. The environment in the province – both physical and in terms of support – is proving to be conducive to world-leading cold-ocean and arctic research. Its sub-arctic conditions, the steady supply of skilled professionals from Memorial University and other academic institutions, and the strength and support of its long-established ocean technology cluster and Government make Newfoundland and Labrador the Path to the ArcticTM for companies like Canatec.

Exploration Drilling in the Arctic

Replicating the Arctic

The National Research Council of Canada (NRC) is a storied Canadian institution that will be celebrating its 100th anniversary in 2016. NRC is the Government of Canada's premier research and technology organization, employing approximately 4,000 people across the country.

NRC-OCRE works with clients and partners, providing innovation support, strategic research, and scientific and technical services. It has a long history of paradigm shifting research and development successes including the electric wheelchair, Canada's immense canola industry, and the Canadarm.

"Our mandate has always been using innovation to drive the growth of wealth in Canada," explains Jim Millan, Director of Research for NRC's Ocean, Coastal and River Engineering portfolio (OCRE).

The OCRE portfolio falls within the engineering division of NRC. The majority of the portfolio's work is carried out in specialized facilities in St. John's, Newfoundland and Labrador and in Ottawa, Ontario.

NRC-OCRE supports a broad cross section of industry sectors, developing solutions to engineering challenges in rivers, lakes and marine environments. It provides expertise and tools to improve the performance and safety of ocean, coastal, and marine operations, meet the challenges of climate change, and protect infrastructure, property and people from severe weather events and other environmental risks. NRC-OCRE provides technology and solutions for distinct market segments: The Arctic, Marine Vehicles, Marine Infrastructure, Marine Renewable Energy and Water Resources.

Its Arctic commitment has a mandate to ensure sustainable, low impact development of the North while increasing the quality of life for its people.

To this end, NRC-OCRE has amassed a world-leading assortment of facilities, equipment, and expertise. Perhaps the most iconic of these is the world's longest ice tank, used to test the effects of ice and icebergs on marine structures and vessels using highly accurate scale models. With this key facility, along with others like its Offshore Engineering Basin, NRC-OCRE researchers are able to replicate a complete ocean environment.

"We simulate harsh environments including those that occur in the Arctic and Antarctic," says Terry Lindstrom, General Manager, NRC-OCRE. "We don't focus on any one area; we can simulate any marine environment, anywhere in the world."

The physical modeling is complimented by advanced numerical modeling systems that replicate the most extreme environmental conditions -- taking into account phenomena such as ice, wave, wind, and currents to determine their impact on marine designs. Full-scale field testing is also carried out, with the culmination of these approaches utilized to reduce risk – be it environmental, personal or financial.

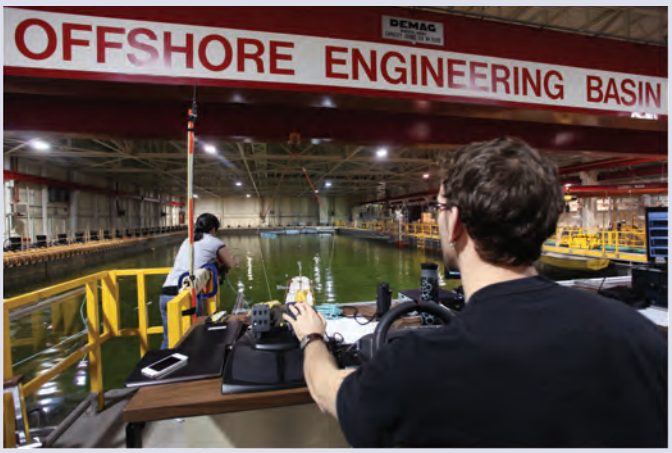
Physically located on the campus of Memorial University in St. John's, NL, NRC-OCRE has access to a vibrant talent pool of marine engineers and researchers, who in turn have access to these world-class facilities.

"At NRC, we capitalize on our investment in world-class infrastructure by creating an enviable research culture to continue our legacy of attracting exceptional researchers," says Millan. "The quality of our work and the rigor with which we test and evaluate ensures that we are able to de-risk the investitures of our partners."

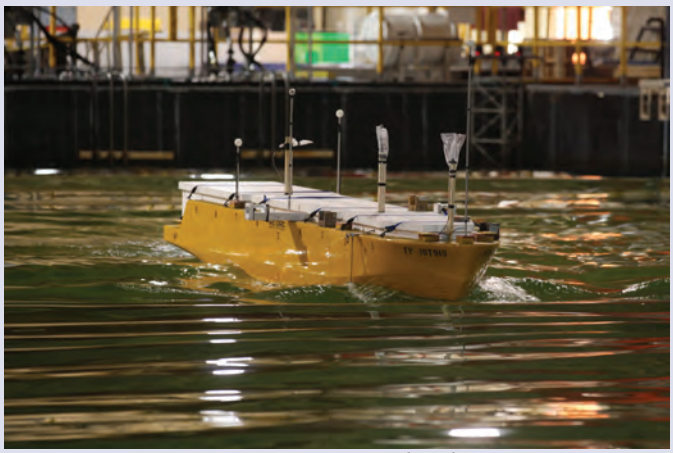
NRC-OCRE has roughly sixty-five people involved in this highly technical work, and they are leading the way for Arctic research and development.

"I believe the pathway to the ArcticTM flows through our facilities here," says Lindstrom. "Having that full toolbox of capabilities including numerical modeling, physical modeling, and full-scale testing is a huge benefit to our partners. There are very few organizations in the world offering all three. " With the ability to sample Arctic ice properties and replicate them in their tanks, NRC-OCRE is already paving the way for a bright future of Arctic exploration and development, led out of Newfoundand and Labrador.

Offshore Engineering Basin



Offshore Engineering Basin



Provincial Aerospace

Eyes in the skies

Provincial Aerospace (PAL) has been flying maritime surveillance aircraft for over thirty-five years for government, military, and industry clientele. In the 1980s, the company underwent a shift from basic visual surveillance and mapping to more advanced radar-based methods and has evolved to become a world-leader in developing and operating airframe-based radar, surveillance, and ice management technologies.

PAL's 1980s metamorphosis is owed much to the forward thinking of one of its owners, Gus Ollerhead, who first had the vision to put anti-submarine radar on an aircraft, something that had never been attempted before.

"Radars designed to pick up periscopes in the Cold War happened to be very effective for picking up ice and icebergs too," explains PAL Chief Operating Officer, Jake Trainor.

It was the kind of innovative thinking that has become the hallmark of Newfoundland and Labrador-based ocean technology companies like PAL, and for Trainor, the environment – both physical and in terms of infrastructure, collaboration and support – that is ideal in the province.

"We have a rich tradition in dealing with conditions in the North Atlantic, and the support of the sector to help develop these capabilities," says Trainor.

PAL is able to create tailored solutions for clients in diverse sectors including defense, offshore oil and gas, maritime domain enforcement, fisheries enforcement, and search and rescue, putting together the best combination of sensor systems to achieve the desired goal, then mating it with the aircraft that is best suited to the task. Altitude, endurance, payload, range, and number of crewmembers on board are all factors that feed into the decision.

"As we continue to evolve and develop, we are becoming more and more a data-driven company that happens to know something about aircraft," says Trainor. "In essence, we are producing sensor systems that happen to have wings."

PAL is particularly well versed in the key area of ice management, having provided such services to operators off Canada's east coast for over twenty years. It provides oil and gas operators with visibility regarding the whereabouts and anticipated movements of sea ice and icebergs that may be a threat to their assets. In turn, early ice management measures can be taken, such as redirecting an iceberg, or, in extreme cases, disconnecting and moving a platform. Such systems are critical to avoid an incident that could have environmental or worker safety implications, and to limit expense.

"We take a layered approach, using all the tools in the box," says Trainor; tools that include satellite imagery, manned surveillance flights, surveillance from seafaring vessels and offshore platforms, as well as highly accurate predictive models.

"We have decades of data on ice movement, so we can create predictive maps, kind of like a weather forecast," Trainor explains. "Here's where the ice is today, here's where it will be in 24 hours, and here's your 48-hour risk pattern. That's an ongoing activity."

As the Arctic continues to become an increasing area of interest for exploration and development, PAL is set to play a key role in the North.

In addition to its ongoing search and assist capabilities and ice management, modeling and detection business, PAL is already heavily involved in ongoing resource exploration and is set to play a key role in future Arctic development and production.

"As development continues in the North, there will be a need for additional awareness of what's going on," says Trainor. "It's a vast space and we're well positioned to take the technology we have developed here and extend that into the North. There will be a need for existing services and new services that we're already engaged in research and development on. In every segment of our business, we're looking to the North."

Ice Surveillance

Hangar

C-CORE

Smart solutions for challenging environments

Founded in 1975 as a partnership between Memorial University of Newfoundland (MUN) and the oil and gas industry, C-CORE (Centre for Cold Oceans Research and Engineering) is known around the world for its depth of knowledge and expertise surrounding the behaviour and prevalence of sea ice and icebergs, and risk mitigation through remote sensing and ice management. Strategically located on the MUN Campus in St. John's, NL, C-CORE works in collaboration with industry to nurture a skilled talent pool that in turn has access to world-class expertise and facilities. C-CORE encompasses two Arctic-related centres of excellence: CARD and LOOKNorth.

CARD (Centre for Arctic Resource Development) is the only independent, industry-guided research and development initiative in Canada dedicated to responsible, cost-effective hydrocarbon development in Arctic regions. It is concerned with applied research to create innovations that can aid industry and places a lot of focus on engaging experts in the ice engineering world.

"They are fewer rather than in abundance," says CARD Executive Director, Freeman Ralph. "So being at MUN is quite strategic and attractive for us, through research and development, helping develop folks who can take the engineering challenge to the next level."

CARD has been responsible for the development of a number of marine technology tools that have become industry standards over the years. A current focus is the continued development of a sophisticated toolkit to monitor and forecast iceberg movements and execute the most effective mitigation strategy, taking into consideration a whole host of environmental factors.

"We've been working on tools to monitor the environment and forecast where icebergs are going to go, to understand the forecast and, if I am to initiate a mitigation strategy, how does that new risk profile now look?" explains Ralph.

It is a simulation-based toolbox based on mathematical models of current ice movement and forecasting that will simulate where icebergs will go if their course is unaltered, and allow comparison of this scenario to the outcomes of multiple potential mitigation strategies.

"It is very important when you have multiple facilities, as you don't want to take away a risk from one facility and create a risk for another facility," says Ralph. "I can plan ahead, look at risk profiles and optimize a strategy that reduces that risk."

CARD is hoping to soon add a new tool to this kit in the form of a towing decision support tool, which will take into consideration factors like iceberg size and drift trajectory, and vessel tow power and direction to predict how the tow will look.

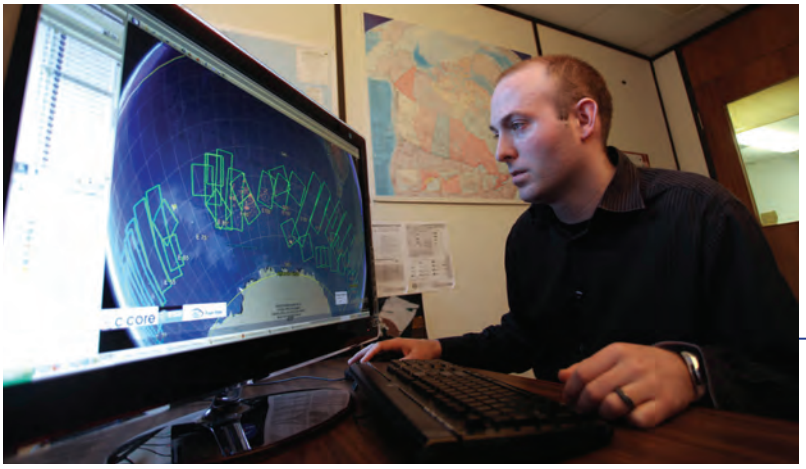
LOOKNorth (Leading Operational Observations and Knowledge for the North) is also unique in Canada as it is the only national centre of excellence for remote sensing research, innovation and commercialization related to northern resource development. LOOKNorth utilizes satellite radar technology to track and predict ice movements.

The technology is also being employed to map out areas of the Arctic and provide information on the always-changing landscape. This data is invaluable for keeping inhabitants of the Arctic (and the increasing eco tourism presence) abreast of the ever-evolving ice environment.

"They can go to Parks Canada in the morning to review this information and then safely go out to the edge of the ice to hunt and fish," says Dr. Charles Randell, C-CORE President and Chief Executive Officer. "It is an extremely high-tech way to help people preserve a way of life they have enjoyed for centuries."

C-CORE houses one of the largest centrifuges in the world, used to simulate Arctic phenomena. The effect of years of freezing and thawing on ocean equipment such as platforms, vessels, and pipelines can be accurately tested using precisely constructed scale models. The utility of such advanced equipment requires an extremely high level of expertise, which is grown and nurtured in the academic halls of Memorial University.

C-CORE and Memorial University are at the core of a dynamic and growing ocean technology cluster in Newfoundland and Labrador, increasingly regarded as the World's Cold Ocean LaboratoryTM. The province provides the sub-arctic conditions and prevalence of sea ice and icebergs that make it the ideal proving ground for this kind of research. The resulting collection of world-class facilities and expertise, infrastructure, government support, and local offshore industry further bolster this burgeoning ocean technology presence.



C-CORE's CARD is the only independent, industry-guided research and development initiative in Canada dedicated to cost-effective hydrocarbon development in Arctic regions.

Fisheries and Marine Institute

Simulating a world of marine environments

While Newfoundland and Labrador's Arctic-like conditions are perfect for field-testing, it is within the walls of Memorial University's Fisheries and Marine Institute (just Marine Institute or MI for short) that the cold, harsh and ice-prone environment can be simulated with an incredible degree of accuracy. MI is home to the most comprehensive suite of marine simulation capabilities in North America, and possibly the world in its Centre for Marine Simulation (CMS).

"The Marine Institute is unique in Canada," says Glenn Blackwood, Vice President, Memorial University, responsible for the Fisheries and Marine Institute. "We have become Canada's Marine Institute. We have students from every province in Canada and are the largest producer of seafarers in the country as well as being the only ocean technology-focused school with unique programs in Remotely Operated Vehicles and Ocean Mapping."

The Marine Institute is certainly well equipped to take on the task. It houses no less than sixteen marine simulators, with a seventeenth soon to be added. The most iconic of these is the Full Mission Full Motion Ship's Bridge Simulator. Commissioned in 1994 and upgraded in 2006 and 2009, this simulator is used to replicate operations conducted on a ship's navigation bridge. The simulator is mounted on a six degree of freedom aviation motion base in a surround theatre. It is one of only two full-motion ship's bridge simulators in the world and can accurately simulate any ship and sea state anywhere in the world.

The Ballast Control and Cargo Handling Simulator is used to replicate operations conducted in the ballast control room of an oil rig. It is mounted on a two degree of freedom motion base and is supplemented by desktop trainers. Float-on/float-off vessels can also be simulated.

CMS also houses three different Dynamic Positioning Simulators with custom-built visualization systems designed by its engineers: the Kongsberg SDP system, the KPOS system, and Converteam's C-series system. These simulators are used to replicate precision manoeuvering systems that are found on vessels operating in the offshore, scientific, cable-laying, and cruise industries.

Other simulators at CMS include a Navigation and Blind Pilotage simulator, a Propulsion Plan simulator, a Tug simulator, and Small Vessel simulators manufactured in a local company, Virtual Marine Technology (VMT).

VMT was incorporated in 2004 and meets a need in the global market for small vessel simulation. Through VMT, MI now has helicopter, lifeboat launch and fast rescue craft simulators that have answered the need for better safety, survival and emergency preparedness training in the industry.

In addition, ROV (Remotely Operated Vehicle) simulators were installed in 2008, an extension of the recently developed ROV program in MI's School of Ocean Technology – the first of its kind in North America. A local company, GRI Simulations Inc., a global leader in ROV simulation, provided the two ROV simulators that currently reside at CMS.

GRI is a Mount Pearl, NL company with a long history of providing support for subsea ROV operations. Established in 1986, GRI began to focus on simulation technology in 1997 to enhance pilot training, mission planning, and rehearsal for offshore operations.

The newest addition to CMS will be the Hibernia Offshore Anchor Handler Simulator, developed specifically for activities relating to offshore oil and gas operations. Funding for this new simulator was provided by the Hibernia Management and Development Company.

Of course, all this simulation technology requires the expertise to utilize it, and MI is training the next wave of ocean experts through its School of Ocean Technology and Centre for Applied Ocean Technology. This school and these centres are committed to developing and delivering education and training programs, and technology to meet the needs of the ocean sector, collaborating with industry in the application of this technology.

By bringing a realm of simulation capabilities together under one roof, Newfoundland and Labrador's Marine Institute is bringing critical training, testing and knowledge to the marine technology world.

MI's Full- Mission, Full-Motion Ship's Bridge Simulator

Oceanic Consulting Corporation

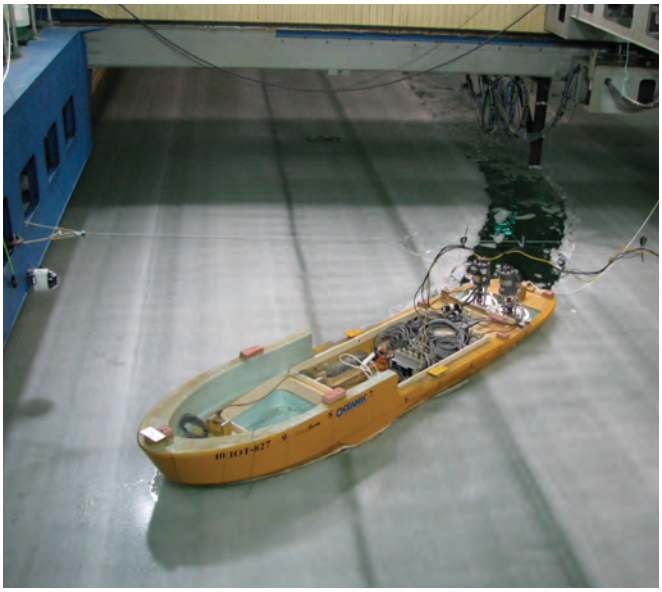
Predicting big things for the Arctic

Founded in the early 1990s, Oceanic began life as the result of a realization that Newfoundland and Labrador was home to such a capacity of marine research facilities that it was time to share them with the world. So began a global operation leveraging close working arrangements with the St. John's-based National Research Council and Memorial University's Marine Institute to offer companies the world over access to leading-edge facilities and support from the province. Today, Oceanic has grown to become a globally recognized commercial research and development company offering services in hydrodynamics and Arctic engineering through extremely accurate physical and numerical modeling simulation of marine structures and vessels.

Over the years, Oceanic has worked on projects as varied as Americas Cup yachts and gravity base structures, in the words of Director of Business Development, Lee Hedd, "Anything that interacts with the marine environment…We are exposed to so many areas of the marine industry that it allows us to pull up ideas, concepts, expertise and tools from sectors in the marine industry to address problems; often using unconventional approaches. We tend to thrive in that environment where you really don't know what question you want to ask."

While its scope is global, much of Oceanic's almost thirty-strong team of experts has been drawn from a rich local talent pool. Nearby Memorial University provides quality undergraduates, graduates and postgraduates in marine engineering, naval architecture and related disciplines, while seniority is provided by staff who have been in the industry and conducting Arctic research since the 1980s.

While the majority of its clients remain international, Oceanic has seen an increase of late in the Canadian contingent, spurred by the development and maturity of the oil and gas industry in Newfoundland and Labrador.



"It's a great place to do the research," says Hedd. "Coming from Newfoundland and Labrador, you understand harsh environments, as a culture and as a people. It's part of who we are, so it's such a natural progression for us to study Arctic issues and understand how we can safely manage and develop projects in the Arctic."

Oceanic has been involved in Arctic research since its inception and is now enjoying the fruits of its labour, assisting companies considering ventures in the Arctic, drawing on its wealth and history of experience. Hedd refers to such assignments as 'over the horizon projects', and says Oceanic's work is often done long before steel is cut or concrete is poured.

"Currently, everyone is very excited about the Hebron platform that is under construction here," says Hedd. "We finished our Hebron work about two and a half years ago. Usually we are well out in front of the construction work. We've been involved at various stages of all of the offshore platforms here: Hibernia, Hebron, Terra Nova and Sea Rose. It's exciting because we get to see what's coming down the pipe."

Oceanic is currently engaged in feasibility studies for an LNG facility in the Arctic and collaborating with another company to understand the type of infrastructure that would be required to make drilling in the Arctic possible.

Hedd believes that the oil and gas developments being discussed and contemplated for the Arctic will be a catalyst for a better understanding of the Arctic's challenging environment, and of how to manage and mitigate risk there. As the World's Cold Ocean LaboratoryTM, Newfoundland and Labrador's global status as the Path to the ArcticTM looks only to strengthen as this interest in the North increases.

"I don't think of it as logistical as much as intellectual," says Hedd. "We (Newfoundland and Labrador) have the infrastructure, the capability and the historical expertise to be that intellectual Path to the ArcticTM…that go-to source for all things Arctic."

Whitecap Scientific

Adding a new dimension to underwater imaging

Whitecap Scientific Corporation is a St. John's, Newfoundland and Labrador-based developer of intelligent visualization systems for the ROV (Remote Operated Vehicle) industry. Established in 2011, Whitecap has created the world's first live 3D video inspection system, ROV3DTM. This technology allows industry standard cameras to be used to create a three-dimensional model that can be analyzed spatially, in addition to standard two-dimensional video imaging.

"This is the pilot's window into the remote world," says Dr. Sam Bromley, Whitecap Co-Founder and Managing Director. "They can see the areas they've already recorded, the shape of the model, and they can zoom in on a certain point of interest in more detail."

The system works by placing two cameras side-by-side, with software then building a three-dimensional image of an undersea site. ROV pilots are also able to place "pins" and annotations in areas of interest that can later be explored and examined, with complete and highly detailed textures of the full 3D image created. Whitecap considers this to be complimentary technology for anyone shooting video underwater, with some distinct advantages: The 3D system provides direct feedback on areas already surveyed, with any gaps in the model clearly visible to the pilot. This feature removes the potential expense of having to return to the site if an area of importance has been missed. he system also helps to remove visual 'noise', shooting thirty frames per second. Every frame is processed, all the data adding up constructively to lessen 'noise' and provide a truer image. For instance, should a jellyfish move into the frame, it will completely obstruct a standard video image, but with Whitecap's technology, the obstruction is diminished and removed. The system has a multitude of potential applications, allowing oil and gas operators to create detailed 3D models of their underwater assets. In environmental remediation and surveying, the technology can be flown over a seabed to create a detailed reconstruction.

For example, "You can get a 3D model of, say, a harbor basin, you can do biodiversity studies, you can examine the effect of an operation that goes into a field and then assesses the impact and how quickly it is remediated once it has been decommissioned," says Bromley.

3D visual modeling has great potential for applications in cold-ocean and Arctic environments, where conditions are more extreme and the importance of regular maintenance, inspection, and a true understanding of the subsea environment is of heightened importance.

"There's no better technology that brings this accessibility to all of these operators, because they use their existing camera systems, flying video inspection as they always have, but they get all this additional information of full 3D capture," explains Bromley. "Year after year, they can then bring up one model, superimpose another one, align them perfectly, and see what's changed. Doing that with video is very difficult."

Whitecap Scientific Corporation is one of many Newfoundland and Labrador-based startups that have grown from the province's vibrant ocean technology cluster. For Bromley, there's no place like home to be developing this kind of groundbreaking technology.

"We have a very healthy, collaborative environment," he says. "You have a lot of complimentary companies in the region. There's an attitude that, 'we're here to build something that's greater than any one company'. There's a lot of support from government agencies to foster innovation. Overall it's just a perfect place to develop ocean technology."

A natural Path to the ArcticTM, and the World's Cold Ocean LaboratoryTM, positions Newfoundland and Labrador as a breeding ground for new, innovative, and paradigm-shifting ocean technology companies.

3D video inspection system. ROV3DTM technology allows industry standard cameras to create three-dimensional models, in addition to standard two-dimensional video imaging.

AOSL

Unmanned Missions in Harsh Environments

The Autonomous Oceans Systems Laboratory (AOSL) is a research facility within Memorial University's Faculty of Engineering and Applied Science, based in St. John's, Newfoundland and Labrador, which was founded in 2010 by Engineering Professor Dr. Ralf Bachmayer, its current Director. Masters and Doctoral students from the university play a key role in driving AOSL's research and development, which is focused on the advancement of persistent unmanned systems technology in harsh environments. This includes exploring new and innovative ways to utilize autonomous underwater vehicles (AUVs), unmanned surface craft (USC) and unmanned aerial vehicles (UAVs) in cold and harsh environments with sea ice and icebergs.

"Autonomous vehicles don't complain about the temperatures being minus-ten and the wind being 70 knots, but that's exactly when you need to make the measurements," says Department Head of Physics and Physical Oceanography, Dr. Brad de Young, explaining that it is critical to understand the most extreme conditions that will be present when considering ventures into harsh, ice prone environments like the Arctic.

AOSL researchers are developing technology that will extend the mission duration of AUVs and utilize bathymetry and GPS to accurately track their location, in addition to technology that will allow for navigation of AUVs underneath ice where GPS position fixes at the surface cannot be used to update navigation of the vehicle. This has been a key area of research for Ph.D student, Brian Claus.

"If you want to travel underneath the ice, then you're not able to stick your tail out of the water and connect to those (GPS) satellites," explains Claus. "So the focus of my thesis was to be able to run the AUVs underneath the ice where we don't have that corrective GPS signal anymore."

The proposed answer involves taking a sequence of altitude measurements and comparing back to a map to determine the AUV's location. It is a similar system to that which is used to navigate cruise missiles. All of AOSL's research is driven by the desire – and the need – to attain more data in hard-to-reach areas of the ocean, such as those found in the Arctic. This includes projects such as acoustic measurement of sea ice thickness and mapping icebergs both above and under water.

"One of things we're interested in is observation of icebergs and sea ice," says Dr. de Young. "Ships are not always in the right place at the right time and don't always have the right instruments on board to make the kinds of measurements we want. An iceberg is mostly underwater and underwater is the hardest place to make the measurements."

By utilizing a smart surface vehicle in unison with the AUVs, algorithms can be fed back and forth and 3D mapping of the iceberg can be achieved both above and below the water. The data can then be analyzed onshore to more accurately predict how the iceberg will react and where it will move, taking into account its shape and size in addition to factors such as sea state, water current, and weather conditions.

"Better observations make better strategies for managing the ice," says Dr. de Young, adding that the ability to replace ships – which have their limitations in environments like the Arctic – with autonomous vehicles offers a great deal of opportunity to better understand any threats to operations such as offshore oil and gas platforms. Mitigation strategies can then be employed, enabling operations to continue undisturbed.

Dr. de Young says there is no better place than Newfoundland and Labrador to conduct this kind of research and development.

"What you have here are real opportunities to study a sub-polar environment where you can live year-round, have good technical access, and where there's a lot of support, as opposed to in the high Arctic and the open ocean, where it's very difficult to work."

AOSL is one among many examples of world-class ocean technology research that is being conducted in Newfoundland and Labrador, contributing to the province's status as the World's Cold Ocean LaboratoryTM and the Path to the ArcticTM.

AOSL technology extends the mission duration of AUVs and utilizes bathymetry and GPS to accurately track their location.

Creating Ocean Technology Opportunities
in a Harsh Marine Environment

By Wade Kearley

Even in the interconnected world of the 21st century, physical location is still a vital factor in determining opportunity. As the Path to the ArcticTM, Newfoundland and Labrador's location means significant opportunities. The most easterly province in Canada, the province's cold and iceberg-riddled waters are testament to the fact that this is as far south as the Arctic comes. Local entrepreneurs, researchers, and supporting partners have developed the necessary infrastructure, expertise, and the collaborative spiritto not only survive, but to thrive in this harsh marine environment.

Nowhere is this spirit of successful collaboration more evident than in Newfoundland and Labrador's ocean technology sector. It has developed into a leading global"innovation" cluster. For the past decade, OceansAdvance has served as the voice of the province's ocean technology innovation ecosystem.

AN OCEAN TECHNOLOGY INNOVATION ECOSYSTEM LIKE NO OTHER

Executive Director of OceansAdvance, Barry Snow says that he is consistently humbled by how highly OceansAdvance is regarded around the world. The Oceans '14 MTS/IEEE Conference, held in the provincial capital of St. John's in September 2014, attracted a record number of exhibitors and delegates. "And this past November, we were invited to present the compelling back story of our innovation cluster to a highly-influential group of leaders at the Maritime Alliance's Blue Tech Summit in San Diego, California," says Snow. He presented alongside such leaders as Rick Spinrad, the Chief Scientist at the United States' National Oceanic and Atmospheric Administration (NOAA) and Kevin Forshaw, Head of Enterprise and Research Impact at the United Kingdom's National Oceanography Centre (NOC).

Snow says, while he was grateful for the opportunity to meet these world leaders in ocean technology, he was struck by what they saw as an imperative to try and inspire a unified voice for national and global interests in ocean technology--a "blue voice." This had such an impact on him because, "Here in Newfoundland and Labrador we already have a blue voice," he says. "While our cluster is focused mainly on products and services for the harsh marine environment, nevertheless our constituencies of research, academia, government, and the private sector are proactively engaged. We speak in unison. All hands are on deck and it's powerful," he explains.

COLLABORATIING FOR INNOVATION, COMMERCIALIZATION AND EXPORT

OceansAdvance was founded in 2005 by a group of Newfoundland and Labrador ocean technology leaders whocame together to create amanagement organization to underpin the emerging ocean technology cluster. Its initial mission was to unite and excite the development of an ocean technology sector that could speak with one voice. "They understood even then that by aligning themselves toward a shared long-term

vision of economic diversification, everyone would benefit," says Snow.

He says that members understood the tendency over time for businesses and researcher centres to become siloes. But if they do, then they will fail to connect with the people in the organizations around them. "OceansAdvance facilitates opportunities for networking to ensure that our members communicate with other leaders who havecomplementary expertise in the community," says Snow. In the case of Newfoundland and Labrador,thecollaborative approach has accelerated the process of bringing companies together, connecting them to researchers, and to global market opportunities. "By operating within this innovation ecosystem we can bring products and services to those markets as quickly as possible. Like in any innovation ecosystem, it's not perfect, but it works, and the cumulative positive effect of the cluster on our province is one of the reasons why it's so compelling."

Today, OceansAdvance's members include more than 50 export-driven companies; more than 20 research and technology organizations; highly-engaged municipal, provincial and federal governments,and post-secondary academic institutes and trade associations. "Even as we build a sustainable cluster, we are united and focused on producing the next generation of ocean technology leaders," says Snow.

This multi-stakeholder technology cluster is underpinned by innovation, commercialization, and export and it is highly influenced by Newfoundland and Labrador's burgeoning offshore energysector. Other significant "innovation influencers" include marine transportation, defence and security,the fishery, and aquaculture.

A GLOBAL ALLIANCE FOR ARCTIC R&D

"As the organization representing one of Canada's most dynamic innovation clusters," says Snow, "OceansAdvance is led by individual professionals, not by organizations." He is particularly proud of that fact because, he says, "That means we are influenced, but independent from the agendas that larger organizations must follow and free to be guided by the people who spearhead cutting-edge oceans research and commercialization."

Those leaders include among their ranks, "award-winning experts", in safe and efficient operation in Arctic marine conditions and entrepreneurs who are successfully competing in the global Blue Economy.

Sustainable private sector growth is vital for any cluster to succeed and particularly successful clusters focus on export success for export companies and technologies. "For example there are significant opportunities with companies such as Petrobrasin Brazil." In that country, although its offshore O&G sector is not in a cold environment, proven harsh marine technologies are required for the very deep wells. "Because of the depth they must operate at, the technologies that work here are relevant in Brazil."

"When it comes to innovation in technology research and

development for harsh marine environments, there is no other ocean technology innovation ecosystem like Newfoundland and Labrador's in the world," says Snow. "We have a head start on Arctic researchand we have adepth of innovative technologies and researchersto prove it." Not only does Newfoundland and Labrador have the necessary subarctic conditions, says Snow, but we also have the "land-based infrastructure such as the ice tanks, tow tanks, flume tanks, simulators and capabilities for modeling and full scale testing that is reflective of our brandas a live cold-ocean laboratory."

"We are enriched through innovation partnerships with similar organizations around the world such as the Maritime Alliance, and others in the United States, Ireland, Iceland, Norway, Denmark to name but a few. They are interested in collaborating with us to focus on what must be long-term, mutually-beneficial activities," says Snow."Weare focusing on finding answers to such questions as: How can we continue to add value to all the constituencies in our respective clusters? Where are the business-to-business opportunities? Where are the collaborative research opportunities?"

THE SYNERGY OF LEADERSHIP

Snow points to locally grown Virtual Marine Technology Inc. (VMT)as a classic example of a company that arose from a market opportunity—in this case to provide marine simulation training. Due in large part to an evolving collaborative relationship with Memorial University, the National Research Council, and the Offshore Safety and Survival Centre, VMT is now the largest manufacturer of marine simulators in Canada, specializing in marine simulation training solutions."This synergy would not be possible outside the specific ocean technology innovation ecosystem that ten years of collaboration have created," he says.

"We are constantly looking to add incremental innovators to this ecosystem," says Snow. "And one of the best waysto enter this environment is to go to our website." (www.oceansadvance.net) He says those with an interest in ocean technology would benefit by checking out their site's innovator profiles on people like Dan Brake of EMSATor Adam Gobi of SULIS Subsea Corporation, or Dr. Michael Graham of the Wave Energy Research Centre, or by visiting their online company directory, or perusing the site's deep bank of hundreds of news stories and features with local, national and international relevance for ocean technology interests."Our organization maintains a strong commitment to communications. It's one of our secret sauces" he says.

"This is arguably the best time in our history to enter Newfoundland and Labrador'socean technology cluster," says Snow, "with the supports, expertise, and a brand that continues to grow and attract international partners." He believes that this is evidence of a dynamic innovation ecosystem. "Located where we are on the Arctic pathway, with such a range of individual expertise in harsh ocean environments, and a successful history of collaboration among our four constituencies, it is no small wonder that others intuitively sense there's something special happening here."

"Our blue voice continues to grow and it's far from a whisper."

R&D

The Ultimate Game Changer

The 2013 World Economic Forum stated in its Global Competitiveness Reportthat firms must,"design and develop cutting-edge products and processes to maintain a competitive edge and move toward even higher value-added activities. This progression requires an environment that is conducive to innovative activity and supported by both the public and the private sectors. In particular, it means sufficient investment in research and development (R&D)…"

While R&D may require funding and hard work, it is essential for generating higher value economic activity, prosperity, and improved quality of life.

Taking Action

In 2009, the Government of Newfoundland and Labrador took decisive action to embrace this economic principal with a groundbreaking R&D initiative to build a stronger knowledge-based economy and plot a course toward sustained prosperity.

The initiative resulted in the creation of the Research and Development Corporation (RDC), an arm's-length crown corporation with a mandate to strengthen R&D for the long-term economic development if the province.

RDC is committed to making strategic investments in business-led and academic-led R&D,with a focus on increased private-sector investment. This commitment provides tremendous opportunities for innovative, results-oriented companies in Newfoundland and Labrador – and from around the world.

Funding Programs

To achieve results, RDC offers a full suite offunding programs and targeted initiatives aimed at enhancing thequality and quantity of business-led and collaborative R&D.One of RDC's main priorities is to increase thelevel of business investment in R&D in theprovince to match the higher levels achievedin leading national and internationaljurisdictions. RDC aims to increase R&D in its priority sectors of energy, mining and minerals, and ocean technology to capitalize on the province's competitive strengths and maximize the potential for economic impact. The province welcomes proposals and initiatives that will bring new R&D projects to the prov-

Rising above the Ice: R&D performer Canatec Associates International is developing a communications beacon capable of operating and transmitting from cold, harsh ocean environments, with demonstrated battery life that's the best in the business. (Photo by Dave Howells for RDC)

ince.

In 2013–2014, RDC's commercial R&Dproject approvals exceeded non-commercialprojects – a positive indicator of growingbusiness investment in R&D.During the year,57 RDC projects hadinvestment from businesses. RDC is investing$10 million in these projects, with totalproject costs of $34 million.A further 78 projects supportedR&D collaborations between businessand academia or government partners.

Newfoundland and Labrador is a 'real-time Arctic laboratory.'

RDC believes in playing to its strengths, or rather, to the province's strengths. For Newfoundland and Labrador those strengths relate to the cold, harsh, ice-prone waters that surround most of the province, and the sub-Arctic climate. For generations Newfoundlanders and Labradorians have successfully worked in this challenging environment and exported their expertise to other regions around the world. Most recently this has led to the development of a strong ocean technology cluster, significant advances in ice science and ice-related R&D, harsh environment remediation work, development of simulators, and advances in remote sensing technology applications.

As a result, Newfoundland and Labrador has been described as "a real-time Arctic laboratory," by Statoil's Senior VP Exploration for North America. In other words, Newfoundland and Labrador is a realistic, cost-effective proving ground for work that will ultimately take place in harsher, more extreme environments such as the high Arctic. This is an accessible Arctic-like location, with significant, globally competitive R&D infrastructure and expertise. To leverage this competitive position and capture economic value, RDC has placed a strategic focus on supporting Arctic and harsh-environment R&D.

This focus has resulted in RDC investing $22 million in 97 Arctic and harsh environment R&D projects since 2009. RDC's flagship program is ArcticTECH, launched in 2012, which supports commercial and non-commercial R&D projects, with RDC contributions of up to $500,000.

RDC has been instrumental in increasing new R&D invest-

ment by industry. Most notably, in March 2013 Statoil established a $5 million Arctic R&D Step Up initiative in collaboration with RDC. This initiative represents not only a major boost to the local R&D landscape, but also Statoil's first major investment in R&D outside of Norway.

How valuable is harsh environment R&D?

Consider the case of the Hibernia oil platform, the world's first offshore gravitybased structure (GBS) built to withstand an iceberg impact. Built with the latest technology available at the time, it was engineered and constructed to withstand a strike from six-million ton iceberg.

But in the 20 years since Hibernia was constructed, significant advancements in ice management, monitoring, and engineering have taken place through R&D. As a result, construction requirements for the next offshore GBS could be safely reduced. The result: the Hebron GBS could be designed and built two-thirds the size of Hibernia, resulting in a saving of approximately $1 billion in construction costs.

New Opportunities in Corrosion Research

Another characteristic of Newfoundland and Labrador's harsh environment is corrosivity. Wind, wave, salt spray, fog, freezing & thawing, frozen precipitation of all forms, all help make this province a deeply corrosive environment. And again, it is also an accessible environment.

RDC recognizes that it can enhance R&D capacity through the development of new R&D assets that leverage this proximity to harsh environments. These assets can be owned by RDC, academia or private enterprise. The assets can help industry solve technical challenges, such as corrosion. They can also help support the attraction and development of businesses and leading researchers, and strengthen the province's competitive position in areas such as Arctic and harsh-environment technologies.

RDC's Atmospheric Corrosion Test Site is one such opportunity. The new site offers year-round fieldtesting to advance the development of solutions and technologiesthat protect vital industry assets. This facility iswell suited for corrosion research and development projects.Its location at the exposed headlands of the southern AvalonPeninsula in the North Atlantic Oceanrepresents one of the harshest and most corrosive naturalenvironments in North America. The site is strategical-

Exposed to the Elements: RDC's Atmospheric Corrosion Test Site is being established in North America's most corrosive environment, where monthly maximum wind speeds exceed 100 Km/h, annual precipitation tops 1,350 mm and the fog rolls in more than 200 days a year. It is ideally suited for corrosion-related R&D projects. (Photo by Dave Howells for RDC)

RDC is Investing in R&D Infrastructure: The Suncor Energy Offshore R&D Centre, left, will house collaborative ocean- and offshore engineering-related R&D projects. The new Centre for Arctic Resource Development (CARD), right, will bring together technology partners to conduct R&D focused on the Arctic and other ice and iceberg prone regions.

(Photo by Dave Howells for RDC)

ly located in Argentia,just 90 minutes from the globally recognized R&Dfacilities and institutions in the St. John's area.

Positive Economic Impact

In 2013, RDC commissioned Wade Locke Economic Consulting to prepare an independent analysis of the economic impacts of research and development in the province, and of RDC in particular. Dr. Locke found that every dollar RDC invests generates $2.4 in total overall R&D project activity, $6 in inter-firm sales (business revenues) and $2.2 in income. His analysis determined that every million dollars invested by RDC results in 21 person years of employment.

While Dr. Locke's findings speak to RDC's impact to date, the real prize of R&D is the application of new discoveries in the provincial economy to generate new businesses, create new products, and grow employment. Dr. Locke's analysis highlighted this long-term potential, stating that "as impressive as these economic impacts are, they pale in comparison to the potential economic impacts that will be realized as RDC-supported R&D initiatives continue to improve innovation and productivity within the province over a longer term."

R&D is Recovering Big Royalties

Dr. Locke undertook a close examination of two R&D projects supported by RDC, one of which could provide significant dividends is the Hibernia Enhanced Oil Recovery (EOR) Laboratory at Memorial University. This new lab houses state-of-theart equipment that will allow researchers to perform enhanced oil recovery experiments under realistic reservoir conditions. It has the potential to unlock 50–100 million barrels of oil and increase the value of output by $5–10 billion. This would mean an additional $2.1–$4.4 billion in royalties for the province.

These fundamental investments support a high-performing R&D environment that consistently solves technical challenges and translates them into economic activity. The resources are being put in place. The R&D that could benefit the province and change the world is underway.

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