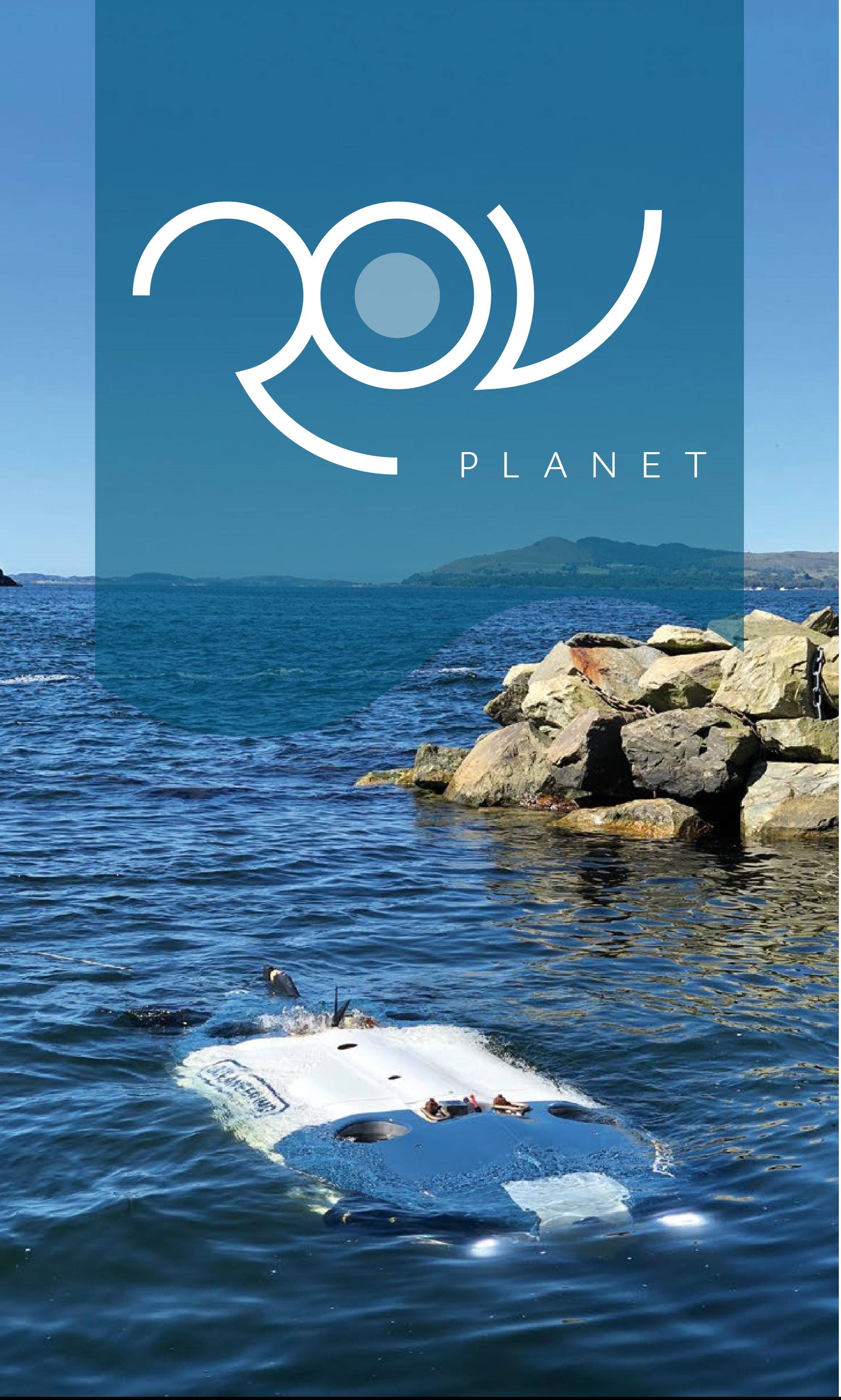
ROV PLANET



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The magazine of choice for Subsea Construction and AUV/ROV/USV Professionals

ISSUE

Q3 / 2020

WELCOME TO ROVPLANET!

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WWW.ROVPLANET.COM

Front Page Cover Photo: Courtesy of Oceaneering
Poster Photo: Aleron MultiROV

My name is Richie Enzmann, and allow me to welcome you all to the latest issue of ROV Planet!

Dear Reader,

I hope this quarter's issue finds you safe and well. Obviously, the coronavirus pandemic is a massively negative thing, affecting our health, industries, and livelihood. However, it also represents an opportunity to re-train and learn new skills via online courses from the comfort of home.

I myself took the opportunity to start the Hydrographic Survey Category B training with Dutch company Skilltrade B.V. Skilltrade are now providing some of their courses partly online, with the practical training taking part in the Netherlands next year (for more course information read the next page).

Besides the training, I can recommend their three volume Handbook of Offshore Surveying, which I also bought. It's an excellent reference point if someone wants to know about topics related to offshore surveying, including acoustics, active sonars, geodesy, underwater positioning, and satellite navigation systems. With the UN Seabed 2030 initiative to map the seabed by 2030, the hydrographic skills, including remote hydrography using AUVs and USVs are more relevant than ever, and will soon be in even higher demand.

As for this issue itself, we have a series of highly interesting and engaging articles for you, starting with an update on the progress of the Freedom resident ROV/AUV from Oceaneering. We also have a comprehensive piece by Jim Cairns explaining the history of wet mateable connectors from the inventor's point of view: a remarkable story of determination, problem solving, highs and lows about getting new products to the market. We also interviewed Jim Delgado about the search for USS Nevada, to find out more about the discovery of this iconic ship - in the age of the pandemic.

One matter from our Sales Director, Nick Search, is to remind all our global readers that should they see an interesting advertisement that they'd like to know more about, all they need to do is click on the ad and they will link to that advertiser's chosen webpage. This system is very much there to encourage business exchange and we encourage you to use it whenever convenient.

Finally, we have another historical article from Bruce Butler about the Theseus AUV, its legacy on AUV development, and Project Spinnaker: a secret Cold War project to lay fibre optic cable from the Canadian North coast to an ice-covered listening station approximately 180 km away in the Arctic Ocean. I can also recommend that you buy his book if you are interested in learning more about the project, the development of the Theseus AUV, and the technical details.

Best regards,
Richie Enzmann

EVENTS CALENDAR

For more information about all events visit WWW.ROVPLANET.COM

OCTOBER 2020

OCEANS 2020
VIRTUAL (5-14 October 2020)

EURONAVAL
Paris, France (20-23 October 2020)

OFFSHORE ENERGY
Amsterdam, Netherlands (27-29 October 2020)

NOVEMBER 2020

ADIPEC
VIRTUAL (9-12 November 2020)

MATS 2020
VIRTUAL (10-12 November 2020)

UNMANNED MARITIME SYSTEMS (UMS)
London, UK (25-26 November 2020)

DECEMBER 2020

OCEANOLOGY INTERNATIONAL
London, UK (1-3 December 2020)

WINDENERGY
Hamburg, Germany (1-4 December 2020)

DEEP SEA MINING SUMMIT
London, UK (7-8 December 2020)

UNDERSEA DEFENCE TECHNOLOGY (UDT)
Rotterdam, Netherlands (8-10 December 2020)

FEBRUARY 2021

OCEANOLOGY INTERNATIONAL
San Diego, CA, USA (15-17 February 2021)

SUBSEA EXPO
Aberdeen, Scotland, UK (23-25 February 2021)

Skilltrade Hydrographic
Survey Training

Since 2001 Skilltrade has been sharing hydrographic knowledge and experience. We started with a two-day Introduction to Hydrography course and evolved into specific courses like Multibeam echosounder, DGPS, RTK, Side Scan Sonar, Sub-bottom Profiler and Tides. Hundreds of people have been trained on these short courses to date.

Since 2008 we also offer a **full Hydrographic Survey Category B curriculum** as defined by the FIG/IHO/ICA International Advisory Board on Standards of Competence for Hydrographic Surveyors (IBSC). Our Cat B training is normally an intense 30 week course (a 13 weeks e-learning programme, 1 week safety training, 12 weeks training in The Netherlands, followed by a 4 weeks Field Training Project).

However, as the development of the COVID-19 pandemic is still unpredictable, we saw no realistic possibility to deliver traditional on-site teaching this year. With approval of the IBSC all lessons that can be delivered on-line will therefore be taught using digital formats for the upcoming 25th class. Workshops, practical assignments and exams will be held in The Netherlands, in line with IBSC regulations, in March 2021.

We can offer you this modified program at a substantial lower rate than our regular on-site program. With both the health and safety of the students and staff and the IBSC regulations in mind, we trust this is an appropriate way to be become a Category B Hydrographic Surveyor during this pandemic.

Handbook of **Offshore Surveying**

The series **Handbook of Offshore Surveying Volume I, II and III** is an encompassing series that is unmissable for the modern day hydrographer. This complete set of books should be on the desks of every hydrographic survey company and the professionals working for them, while it can be used as reference book for daily practice in offshore surveying in the fields of projects, preparation & processing, positioning & tides and acquisition sensors.

Please visit **www.skilltrade.nl/bookstore** for further information or to purchase them on-line.

Price: € 194,- per 3 volume set
(excluding VAT and Shipping).

Interested?
Visit our website **www.skilltrade.nl** or contact us at **office@skilltrade.nl**

SKILLTRADE

QUALIFYING FREEDOM

OCEANEERING'S FREEDOM™ AUTONOMOUS VEHICLE HAS BEEN PUT THROUGH ITS PACES IN NORWAY TO RIGOROUSLY TEST ITS SUPERVISORY CONTROL SOFTWARE

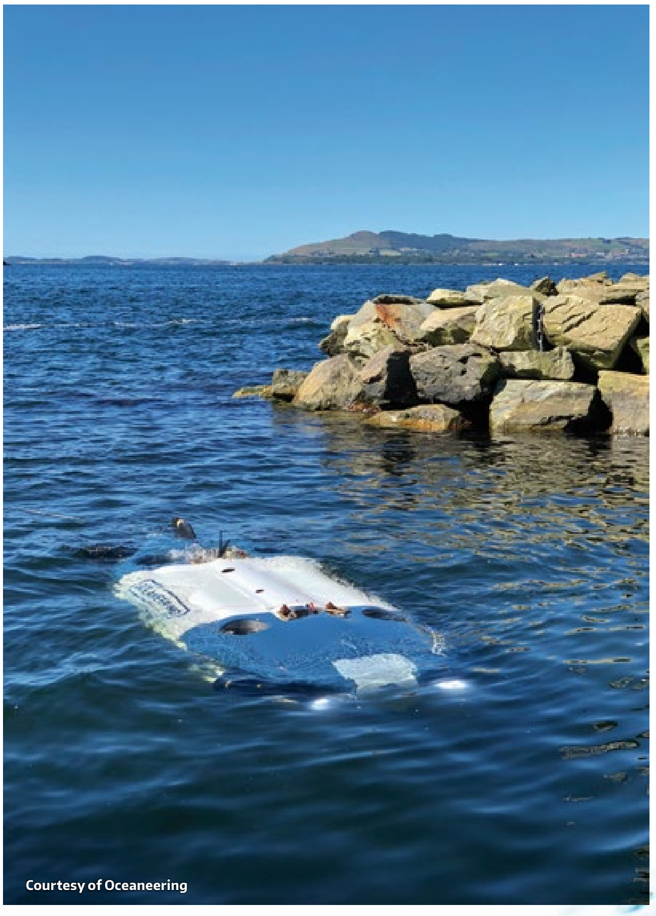
Steffan Lindsø, Subsea Robotics Product Manager, and Casey Glenn, Electrical Engineer Lead

The industry has long sought a new kind of underwater drone. One that can stay subsea for longer durations without need of a support vessel, offering more flexibility, less frequent maintenance, and reduced health, safety, and environmental risks.

Since 2004, Oceaneering has been at the forefront of remote piloting and control technology, which allows subsea vehicles such as remotely operated vehicles (ROVs) to be piloted from shore. Recent advances in offshore communication networks are ensuring that resident remotely operated and autonomous vehicles are a true option for carrying out offshore operations. Advanced subsea vehicles are benefiting from increased 4G offshore coverage along with faster, stable, and more cost-efficient satellite communications. Additionally, we are seeing more offshore installations with direct fiber to shore connectivity allowing for lower latency and higher fidelity connections.

Other key advances that have helped push forward the development of resident and autonomous vehicles are safer, more energy dense, batteries and higher accuracy aided positioning sensors. Both have seen a huge improvement since the early 2000s and these technology advances make resident autonomous vehicles commercially possible.

Oceaneering's Freedom™ Autonomous Vehicle provides a new level of efficiency by combining the work class functions of a remotely operated vehicle (ROV) with the speed, range, and maneuverability of an autonomous underwater vehicle (AUV). Freedom is supported by a docking station at seabed and can operate in two modes: remotely piloted via tether to provide real-time control – or operated in an autonomous and tetherless mode, using battery power.



Courtesy of Oceaneering

Courtesy of Oceaneering

Freedom boasts a working range of 200 km, a working depth rating of 6000 m, speed of 6 knots, and subsea deployments of up to six months.

The case for a hybrid autonomous and resident remote vehicle like Freedom, particularly in the North Sea, is evident. For example, offshore Norway, there are dozens of fields and associated pipelines located within a 100 km of the coastline. With the Freedom vehicle's long reach, it can be easily launched from the Norwegian shoreline to service these assets, dock subsea as a resident vehicle, recharge and transfer data, and move between fields to support other assets as needed

Freedom can inspect miles of flowlines and remote wellheads as it flies around the field. The vehicle, like our Liberty™ E-ROV resident system, can be remotely piloted from an Oceaneering Onshore Remote Operations Center while in tethered, free-swimming mode. While in autonomous mode, free of the tether, through-water communications will allow the vehicle to be flown real-time.

AUTONOMOUS SOFTWARE DEVELOPMENT

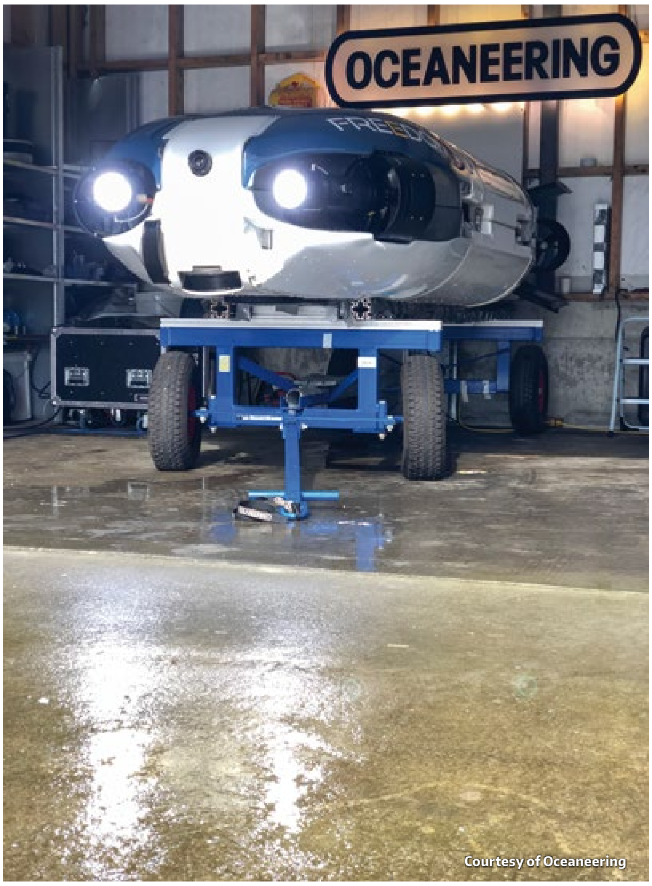
Oceaneering has focused on developing a next-generation supervisory control software for all types of autonomous vehicles, including land-based automated guided vehicles (AGV), work class autonomous underwater vehicles (AUV), and ROVs. The software is an agnostic operating system and supports various mission types. By adopting an agnostic approach, updates can be easily rolled out to an entire fleet and generate an ever-expanding track record for autonomy sub-modules. This consistency of use will result in an unprecedented amount of autonomous running hours, which will then aid in developing the confidence of customers and support their acceptance of new feature modules in a proven system.

Oceaneering sees the future of offshore energy industry robotics as a combination of man-in-the-loop operations, like our traditional remotely operated vehicles (ROVs), as well as autonomous capabilities, without anyone in direct control of the vehicle, being used to complete parts of a work scope. We believe that the line between what is remote controlled and what is autonomous will become increasingly blurred over the next few years, so much so that we anticipate every vehicle must have the capabilities to operate in both scenarios.

Freedom's software enables the vehicle to carry out low altitude pipeline inspections for pipeline surveys. The vehicle can track pipelines 1 m off the seabed to provide high resolution data. Freedom boasts maximum speeds of 6 knots, survey speeds of 1-3.5 knots, survey altitudes of 1-5 m for inspection and 8 m for reconnaissance.

This configuration of the vehicle will be able to track pipelines with unprecedented proximity and tolerances, providing significantly improved data acquisition. However, tracking a pipeline this closely adds complications. To compensate, the software includes a heightened level of obstacle detection, autonomous obstacle avoidance, and situational awareness. These features allow the vehicle to re-plan its route and re-engage with the tracked pipeline. Freedom has been outfitted with Sonardyne's SPRINT-Nav navigational instrument as well as Teledyne's Reson T20 technology.

Freedom's control software features recognition of pipeline features including free-spans, depleted anodes, mattress crossings, and anomalies which can trigger sub-missions for further inspection, thus avoiding the requirement for subsequent inspection operations post initial survey.



Courtesy of Oceaneering

Courtesy of Oceaneering

TESTING AND QUALIFICATION

In order to ensure that the Freedom autonomous vehicle meets its specifications (range of 200 km, a depth of 6000 m, speed of 6 knots, and durability of up to six months subsea), a rigorous testing schedule was required.

In March 2019, Oceaneering created a Living Lab near Tau, Norway devoted to the development, testing, and verification of the new control software and next-generation vehicles.

From the Tau site, a vehicle can be launched and controlled from the quayside and navigate to a shore-side obstacle course, which includes a subsea docking station, various pipelines, and infrastructure designed to replicate an offshore environment. This setup is used to ensure the software developed works as intended and is thoroughly tested for reliability during the development program.

The location at Tau enables daily testing of Freedom's software, both in very shallow water and water depths of up to 300 m. The facility and the test vehicle are used to evaluate software modules as they are being created by Oceaneering's highly experienced internal software development team. The team is in both the US and Norway, which allows near-round-the-clock development testing and verification. Once our US software team starts their day, they effectively have a full day's testing available to dig into and improve their code. This process has enabled us to greatly accelerate our software development and verification.

The software platform was qualified in May 2019 using a test vehicle that was more robust and well suited for the testing environment and enabled us to bump the vehicle as much as possible while testing the autonomous software. In the water at Tau, we can simulate the offshore environments that the Freedom vehicle may encounter with a variety of pipeline types from 10 m to 240 m.

In January 2020, the Freedom vehicle arrived at Tau for testing in water. In June 2020, we began testing the vehicle untethered and it is currently at an API Technology Readiness Level (TRL) 5. We expect to begin offshore trials in August/September 2020.

PROJECT TIMELINE

2017	Freedom Project Begins
May 2019	Commencement of the Living Lab Software Qualifications
January 2020	Freedom Vehicle in the Living Lab
June 2020	Freedom in Living Lab Untethered with Batteries
July 2020	Freedom Undergoing Software Reliability Qualification
August 2020	Offshore Trials
Q4 2020	Freedom in Operation

AUV Launch – Launching an AUV from an Ocean Infinity vessel. Capable of working in the deepest, darkest, and coldest reaches of the ocean, AUVs return to the surface with data that provides a detailed sense of what sonar and other sensors have revealed. (Photo courtesy of Ocean Infinity)

USS Nevada's departure from Pearl Harbor under tow by the USS Jicarilla (ATF-104) on July 26, 1948. Bearing the scars of two atomic blasts, Nevada is about to be bombed and shelled by ships and aircraft for four days before sinking. (Official U.S. Navy Photograph, Naval History and Heritage Command)

FINDING USS NEVADA

OCEAN DISCOVERY AND REMOTE WORKING IN THE AGE OF THE PANDEMIC

SEARCH, Inc. and Ocean Infinity have announced the discovery of the USS Nevada (BB-36), one of the U.S.Navy's longest serving battleships, viewed by some as the epitome of American resilience and perseverance. The USS Nevada was located 65 nautical miles southwest of Pearl Harbor, at a depth of over 15,400 feet. The discovery was the result of a successful collaboration between SEARCH and Ocean Infinity, and marks the combination of SEARCH's leading maritime archaeological expertise, and Ocean Infinity's unrivalled robotic technology and deep-water search capability.

AUV at sea. These unmanned robotic craft have revolutionized deep ocean survey and exploration.
Ocean Infinity's HUGIN AUV surveyed a hundred square mile area of the Pacific at a depth of nearly three miles to find the wreck of USS Nevada. (Photo courtesy of Ocean Infinity)

The mission was jointly co-ordinated between SEARCH's operations centre and one of Ocean Infinity's vessels, Pacific Constructor. It set sail for a range of commercial tasks in the Pacific in early 2020, before the COVID-19 pandemic. As a result of the global health crisis, the ship has remained at sea on a range of tasks. ROV Planet Interviewed Dr. James Delgado to find out more about the discovery of this iconic ship.

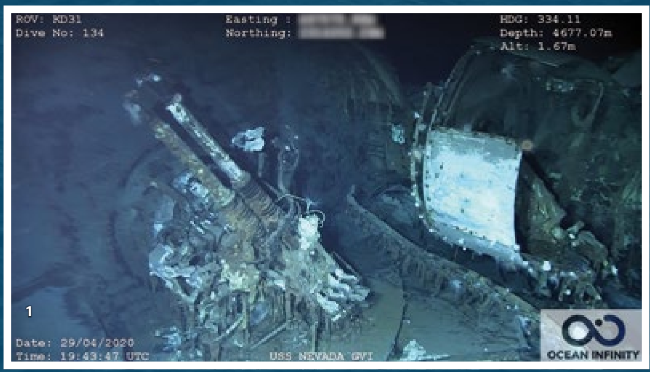
RICHIE ENZMANN: Hi Jim. Great to have you here! Please tell us more about your organisation. What kind of work does SEARCH do?

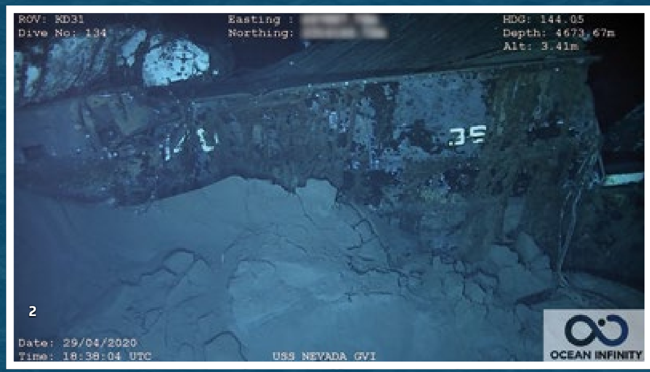
DR. JAMES DELGADO: SEARCH is the largest underwater and terrestrial archaeology firm in the United States that does cultural resources work, including archaeological work on land and underwater. This also includes historical research, historical architecture, and museum services.
SEARCH also has a branch that is helping to share archaeology with the public, and we typically do that with partners like National Geographic. SEARCH was the principal adviser for the series 'Drain The Oceans' for example. The organisation works around the world, and many of our people have extensive experience on projects, particularly in deep ocean work.

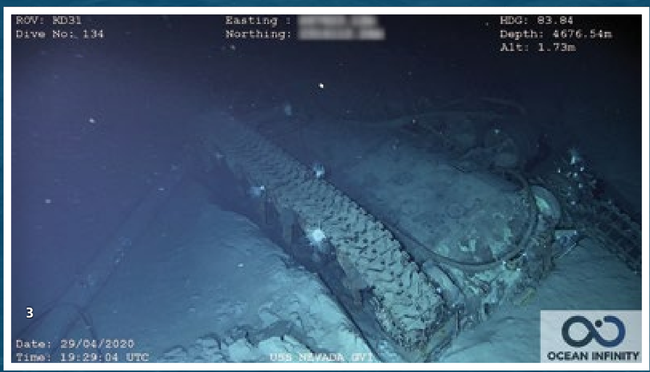
RE: How did the idea of the expedition for USS Nevada came about? What is the background to it? I would imagine that there are a lot of ships that you could have dived down to explore.

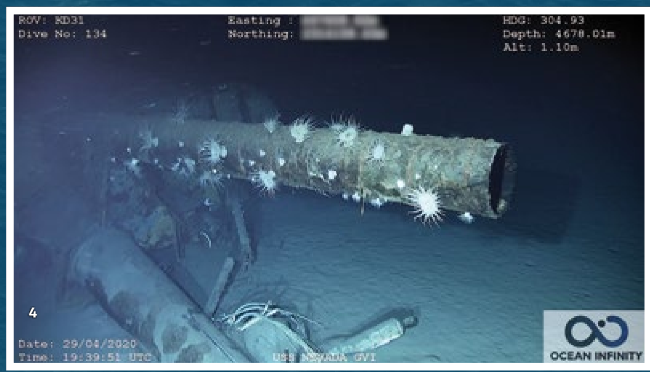
JD: I used to work for the National Oceanographic Atmospheric Administration (NOAA), where I was the director of maritime heritage. There were a group of ships that were of interest to us. We are close to areas where there are national marine sanctuaries or monuments, as well as ships tied to significant events in history. Some of those were long standing projects or desires to go and find something. But when I retired and joined SEARCH as Senior Vice President – working with my colleagues Michael Brennan and Michael Arbuthnot – we developed a list of 100 shipwrecks we would most like to find.
So at the end of April we were in discussions on the phone with Ocean Infinity's team... when we ended the conversation the question was asked, "Where are these ships today?" And when I was told that there was a ship in Honolulu, getting ready to sail, I said, "Oh, would you be interested?".
Pam Orlando – who worked with me at NOAA – had pulled the original logbooks of the ships that sank Nevada, and I had the plots from these logbooks. They have been classified for years but have been declassified lately; there is nothing secretive in them, just a matter of national security right after the War.
Looking at that, Mike Brennan and I were able to draw up a 10-by-10-mile box for survey. Some people would say that this might not be a big box. If you consider that it has not been surveyed yet and was a hundred square nautical miles in three miles of water depth, then it becomes a bit more challenging, but not if you are Ocean Infinity.
Their ships are good, their teams are very good, and their technology is exceptionally good. We sent over the information and they deployed their two AUVs on the ship... about 24 hours later they said that they got a target. There is a debris field and then what looks to be a hull. And I said, "Great. When can we take a look?" And they said, "We have launched the ROV a couple of hours ago. It's on its way." So we all dialled in. Ordinarily, we would use satellite links, but this time – with everybody being at home – we all joined in using Microsoft Teams. Mike and I watched the dive with me as the archaeological lead while they dropped down to the maximum depth of 15,476 ft. to see Nevada for the first time.

RE: Were there any difficulties or challenges during the dive? It actually seems like a straightforward "job".









1 By the end of World War II, Nevada carried thirty-two 40mm Bofors antiaircraft guns. The airplane had changed naval warfare and guns like this helped the crew fight off enemy attacks from the air. This 40mm gun, still in its gun "tub," is mounted next to a partly fallen, standard-issue Mark 51 "gun director" used by the crew to direct the fire of these guns. (Photo courtesy of Ocean Infinity/SEARCH, Inc.)

2 The stern of the wreck has the remains of "36" and "140." Nevada's designation was BB-36 and the 140 was painted on the structural "rib" at the ship's stern for the atomic tests to facilitate post-blast damage reporting. (Photo courtesy of Ocean Infinity/SEARCH, Inc.)

3 USS Nevada, like other ships at Bikini, was a floating platform for military equipment and instruments designed to see what the atomic bomb would do to them. One of four tanks placed on Nevada, this is either a Chaffee or Pershing tank that survived a 23-kiloton surface blast and a 20-kiloton underwater blast and remained on Nevada until the ship was sunk off Hawai'i on July 31, 1948. (Photo courtesy of Ocean Infinity/SEARCH, Inc.)

4 Like its sister battleships of the World War I/(early) World War II-era, Nevada's superstructure was built around a towering steel tripod mast that supported the navigation and command centers, lookout stations, and radar. This is the top of the mast that once towered more than a hundred feet over Nevada's deck. (Photo courtesy of Ocean Infinity/SEARCH, Inc.)

JD: It was a very straight forward dive... Since I began my field in underwater archaeology, we practised hard to find wrecks using technology that has rapidly evolved. Visual surveys, to the introduction of side-scan sonars and magnetometers, to taking that technology and going to the extreme depths: it's all happened quickly and within the span of my career.

I remember being in Washington D.C. in the Government when Dr. Robert Ballard found the Titanic and recognising that it was a game changer. Following that we've not only to see the technology for finding, but for close-up characterisation move forward.

I made my first dive to Titanic in 2000. In 2010 I was chief scientist when we went back and mapped the entire site with two Remus AUVs, and then with a workhorse ROV. We used these to drop down and do very careful characterisation – precision visual mapping – to come up with what people saw in 2012: these amazing full scale colour images of Titanic, not just looking down or sideways, but giving people a 3D sense about the bow and the stern. There was also the view of this articulated piece of the hull, and some of the artifacts.

Moving forward, working closely with Bob Ballard and others when I was at NOAA, I've seen that we could not only use that technology to go there, but through telepresence and with satellite links we're able to bring people "with us" from all over. That was not just fellow archaeologists, but also ocean scientists. Nowadays what you might say is, "Okay, so what?", but...they searched 100 square miles in 3 miles of water depth, found the battleship, and then took a careful look at it within a few days. That would be the stuff of science fiction just a few decades ago; now it's science fact.

And this is the way which we are going to increasingly connect, not just with science, but to connect people to this final frontier which is the deep ocean. And an ocean largely unknown: 95% unexplored, and yet so vital not only to understanding our past, but also understanding what is happening now, and what the future of life on Earth might be.

As far as we know, this is the first socially distanced deep ocean science mission with maritime heritage in the age of the pandemic, with a quarantined ship, a quarantined crew, and folks socially distanced working from home using Microsoft Teams. But what's also important is that what I said earlier.

It wasn't just us with these kinds of systems: it's others, other scientists. When we have done work in the Mediterranean, the Gulf of Mexico, the Atlantic, the Pacific, or elsewhere, we are simultaneously working side-by-side virtually with oceanographers, marine biologists of different specialties, ocean geographers, geologists, chemical and physical oceanographers, archaeologists, and historians who study every aspect of human history. All of that is made possible because you have a sophisticated ROV, with great instrumentation, hanging on to the end of a fibre optic tether, connected to a ship – being worked capably and brilliantly by the ship's crew – and then to satellite connecting the

The engraving is on the exterior bulkhead above the hatch leading into a shell handling compartment for one of USS Nevada's 5-inch/38 caliber guns. The first line of the inscription is the number of the door, the second is the designation of the compartment, and the third is the compartment number to which the door gives access. This remarkable level of preservation is occasionally found on deep-ocean shipwrecks due to the lack of light, oxygen, and the extreme cold at 15,400 feet down. (Photo courtesy of Ocean Infinity/SEARCH, Inc.)

rest of us. Then when the switch is thrown, the entire world watches as we have done with some of these missions.
Every time I'm on these ships I've always been struck by the incredible skill and knowledge of the ROV teams. They drive them because they know them, because they designed them, built them, maintained them, because they are constantly modifying them. When we used a tethered system like the Argus Hercules system with Ballard at NOAA, with that dual system looking down where the other ROV is – that's been incredible. Mike Arbuthnot, who worked with Jim Cameron used ROVs from the MIR submersibles to do dives into the Titanic to carefully survey and assess. And thanks to their work not only we have actual scenes from Titanic in Jim Cameron's movie, but also a fair amount of data that documents what Titanic looks like and what levels of preservation are inside the hull.
Referring to the work that we have done with our colleagues at Woods Hole with the deep submergence team, with the advanced imaging and visualisation lab: Bill Lange, Evan Kovacs, small ROVs that Evan has built has taken people inside the fragile USS Arizona. We could still see uniforms hanging in closets, desks and other furniture in place, frozen in time from December 7th, 1941.

RE: So do you think that this is going to be the gold standard for marine archaeology in the future?

JD: I think what we are seeing going forward is groups like Ocean Infinity practising the gold standard. But I think it is going to continue to evolve into the platinum standard! The more work that is done, the more I think we will see improvements, the more we will see connections. And I think that the connections are important when it comes back to why USS Nevada...
We were having a discussion about moving forward to the post-pandemic time when it comes, and we were also talking about the realities in this time, with people at home, and the concern that people had, the fear some people have. ... With that I thought about the Nevada.
The Nevada is an American ship, and it's career spoke to not just what happened at Pearl Harbor but with how Americans respond to crisis.
The attack on Pearl Harbor came as a stunning shock to many people. It seemed at the time with the near-destruction of the Pacific Fleet as the loss of the main battle line in Pearl Harbor... Japan were also opening the war in the Pacific with assaults in the Philippines, Wake, Guam, and elsewhere. Americans could rightly feel that the country was on the ropes. The next day the President of the United States stood up and while noting the attack was a day that would live in infamy, he also promised everybody an inevitable triumph.
Nevada spoke to that: that human ability. Sometimes when... you have been knocked to the mat; you get up. You are resilient, you bounce back, maybe because you are stubborn. And so, with that I said let's find Nevada to focus on that message.

We more or less knew where she was, but now was the time to pinpoint that... Let's respectfully film it, and let's share that not just with the United States, but with the world as a reminder; there have been dark times in our history, and yet we persevere. The response we have seen from the public and from other countries: the news spread internationally. Just the other day, the story was in the Washington Post. In the comments section, where there are always a few people that want to say less-than-nice things, many people said thank you. They were inspired by it and said it made the Memorial Day holiday extra important this year. It reminded people that this wasn't just a weekend that went for three days and you had a day off to go to a BBQ, but because the freedom to do so has been secured in this country and in other countries by those who had shed their blood, sacrificed their youth, and their families who saw people never come home. There were also those who came home wounded...those sacrifices have given us – pandemics and other struggles notwithstanding – the most prolonged period of peace between major powers in the history of the modern world. So that is why we did it. We didn't get paid for it, neither did Ocean Infinity. It was done because it was the right thing to do.

RE: That is quite an interesting parallel to make between the COVID-19 pandemic and Pearl Harbor. I can see the connection there and where you are coming from.

JD: Well, human history does have a tendency to repeat itself. But with that, hopefully we will learn each time.

RE: What is going to be the next thing? Any more expeditions and discoveries in your pipeline?

JD: Well, we've still got a list of 99 wrecks left. Having said that, sometimes discoveries are made that you are not looking for. For me and the rest of our team, and for our colleagues at Ocean Infinity, the quest is always there to make meaningful discoveries. We want to connect to the past as well as to the ocean frontier...it's so vital to this planet, for our survival, and also a reminder that you never know what's just around the corner.

Kraken SeaThrust™

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Kraken's SeaThrust™ is a rim-driven, centerless motor with a seawater lubricated bearing. Direct drive means it doesn't suffer the efficiency losses of a typical gearbox, and the centerless propeller means it won't get fouled by debris. This makes it the perfect choice for AUVs and ROVs.

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- Low maintenance
- High performance at a low cost
- Easily integrated

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KRAKEN

NOAA TESTS DRIX

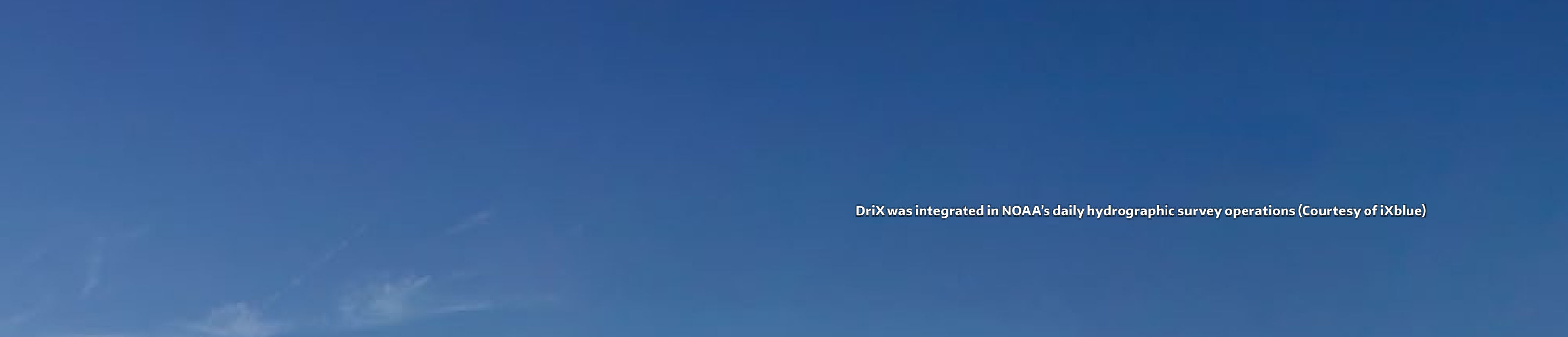
TO DEMONSTRATE SURVEY FORCE-MULTIPLIER CAPABILITY

The end of 2019 saw DriX sailing alongside a U.S. NOAA's (National Oceanic and Atmospheric Administration) hydrographic survey vessel, NOAA SHIP Thomas Jefferson for a series of sea trials. Those tests, designed to demonstrate hydrographic survey force-multiplier capability in offshore waters, were successfully conducted thanks to the ship's crew, DriX and its unique Deployment System (DDS).

"We had the chance to meet with NOOA's Office of Coast Survey Director, Rear Admiral Shepard M. Smith, right after the launch of DriX in December 2017" explains Guillaume Eudeline, Global Business Developer for the Shipyard division. "He is advancing NOAA's Office of Coast Survey initiatives by modernizing digital charting, and by increasing the use of autonomous systems for hydrography and was truly impressed with DriX capabilities. We worked through an industrial partnership with the University of New Hampshire in order to test DriX and assess how NOAA and the U.S. hydrographic community could benefit from our USV."

DriX Deployment System (DDS) has been designed for the safe and efficient launch and recovery of the USV (Courtesy of iXblue)

One DriX was subsequently sent to New Hampshire (New England) in October 2018 and stayed with UNH for over a year. The University's team of surveyors ran a series of tests to assess how DriX could



DriX was integrated in NOAA's daily hydrographic survey operations (Courtesy of iXblue)

DriX being deployed from the Thomas Jefferson survey's launch davit (Courtesy of iXblue)

be operated in the field, and if it could be used to conduct continuous survey operations in unchartered waters to increase surveying efficiency.

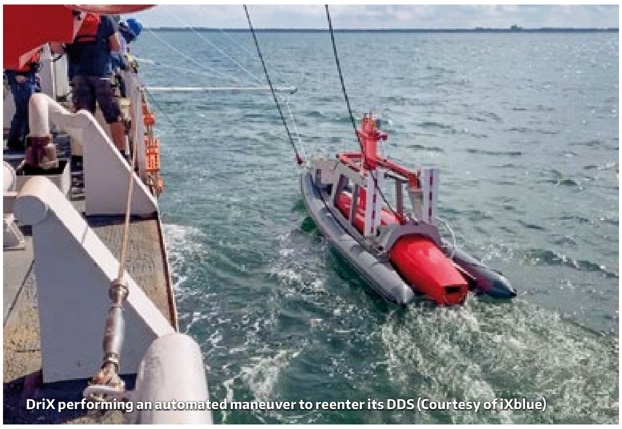
The tests being a success, NOAA decided, in October 2019, to integrate DriX into its daily hydrographic survey operations in a field trial, to see if iXblue's USV could overcome the drawbacks of many ship-deployable USVs such as their speed, sortie endurance, ability to collect multibeam data in moderate sea states, as well as the difficulty in deploying and recovering them from a pitching and rolling ship in a seaway. USVs' launch and recovery is indeed a true challenge for operators trying to bring more autonomy in their surveys and represents about 50% of the operational effectiveness.

"The tests, during which we learnt a lot, were overall another great success and NOAA was truly pleased with the DriX evaluation and that of its DDS, as it demonstrated a novel, custom-designed method for deployment and recovery via the Thomas Jefferson's installed survey launch davits," concludes Guillaume Eudeline "It was also a great opportunity for iXblue to work with an iconic administration, and benefit from their first-rate feedback, opening possibilities for improvements. We now look forward to the next steps in our collaboration, with further sea trials in 2020."

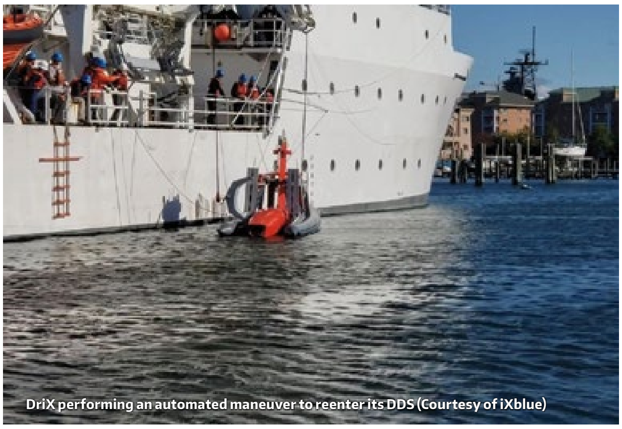
DRIX DDS: A FUNCTIONAL LAUNCH AND RECOVERY SYSTEM

Certified by Bureau Veritas, the DriX Deployment System (DDS) has been designed for the safe and efficient launch and recovery of the USV. Benefiting from a RHIB shape and making use of either one or two lifting points, DriX DDS can be deployed from a davit, a crane or an A-frame. On this particular occasion, the Thomas Jefferson's Vestdavit was temporarily altered with the addition of a removable metal adaptor, bolted on the existing structure, that acted as a cradle for DriX and its DDS during the sea trials.

DriX furthermore benefits from an auto-docking capability, which enables the USV to perform an automated maneuver to reenter its DDS, without the need for human intervention. The auto-docking capability relies – amongst other things – on continuous exchange of positioning information between DriX (provided by its embedded GNSS and Phins C7 INS) and the DDS (through its GNSS and Quadrans AHRS). This auto-docking will be a feature of future trials on the NOAA Ship Thomas Jefferson.



DriX performing an automated maneuver to reenter its DDS (Courtesy of iXblue)



DriX performing an automated maneuver to reenter its DDS (Courtesy of iXblue)

More information about these sea trials can be found at:

FILM-OCEAN INVESTS FURTHER IN NEW WORKCLASS ROV

DELIVERING OUTSTANDING SOLUTIONS TO MATCH GLOBAL OFFSHORE DEMANDS.

Film-Ocean, a renowned expert in specialised ROV systems for the offshore energy sectors; oil and gas and renewables, has announced its latest investment in an additional Workclass ROV.

Courtesy of Film-Ocean

Courtesy of Film-Ocean

The company recently invested in a further Quasar Workclass ROV, adding to its growing rental fleet of ROV systems, tooling suite, and auxiliary equipment. All of this helps which ensure that Film-Ocean can meet increasing demand and enables them to improve their availability of Workclass ROVs to support their global client base.

Film-Ocean's Quasar 150HP Workclass ROV is a medium-sized high-power Q-Series Workclass ROV offering high thrust performance, tooling/instrument capability, instrument space and ease of access for maintenance, utilising the latest multi-platform Curvetech™ components. The Quasar ROV systems are fitted with enhanced survey upgrades which accommodate a variety of sensors and tools.

The Quasar system is contained within control containers, allowing the equipment to be installed on vessel's back decks or fixed/floating platforms. This can help to reduce costs during mobilisation.

Working at a maximum depth of 3000m, the Quasar is a proven workhorse of the industry. It can successfully perform a vast selection of complex tasks required by the offshore energy and marine sectors.

Film-Ocean has been specialising in providing innovative, cost-effective subsea solutions for global clients since 2004 and has an extensive and established track record. Their latest acquisition of an additional Quasar will help to accommodate the growing demand and allows them to undertake more projects. An example of the type of work that they have mobilised ROV systems for includes:

| Pipelaying or pipeline inspections and surveys
| Platform/Offshore wind and subsea structures inspection
| Cable inspection and maintenance
| Exploration drilling/field installation support
| SPS installation completions
| Work-over operations
| Construction – subsea infrastructure installation and support
| Drilling and completion support
| Offshore decommissioning
| Offshore Wind Farm – pre-installation surveys

Film-Ocean's ROV systems support a wide variety of operational activities in addition to their offshore field experience and a fleet of over 20 different ROV systems. They are well equipped to deliver solutions for project-specific challenges. Each project is supported through all stages; from deployment to completion by Film-Ocean's team of highly skilled, qualified, and competent onshore and offshore personnel.

Film-Ocean delivers inspections on pipelines, offshore structures, and subsea equipment in water depths where divers can't operate. The Workclass ROV's are equipped with Schilling manipulators and intervention tooling capable of working at depths of up to 3000 metres.

The ROV fleet frequently supports both pipelay and pipeline projects. They are regularly deployed for pipeline surveys, inspection, repair, and maintenance (IRM), including internal and external investigations of underwater pipelines. Clients can use the high-resolution imagery and real-time data, collected by Film-Ocean's ROV's to make informed decisions on pipelay strategies, pipeline maintenance, and replacement programmes. All of this can extend the pipeline's lifespan.

Further services include visual inspection of structures, scour monitoring, cable touchdown-point monitoring, and measuring cathodic potential.

With Film-Ocean's extensive subsea expertise, a wide range of ROV systems, and technical support team to manage each project, they can accommodate the demands of oil and gas subsea operations, including drilling and completion support. Integrity inspections on floating and fixed structures are routinely conducted by Film-Ocean, with equipment that can be deployed directly from the asset or support vessel.

The Quasar Workclass ROV is stable in strong currents, and its independent hydraulic system which runs high power tools ensures the ability to undertake decommissioning operations.

Film-Ocean's Workclass ROV's also support the offshore renewable sector where their capabilities and tooling can be utilised for operations relating to pre-installation, construction, and maintenance of offshore wind farms. Established fixed and floating offshore wind farms need long-term installation, maintenance, and repair (IMR) to include inspection and control of connection and cable networks, all of which is supported by Film-Ocean's ROV rental fleet.

Providing cost-effective solutions is one of Film-Ocean's core values, and with the addition of another Quasar ROV, clients will be provided with numerous benefits, such as:

- Excellent performance and high versatility
- Configurable for a wide variety of projects
- Field-proven
- Fitted with enhanced survey upgrades accommodating sensors and tooling
- Supported by a team of highly skilled, experienced, and competent personnel on and offshore
- Withstands environmental conditions such as low visibility and high currents

Film-Ocean offers the complete ROV solution for oil and gas, decommissioning, offshore wind, marine, and salvage operations.

Film-Ocean's fleet includes a range of ROV systems – from Workclass to micro ROVs. They stock an extensive range of ancillary equipment, including subsea cleaning equipment, torque tools, and pipe trackers. This comes alongside a range of specialist in-housing inspection tools, all of which are managed by Film-Ocean's team of highly capable personnel.


Courtesy of Film-Ocean

Film-Ocean's facilities in Ellon, Aberdeenshire are ideally suited to mobilise systems for projects in the North Sea and the Norwegian Sea. They also cover global projects in West Africa and the Middle East, where they operate out of Stapem Offshore facilities in Qatar and Angola.

Over recent years, Film-Ocean has seen a growing demand for Workclass ROVs. Its new investment in a further Quasar Workclass ROV ensures they are fully equipped to supply clients with a complete range of ROV solutions, to support specific project requirements globally.

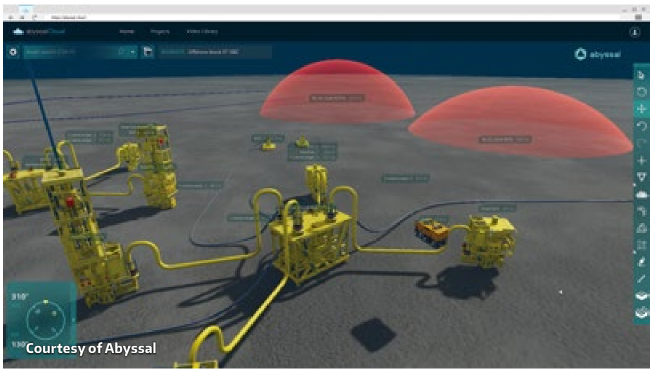
Scott Jenney, CEO at Film-Ocean, said of the recent acquisition, "Film-Ocean has a renowned reputation for providing outstanding, high quality and cost-effective solutions. I know that our latest investment in the Quasar will ensure that we can offer clients an enhanced solution to support projects globally."

Courtesy of Abyssal

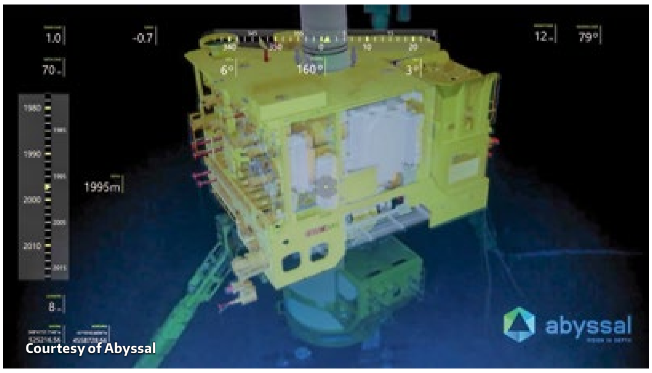
THE ABYSSAL ECOSYSTEM

THE EASY, SAFE, AND EFFICIENT SOLUTION

The Abyssal Ecosystem provides you with a suite of solutions that ensure you have exactly what you need throughout all stages of your project. From FEED and Life of Field, until decommissioning, Abyssal's advanced solutions tie into third-party tools, devices, and vehicles seamlessly to ensure that you can execute all your tasks from anywhere in the world. Whether it is designing subsea fields, simulating and monitoring operations, or collaboratively evaluating missions, the Abyssal Ecosystem ensures that you can do it safely, efficiently, and remotely.



Courtesy of Abyssal

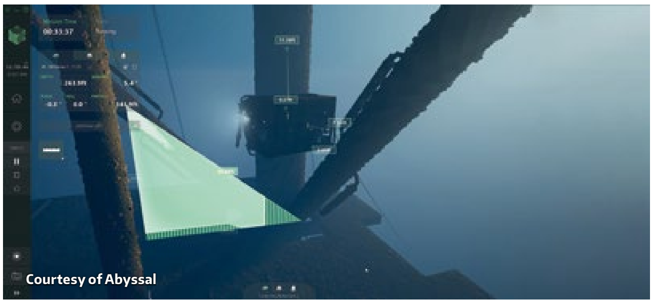


Courtesy of Abyssal

DESIGN AND MONITOR FROM THE BROWSER

Abyssal Cloud, a fully-fledged browser-based application, gives you a birds-eye view of your subsea fields, contextualised with additional sources, such as vessel localisation and weather information. It also allows you to collaboratively design your fields in 3D with GIS-backed survey-grade accuracy.

Any alteration is available in real time, resulting in engineers no longer having to be onsite in order to view the status of the field; from anywhere in the world they can access the 3D representation of a field, manipulate it, and collaborate as a team on ROV routes. Once ready, use the field and plan multiple simulations of your next mission.



Courtesy of Abyssal

PLAN, SIMULATE, AND TRAIN

With your digital field available anywhere and anytime, you can plan any intervention beforehand. This means more visualisation and context in your meetings for enhanced stakeholder communication, identifying any potential issues, and define contingencies.

Combined with a state-of-the-art real-world physics engine, you can plan and navigate through your mission, with a 3D-modeled 360-degree view of your environment. Use it to run countless mission permutations, discover and account for problem areas, and reduce ROV intervention training time for pilots by up to 30%. Most importantly, before committing to a real-world mission, you are guaranteed to have prepared to the highest degree. All combined, Abyssal Simulator provides you with the most advanced mission planning tool, ensuring that your operation can be executed optimally and safely.

EXECUTE MISSIONS WITH THE MOST ADVANCED TOOLKIT

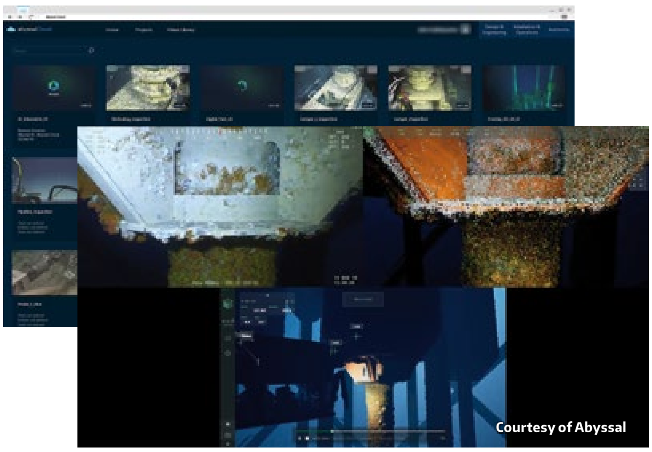
Having planned and run countless bespoke simulations, pilots can then operate missions in the field with Abyssal Offshore. Providing pilots a complete digital toolkit that includes an advanced overlay system that enhances visibility, augmented reality, and spatial contextual awareness, Abyssal Offshore has been field-proven to improve pilot navigational efficiency by up to 40%, and eliminate downtime in low visibility conditions.

An inbuilt media manager that captures, tags, and allows for easy management of screenshots is readily available, alongside an advanced DVR which allows multiple HD camera feeds recording simultaneously. Dive Logs can be created with every relevant piece of information, such as metadata, screenshots, video, and then exported in portable HTML5 reports, for an efficient, customised delivery.

CAPTURE AND CONTEXTUALISE

Your mission videos are automatically uploaded, processed, and analysed in Abyssal Cloud, updating your 3D representation of the field with the most up-to-date data. Not just used for field planning, Abyssal Cloud contains a comprehensive video database where offshore videos are automatically stored, played, and correlated with other intervention data such as telemetry.

Several advanced AI models evaluate your videos to update and contextualise your 3D subsea field, identify integrity threats, and improve your simulations. Fully indexed and tagged, your mission videos can be securely accessed in the browser from anywhere in the world by clicking on an ROV flight path or searching for your desired entities. With your videos in the cloud, you can easily set up any command centre, custom made to suit your needs.



Courtesy of Abyssal


Courtesy of Abyssal

BUILD FROM LEGACY VIDEOS

Designed with safety in mind, the Abyssal Ecosystem does not depend solely on information gathered from videos recorded after the suite has been installed. Upload thousands of hours of legacy video footage to Abyssal Cloud, and our advanced video processing AI volumetrically reconstructs every object captured during the mission in 3D, and places it to within half an inch of its real location on the globe. Enriched with metadata, having used AI algorithms to create annotated missions in 3D and identify structural threats, you can historically contextualise your operations and fields easily.

CONSTANTLY LEARNING AND CONTEXTUALISING

The information gathered during missions and legacy video is leveraged with Abyssal AI, improving the ability to understand, reconstruct, and contextualise new or legacy data.

Learning from every mission, the AI is able to measure biofouling thickness, determine pipeline integrity threats, and identify subsea entities, without spending hours reviewing images and subsea videos. All of this continuously feeds the 3D representation of your field, making sure that at every stage of the project – from designing, to simulating, and executing – you will have the most advanced and contextualised information on hand to efficiently and safely run your operations.

Abyssal – the most advanced software suite for monitoring your operations safely, efficiently, and environmentally friendly from anywhere in the world.

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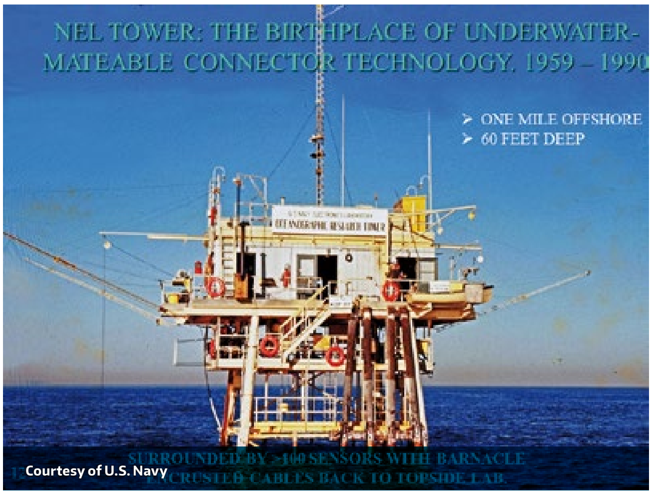
THE HISTORY OF
UNDERWATER WET-MATEABLE CONNECTORS
FROM THE INVENTOR'S POINT OF VIEW

Dr. Jim Cairns

I came to this industry in the 1960s and in the intervening 60 years I've been intimately involved with these products, first as a user, and then later as an inventor, and even later as a manufacturer. So, I'd like to tell the story of their history from the point of view of someone who has invented some of this technology. I'd like you to experience how hard it is to introduce new technology into an industry, and the roller coaster ride that sometimes takes the inventor through low periods of abysmally disappointing failure and other times through euphoric high points of success.

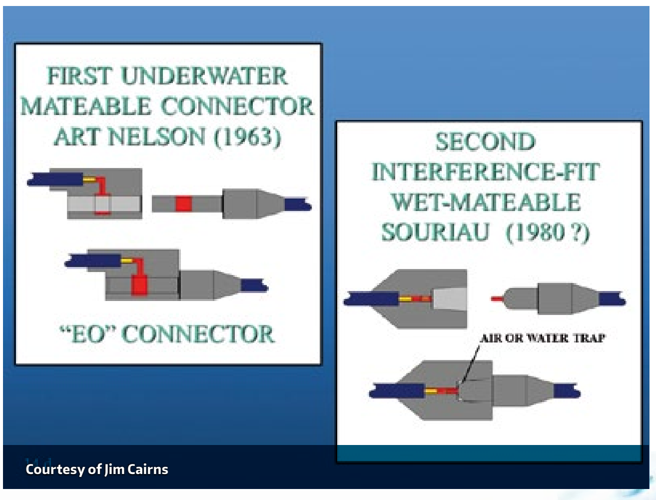


Courtesy of U.S. Navy

The Navy Electronics Laboratory (NEL) offshore tower was built in 1959 for the Naval Electronics Laboratory (now SPAWAR), which is in the Point Loma area of San Diego, California. I refer to the tower as the birthplace of underwater mateable connector technology. It was built one mile offshore of the San Diego community of Mission Beach, in water 60 ft deep, which is a nice depth for a research tower particularly because it's an easy diving depth. You could make 2 or 3 dives a day there on compressed air... short dives, but without worrying much about decompression. The tower in its early years was a beehive of activity. It was surrounded by upwards of 100 sensors, most of them attached to cables that went from the platform seen in the figure, down the tower legs, and maybe 200 or 300 hundred feet away from the tower, and thence upward to subsea buoys in vertical arrays. It was used as a research platform by the scientists at NEL and very often by the researchers at Scripps Institution of Oceanography.

In the tower's heyday a man named Arthur Nelson had responsibility for its operations and had the chore of keeping all those sensors working: replacing them, setting up new experiments, knocking down experiments, and so on. During his time there he came up with the World's very first – to my knowledge – underwater mateable electrical connector. It was of a sort called "interference-fit" connectors.

The below sketches don't necessarily represent exactly what these connectors look like today, but they show the essential ingredients of two types of existing interference-fit connectors. The panel on the left shows a schematic of Art's 1963 connector. The grey areas represent elastomers, such as rubber. In the upper left panel the receptacle



Courtesy of Jim Cairns

unit is cut-away in half, so that you can see a lighter shade bore that goes through it. The red portions are electrical contacts. The plug connector on the receptacle's right has an elongated shaft with an electrical contact somewhere along its length. When the connectors mate, the plug shaft goes into the bore of the receptacle. It's slightly larger than the bore of the receptacle so it makes an interference fit with the receptacle's rubber bore. The schematic just above the "EO" CONNECTOR label shows the connector mated.

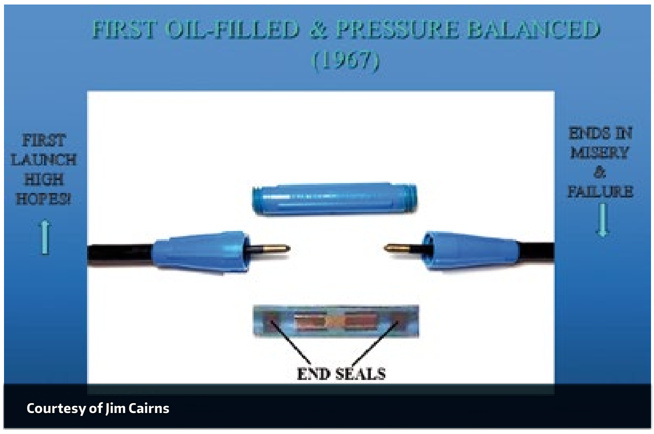
The schematic on the right illustrates the second type of interference-fit underwater connector. This one was first produced by the French company Souriau about a decade or two after Art introduced his. Here again, in the Souriau connector schematic, the grey areas represent an elastomer. In the plug unit on the right you can see a red contact. Another red contact is at the base of a tapered recess into the face of the receptacle. The plug has a rubber base around its pin with a conductor sticking out the end. When the Souriau connector is mated, the plug pin goes into the tapered bore. The water or air it displaces is forced out back past it, and when fully mated the interference fit between the tapered bore and the fat base on the plug pin form an interference-fit seal.

The EO and Souriau designs are, to my knowledge, the only two sorts of interference-fit wet-mateable connectors on the market. Both are now made by several suppliers.

These interference-fit connectors are excellent products when used correctly in the proper environment. But they are not good for every operation and every environment. For instance, if mated in water that has a lot of suspended sand and silt, that material gets pulled in and interferes with the seal, possibly allowing electrical leak paths out to the saltwater surrounding the connectors. That's one disadvantage, and operators must be careful where these are used. Another disadvantage is that they often do not come apart under high pressure.

When Art Nelson started Electrical Oceanics to produce what are now called "EO" connectors, he left the U.S. Navy lab and quit his work on the tower. The man who took over many of his responsibilities there was me. And so, I also had a lot of responsibilities for keeping the sensor arrays working. When Art was still on the tower, he connectorized many of the sensors, but his early connectors were as much of a problem as were the breakdowns of other sorts.

As I worked on the tower, I thought that there must be a better way to make electrical connections underwater. I had the not-very-profound realization that the real problem was trying to mate these electrical contacts in corrosive and conductive seawater. That's always going create problems of one sort or another, unless you're very lucky. The idea that came out of that thought process was to not make the connections in seawater at all, but to make them in a benign fluid bath (non-conductive), and to keep that bath sealed from the outside environment. From that thinking I proceeded to design what I think is the first of the second kind of wet-mateable connectors: the "fluid-filled, pressure-balanced" kind.



Courtesy of Jim Cairns

As illustrated in the above figure, the designed connector consisted of three parts: The upper cylindrical portion was a capsule, and the lower two portions were electrical plugs. The plug pins had pointed conductive tips and insulated shafts. The lower panel is an axial cutaway of the capsule showing a central barrier that blocked the two halves (left and right hand portions) of the capsule from each other. The barrier seated back-to-back electrical receptacle contacts, each in its own separate chamber. There was an end-seal at the end of each chamber. The end-seals were tubular with outer diameters slightly larger than the capsule bore, and inner diameters very slightly smaller than the plug pins. The outboard surface of each tubular end-seal had a membrane over it. As the connector mated, each plug pin pierced the membrane of its respective end-seal and went on into a fluid-filled chamber wherein it mated to a receptacle contact. To compensate for the fluid displaced by the entering plug pins, the end seals moved outward in the capsule. The end-seal movement also compensated for any volumetric thermal or pressure changes that might subsequently occur in the fluid.

This remarkably simple first connector had every ingredient that all subsequent fluid-filled pressure-balanced connectors have. It had penetrable end-seals which wiped the pins clean as they entered the fluid chamber where, sealed within a benign fluid from the outside environment, they mated to receptacle contacts. When I conceived of this invention, I was working for the U.S. Navy as a civilian. I asked the NEL patent committee to patent on it on my behalf, and they did. They didn't want any rights to it, so they assigned all the rights to me. As you can imagine, that was an exciting moment of high hopes for a young inventor with his first patent. I took the patent and my rudimentary models to San Diego connector manufacturer Brantner & Associates, run by Bill Brantner. I asked Bill if he would take a licence for a year and see if he could make it and sell it, and he took it. Brantner & Associates invested money for injection and compression moulding tools, for plug pins and terminations, manufactured the product shown in the previous

Courtesy of Jim Cairns

Courtesy of Jim Cairns

figure, and attempted to market it. However, at the end of one year my high hopes completely sank and misery followed; nobody wanted to buy it. Bill gave up on it. When that failed, I decided to take another approach to the oil-filled pressure-balanced technology.

The above figure shows the next generation of oil-filled technology, I called it "Pisces." If you look at the lower portion on the left, you can see the open face of the plug. It has four blade-like electrical contacts with insulated shafts and conductive tips. On the right, on the receptacle's face, there are four slit-like openings to accept the plug contacts, and there's a central hole which went down into an elongated bladder within the fluid chamber. The bladder compensated the fluid pressure within the chamber to the environmental pressure. The red material behind the receptacle face is an elastomeric seal with four slits to sealably accept the plug pins. This design followed my previous one by a few years.

Again, I went back to NEL and asked if they would file a patent on my behalf; this time they said no. They could see no interest whatsoever in connectors that could be mated and unmated underwater, so they gave me all rights to it. I went to my own attorney and patented it. Then, I again went to Bill Brantner and offered him a licence for the new product. Bill took a one-year licence. A young engineer at the time, Pat Simar, whom many of you knew, finished up the designs and the company made nice prototypes, but after a year Bill was not able to do anything with it. Brantner & Associates turned out to be a hugely successful company, later becoming SEACON. Even back then they were a good company, but they didn't have what it took that year to get the product on the market, so once again what started out with very high hopes ended in failure.

When Bill Brantner gave up his licence, I had his prototypes on my bookshelf at home and a good friend and neighbour of mine at the time, John Folvig, saw them. He offered to try to license the technology again. John was a graduate student completing his MBA, and I was a full-time graduate student at Scripps. John had a little bit more time than I did so he took on the licensing task. He quickly licensed it to Amphenol, a very prominent company, but their engineers wouldn't do anything with it. That is something inventors run into from time to time when they go to a big company; their engineers just don't want to fool around with an outside inventor, so after the end of the first year they gave up and we took the licence back. Flopped again!

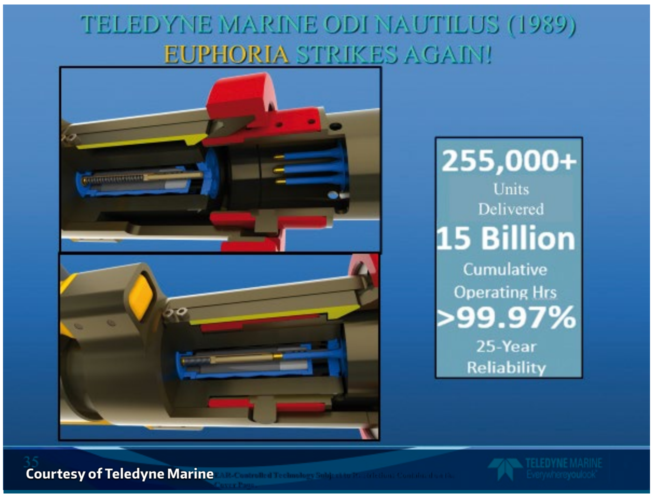
John licensed it again to a third company that worked on it for another year, and they too gave it up; another disappointing failure. The fourth and last licencing agreement was with Viking Industries. The very robust and reliable product that you see in the preceding figure was built by Viking. They put it through an immense number of qualifying tests. It past them all, but then again at the end of the licencing agreement (now more than four years after the product was first licensed to Brantner) they couldn't get anybody to buy it. We had gone through four periods of high excitement, each followed by dismal failure.

When I finished my graduate work I took a three-year research contract with NATO at La Spezia, Italy and John went off to do other things. Three years in Italy changed my outlook on life. I loved doing research, but I really wanted to see if I could make a living as an inventor: a bold move for someone who had never yet sold a product, but I did it. When I got back to the States I invented, for reasons I cannot explain, a coaxial wet-mateable connector. The only reason I can think of why I might have done that, was that no such product existed in the world at the time, and I thought tapping into a different market segment might work. John Folvig and I decided to pool our funds and start a manufacturing company. We called it Challenger Marine, and we ran it out of half of a small building in a rural Florida town. We bought all the moulding presses and everything we needed to start making connectors. When we were set up, and pretty much knew what that connector was going to look like, we made a hand-drawn sketch of it including specifications. We bought a magazine mailing list and sent it out. Surprisingly, a couple weeks later we were getting calls from every major defence contractor in the United States.

Everybody wanted to know about our technology, and a short time later three gentlemen in dark suits from Lockheed showed up. They wanted to buy our technology and they also wanted to buy us. Their proposal was so tempting we couldn't refuse. They offered to set us up in a proper manufacturing plant; they gave us all the engineering help, programme management support, quality assurance support, and everything we needed. A short time after we were in the new factory, we were able to build a coaxial connector that satisfied their programme requirements. What we didn't know, until much later, was that there was a very important government programme that had been stuck for several years because there was no coaxial connector that would mate underwater, and ours fulfilled their requirements.

So, after more than 15 years of agonising failures and ups and downs we had the euphoria of a very great success. I can tell you from an inventor's view, to see a problem, solve the problem, develop a product to fulfil the needs of that problem, and then to see it out in public use letting people do things that they could never do before; boy, that's an euphoric moment! To me it's the greatest feeling in the world.

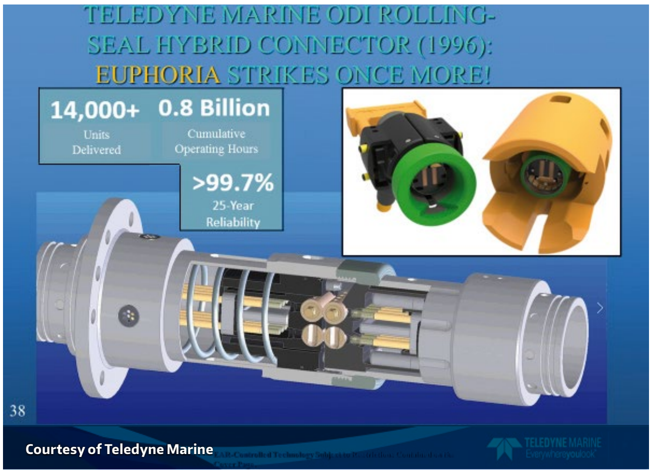
Anyhow, after Lockheed had successfully completed their government programme, they bought the company from us. It became Lockheed Challenger Marine. Once the government programme proved the high reliability of these fluid-filled connectors, offshore oil company engineers finally accepted them. And I would say in the decade following that they pretty much became the gold standard for subsea oil well completion systems. So, after many years of trying to introduce the fluid-filled wet-mateable connector technology, it was finally accepted!



Courtesy of Teledyne Marine

When we sold Challenger Marine to Lockheed, I moved back to Italy for a few more years. While there, I decided to try to design the most reliable, versatile, wet-mateable connector I could think of, without regard for cost. And the product I came up with was called Nautilus. When I patented this design, I went back to John Folvig and asked if he would join me once again – and he did – and in 1989 we formed Ocean Design, Inc.. Nautilus was our first product.

Briefly I will explain how it works. On the upper right in the figure, you can see plug pins, the dielectric portions of which are blue. Three plug pins are visible from this point of view; you can't see the fourth. Each pin has a long insulated shaft with a conductive tip. On the left-hand upper portion you can see a receptacle with one circuit partially cut away. It houses a white piston and a spring. The spring is in an electrically conductive tube that goes back to the termination portion of the electrical contact. The tube, having an electrical contact on its forward end, is contained in an individual fluid-filled bladder. Each circuit is like that, and those individual circuits are all contained within an overall fluid-filled bladder. When the connectors are mated, as you can see in the bottom panel, each plug pin enters the receptacle end-seal and pushes its respective dielectric piston back against the spring. The pistons have been keeping the end-seals busy while unmated. As each pin enters, corrigated elastomeric end-seals stretch and seal around it. The corrugations collect any contamination that might have been drawn in by the pins. The pins and sockets engage in the fluid filled chambers, doubly sealed from the outside environment.



Courtesy of Teledyne Marine

Once again this was a huge success and of course John and I were very happy with that. Right now, over a quarter of a million of these units have been delivered with 15 billion hours of accummilating operating time and nearly 100% reliability. I would say that if there were some failures, they were probably in the early years when fastedious deck-hands would rinse them off in kerosine before and after use... the elastomers didn't like that very much .

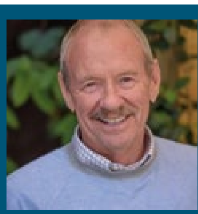
The last product I'm going to mention is Teledyne ODI's Rolling Seal Connector. In the upper right-hand panel you can see two beige parallel lines in the faces of the connector's plug and receptacle. These are the protruding faces of cylindrical end-seals. When the connectors come together, the plug and receptacle cylindrical end-seals press tightly against each other. In the lower panel, which is a cutaway, you can see in the opposed end-seals pressed together in the initial part of the mating sequence. You can maybe see that in each of those cylindrical end-seals there are bores orthogonal to the long axis of the connector. Those bores are also filled with oil and are within the oil system of the plug and receptacle before mating takes place. As the connector plug and receptacle mate, those opposed rolling seals are actuated to turn in opposite directions like the wringers of an old washing machine, so any material that's been trapped in between them when they first come together is rolled sideways and out of the area where the connections are going to be made. Those through bores roll into alignment with the plug pins, then the pins proceed through them to penetrate the receptacle on the left.

You will see likenesses between this and the other wet-mateable connectors in that the plug pins have insulated shafts (beige in the figure) and conductive tips. In this case the tips can be electrical or optical, or any mix of those. You will also see one difference: the plug half of the connector is also oil-filled and has a flexible bladder (dark in the figure). That of course is very necessary for optical connectors because the optical contacts have to be kept immaculately clean. So, as the connectors mate this is the sequence: the rolling seals push together, the rolling seals roll, the through-bores rotate into axial alignment, any material trapped between the rolling seals is moved off to the side, the plug pins go through those through bores and finally engage the receptacle contacts in the receptacle's fluid-filled chamber.

Since 1997 there have been over 14,000 of these connectors delivered, with nearly a billion hours of cumulative operating time, and once again pretty darn close to a 100% reliability. This is another hugely versatile and reliable product.

I thank Teledyne for loaning these images to me. I have to say I have a great paternal attachment and pride in Teledyne, and I'm very grateful to them for carrying this technology forward while continuing to keep up reliability and improving the versatility of the products.

ABOUT DR. JAMES CAIRNS



Jim is the father, the pioneering inventor, of underwater wet-mateable connectors that have enabled so many vital subsea systems from cable observatories to tsunami early warning systems. He is a physicist, oceanographer, and lifelong inventor with more than 60 issued and pending US patents. His most successful inventions have been components of subsea fibre optic and communications networks. He has cofounded two significant companies; the first: Challenger Marine he sold to Lockheed Corporation in 1985, and the second: Daytona Beach based Ocean Design, Inc. (ODI) sold in 2009 to Teledyne. In 2003, Jim started the Cairns Foundation, a charitable organisation supporting and encouraging innovation by creative students.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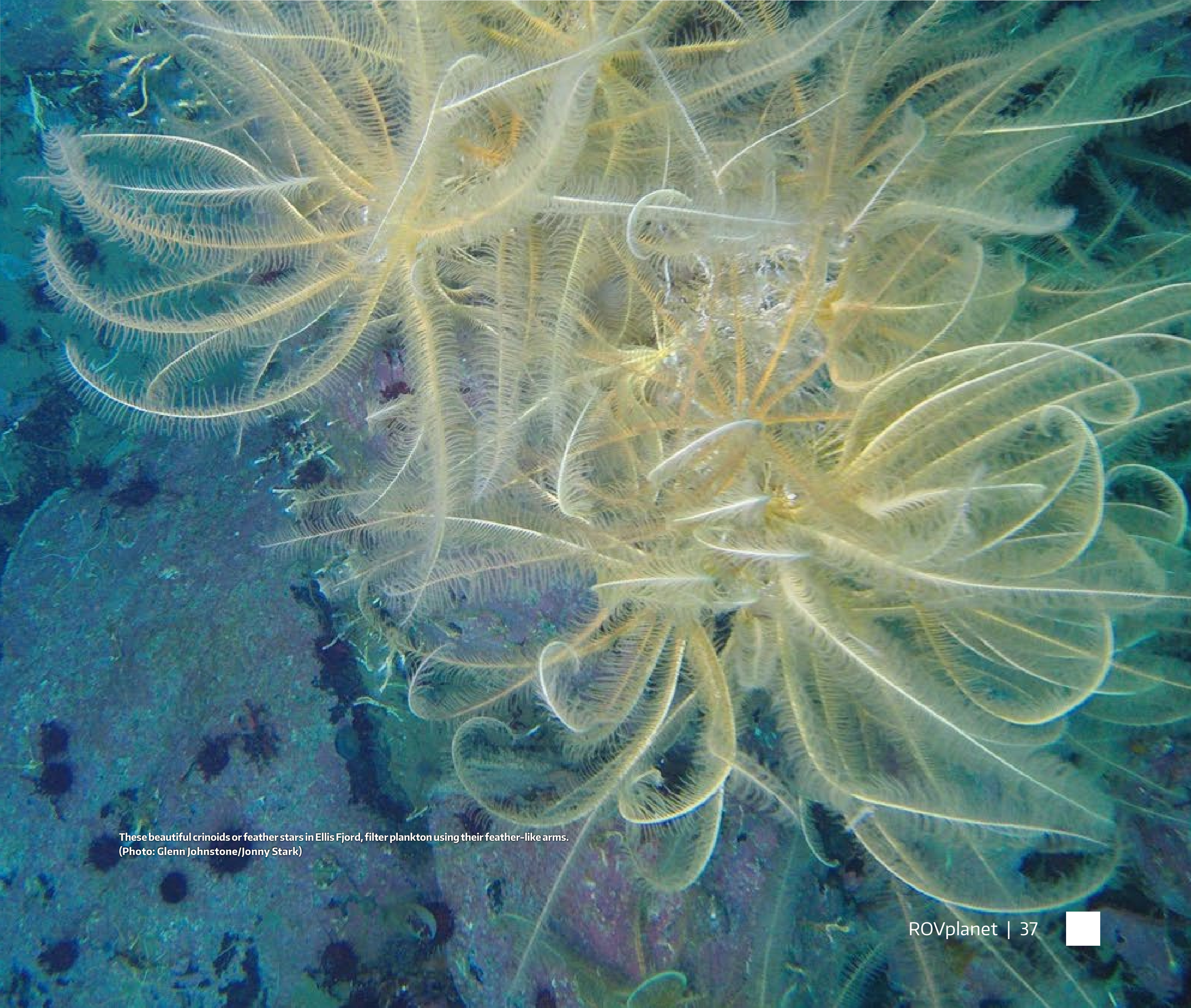
THE ICE-O-POD

EXPLORING ANTARCTICA'S UNDER-ICE MARINE LIFE

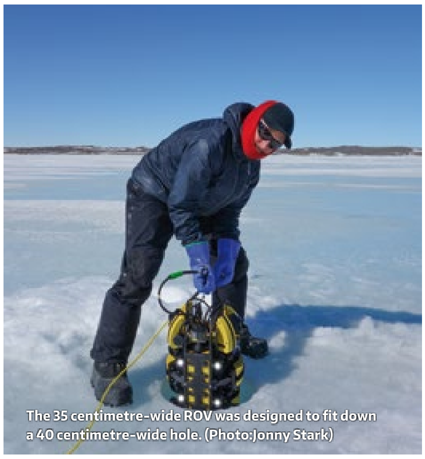
By Glenn Johnstone and Jonny Stark, Australian Antarctic Division

A small remotely operated vehicle (ROV) nicknamed the 'Ice-o-pod' has revealed colourful and diverse sea floor communities under the sea ice around the Vestfold Hills, near Davis research station. The research, conducted as part of environmental surveys for the Davis Aerodrome Project (Australian Antarctic Magazine 37: 2-5, 2019), discovered a range of communities and rarely encountered species.



These beautiful crinoids or feather stars in Ellis Fjord, filter plankton using their feather-like arms. (Photo: Glenn Johnstone/Jonny Stark)

These dense colonies of the tube building polychaete worm, *Serpula narconensis*, form reefs that extend for kilometres around Ellis Fjord, generally on slopes between depths of five to 35 metres. (Photo: Glenn Johnstone/Jonny Stark)



The 35 centimetre-wide ROV was designed to fit down a 40 centimetre-wide hole. (Photo:Jonny Stark)

Drilling a hole through up to 1.9 metres of sea ice was back breaking work. Photo: Glenn Johnstone

The Ice-o-pod proved to be a logistically efficient way of exploring under-ice habitats and conducting quantitative photographic surveys of sea floor communities in the Davis region. Most sites we visited during the 2019–20 summer have never been explored, and much of what we saw was unexpected, including extensive polychaete reefs.

The ROV surveys were undertaken to inform a Comprehensive Environmental Evaluation for the Davis Aerodrome Project and were part of broader survey and sampling work of lakes, vegetation, seals, and seabirds.

The benthic marine program visited 28 sites and collected macroinvertebrates from the sea floor, sediment profiles for chemical analysis, and seawater and sediment samples for environmental DNA (eDNA). We conducted ROV surveys at 10 of these sites, which ranged from Hawker Island and Ellis Fjord in the south, to Bandits Hut in the far north of the Vestfold Hills.

All our sites were covered by between 1.6 and 1.9 metres of sea ice, presenting one of the key challenges for Antarctic coastal marine fieldwork; getting to the water in the first place. The 35 centimetre-wide Ice-o-pod was specifically designed to fit down a 40 centimetre wide access hole, drilled through the sea ice using an easily transported post-hole drill. But it was hard work, particularly after the first metre, when a second metre-long auger section had to be added. The torque generated by over 1.5 metres of auger in a sea ice hole filled with ground-up ice and slush was unbelievable. It was backbreaking work and our record of eight holes in one day isn't one we'll try to beat in the future.

After almost an hour of ROV setup and pre-dive checks, the Ice-o-pod was attached to a 300 metre-long tether and to our control centre – a laptop and X-box game controller. These were housed on a portable table with a custom-built vinyl cover to block out the high ambient light. The back of a hägglunds made an excellent shelter from which to operate the ROV, providing protection from the freezing wind blasting across the sea ice. The Ice-o-pod was easily manoeuvred down the access hole and, after a series of in-water checks, went to work surveying the sea floor.

Photoquadrat surveys were conducted by driving the ROV in a series of transects, either down-slope (between approximately 3 and 45 metres depth) or across-slope, between specific depth intervals of four to six metres, 12 to 15 metres and 20 to 25 metres.

Transects were driven at approximately one metre above the sea floor using an on-board altimeter, while two downward facing GoPro cameras captured video and photos. The sea floor was illuminated by four 1500 lumen lights, while a laser scaler projected points 100 millimetres apart onto the sea floor within the area imaged by the front GoPro. Maintaining a steady height above the sea floor was tricky as many of the sites had complex topographies, particularly on steep boulder-covered slopes.

The Ice-o-pod performed superbly, allowing us to capture photoquadrats of known area, thanks to the laser scaler, within which we can identify and count the organisms living on the sea floor. Importantly, quantifying diversity and abundance in this way allows us to compare the composition of these communities spatially, between sites, and to monitor how they change over time.

The images we captured revealed colourful, diverse and complex communities, with every site providing new and unexpected surprises. The polychaete reefs in Ellis Fjord were a particular highlight. These dense colonies of the tube building polychaete worm *Serpula narconensis* form reefs that extend for kilometres around the fjord and generally occur on slopes between depths of five to 35 metres. Like reefs anywhere, they provide a complex habitat for a diversity of other organisms, including sponges, ascidians, sea cucumbers and large numbers of the common red urchin *Sterechinus neumayeri*.

Polychaete reefs were also found in Long Fjord, although not in as large congregations, and we found small colonies of *S. narconensis* far to the north, in the steep rocky bays near Bandits Hut.

Another surprise was the presence of three species of crinoids (feather stars) that we haven't seen around Davis before. These strangely beautiful echinoderms move around the sea floor filtering plankton from the water column with their feather-like arms.

It wasn't all plain-sailing however, as the Ice-o-pod had a few teething problems that only Antarctic conditions can induce. Sealant used in some of the cable housings cracked or shrank in the very cold Antarctic water (-1.85°C), bringing our first dive to an abrupt end after only 10 minutes. These very hard to find leaks almost derailed the season but with some relentless detective work in the lab and the application of lots of Sikaflex we fixed the problem and operations resumed.

This first summer of work proved that the Ice-o-pod is a superb tool for exploring under-ice habitats with a small team and relatively simple logistics. Importantly, it also captured high quality imagery that will allow us to determine how Antarctic marine communities may change over time – vital for future monitoring efforts.

The Ice-o-pod is also a highly adaptable research platform that can be modified to provide upgraded or new capabilities. ROV control and data collection software is rapidly evolving and a range of potentially useful sensors are becoming smaller and easier to attach. In the coming year we'll use this flexibility, along with the lessons learned this summer, to improve the Ice-o-pod's capability and performance as an exploration and survey tool and to meet emerging research needs.

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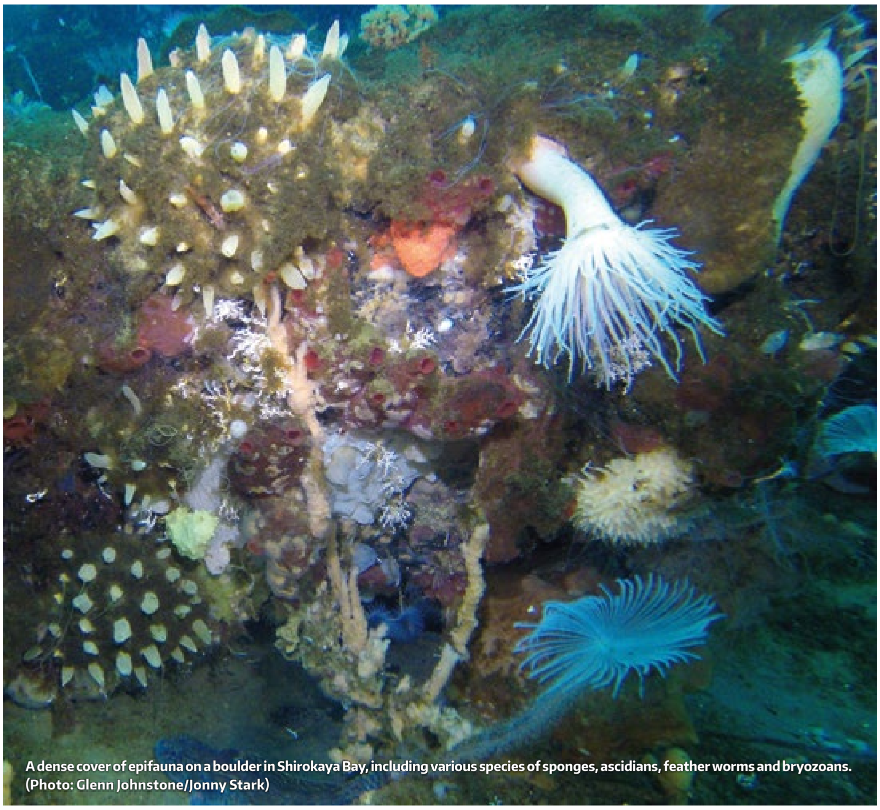
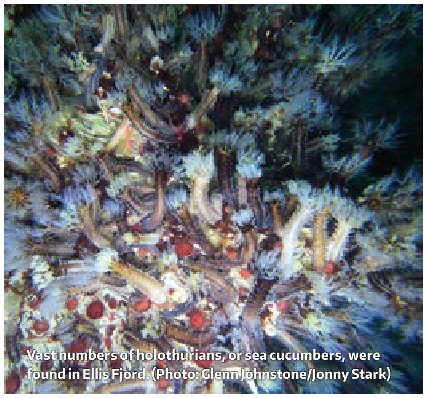


A dense cover of epifauna on a boulder in Shirokaya Bay, including various species of sponges, ascidians, feather worms and bryozoans. (Photo: Glenn Johnstone/Jonny Stark)



Vast numbers of holothurians, or sea cucumbers, were found in Ellis Fjord. (Photo: Glenn Johnstone/Jonny Stark)

Dr Jonny Stark with the ROV and its control centre, in the back of a hägglunds. (Photo: Glenn Johnstone)

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INTERVIEW:

RUD ROV HOOK

SUBSEA LIFTING TO THE NEXT LEVEL

RICHIE ENZMANN: David, In our previous edition we reported about our impressions at QSTAR's in Barcelona using the newest ROV Hook developed by RUD. You have been at the forefront of development of this game-changing product from the beginning, tell us how all this started and why.

DAVID JARAMILLO: Well, as in every good product development process, it started with a customer's request, back to early 2014. One of our customers in the marine sector, Subsea7, approached us, requesting a solution for their rigging issues resulting from the use of conventional ROV-assisted hooks. A long-existing problem, well documented by IMCA and HSE i.a. and which so far no manufacturer was willing to approach. At that time I was quite new at RUD, defining new strategies for the Marine & Offshore sector and immediately I identified an ideal opportunity, despite the relative small market volume for this particular piece of hardware, to evidence the immense potential and strength of RUD in being innovative. Thus, yes, we took the challenge.


Courtesy of RUD

R.E.: Which were those "issues"?

D.J.: Basically, there were two major safety issues to be solved. However, many other important challenges appeared in between as well. Firstly, the so-called "shedding" was a big concern. This means the loss of loads as a result of unintentional opening of the hooks. Secondly, the "snagging" or accidental rigging due to protruding parts, such as an enlarged tip of the hook's nose and also the very commonly used "monkey fist" attached to the hooks for operation. Both issues pose major operational safety risks when working in deep waters, remotely manipulating sophisticated and expensive equipment in short time windows and due to the extremely challenging operational environment.

R.E.: And how was it solved?

D.J.: Based on the specified requirements we had to design a complete new type of hook. Putting aside most concepts found in the traditional designs. The outwards opening latch was a key element in preventing shedding, the overall smooth shape aimed at solving the snagging issues.

R.E.: Which were the main challenges?

D.J.: From the beginning, beside operational safety, we based our concept on "ease and speed of use". We knew this was crucial for the success of the product. Then, at the end of the day the reduced operational time incrementally turns into visible monetary savings for the operators and contractors. The reliability and robustness of the hook played also an essential part in our development objectives.

Courtesy of RUD

The other side is the manufacturing perspective. We needed a product that could be produced in a feasible way, and to be accessible to a reasonable price in the market.

R.E.: What was wrong with conventional ROV Hooks?

D.J.: looking at conventional ROV-assisted hooks, we realised that the problems often occur because these hooks were basically adaptations of hooks used in topside, mostly onshore applications. Here we speak basically about two types of hooks: the snap hook and the self-locking style hooks, which are respectively equipped with a lanyard or wired extension for ROV operability. None of the available designs was specifically developed for subsea use and therefore did not take all relevant operational conditions into consideration.

R.E.: What is the novelty of the RUD ROV Hook?

D.J.: To start, a one-hand operation for both attaching and releasing of loads was an important requirement, therefore the opening/closing mechanism needed to be completely re-engineered. On top of that, a reliable locking mechanism was in the focus of the development efforts. Here is where the trigger concept comes into scene; pressing the trigger opens the hooks, releasing the trigger automatically closes and, most importantly, locks the hook. So we can say that the opening/closing/locking mechanism builds up the novelty and uniqueness of this design.

R.E.: How long did it take to develop this solution?

D.J.: The project started officially in spring 2015 and it took us something more than two years to finalise the design and come up with a satisfying solution for our customer and developing partner Subsea7. In this period we designed and extensively tested in the field, under operational conditions, four different prototypes and variants. It was an interesting and intensive process, with new aspects and requirements appearing each round, and with adjustments, refinements and enhancements at the end. There are thus, many design details that make this ROV hook a unique solution with quite interesting and value-adding features.

R.E.: Can you give us an example?

D.J.: The reliability of the hook starts in the approaching phase. In this situation the first contact is quite crucial for a speedy operation. Ideally gripping the hook correctly should work at once, right away, with whatever type of manipulator, three or four fingers, intermeshed or parallel. The rounded shape with ripples of the trigging area and the curved form of the trigger's contact surface are therefore optimised for a maximum gripping effect in interaction with the ROV, even at inclined approaching angles, up to 30° from the ideal approaching position. This, in combination with the innovative locking mechanism, makes the hook unbeatable in terms of "speed and ease of use". At that time some users categorised this as "disrupting technology" other called it a "revolution". That's how the latter became part of our initial promotional slogan.

R.E.: Do the ROV pilots require additional skills for operating this hook?

D.J.: The human factor plays always an important role. The ease of use of this ROV hook makes it however simple also for say "less skilled" ROV Pilots or trainees to manipulate loads. We know that most users out there are used to the "wired solutions", just because there was no other option

Courtesy of RUD

before. With our solution this has now changed and according to the feedback we have received so far, once the ROV Pilots understand and experience themselves the advantages of the new approach they rapidly get used to it and it becomes they preferred way of working.

R.E.: Meanwhile there is new twin-trigger version of the Hook, why?

D.J.: Just after the first users started using the new hook the enthusiasm was so big, that few of them started doing things with the hook, for which it was initially not designed. For example turning and positioning loads under water. Basically, using the hook as a shackle connection while turning the hook upside down and things like that. We rapidly acknowledged that a "secondary locking system" had become an unforeseen requirement to cope with these situations as well. So we started thinking about it, within the process of normal user-driven product evolution. The result of this is the new twin trigger mechanism, which we have successfully launched in September 2019 at the Offshore Europe Show in Aberdeen.

R.E.: Could you explain a little bit more about it?

D.J.: It is a basically a two-stage securing of the hook opening/closing mechanism that works by means of two triggers that are engaged together. Only when pressing both triggers simultaneously -something that will never accidentally happen- the hook would ever open. This is what we have called "ultimate safety". And yes, now the hook can even be deployed for connections, where shackles are typically used, e.g. turning and positioning of loads, providing a wider scope of uses in subsea, but also in topside applications.

R.E.: And now there is also a bigger version than 10t WLL?

D.J.: Yes, upon users' request we decided to provide, beside the 10t WLL version, a 25t WLL version which, as expected, has been well received in the industry. With these two sizes we can now cover a wide scope of subsea lifting operations, typically for equipment installation, maintenance and repairs, material and tooling transport under water, etc.

R.E.: And what does come next?

D.J.: As a top innovator RUD is continuously seeking for new and exciting challenges for product developments. In this sense we always keep an eye and an ear on our customers' needs and actively request for feedback on existing products. Innovation is a two-way process and as I said at the beginning, we are convinced that successful product development starts always with a customer's request, a particular issue, a particular problem to be solved. We don't see ourselves just as a manufacturer, but rather as solution provider, solutions based on cutting edge technology and innovation. That is where RUD excels.

R.E.: Thank you David for these interesting insights.

D.J.: Thank You!

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CYBERSECURITY UNDER AND ABOVE WATER

Daniel E. Turissini, CTO, SPYRUS Solutions, Inc. | www.SPYRUS.com

Critical systems that are essential to the safe operations in the maritime domain (under and above water) are increasingly automated and connected to the internet, both at sea and when docked. This makes them open to various vulnerabilities that threaten the integrity and confidentiality of the data being shared, such as performance monitoring, maintenance, and spare parts management. Systems that provide data – which may be of interest to cybercriminals to exploit by connecting to a network, directly or indirectly – expose vulnerabilities that the maritime domain (ROV, AUV, USV, glider operators/manufacturers, etc) should consider early in the design phase.

ANALYZING THE ISSUE

Like many industries, the maritime domain is increasingly using systems that rely on digitization, digitalization, integration, and automation, which call for the inclusion of cyber risk management. As technology continues to develop, vessel systems are being networked together, and increasingly connected to the internet. A 2016 Maritime Cyber Security University Research report (USCG Research and Development Center, Rutgers University, American Military University, University of Southern California, and the University of Southern California) suggested that "modern maritime systems are highly complex digital systems to ensure the safety and efficient operation of the shipping traffic so vital to the global economy.

"The vulnerabilities associated with reliance on digital systems in the maritime environment must be continuously examined. System protection must be ever ready to monitor vulnerabilities and secure maritime traffic systems. The U.S. Coast Guard must ensure the integrity of the entrances to our 'digital ports' and work to develop practical cybersecurity solutions to protect the nation's maritime infrastructure."

Access, control, and protection of maritime systems and sensors – such as video, navigational alarm systems, security alerts, and all connected systems – need to be segregated to guarantee confidentiality, integrity, or any denial of service that attacks like ransomware or worms expose us to. On-board computer systems that maintain safe operations must be able to prevent intrusions.

OUT-OF-DATE STANDARDS

Unfortunately, neither the standards for the safe operations of automated and connected systems have kept up with the deployment of these systems. Systems security is largely not part of the engineering design requirements.

In a recent ASTM workshop that I attended, a young cadet from one of our maritime institutions observed that their education programs are not keeping pace with technology. He noted that these programs spend a lot of time teaching about systems that no longer go to sea. Currently, from an ROV, AUV, USV, glider operators' perspective, all they can do is deal with a Cybersecurity incident when it hits. This is common to many industries.

In a MarineLink article entitled "Work'bots': Autonomous Vessels Arrive" Vince den Hertog, RAL VP, Engineering, said, "There are capital cost savings from dispensing with the deckhouse, wheelhouse, domestic systems, or lifesaving equipment, but these are offset by a premium for electronics, communications, sensing, and operator console equipment to operate remotely." Of course, this also brings a greater risk of unauthorized access or malicious attacks to systems and networks.

As control systems are upgraded and networked, inherent protections of isolated controls that traditionally relied on human attention are quickly exposing many vulnerabilities. While international organizations are attempting to address these issues in workshops and conferences, quick research indicates the essential requirements for any unattended machinery spaces for at-sea operations (enumerated in the SOLAS 1974 Chapter II-1, regulations 46 to regulation 53 and 46 CFR 62.50-30). These address additional requirements for periodically unattended machinery plants. However, the regulations have not kept up with increasing reliance on automation, autonomy, and artificial intelligence.

Systems managing propulsion and the operation of machines, such as energy control systems and engine regulators, as well as the integrated control system, and the alarm and emergency systems are all entry points for cyberattacks. These attacks can leave any vessel, attended or autonomous, stranded, cause a breakdown, or even threaten safety. The potential for a ransomware attack is very real.

"CYBER SKILLED MARINERS" IN AN EVOLVING DOMAIN

Cybersecurity, like its internet platform, is a quickly evolving animal. Often, each network and external connection is a different challenge. To ensure the security and the integrity of ship operations, maritime professionals must be aware of the flaws they are exposed to so they can define, demand, and implement the necessary protections. The "Cyber Skilled Mariner" must be equipped to identify different network vulnerabilities and be savvy enough to influence the use of high-performance cybersecurity systems in an industry that is moving toward more autonomy and artificial intelligence.

We must also be cognizant of how the state of a marine vehicle can be manipulated in the absence of any preventive mechanism from cyber-attacks. Examples of potential navigation vulnerabilities include GPS manipulation, disruption of the global supply chain, ECDIS (Electronic Chart Display and Information System), Radar/ARPA (Radio Direction and Ranging) (Automatic Radar Plotting Aid), Compass (Gyro, Fluxgate, GPS, etc), Computerized Automatic Steering System, Data Recorder or "Black Box". These are all systems increasingly dependent on connectivity to timely and accurate data. With ROV, AUV, USV, and gliders these vulnerabilities are becoming more pronounced, with increasing reliance on external data transmitted over various networks.

At a minimum, manufacturers need to address the basic security attributes of confidentiality, integrity, and availability in their designs. And operators need to understand and recognise the implication of design shortfalls so that they can insist on proper replacements and upgrades.

For more information about how the industry is addressing Cybersecurity training challenges view the Cyber-Skilled Mariner Call to Action series at: http://www.maritimetv.com/Events/Cyber-Skilled-Mariner-III-2020.

ADDRESSING HUMAN ERROR

Technology systems across any industry or consumer system are also vulnerable to human error. While Cyber awareness and hygiene are very important, the need for expedience and common carelessness are both impossible to overcome. It only takes one mistake (not necessarily malicious) to infect a vessel, a fleet, and/or an enterprise.

We need to go beyond just paying attention to what one does. We need our maritime professionals to also be aware of and demand technology upgrades to our systems that specifically address human error. As an example, some solutions will not allow any unauthorized devices or software to execute within a specific system or network, if inadvertently introduced during maintenance by an infected computer or media.

Maritime professionals, designers, manufacturers, operators, and maintainers must have an understanding of vulnerabilities of confidentiality. Data such as a vessel's position, course, destination, and speed can all be used maliciously. While sharing this data is essential to management and coordination, in the wrong hands it can be weaponized.

Systems must be upgraded and designed to provide all stakeholders high levels of confidence in the integrity of the data they are using. The maritime professional must be armed with the knowledge necessary to drive short and long-term protection of their fleet.

In the cyber domain, there is the term "Authoritative Source", and the concept of verifying that source before data use. In automated and autonomous shipping data integrity can easily be considered the holy grail of accurate operations. Maritime professionals must be able to contribute to the systems upgrade and design discussion that will lead to stronger mutual authentication and data protection against data manipulation and man-in-the-middle vulnerabilities.

CREATING A SHARED VERNACULAR

Availability is another aspect of this discussion that ties into both confidentiality and integrity. Humans – particularly those entering the workforce – are used to immediate response and less concerned with its protection or accuracy. This may be due to confidence in an individual's ability to parse the data and the growing uncertainty of privacy expectations.

In any case, even automated decisions are negatively affected by bad data. Even as we make advancements in artificial intelligence, we must keep in mind that decision making will only be effective if the data collected is accurate. While advances in AI will allow many more data points to be considered, it will also allow more data points to be compromised more effectively.

Part of the challenge is translating basic vulnerabilities of all computing systems into a vernacular that the maritime domain can relate to in order to develop the skills to identify issues and allow the industry to leverage solutions from other industry verticals. We can then fit them into specific Maritime systems and workflows in order to start getting ahead of cybersecurity challenges. Like other industries, the vernacular can differ within. A data dictionary that aligns the vernacular across the maritime domain and with other industries would be helpful (although, we must keep in mind that the developer/ manufacturer is most likely not educated in the maritime domain).

As an example, when discussing security requirements with a surveillance camera manufacturer that moved to an internet protocol camera, they commented that they were camera experts and not network security professionals. None the less, by adding IP to their device, they became a network device vendor with all the associated vulnerabilities.

With limited investigation, you can confirm the thesis that there are plenty of "we have a problem" discussions and articles across all domains, taking advantage of connectivity without proper security. However, little is written about that can arm stakeholders with the tools to begin addressing these problems beyond cyber-hygiene. While awareness is hugely important, action – not words – are what will keep the operation of vehicles in the maritime domain along with their support systems and supply chains safe and profitable.

ABOUT THE AUTHOR

Dan joined SPYRUS Solutions, Inc. as Chief Technology Officer, and is a thought leader in identity verification and trusted authentication. Dan Chairs the Marine Technology Society, Maritime Cyber Security and Infrastructure Committee and Vice Chairs the AFCEA, Homeland Security Committee. He holds a BS degree from the US Merchant Marine Academy, Dual License, and a Masters from the George Washington University, where he also completed the required credit hours in a formal program of study at the graduate level beyond master's study in pursuit of Doctoral program in Systems Engineering & Applied Sciences.

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Theseus suspended above launch ice hole, Ellesmere Island, Canada. 1995. Photo credit: Bruce Butler

THE THESEUS AUV

A COLD WAR LEGACY

by Bruce Butler, P.Eng.

THE COLD WAR

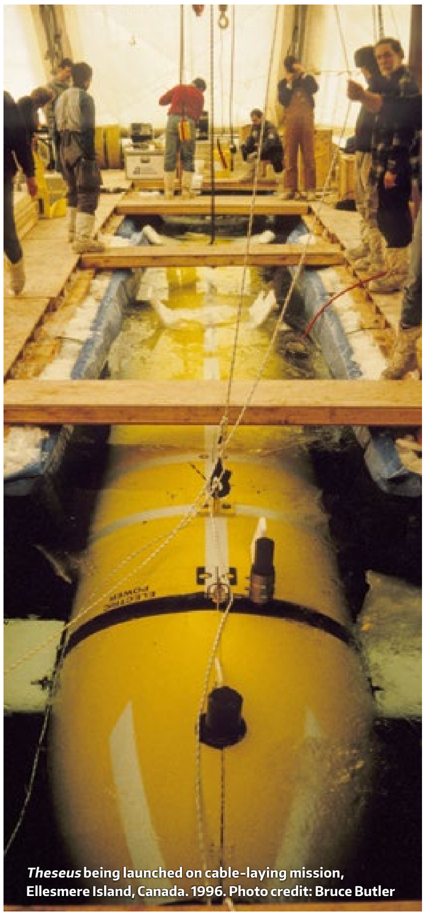
In 1987, the Canadian government released a long-awaited White Paper on Defence, identifying perceived gaps between Canada's current defence capabilities and its commitments to NATO. Even though the Cold War was waning, Canada was concerned that in times of conflict, Soviet submarines could use the deep channels of the Canadian Archipelago to reach the North Atlantic.

The Canadian government tasked its Department of National Defence (DND) with determining how to monitor Canada's Arctic waters for submarine activity. DND initiated a joint Canada-US defence research project, codenamed "Spinnaker," to install a prototype, seafloor-mounted acoustic listening post on the edge of the Continental Shelf north of Ellesmere Island, Canada's northern-most point of land. This would require laying nearly two hundred kilometres of fibre-optic cable on the seafloor in waters with a permanent ice cover.

To solve the cable-laying problem, DND scientists assigned to Project Spinnaker consulted Canadian subsea experts. International Submarine Engineering Ltd. (ISE), based in British Columbia, Canada, had recently completed development of the ARCS autonomous underwater vehicle (AUV), built for the Canadian Hydrographic Service for under-ice hydrographic surveying. The DND scientists held several exploratory meetings with ISE engineers, and they soon agreed that a purpose-built AUV was the best solution.


ARCS AUV outfitted with prototype cable-laying hull section. Photo credit: Bruce Butler


Theseus floating in launch ice hole, Ellesmere Island, Canada. 1995. Photo credit: Bruce Butler


Theseus being launched on cable-laying mission, Ellesmere Island, Canada. 1996. Photo credit: Bruce Butler

TECHNOLOGY GAPS

To build an AUV that could lay cable while travelling up to two hundred kilometres through frigid waters with unknown bottom terrain and ice cover then deliver the cable to a precise location, ISE engineers identified several technology gaps:

- A navigation system with an en-route accuracy of better than 0.1% of distance travelled, and metre-level accuracy during terminal navigation.
- An obstacle avoidance system capable of detecting bottom obstacles and ice keels extending down as far as fifty metres below the surface.
- A high-reliability fault-tolerant computing system that could respond not only to computer hardware and software failures but also to faults in external sensors, actuators, and other onboard systems.
- Modular design: the vehicle had to be broken down into components small enough for transport by heavy-lift aircraft, helicopters, small fixed-wing planes, and land vehicles.
- Launch and recovery: the handling system and vehicle design had to accommodate horizontal deployment and retrieval through a two-metre-thick ice cover.
- Automated compensation for a change in buoyancy due to loss of cable.

ISE used the ARCS AUV as a technology development platform to resolve many of these gaps. In the fall of 1990, they held a series of demonstration dives in local BC waters, proving that an AUV could lay cable. The Canadian government gave Project Spinnaker the green light.

MISSION-DRIVEN DESIGN

The new AUV, designated *Theseus* after the hero from Greek mythology, would be purpose built for laying cable. *Theseus* was designed using a top-down, mission-driven, systems approach: the vehicle system was decomposed into seventeen subsystems, each with its own mechanical, electrical, and software requirements. Each subsystem was assigned to an ISE engineer who would follow it through the development process, from requirements to design to construction to test. A Systems Engineer ensured all subsystems were harmoniously integrated at each development stage.

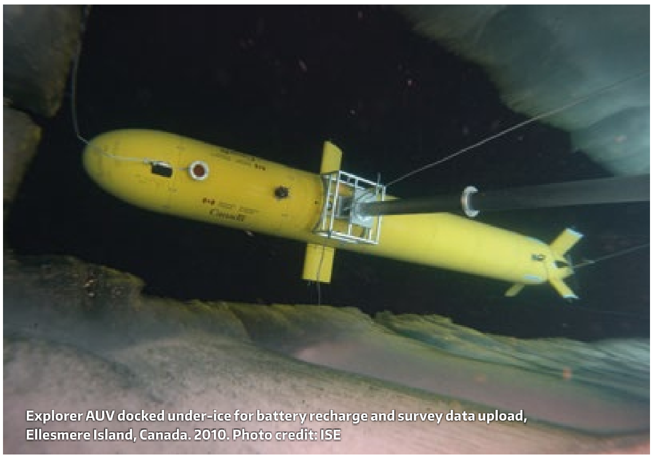
During the vehicle design phase, ISE engineers were invited to take part in DND's annual arctic field trials, codenamed Project Iceshelf. Based out of Canadian Forces Station Alert on the northeastern tip of Ellesmere Island, these trials gave the ISE engineers considerable "on ice" experience and valuable insight into the hostile environment *Theseus* would operate in.

TESTING

Following a one-year construction period, *Theseus* underwent two years of testing and local sea trials during which all its subsystems were exercised. *Theseus* was deployed

Theseus undergoing sea trials, Indian Arm, BC, 1994. Photo credit: Bruce Butler

nupiri muka AUV preparing to dive under Sørsdal ice shelf, Antarctica, 2019. Photo credit: University of Tasmania Autonomous Maritime Systems Laboratory.



Explorer AUV docked under-ice for battery recharge and survey data upload, Ellesmere Island, Canada. 2010. Photo credit: ISE

to the Arctic in the spring of 1995 for a series of short test dives to validate transportation logistics, key subsystems, and demonstrate cable laying and delivery. In early 1996, *Theseus* underwent a full-length mission simulation at the Canadian Forces maritime test range near Nanoose Bay, BC. During this fifty-hour mission, it demonstrated acceptable reliability, endurance, and navigational accuracy to confirm it was ready for its full-length arctic cable-laying mission.

THE MISSION

In March 1996, *Theseus* was disassembled, crated, and loaded into several Canadian Forces C-130 Hercules aircraft for the four thousand-kilometre flight to Canadian Forces Station Alert. It was then transported by helicopter and land vehicles to a near-shore ice camp ten kilometres from Alert, where it was assembled and tested inside a large launch tent.

Just after midnight on April 17, *Theseus* was lowered horizontally through an ice hole cut through the two-metre-thick ice to a launch depth of twenty metres, then released. Twenty-four hours later, after laying over one hundred and eighty kilometres of cable on the seafloor, *Theseus* arrived at the edge of the Continental Shelf. It ascended and delivered its cable to an ice camp where the American members of Project Spinnaker anxiously waited. The cable was recovered, connected to the just-deployed listening post, and *Theseus* was commanded to return home.

By the time *Theseus* returned to its launch ice hole thirty-five hours later, data from the listening post was already streaming back to CFS Alert on the fibre-optic cable. The Spinnaker installation was complete.

THE LEGACY

In 2008, ISE received a contract from the Canadian government to build two AUVs for under-ice surveying. These Explorer-class AUVs resemble a scaled-down version of *Theseus* and contain state-of-the-art technologies that support a wide variety of customer payloads. In the spring of 2010, an Explorer AUV mapped the seafloor off the western coast of Ellesmere Island in support of Canada's UNCLOS submission. Over a ten-day period, the vehicle travelled over one thousand kilometres, smashing several of *Theseus*'s records. In 2011, that AUV performed under-ice surveys from an icebreaker above 88°N latitude.

ISE has delivered Explorer-class AUVs to several institutions and governments around the world. In 2017, ISE delivered an AUV, rated to five thousand metres and outfitted for under-ice operation, to the University of Tasmania. The vehicle, named *nupiri muka* ("eye of the sea" in the language of Tasmanian Aboriginals), performed several test missions in the spring of 2019 under the Sørsdal Glacier near Davis Station, Antarctica. It returned in 2020 and performed several more missions, venturing up to thirty kilometres under-ice while collecting a vast amount of environmental

Solus-LR AUV about to undergo tank testing. Photo credit: Cellula Robotics Ltd.

Imotus-1 hovering AUV in test tank. Photo credit: Cellula Robotics Ltd.

data, information that will help scientists understand the dynamics of this complex environment and how climate change is affecting the polar regions.

ISE's autonomous underwater vehicles have reached towards both poles, establishing ISE, and Canada, as a world-leader in under-ice AUV technologies.

SPIN-OFFS

Most of the ISE engineers and technologists involved in Project Spinnaker have since moved into other fields, some have retired, but a handful still go to work at ISE every day. Two notable alumni have started their own technology-based companies.

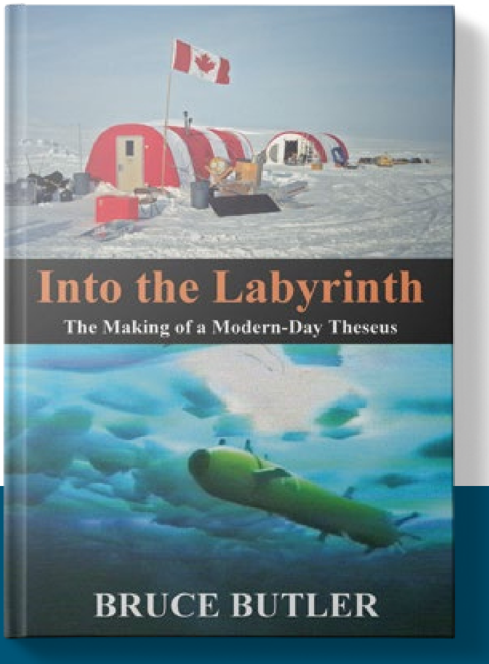
Vancouver-based TRAXX Automation, co-founded by ISE engineer Dave Eddy in 2006, provides control system expertise in land and marine applications. TRAXX employs over ten engineers, technologists, and software specialists.

ISE engineer Eric Jackson started Vancouver-based Cellula Robotics in 2001, providing automated solutions for subsea geotechnical and geophysical operations. Their first AUV, called Imotus, is a hovering AUV used to perform inspections in complex confined spaces. Cellula is currently testing their Solus-LR AUV, powered by a hydrogen/oxygen fuel cell and equipped with a patented suction anchor that allows it to hold station at a surveillance location for up to several months at a time. Cellula employs over twenty engineers, designers, and technicians.

CONCLUSION

The Cold War is often considered to be a period in modern history that produced terrifying legacies of a chemical, biological, and nuclear nature. It did, however, also leave behind many positive ones.

The under-ice voyages of this modern-day *Theseus* extended Canada's knowledge not only of the Arctic seafloor, but of the hostile environment above and below the ice pack. The technological seeds planted during Project Spinnaker will continue to bear fruit in the years to come, expanding our limited, but rapidly growing knowledge of the oceans.



ABOUT THE AUTHOR

Bruce Butler, P.Eng. worked at International Submarine Engineering for fourteen years (1985 to '97, 1999 to '01). He was the *Theseus* Systems Engineer, responsible for the vehicle's inertial/acoustic navigation system, and he took part in several arctic field trips, including acting as Chief Pilot during the 1996 cable-laying mission.

Want to learn more about *Theseus* and its Cold War mission? Bruce has written *Into the Labyrinth: The Making of a Modern-Day Theseus*, which is available in print, e-book, and audiobook format. Check out the book here:

www.theseusbook.com

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