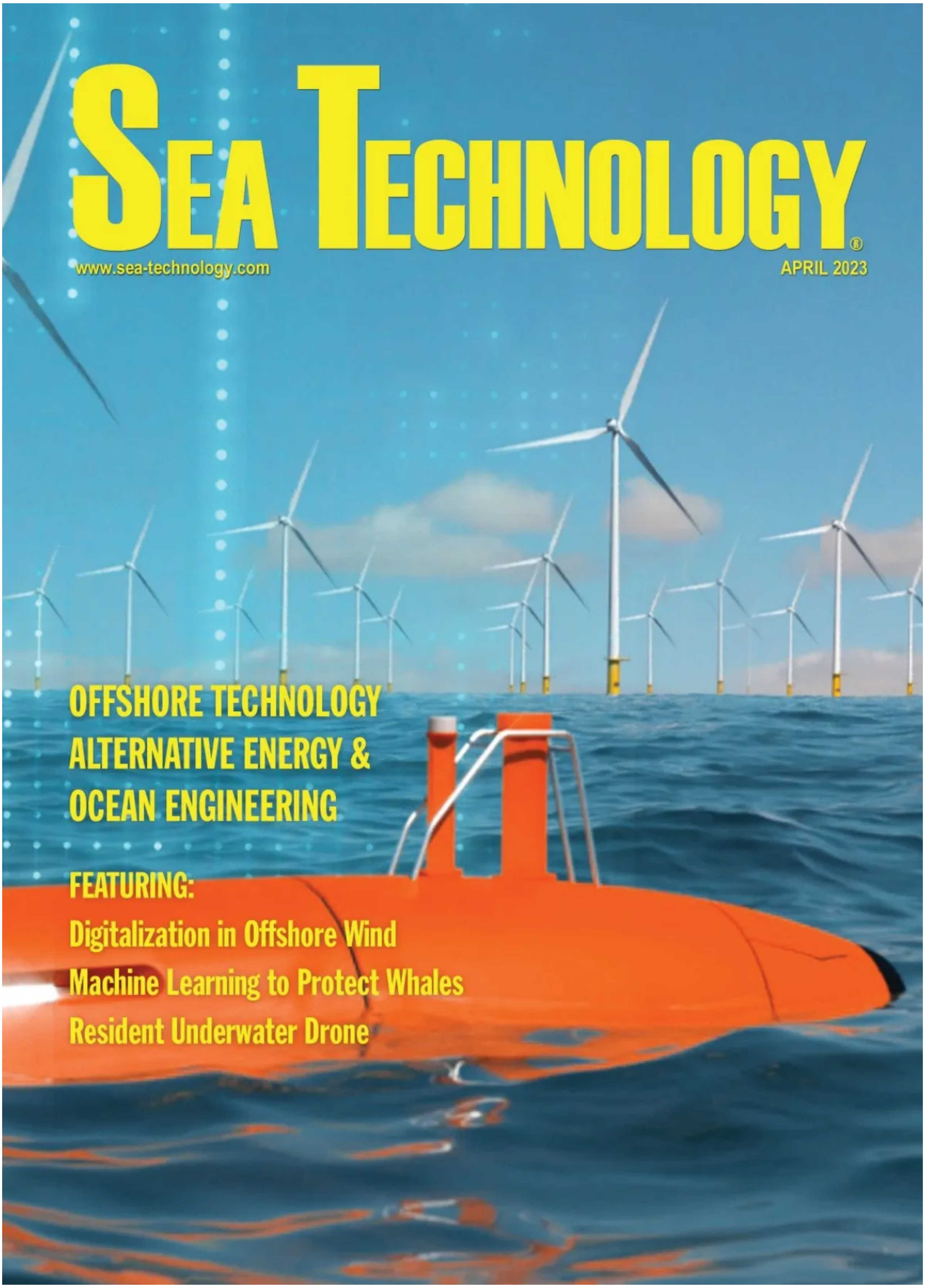

SEA TECHNOLOGY®
www.sea-technology.com
APRIL 2023
OFFSHORE TECHNOLOGY
ALTERNATIVE ENERGY &
OCEAN ENGINEERING
FEATURING:
Digitalization in Offshore Wind
Machine Learning to Protect Whales
Resident Underwater Drone

Resident Underwater Drone

Fully Automated Small Vehicle Increases Ocean Accessibility

By Leif Hugo Arntsen • Craig Anderson

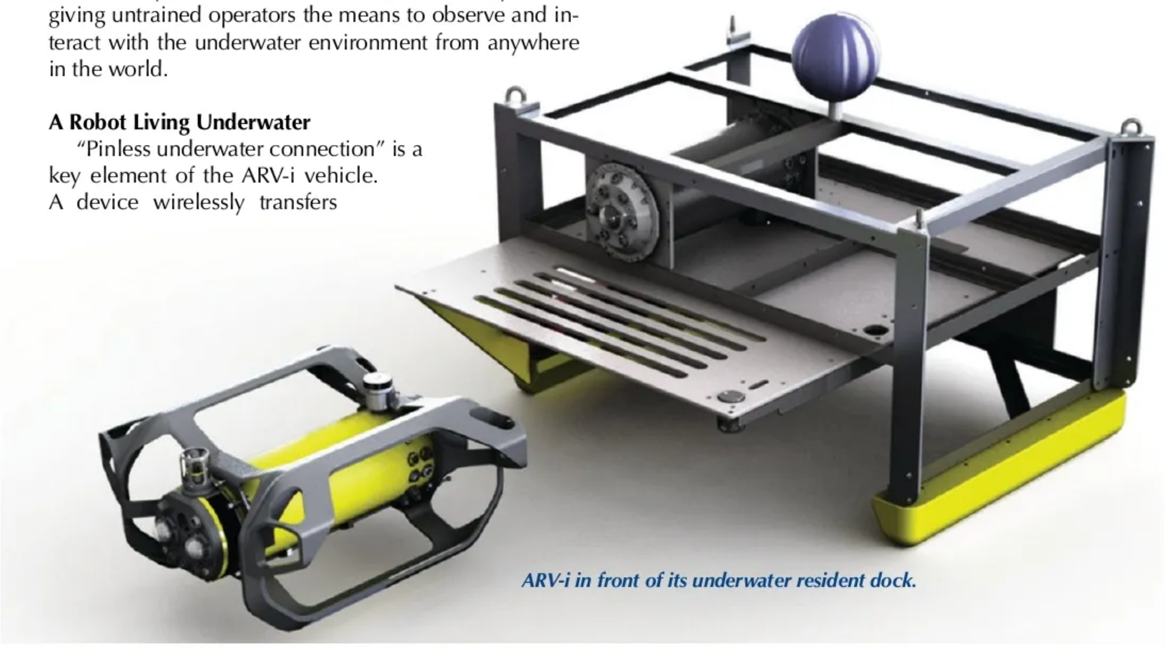
For over a half-century, ROV and AUV systems have given humanity rare access to the underwater world, revealing one small piece at a time of the obscured and valuable puzzle that is our ocean resources. Highly trained personnel operate these underwater robots from ships and rigs, mapping and exploring the depths, installing and maintaining structures, helping to document and recover a lost past, and increasingly helping in the process of growing our food.

The development and delivery of the ARV-i (Autonomous Resident Vehicle) system described here is enabling a reduction in cost and increase in accessibility of ocean exploration and commercialization by offering a resident system that is both affordable and easy to use, giving untrained operators the means to observe and interact with the underwater environment from anywhere in the world.

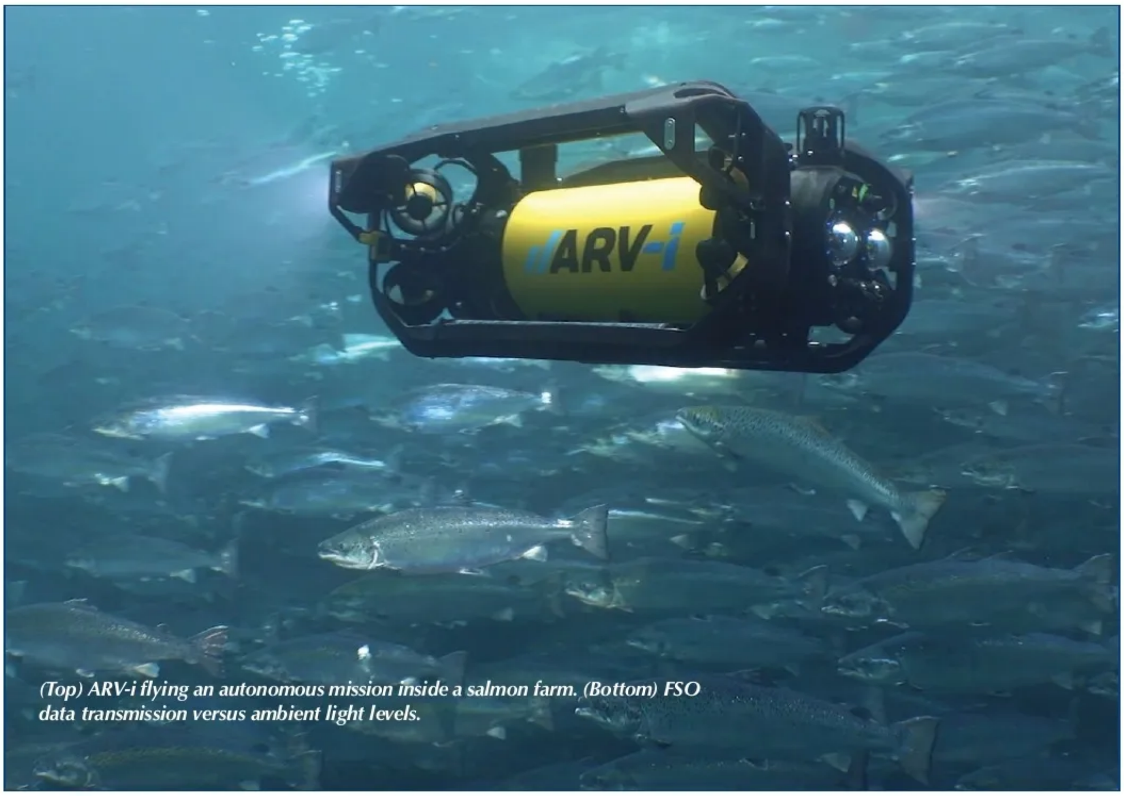
A Robot Living Underwater

"Pinless underwater connection" is a key element of the ARV-i vehicle. A device wirelessly transfers power and data electromagnetically between two transducers placed very near each other. Such connection has been used by large-AUV builders such as Saab and Saipem to enable subsea residency of their vehicles, requiring several kilowatts of power transfer and high volumes of data transfer.

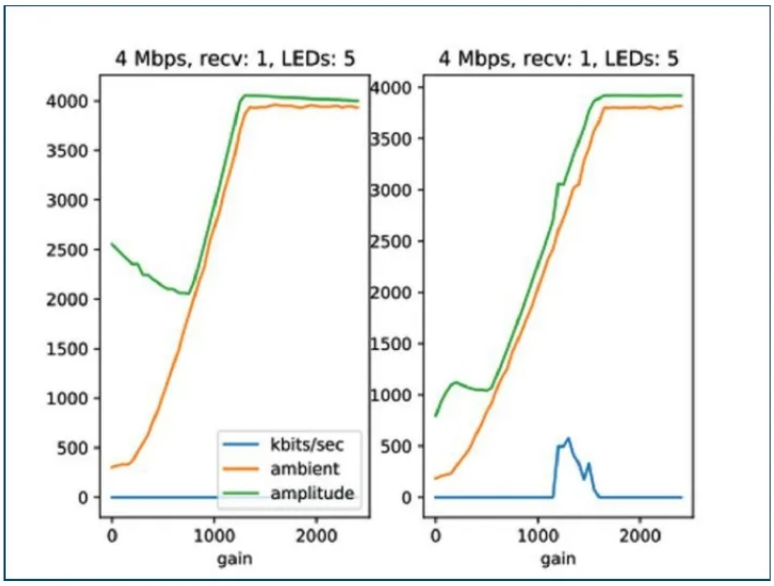
A niche for smaller resident vehicles seemed logical: lower-cost systems that could access tighter spots, though with shorter range and payload capabilities. Norway's Transmark Subsea and New Zealand's Boxfish Research conceived the merging of pinless connection and a small, battery-powered vehicle, respectively, to create the ARV-i.



ARV-i in front of its underwater resident dock.



(Top) ARV-i flying an autonomous mission inside a salmon farm. (Bottom) FSO data transmission versus ambient light levels.



Fish Farm Monitoring

The first application of the ARV-i has been in salmon farming off the west coast of Norway, involving the integration of photogrammetry systems developed by SubC3D, based in Haugesund, Norway.

Monitoring the health of the fish, the environmental conditions in the cage/net, and feeding and growth yields important metrics for the responsible management of farmed fish. Current solutions employing fixed-location cameras have proven unsuitable for gathering the required data; consider that some cages contain over 200,000 fish each. Bringing the sensors to the fish, instead of having the fish come to the sensors, was the preferred solution—and the challenge.

To meet the fish farmer's needs, Transmark Subsea defined the specification of a small vehicle and dock, with command and control of the underwater drone to be achieved using free-space optical (FSO) modems; in other words, a "wireless tether" to enable the user to direct the vehicle's excursion live. Limited autonomy was specified for undocking and docking of the vehicle, mirroring the "return to home" feature that many commercial aerial drones offer. Once in the dock, the specification called for fast transfer of acquired data and charging of drone batteries.

Limitations of FSO

When one sees the maze of ropes suspending various equipment in a salmon cage, the tangling hazard becomes apparent, and the need for a tetherless drone is obvious. Controlling the underwater drone via acous-

"The ARV-i system is demonstrating its ability to live off-grid through participation in the Renewables for Subsea Power (RSP) project."

tics was deemed unsuitable due to a bandwidth so low that user navigation by video would be impractical. FSO seemed promising.

Wireless control via FSO was chosen primarily for the claimed 10-Mbps data speeds. Trade-off considerations included angular alignment of transducers, range, data throughput and, most notably, FSO's extreme sensitivity to ambient light. In the end, the FSO was no match for the Norwegian midnight sun; effective range and data throughput of these devices were significantly reduced and, in most conditions, completely inoperable. Based on this experience, a more reliable solution was sought.

From Wireless to Autonomous

The undock/dock feature was already in development when the decision to go fully autonomous was chosen; hardware and software were already available for positioning and control via USBL acoustic positioning, with machine vision cameras guiding the drone home. Having overcome these hurdles lent confidence to the decision to proceed toward full autonomy.

The next hurdles in developing and delivering a small autonomous vehicle would include training it to recognize objects, such as fish, and programming it to successfully navigate a path through the environment. Achieving these goals had specific challenges: how to compensate for varying ocean currents; plan missions within the vehicle's battery life; develop reliable docking to survive undesired motion from adverse weather; adjust for data storage constraints; carefully consider power budgeting; resolve acoustic positioning fidelity; and compensate for various other factors.

Off-Grid Residence and 3D Digital Twinning

The ARV-i system is demonstrating its ability to live off-grid through participation in the Renewables for Subsea Power (RSP) project. The vehicle and dock have been integrated to a wave power generator and a subsea battery, with operations off the Orkney Islands at the north end of Scotland. These open-water operations offer another opportunity to demonstrate the versatility and advantage of a system located at sea, with missions steered from shore, obviating the need for a 24/7 surface support crew on site. Equipped with its own power and generator, such a system could be deployed anywhere.

3D mission planning and the ability to compare virtual mission data to actual gathered data are also becoming a reality. Underwater-resident ARV-i data collection hardware combined with analytic software enables a digital twin of the environment, which is useful, for example, in the continuous monitoring of subsea structures. Key software elements to enable this functionality are the product of GRI Simulations, based in Newfoundland, Canada. These tools are being further developed and demonstrated within the Digital Offshore Canada Project.

Conclusion

Developing an autonomous, untethered vehicle that lives as a resident in the ocean has had its share of challenges for the team, but the collaboration between Transmark Subsea in Norway and Boxfish Research in New Zealand has been successful in creating the ARV-i drone.

Developing and testing within a salmon farm cage offered the advantage of minimizing risks, such as the vehicle flying unexpectedly into the depths of a fjord, instead of into the embrace of its resident dock. Operating the drone at various field test sites along Norway's rugged west coast also contributed to development of ARV-i.

The result is that we have proven the world's first autonomous resident vehicle and dock of its class—a small, battery-powered system at lower cost—and brought it to market. We believe this system has the potential for significant impact and global adoption as a solution that will dramatically increase people's access to the ocean's resources and its secrets, which remain hidden in a frontier still very much unexplored. **ST**

Leif Hugo Arntsen is the CEO of Transmark Subsea, an underwater solutions provider based in Bergen, Norway, and Aberdeen, Scotland. The ARV-i and the technology involved in its operation add to the company's core technology within subsea distribution and pinless connector development.

Craig Anderson is a co-founder of Boxfish Research, and he specializes in control systems, software and electrical and electronic development. He has key skills in electronics, software, optics and telecommunications, and experience in delivering highly technological products to market, including advanced underwater camera and ROV solutions.