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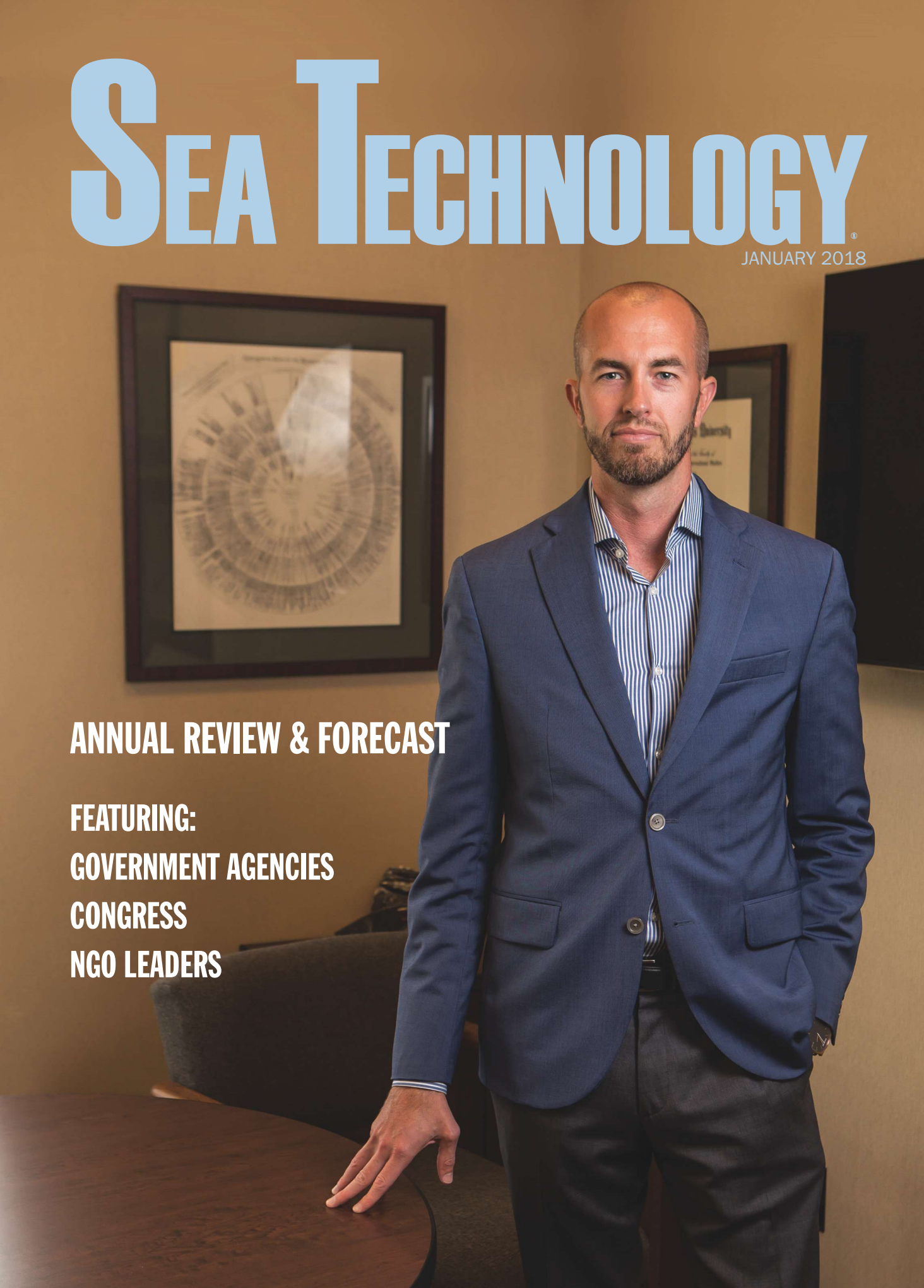
JANUARY 2018



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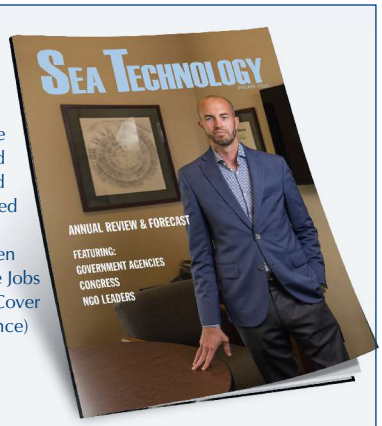

COVER IMAGE

Greg Murphy is the executive director of The Maritime Alliance (TMA), the nonprofit industry association and organizer of the largest BlueTech Cluster in the United States, with more than 85 member organizations. Based in San Diego, California, it helped launch the global BlueTech Cluster Alliance with nine clusters from seven countries, and it actively promotes BlueTech and Blue Jobs regionally and internationally. See editorial on p. 7. (Cover photo by Ron Estevez, courtesy of The Maritime Alliance)

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Celebrating more than 54 years of serving the global ocean community - Since 1963 -

editorial

***Greg Murphy**, Executive Director, The Maritime Alliance*

Promoting a Sustainable Blue Economy

The blue economy is gaining global attention as more people from academia, industry and government (the "Triple Helix") recognize that we have the responsibility and the opportunity to optimize conservation and economic development of ocean resources. Increasingly, we are looking at the "Quadruple Helix," which includes civil society; specifically, how blue economic activity impacts the public at large through the lens of the natural environment, jobs and quality of life.

We believe the best way to achieve sustainable usage of the ocean, which is the premise of UN Sustainable Development Goal 14, is through regional organized clusters with dedicated management. In January 2017, The Maritime Alliance helped launch the BlueTech Cluster Alliance (BTCA) with nine leading clusters from seven countries (Canada, France, Ireland, Portugal, Spain, U.K. and U.S.) that act independently but collaborate internationally to promote sustainable, science-based ocean and water industries.

The ninth annual BlueTech Week in San Diego November 2017 was our biggest yet, with seven events over five days and more than 450 attendees, including 18 clusters or clusters-in-formation from 11 countries and eight U.S. states. We held the third annual BlueTech Cluster Convening during #BlueTechWeek at Scripps Institution of Oceanography, moderated by Craig McLean, assistant administrator for Oceanic and Atmospheric Research and acting chief scientist of NOAA, to discuss how clusters collaborate, promote each other's members, share information and resources across regions and link regional centers of innovation and incubators to accelerate technology.

The role of clusters was the theme of our side event at the UN Ocean Conference June 2017 in New York, co-hosted by The Maritime Alliance and the Maritime Cluster of West Sweden, which explored how developed clusters promote sustainability and help developing clusters in other regions. BTCA is committed to helping develop and promote a network of organized, collaborative clusters around the world that have a demonstrated commitment of working on joint projects and attending large international conferences. TMA helped promote this theme at the Our Ocean conference in Malta October 2017 and the Organisation for Economic Co-operation and Development (OECD) Ocean Economy Week November 2017 in Paris.

The year ahead will be equally important. The Maritime Alliance is supporting the World Ocean Summit, hosted by *The Economist* March 2018 in Playa Del Carmen, Mexico, where, for the first time, Blue Economy Clusters will be a theme at this international event. The week after, TMA will host a U.S. BlueTech Pavilion at Oceanology International in London with up to 16 small- to medium-size U.S. BlueTech companies, with a follow-on trade mission March 19 to 23 for B2B matchmaking in France, Italy, Portugal and Spain, where TMA has partnerships with regional clusters. This work is supported with funding from the International Trade Administration and on-the-ground efforts by U.S. Commercial Service officers worldwide.

It is exciting to help accelerate the growth of BlueTech clusters internationally. However, there is a paucity of information on the blue economy and the fast-growing BlueTech sector. We are, therefore, encouraged by a satellite account project organized by NOAA to track economic data from BlueTech companies to help economists better understand and communicate the total value of the blue economy. The Maritime Alliance is pleased to be a subcontractor on this important work in the U.S., which parallels similar efforts in other leading BlueTech countries and at the OECD. It is critical to communicate the value of the ocean to the global economy and society at large. **ST**

)) **3D Printing Shown as Viable for Shipbuilding.** Following a rigorous testing process, verified by Bureau Veritas, the world's first class-approved, 3D-printed ship's propeller, the WAAMpeller, was unveiled at Damen Shipyard Group's headquarters in the Netherlands. This is the result of a collaboration between RAMLAB, Promarin, Autodesk, Bureau Veritas and Damen. Promarin provided the design of the triple-blade propeller. The Port of Rotterdam's RAMLAB (Rotterdam Additive Manufacturing LAB) carried out fabrication using Wire Arc Additive Manufacturing (WAAM) techniques, supported by Autodesk's expertise in software, robotics and additive manufacturing. Damen provided research and development resources and a Stan Tug 1606 vessel for operational testing purposes. Bureau Veritas's role was to verify the entire development, production and testing process. The WAAMpeller displayed the same behavior as a conventional casted propeller in all of the tests, including the crash stop scenario, showing the potential of 3D-printing techniques for vessel components.

)) **Dutch Consortium Collaborates on Autonomous Shipping.** A Dutch consortium of nearly 20 partners has launched a two-year applied research program to study and demonstrate the technical possibilities for autonomous shipping. This is expected to help reduce operating costs and improve safety and sustainability in shipping. The Delft University of Technology, MARIN and the Netherlands Organisation for Applied Scientific Research are all contributing their expertise. The study will start with an exploration and analysis of possible applications. Next, it will look at the requirements for safe navigation in shipping environments. Then, the project will examine whether it is possible to use existing techniques to mitigate or fix malfunctions from shore. This will be tested by simulations and various demonstrations, both in the office environment and on board actual vessels. The project should lead to a road map for the introduction of autonomy in shipping.

)) **Growth Spurt in Marine Big Data Market.** Considering that big data analytics in the marine sector is an upcoming technology, the global marine big data market is poised to witness a highly competitive environment. As the market is at a booming phase, Transparency Market Research (TMR) forecasts strong growth in a new study. Most market players are focusing on product differentiation, and there is also an emphasis on strategic collaborations through partnerships. TMR has identified Intertrust Technologies Corp., Splunk Inc., Teradata, BigOceanData and Datameer Inc. among the leading

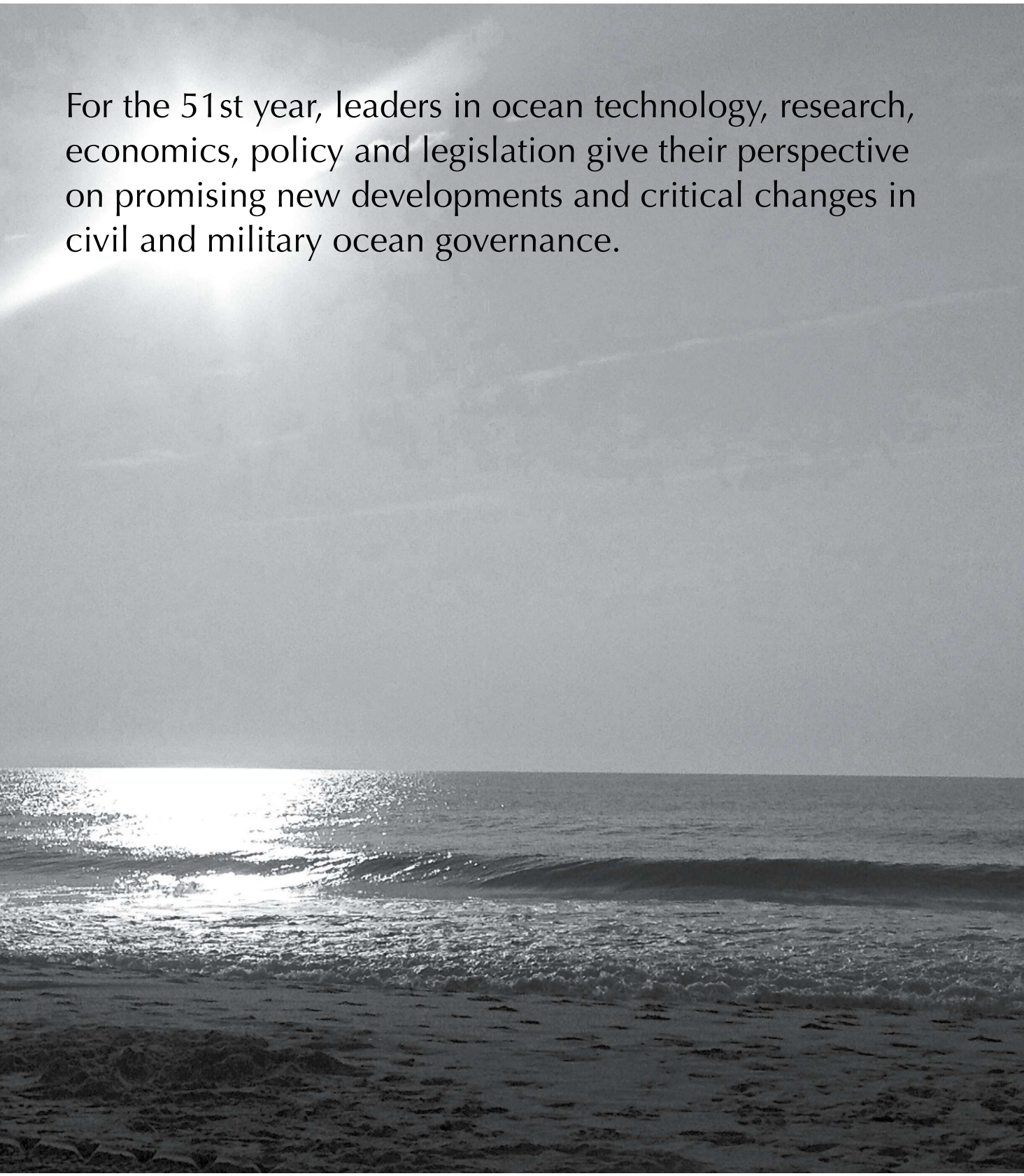
companies operating in the global marine big data market. The market is forecast to expand at 21.5 percent CAGR between 2017 and 2025, with valuation to reach $3,240.5 million by the end of 2025. The service segment currently has the larger share of the market compared to software packages. Regionally, the Asia-Pacific currently has market lead as the region boasts the presence of large shipping corporations in South Korea, China, Singapore and Japan. A staggering volume of data is generated on a daily basis in the marine sector. Big data helps discover hidden trends and patterns.

)) **New Full Owner for DNV GL.** Stiftelsen Det Norske Veritas (The Foundation) and Mayfair announced the sale of Mayfair's 36.5 percent shares in DNV GL Group AS to DNV Holding AS. The agreement regarding the major quality assurance and risk management company DNV GL was signed December 2017. In 2012, Stiftelsen Det Norske Veritas and Mayfair agreed to build a global quality assurance and risk management leader well positioned to succeed in a rapidly transforming market: Germanischer Lloyd was merged with Det Norske Veritas to create DNV GL. Since the merger, the joint company strengthened its position in research and innovation and moved forward with its digital transformation. The Foundation now assumes full ownership of DNV GL. There will be no changes to the management, organization, name or branding of DNV GL, and the headquarters for the maritime business area will remain in Hamburg, Germany.

)) **2017 Arctic Report Card.** NOAA's new Arctic Report Card shows that the warming trend transforming the Arctic persisted in 2017, resulting in the second warmest air temperatures; above-average ocean temperatures; loss of sea ice; and a range of human, ocean and ecosystem effects. While 2017 saw fewer records shattered than in 2016, the Arctic shows no sign of returning to the reliably frozen region it was decades ago. Arctic temperatures continue to increase at double the rate of the global temperature increase. The current observed rate of sea ice decline and warming temperatures are higher than at any other time in the last 1,500 years. "This year's Arctic Report Card is a powerful argument for why we need long-term sustained Arctic observations to support the decisions that we will need to make to improve the economic well-being for Arctic communities, national security, environmental health and food security," said Assistant Secretary of Commerce for Oceans and Atmosphere Timothy Gallaudet. **ST**

AnnualReview&Forecast

For the 51st year, leaders in ocean technology, research, economics, policy and legislation give their perspective on promising new developments and critical changes in civil and military ocean governance.



Review&Forecast

Sea Technology: Evolving, Expanding To Serve Industry Better in 2018

By Rick Martin
Vice President
Compass Publications Inc.

For nearly six decades, *Sea Technology* has served as the undisputed world leader in providing vital information for the marine business, science and engineering communities.

We recognize that with that leadership comes the responsibility to keep pace, to change and evolve and to find ways to better serve the ever-changing needs of our readers and advertisers.

So as the curtain rises on a new year, we are excited to share with you several developments at *Sea Technology* that will allow us to expand our mission and maintain our dedication to continued leadership.

First, we call your attention to this month's cover, with its bold new look and a well-deserved spotlight on a rising member of the new guard of ocean leaders setting direction for the 21st century. Our statement: The future is now.

Then, inside this issue, you will find *Sea Technology*'s exclusive Annual Review and Forecast, featuring contributions from leading experts in science, government and industry outlining a wide range of challenges and opportunities for the year ahead. Included is a preview of emerging technologies that may be instrumental in shaping the course of industry in the months and years to come.

Not available elsewhere, *ST*'s Review and Forecast is carefully compiled by our editors to bring you the information and insight you need to prepare and stay ahead of the curve in 2018.

Watch *Sea Technology* in 2018 for even more timely, topical coverage of the people and products making a difference in our industry. This, of course, will be in addition to our ongoing mission of providing the best in technical information in every issue covering the design, engineering and application of equipment and services in the global ocean community.

While we continue to refine and improve our print publications, we are also significantly expanding our digital presence.

Growing steadily since its launch last winter, we call your attention to the *Sea Technology* daily blog.

The blog is a spin-off of our print product, but has its own direction, overlapping with what the print magazine typically covers, while taking a look at more cutting-edge technology, a few general interest items here and there, and even an occasional dip into pop culture. (See our interview with the director of the critically acclaimed doc-

umentary "Chasing Coral" at http://bit.ly/2BxmYG7).

The goal of the blog is to give our readers more information, and faster, than is possible with our monthly publication.

We hope the blog will entice people to discover *Sea Technology* and stick around. To access and sign up to receive blog updates, visit https://seatechnologymagazine.com.

The blog, however, is just one component of the changes we're making in our online presence.

Visit https://seatechnologymagazine.com to view our revamped website, now featuring both our blog and material found in the print magazine—which is available in a complete, interactive online edition, free of charge to qualified readers just by signing up.

We think you will find a more attractive and useful site, chock full of interesting information and offering a range of marketing opportunities for companies seeking digital coverage as either a supplement or alternative to their print advertising.

Helping guide those advertisers will be MJ McDuffee, who joined our staff late last year as director of business development. MJ, well known for her years of experience in the oceans publication community, is also directly responsible for advertising sales in a large North American territory, serving companies east of the Mississippi River.

She joins John and Barb Sabo, handling the rest of North America, and John Gold, our international sales representative, in rounding out the *ST* sales organization—supported by Sue Ingle Owen in the home office.

Contact information for our sales team can be found in the masthead on p. 7.

Further advancing our leadership position this year, *Sea Technology* is pleased to be working with the newly formed International Ocean Science and Technology Industry Association (IOSTIA) on a variety of initiatives in 2018. (See *ST* November 2017, p. 40 for details.)

We are particularly pleased to be partnering with IOSTIA on a networking event to kick off Capitol Hill Ocean Week (CHOW), June 5 to 7, 2018, the premier annual conference in the U.S. examining current marine, coastal and Great Lakes policy issues.

Convened by the National Marine Sanctuary Foundation every June, CHOW brings together more than 600 national and global policy makers, scientists, scholars, businesses and conservation leaders to address pressing science, conservation and management issues facing our ocean and Great Lakes. People around the world have a virtual all-access pass to the conference and its headliners through free live streaming of every session, access to additional Web-only interviews and a dynamic social media presence.

Details were still being finalized as this issue went to press, but *Sea Technology* and IOSTIA, in association with the U.S. Senate's Commerce Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard, plan to host an event on the evening of June 4, in conjunction with IOSTIA's Blue Tech expo to be held earlier that day.

Supported by select corporate sponsors, the gathering will be held on Capitol Hill and provide a unique business networking reception with government decision makers—including procurement officers—along with key industry representatives and decision makers all in attendance. Watch these pages for additional details as they become available.

Lastly, thank you to our loyal readers, advertisers and industry colleagues for your many years of support and encouragement.

We could not do this without you and we look forward to serving you even better in 2018 and beyond. **ST**

Review&Forecast

Investing in Fundamental Wave Energy R&D: 2017 Success Stories

By Alejandro Moreno
Director, Water Power Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

The U.S. Department of Energy's Water Power Technologies Office (WPTO) is advancing cutting-edge technologies to grow and modernize the U.S. hydropower fleet and drive U.S. leadership in the emerging marine energy sector, while delivering low-cost power, resiliency and energy security to the nation's power grid. WPTO recognizes and supports the potential of marine energy technologies—which harness the energy of waves, tides, river currents and ocean currents—to provide millions of Americans with locally-sourced, clean and reliable energy. Marine energy technologies could also provide cost-effective energy for numerous distributed and alternate applications, such as forward-operating military bases, remote communities and desalination technology in the nearer term.

Marine energy is an emerging global industry. In the past, available technology and engineering know-how could not meet the formidable challenge of creating reliable energy from turbulent, corrosive seas or rushing rivers. Today's advancements in computer modeling, sensors, materials and other basic tools of technology innovation—many of which are the result of WPTO-funded research—have put the United States closer than ever before to harnessing the vast potential of its marine energy resources. From the tidal basins of New England to the powerful waves off the Pacific Northwest, developed marine energy plants could deliver forecastable, reliable electricity to the nation's electric grids (http://bit.ly/2Bf5LS8).

Yet significant challenges to marine energy development persist. Marine energy technologies are at an early stage of development due to the fundamental scientific and engineering challenges of generating power from dynamic, low-velocity and high-density waves and currents while surviving in corrosive ocean environments. These challenges are intensified by high costs and lengthy permitting processes associated with in-water testing. To meet these challenges, WPTO funds marine energy research and development in four primary areas: system design and validation; testing infrastructure; resource characterization; and environmental monitoring instrumentation research and development. Work in each area provides the marine energy industry with fundamental tools, research and innovations that tackle specific challenges hindering marine energy technology development. The aggregate result is fundamental science and engineering knowledge—the bedrock for a successful, market-driven marine energy industry. The following are just some of the successes achieved during the last year by the Energy Department's national labs, WPTO funding opportunity recipients and numerous project partners across the country.

System Design and Validation

WPTO's strategy focuses primarily on technology research and design tools to enable cost reductions and performance improvements of wave energy concepts. This research involves testing proof-of-concept systems in laboratory and ocean settings to understand performance characteristics, identifying and mitigating reliability risks and providing data to inform future research to improve early-stage designs across the industry.

Wave Energy Prize Competition. This 18-month, design-build-test competition catalyzed the largest single leap in wave energy device technology, with four teams exceeding the competition goal of doubling energy capture potential from wave energy devices. The grand-prize winner, AquaHarmonics, produced a five-fold performance potential increase over state-of-the-art devices and a potential reduction in projected energy costs of 50 percent by 2030. WPTO partnered with the U.S. Navy on the competition, with final tests occurring at the Naval Surface Warfare Center's Maneuvering and Seakeeping (MASK) Basin in Carderock, Maryland—the nation's most advanced wave-making facility.

Azura Evaluation. Azura, a prototype wave energy device developed by Northwest Energy Innovations, was the nation's first grid-connected wave energy device independently tested by a third party in the open ocean. The device, which was installed in the 30-m test berth at the Navy's Wave Energy Test Site (WETS) in Kaneohe Bay, off the island of Oahu, Hawaii, demonstrated remarkable reliability, with 98 percent uptime over 19 months and survival through Hurricanes Ignacio and Lester. The device validated electricity price models while increasing knowledge of operations and maintenance costs.

ABB Generator. ABB and project partners, including Texas A&M's Advanced Electrical Machines Lab and Resolute Marine Energy, developed and tested an integrated magnetic-gear generator with the potential to convert low-speed, high-torque waves into grid-ready electricity more economically than current solutions, according to ABB. The magnetically-geared generator was tested at ABB's corporate research lab in Raleigh, North Carolina. The prototype was part of WPTO-funded research into novel direct-drive generators that could eliminate hydraulic components in some wave energy power take-off systems. Innovative solutions such as this one help drive down the cost of wave energy.

Advanced Controls. The Sandia National Laboratories engineering team designed, modeled and tested a wave energy converter control system that doubles the amount of power a converter can absorb from ocean waves, making electricity produced from wave energy less expensive. The team applied classical control theory, robotics

"Marine energy is a predictable, forecastable energy resource with a generation profile complimentary to the seasonal or temporal variations of other resources, such as onshore wind and solar."

and aerospace engineering design principles to improve the converter's efficiency. Testing occurred at the MASK Basin, in partnership with the Navy.

Testing Infrastructure

Wave energy engineering challenges are intensified by the high costs of research and development—especially open-water prototype testing. Testing in open water requires prohibitively expensive infrastructure and navigating lengthy permitting processes, yet it is essential because laboratories cannot fully replicate the complex physics of wave-device interactions. One of WPTO's highest priorities has been developing pre-permitted and grid-connected open-water testing infrastructure to enable systematic technology development testing by industry at multiple scales.

National Wave Energy Test Site. Oregon State University, through a competitive funding process that concluded in 2016, is building a world-class Pacific Marine Energy Center-South Energy Test Site (PMEC-SETS), a pre-permitted and grid-connected facility in the open ocean to help wave energy device developers bridge a major gap to commercialization—access to economical testing. The planned facility includes four grid-connected berths where researchers can test full-scale devices and device arrays. Testing at this level will inform future device iterations. Initial operation is expected beginning summer 2021 in the waters off Newport, Oregon.

Resource Characterization

Resource characterization—the act of surveying, analyzing, inventorying and identifying available and potential energy resources—is a fundamental step to successfully harnessing wave energy. All energy sectors analyze their resources to inform business practices. Comprehensive resource assessments of U.S. waters will enable the marine energy industry to make better informed project siting decisions and helps de-risk projects for potential investors—a prerequisite to commercialization.

Updated Wave Energy Resource Assessments. WPTO's first national wave energy resource assessment, published six years ago, was based on only 51 months of wave data from NOAA, and it did not include directional analyses critical to the assessments and, consequently, site selection and project layout. The National Renewable Energy Laboratory (NREL) and project partners are now concluding a project using a 30-year data set that better represents long-term ocean wave conditions and, critically, includes directional analysis, which will reduce resource uncertainty among industry. Final data are expected in 2018, viewable on the NREL Renewable Energy Atlas at https://maps.nrel.gov/re-atlas.

Department of Defense (DoD) Deployment Opportunity. Building on existing cooperation between WPTO and the armed forces, researchers have ranked tidal and wave energy potential for coastal Coast Guard, Army and Air Force bases. The effort further informs military officials about the state of marine energy technology development and the differences in tidal and wave technologies and allows bases to enhance energy security and resiliency planning with marine energy technologies. The ranking produced numerous useful byproducts, including a transparent scoring mechanism that can be adjusted to reflect differences in mission or operations. The system can serve as template for future DoD marine energy evaluation. Present work involves an in-depth analysis of two high-ranking sites, Camp Edwards in Massachusetts and Cape May in New Jersey. These sites could one day serve as testing facilities or even become the first major deployments of marine energy in the nation.

Environmental Monitoring Instrumentation R&D

Uncertainty around the environmental impacts of marine energy devices leads to long, costly permitting processes and extensive monitoring requirements, even for single prototypes in the testing phase. WPTO seeks to provide new research and technology that can reduce the cost of the regulatory process and allow more efficient iterative testing of devices.

Animal Interactions. A team of researchers from Pacific Northwest National Laboratory (PNNL) and Sandia National Laboratory (SNL) published research concerning injury risks tidal turbines pose to seals. The research examined swimming behaviors and habitat use to determine the likelihood of seals encountering a tidal turbine, provided data on the strength of seal skin and blubber and then modeled the potential outcomes if a seal were to be struck with a tidal turbine blade. Results showed a very small risk to seals, as a number of unlikely events must occur in a specific order for the seal to be injured. This work follows research into the effect of tidal turbines on orcas. Conducting detailed study on the skin and blubber tissue of stranded, deceased killer whales, WPTO determined that a strike from an open-center, ducted tidal turbine would have minimal impact.

Monitoring Hardware, Software. WPTO seeks to support the development of new tools to collect and analyze the data required by permitting authorities. Notably, existing environmental monitoring technologies are not designed for use in the high-energy, and often low-visibility, conditions of marine energy sites, and processing the large data streams collected during environmental monitoring is time intensive and costly. New work from a handful of competitive funding opportunity awardees will improve the technical performance of monitoring instrumentation, reduce the overall costs associated with

data collection and analysis, and develop purpose-built, cost-effective tools ready to be used for environmental monitoring by the marine energy industry.

One successful hardware project is iAMP (Intelligent Adaptable Monitoring Package), a multisensor device designed by the University of Washington, which demonstrated operation in wave and river energy sites. iAMP used cameras, sonar, hydrophones and water motion profilers to successfully track the movements of fish, demonstrating 90 percent uptime at PNNL's Marine Sciences Laboratory. The University of Washington also set the stage for future environmental monitoring with an open-source software framework that uses machine learning to reduce data mortgages. The software, available on GitHub, detects and classifies images so only important ones are saved for human review.

Looking Ahead

Marine energy is a predictable, forecastable energy resource with a generation profile complimentary to the seasonal or temporal variations of other resources, such as onshore wind and solar. These characteristics enhance marine energy's potential contributions to grid resiliency and reliability. The near-load nature of marine energy generation also decreases the cost and complexity of electricity transmission. In addition, marine energy has the potential to supply reliable, least-cost power in the near term for a number of coastal or offshore applications, such as remote communities currently importing diesel, desalination or charging underwater vehicles. In 2017, WPTO hosted the "Marine Energy Technologies Forum: Distributed and Alternate Applications," which brought together experts in marine energy and those from ocean industries who might benefit from local, reliable energy from waves and currents. Attendees evaluated high-potential alternate markets for developing marine energy technologies. A full report will be available in 2018, supporting WPTO's goal of aligning marine energy technology research and development initiatives with high-priority opportunities. WPTO will continue investing in science and engineering research that will help the United States lead the way in developing this cutting-edge technology, including work in prototype evaluation.

For example, two companies, Ocean Energy USA and Dresser-Rand, will combine expertise to build and test a 500-kW wave energy device. This will be the first grid-connected wave energy converter (WEC) system tested in one of Hawaii's open-ocean WETS deep berths. The testing is planned for one-year duration. Dresser-Rand, a part of Siemens AG, is contributing an advanced air turbine that can be used as a building block in a variety of wave energy devices. The innovative power take-off will be integrated with the OE Buoy, a deepwater oscillating water column device. With advances in engineering and materials, researchers are expecting to see improvements in efficiency, reliability and survivability.

For a complete listing and details about WPTO-funded projects, visit our project map at energy.gov/eere/water/projectmap. **ST**

Review&Forecast

The Ocean Observation And Exploration Imperative

By Craig McLean
Assistant Administrator for Oceanic and Atmospheric Research, Acting Chief Scientist
NOAA

Demand for ocean data is growing, fueled by societal need. Within six weeks in 2017, four major hurricanes swept across the Gulf of Mexico and the Caribbean. Three of them—Hurricanes Harvey, Irma and Maria—were among $15 billion weather and climate disasters in the first nine months of the year. Frequent tidal flooding is occurring in 25 U.S. Atlantic and Gulf Coast cities.

Ocean observations from space, air and sea are essential to helping communities and businesses prepare for weather and climate events. Ocean data contribute to subseasonal and seasonal forecasts and beyond. Scientists use data from sustained ocean observations to more fully understand the Earth's climate system, devel-

op climate projections and monitor changes in ocean conditions that affect marine ecosystems, including commercially important fisheries and aquaculture. Resource managers and policymakers can use NOAA science to inform policy that affects public safety, national security and economic outcomes.

As need and demand for ocean data grow, the blue economy is gaining traction. Ocean-based industries generated $1.5 trillion in global revenue in 2010 (the latest report) and supported 31 million full-time jobs. In the U.S., more than 400 companies are responsible for a $7 billion ocean enterprise. In 2017, the Group of 20, the world's leading industrialized and emerging national economies, called for investment and growth in a sustainable ocean economy.

Progress in Ocean Observations and Exploration in 2017

Launched in late 2016, NOAA's GOES-16 geostationary weather satellite provides unprecedented access to high-quality data to improve hurricane forecasting and tornado warning lead times. The newly launched Polar-orbiting Joint Polar Satellite System, JPSS-1, is providing unparalleled perspective on the planet's weather plus higher-resolution sea surface temperature; analyzing ocean color to measure marine species at the base of the food chain; and using sea-ice data to aid maritime industries, search and rescue, and fisheries and protected species management.

NOAA aircraft collected more than 65,000 aerial images over 9,200 square miles to assess damage to homes, communities, infrastructure, major ports, waterways and coastlines and to assist with recovery and port and waterway reopenings after the 2017 hurricanes.

Seasonal and long-range forecasts require ocean data. NOAA is leading the international redesign of the Tropical Pacific Observing System by 2020 to improve seasonal forecasts and prediction of El Niño- and La Niña-related events.

We continue to improve observational capacity. This year, in a new partnership, Paul G. Allen Philanthropies and NOAA will deploy the largest-ever array of Deep Argo floats. It will be the first to cover an entire ocean basin, the Brazil Basin of the western South Atlantic Ocean. At the other pole, the U.S. Arctic Observing Network, to which we contribute, is expanding sustained observations in the Arctic.

NOAA is also working with the U.S. Navy on design and construction of the first vessels in the NOAA fleet recapitalization project. Ships are vital components of our ocean missions.

Sustainability of valuable fisheries and marine resources depends on our ability to monitor ocean ecosystems and changing ocean conditions. For example, the U.S. Integrated Ocean Observing Systems (IOOS) initiated the Marine Biodiversity Observing Network, a sustained, integrated, biological observing program, with federal, academic and industry partners that include NOAA scientists. Another example is the U.S. (NOAA) bio-Argo program, with the National Science Foundation, starting a Southern Ocean experiment.

We are always looking to new technologies to fill observational gaps and improve capabilities and cost-efficiencies. Unmanned systems are helping fill those gaps. Saildrones are being tested in the tropical Pacific and collecting data in the Arctic. For just $10 in parts, NOAA's sea temperature sensor can now monitor temperatures on any coral reef with high accuracy. A unique freshwater environmental sample processor was deployed to monitor western Lake Erie for harmful algal bloom toxin. A new, integrated, cost-effective nutrient sensor was also developed.

The recently released final National Charting Plan will improve NOAA nautical chart coverage, products and distribution. Navigating narrow channels will be safer because NOAA's acoustic Doppler current profiler system is now operational.

Charismatic deep-ocean species became media stars when high-definition video and photos taken by the ROV Deep Discoverer were transmitted to shore in real time. This was part of a three-year NOAA ship *Okeanos Explorer* mission to study, survey and map deepwater in U.S. marine protected areas in the central and western Pacific. The two-body ROV, capable of diving to 6,000 m, carried a scientific sensor payload for ecosystem measurements.

A comprehensive international seafloor mapping effort, Seabed 2030, intends to create a high-quality, high-resolution digital model of the ocean floor. NOAA is collecting and hosting data to support this initiative.

Ocean Observations and Exploration In the Blue Economy Future

Investing in ocean observation science and technologies makes sense. The ocean, both its natural resources and uses, is a key economic driver.

The future of ocean observations and exploration depends on a science and technology community that can do several things effectively. First, we must sustain ocean observations and exploration to meet immediate and future societal needs. This includes data to improve weather forecasting, climate science and climate prediction. We also must fully embrace the biological, so we can sustainably manage fisheries, coral reefs, protected species and other valuable marine resources and activities, from deep-sea mining to aquaculture.

Second, we must develop technological tools to achieve science and operational goals. Observational platforms should be cost-effective, multipurpose, adaptive samplers capable of withstanding the elements. Data integration and visualization should be firmly planted in our strategy. Policies and programs need to keep pace with emergent technologies.

Third, coordination is essential to optimize impacts and dollars across the observation and exploration enterprises. Agencies benefit from regular dialog with academia, industry and other private sector organizations to communicate the nation's needs and match partners with needs. Novel partnerships and approaches are emerging. The Ocean Exploration Trust, XPRIZE Foundation, Schmidt Ocean Institute and Paul G. Allen Philanthropies have already stepped forward.

Finally, funding pressures demand we more effectively communicate the value of ocean observations to people, communities, businesses and governments.

We are at a pivotal time for society. The blue technology community has an opportunity to rally around the cause of ocean observations and exploration. Society, the planet and the blue economy will be the beneficiaries. **ST**

Review&Forecast

Staying Committed to Basic Science: Discovery in a Time of Change and Uncertainty

By Jessica F. McGrath
Policy Advisor
Dr. Richard W. Murray
Director
Division of Ocean Sciences
U.S. National Science Foundation

The National Science Foundation (NSF) stands at the forefront of U.S. research and advancement to support basic science and research that seeks to explore, discover and understand the unknown. With an annual budget of $7.5 billion (fiscal year 2017), NSF funds approximately 24 percent of all federally supported basic research conducted by America's colleges and universities as part of its mission to act as a driver of the U.S. economy, enhance the nation's security and promote U.S. global leadership (https://nsf.gov/about).

Within the NSF Directorate of Geosciences, the Division of Ocean Sciences (OCE) supports research, infrastructure, technological innovation and education to advance understanding of all aspects of the global oceans, including the impacts on human health and integrated Earth and climate systems. OCE participates in collaborative efforts within the scientific and educational community, on both a domestic and international scale. The division works with numerous U.S. programs to direct funding toward advancing the frontiers of science and technological development. OCE is committed to supporting the continued need for ocean research infrastructure, advanced technology and education.

'RAPID Response' to Hurricanes, Major Storm Events

As it appears, 2017 is likely to be the most expensive hurricane season on record in U.S. history (http://nyti.ms/2nzMY15). Most of the focus on these events surrounds community impacts and recovery, while the science to understand how such disasters happen and how the U.S. can best respond is also important to help prepare for the future.

To address the need for quick-response research on unanticipated events, NSF has a Rapid Response Research (RAPID) funding mechanism. RAPID grants are used for proposals identifying an immediate and critical need for support with regard to availability of, or access to, data, facilities or specialized equipment, including research on natural or anthropogenic disasters (http://bit.ly/2iYtv92). These proposals are reviewed internally and are turned around, well, "RAPID"-ly, often within a matter of a few weeks.

As of October 10, 2017, NSF has awarded approximately 60 new grants totaling $5.3 million in response to Hurricanes Harvey, Irma and Maria (http://bit.ly/2jZFMGP). For example, NSF is currently supporting RAPID research to evaluate the effectiveness of mangroves and salt marshes for coastal protection; the potential response and ability to recover of the Texas barrier islands; and determining the level of threat on human health from liquid mercury that was released into floodplain sediments of the San Jacinto River in Texas.

Sensor Research and Advanced Technology Efforts

NSF is collaborating with the National Oceanic Partnership Program (NOPP) to support ocean sensor research and development (http://bit.ly/2zTVf1G). The specific grant program may collectively support up to $18.5 million over five years to investigate CubeSat sensors to study littoral ocean and atmosphere dynamics; improved and routine production, stewardship and application of the Group for High Resolution Sea Surface Temperature (GHRSST) Data; and in-situ ocean sensor research and technology development. OCE's main interest is in the last of these subjects, and we are partnering with fellow agencies Office of Naval Research and NASA in this program, along with NSF's Office of Polar Programs.

Long-Term Ecological Research

In 1980, NSF established the Long Term Ecological Research Program (LTER, https://lternet.edu) to address ecological questions that require collaborative partnerships to conduct observations or experiments over multiple spatial scales. The program aims to understand how diverse components of an ecosystem interact to influence ecosystem function. Each of the 28 LTER sites are organized around a scientific theme specific to its location and ecosystems, including the open ocean, coral reefs, deserts and grasslands.

NSF awarded $5.6 million (http://bit.ly/2k0KLqw) to support two LTER coastal sites along the Northeast U.S. Continental Shelf and in the northern Gulf of Alaska. Both sites are home to productive fisheries and abundant resources, in addition to facing significant environmental changes and stressors. Scientists will have the ability to make observations across a larger geographic region, exploring the links among the ocean environment, plankton food webs and fish stocks to better predict how the ecosystem will respond to environmental change.

Ocean Observatories Initiative

The Ocean Observatories Initiative (OOI, http://oceanobservatories.org) transitioned into operations in 2016. OOI includes a network of cabled, moored and autonomous instrument arrays with more than 800 individual sensors distributed across four global arrays, two coastal and a cabled array. This facility is enabled by an integrated system of cyberinfrastructure that collects, analyzes and disseminates the data, enabling interdisciplinary investigation of short-term and long-term oceanic trends.

OCE is in the process of recompeting the cooperative agreement to manage and operate OOI through an open, merit-based external peer-review process, open to U.S. institutions, universities, colleges and other nonprofit, nonacademic organizations. The awardee will serve as the single lead to fulfill the OOI objectives through strategies that capitalize on the federal investment to serve the scientific community and to promote world-class oceanographic research. OCE hopes to announce the outcome of this recompetition in the middle of 2018.

International Ocean Discovery Program

In the summer of 2017, a team of scientists with the International Ocean Discovery Program (IODP) spent two months aboard the drill ship *JOIDES Resolution* drilling into part of the 2 million-sq.-mi. mass of continental crust that lies just east of Australia. This mysterious region, called Zealandia, broke away from Australia and subsided about 80 million years ago. The expedition collected 2,500 m of sediment cores that record how the geography, volcanism and climate of Zealandia have changed over the last 70 million years. Findings revealed that the chain of volcanism that makes up the Pacific's "Ring of Fire" may have caused Zealandia to buckle about 40 million to 50 million years ago, which also dramatically reshaped the landscape. In addition, studies of the sediment cores obtained during the expedition will focus on understanding how Earth's tectonic plates move and how the global climate system works.

In 2016, a team of international scientists drilled into the site of an asteroid impact, known as the Chicxulub Impact Crater, near the Yucatán region of México. The Chicxulub impact structure formed when a large asteroid hit the Earth around 66 million years ago, which is linked to the end-Cretaceous mass extinction. The eight-week-long expedition aboard the liftboat *Myrtle*, a joint expedition organized by IODP and International Continental Scientific Drilling Program (ICDP), recovered a nearly complete set of rock cores from 506 to 1,335 m below the modern-day seafloor. The cores include 120 m of limestone sediments deposited between 66 million years ago to around 50 million years ago, as well as some 120 m of broken and melted rocks burying a ring of mountains. Sampling and analyzing the peak ring sediments will provide valuable insights into the processes that govern impact formation during large impacts and the understanding of planetary crustal composition via remote sensing.

Academic Research Fleet

The U.S. Academic Research Fleet (ARF) included 18 vessels in calendar year 2016, ranging in size, endurance and capabilities to enable NSF and other federally and state-funded scientists to conduct ocean science and technology research in coastal and open-ocean waters.

NSF received congressional appropriation in 2017 with partial funding for three Regional Class Research Vessels (RCRVs) and is awaiting 2018 budgetary guidance. RV *Thomas G. Thompson*, operated by the University of Washington, is completing a mid-life refit, and the new vessel RV *Sally Ride*, operated by the Scripps Institution of Oceanography, transitioned into operations in 2016.

Coordination for ARF vessel use occurs through the University-National Oceanographic Laboratory System (UNOLS), which schedules all scientific seagoing missions for the ARF in collaboration with the funding agencies. The vessels within the ARF are operated by academic institutions through cooperative agreements (NSF) and charter-party agreements (ONR) and are part of the UNOLS organization.

Moving Forward

In a time of uncertainty and change, NSF remains committed to basic science and education while continuing to support groundbreaking research and technological innovation. This advancement will incorporate broader impacts to society to help inform policy decisions. NSF continues to use the recommendations provided in the "Sea Change: 2015-2025 Decadal Survey of Ocean Sciences," or "Sea Change" (*Sea Technology*, June 2015), as a guide to ensure a strong ocean science enterprise through 2025. **ST**

Review&Forecast

A Vision for a Safe and Secure Arctic

By Admiral Paul F. Zukunft
Commandant
U.S. Coast Guard

The Coast Guard has been operating in the Arctic since the U.S. became an Arctic nation. In 1867, the Revenue Cutter *Lincoln* carried U.S. government officials to Sitka to transfer the territory to the U.S ultimately making our country an Arctic nation. This transfer of the Alaska territory from a financially strapped Russia to the United States at an affordable cost of two cents per acre was dubbed "Seward's Folly." But with the passage of time, as vast natural resources were discovered in the region and its strategic positioning provided leverage throughout the Cold War, we realized this purchase was no folly. It was visionary.

We will need the same courage and foresight of Secretary of State William Seward and his president, Abraham Lincoln, to craft a vision for a safe and secure Arctic region. As we commemorate 150 years of Coast Guard operations in Alaska, we are witnessing the acceleration of rising temperatures in the higher latitudes at a much faster pace than anywhere else on the globe. Even though ice coverage hit record lows during the 2017 season, our International Ice Patrol recorded the fourth consecutive "extreme ice season" with more than 600 icebergs in the shipping lanes. Many of these are calving from the Jakobshavn Glacier in Greenland—the same source of the icebergs that sank the *Titanic* in 1912.

In the face of an already dangerous Arctic, safety risks increase as human activity from cruise ships, offshore drilling and commercial shipping also increase. From 2008 to 2016, traffic in the Bering Strait more than doubled and is expected to increase two- to four-fold in the next eight years. The retreat of sea ice, which once served as a natural breakwater for indigenous residents, has caused severe coastal erosion that threatens the habitability in multiple Arctic communities. Fishermen and indigenous whalers push further offshore, facing a litany of new threats. Between 2010 and 2016, search and rescue cases doubled. This summer alone, Coast Guard crews deployed in support of Operation Arctic Shield responded to 20 cases, saving 16 lives and assisting 23 others.

A seabed full of oil, gas and minerals in the Arctic provides rich resources for the United States and other Arctic nations to access and draw from. This opportunity is not without risk, as any oil spill would be catastrophic in this pristine environment and could directly affect subsistence living, as well as endangered species. With less than 5 percent of the Arctic surveyed and charted to 21st century standards, the potential for a vessel grounding with catastrophic loss of life and environmental damage cannot be overstated given the remoteness of that region and the distance that our Coast Guard search and rescue crews must travel.

Further—and most importantly—extraterritorial claims backed with military force from select nations pose an additional security threat to the Arctic region. The Coast Guard's dedicated Arctic presence is one of the few constants in this dynamic region, and with it comes an increased demand for our finite resources. Given what is at stake, how is the Coast Guard ensuring security and prosperity in the region? Two words: diplomacy and presence.

Diplomacy

When the Unites States formed the Arctic Coast Guard Forum (ACGF) in 2015, top Coast Guard officials from each of the eight Arctic nations were largely strangers. Now, we work closely together for the common good. We established the first layer of maritime governance in the Arctic, creating a network of partners built on mutual trust and common interests overlaid by strategy and operational protocols. Just two years after this cooperative body was formed, we organized and executed the largest search and rescue exercise in the Arctic, "Arctic

"State and nonstate actors alike are posturing to take full advantage of the opening Arctic, which requires diplomacy and cooperation, along with an appropriate maritime domain awareness footprint."

Guardian," which occurred off the coast of Iceland in September 2017.

This governance mechanism provides a unique opportunity to cooperate with each Arctic nation, and our ability to engage directly with Russia on security issues provides a critical de-escalatory capability in the region. These established relationships continue under the Finnish Border Guard chairmanship of the ACGF, ensuring that this body remains the premier platform for fostering safe, secure and responsible maritime operations in the Arctic.

Presence

State and nonstate actors alike are posturing to take full advantage of the opening Arctic, which requires diplomacy and cooperation, along with an appropriate maritime domain awareness footprint. This includes a fleet of polar icebreakers that can provide assured year-round access to exert our sovereign rights, ensure our national security and protect our economic interests.

The U.S. Navy maintains a formidable deterrent force underneath and above the Arctic Ocean, but the Coast Guard is the visible presence in the Arctic region. Assured access is the only way we can effectively respond to threats and facilitate emerging commercial activities.

To that end, we are working to recapitalize our aged fleet. Our immediate focus is to get the first "heavy" icebreaker in the water by 2023, before building the second to reestablish self-rescue capability. Our threshold requirement for year-round access and to support all missions in the Polar regions consists of three heavy and three medium polar icebreakers. These icebreakers must be built and equipped to respond to our current needs while reserving space, weight and power to meet future demands.

As an Arctic nation, we must provide visible presence in the high latitudes. History proves that no other investment will return more operational value on each dollar than the extraordinary men and women of the United States Coast Guard. With the continued support of Congress, we must maintain momentum for ongoing icebreaker recapitalization, as it would be a "folly" not to invest in our sovereign interests in the Polar regions.

While many challenges remain, the Coast Guard's fu-

ture is bright. We will continue to live up to our motto and be "Semper Paratus"—always ready. **ST**

Review&Forecast

Making Bipartisan Progress For the Oceans, One Step at a Time

By Sen. Sheldon Whitehouse (D-R.I.)
Co-Chair
U.S. Senate Oceans Caucus

We're living in challenging times. Our environment, including our oceans and the coastal communities that rely on them, are facing unprecedented threats from climate change, pollution and overexploitation. It doesn't help that a significant number of the people appointed to lead our federal agencies are woefully unqualified and inexperienced. And the divide between our political parties is growing, making compromise more difficult.

Fortunately, oceans policy remains an area primed for bipartisan agreement in Congress. And I'm proud to say the bipartisan Senate Oceans Caucus—with 36 members—continues to pursue progress in the areas of pirate fishing, marine debris and ocean data monitoring.

Our caucus's first challenge was to combat illegal, unreported and unregulated fishing. After getting four international agreements approved to help stop pirate fishing, as well as the enabling legislation to put them in force, the caucus continues to push for policies that boost sustainable fishing practices around the world. Pirate fishing often accompanies other illegal activities, including forced labor and human trafficking.

To pave the way for additional progress, we recently secured passage of a provision directing the Navy to assess its capabilities to support the Coast Guard and our international allies in combatting human trafficking, pirate fishing and other illicit activities at sea. I look forward to working with my colleagues to address the Navy's recommendations.

This past year also saw a big win on the caucus's second priority: action against marine plastic pollution. The Senate passed the Save Our Seas Act, a bipartisan bill that would reauthorize NOAA's Marine Debris Program, expand the agency's authority to respond to natural disasters that worsen the spread of marine debris like the 2011 Japan tsunami and encourage the president to promote better management of plastic waste in developing nations. The bill would support investments in research to better understand global marine debris and develop biodegradable plastic alternatives. The U.S. Trade Representative is also encouraged to use future trade agreements to address the marine debris crisis. We hope the House of Representatives will take up this legislation soon.

We must find common ground and work together toward ensuring healthy oceans for future generations. Together, we can regain the United States' place as the world leader in ocean innovation, environmental protection and marine industries.

Building off of these successes, the caucus is gearing up for next year's legislative push on ocean data monitoring. Long-term, consistent monitoring of ocean conditions is vital to researchers, shipping and fishing interests and our military, all of which rely on accurate and timely information about the sea. From fishermen to university researchers to cargo vessels and cruise ships, being able to access real-time data on ocean conditions and to track changes in ocean chemistry and biology over time is invaluable to the successful conservation and utilization of our marine resources.

We need to bring our ocean data collection fleet up to date, including using technologies such as autonomous gliders and passive sensors on fishing equipment and vessels. There is an opportunity for innovation and commercial development in this space, as readers of *Sea Technology* magazine are well aware. In fact, the National Academy of Sciences recently released a report on ways the United States can improve ocean observation. Among the academy's recommendations was an Advanced Research Projects Agency for the oceans. I have long championed the idea of an "ARPA-O," and I look forward to working with the National Academies and Oceans Caucus members to make this idea a reality. An agency as successful as DARPA and ARPA-E dedicated to ocean and coastal research could give the United States a winning advantage in technology at sea.

The U.S. has long been a world leader on ocean and environment issues. But we are quickly losing our place. At the Our Ocean Conference in Malta this year, the U.S. fell short of what we should expect from the country that founded this premiere world ocean conference. I saw the same troubling trend at the UN Climate Change Conference in Bonn. The U.S. stood alone as the only country not committed to the Paris Climate Agreement. Instead of being the example to follow, we're being left behind.

If we let political divisions and polluting industries win the day, we will only hurt ourselves. We must find common ground and work together toward ensuring healthy oceans for future generations. Together, we can regain the United States' place as the world leader in ocean innovation, environmental protection and marine industries. **ST**

Review&Forecast

Partnerships Will Encourage Novel Tech Development, Innovation

By Rep. Eddie Bernice Johnson (D-Texas)
Ranking Member
U.S. House Committee on Science, Space, and Technology

When all the data have been analyzed, 2017 is expected to be one of the hottest years on record, continuing three consecutive years of record-breaking warmth globally. These warmer global temperatures have led to warmer ocean temperatures, with a myriad of impacts ranging from coral bleaching to sea level rise. Warmer oceans also mean that the 2017 hurricane season is likely a harbinger of what we can expect to see in coming years with increased severity of storms and longer hurricane seasons that will have broad and long-lasting impacts on Americans. We don't yet know the full costs of Hurricanes Harvey and Irma, but according to NOAA's National Centers for Environmental Information (NCEI), Superstorm Sandy alone cost more than $70 billion.

These impacts can negatively affect the resources that make up our coastal and ocean economy, which in just the year 2014 contributed more than $352 billion to the U.S. GDP and provided 3.1 million jobs. Additionally, approximately 39 percent of the nation's population lives in counties that are directly on shorelines, which comprise more than 95,000 mi. along coastal states, the Great Lakes and outlying U.S. territories. These coastal industries and population are heavily reliant on ocean health measurements and timely and accurate predictions for climate and weather events that are made possible by observations and monitoring. The ability to monitor changes in the oceans and predict with detail and accuracy the path of storms and their potential rainfall is essential.

The federal government is one of the largest users of ocean data. Moreover, the technology currently used by federal agencies to track and monitor ocean data is the gold standard. However, as our environment rapidly changes in ways that we have not seen before, additional innovation in these technologies will be needed. Federal R&D investments in the research and development of novel marine technologies in partnership with nonfederal partners from the private sector and academia can help to drive that innovation.

Many cutting-edge marine technologies that likely would not have been funded by the private sector alone are beneficiaries of federal collaborations or investments that helped incentivize and speed their development. Federal research grants from agencies such as NOAA, NASA and the National Science Foundation can continue to provide seed funding for projects without the need for researchers to first demonstrate a proof of concept, a high barrier to entry for many researchers seeking to gain funding from nonfederal sources. New marine technologies are not only beneficial to large users of ocean observation data such as the federal government, but can also have broader impacts through the development of tools that can aid niche economic markets or entire sectors. For example, monitoring technologies that were initially developed through federal research grants, and later made commercially available, have been instrumental in a vast array of industries, such as improving the ability of West Coast shellfish to bounce back from significant die-offs.

In addition to traditional research grants, there are other existing avenues for collaboration between federal agencies and nonfederal partners. NOAA's Cooperative Institutes co-locate academic and nonprofit institutions to encourage high-level, collaborative research. Cooperative Research and Development Agreements (CRADAs) at NOAA and other agencies are partnerships between agencies and private companies on specific projects that allow for sharing of intellectual property and technical resources and help speed the commercialization of agency-developed products. This allows novel technologies to move swiftly from the lab bench into the hands of end-users, such as commercial fishermen.

Regional partnerships between federal partners and nonfederal entities, such as the U.S. Integrated Ocean Observing System, or IOOS, provide a robust set of ocean observations that allow for increased understanding of regional marine circumstances. The IOOS program successfully integrates federal observations and monitoring with nonfederal resources. These integrated capabilities allow for more informed decision making, and allow access to this data in near-real time, putting essential resources directly in the hands of the public.

Novel marine technologies provide the opportunity to augment our existing observations and monitoring systems. This allows for more robust data collection, which leads to more informed decisions at the federal level. Federal investments not only drive the development of novel technologies, but can also help in the commercialization of technology that could be valuable to local fishermen and shellfish growers. Entities ranging from Fortune 500 companies to start-up companies to individual researchers have all benefitted from federal investments and collaborations to help support their research and technology development at almost every stage. Cutting the budget for external research grants at federal agencies would stifle organic and innovative approaches to our most urgent challenges.

In my role as the ranking member for the House Committee on Science, Space, and Technology, I strive to find ways for Congress to develop solutions for our most pressing needs as a nation. When the problem is as big as a changing climate, it is essential that we get all hands on deck to help us observe, monitor and prepare ourselves for the future. This means encouraging creative solutions by individual researchers, universities and private

companies with support and investment by the federal government. Without continued engagement by federal agencies in these collaborations, we will not reach our full potential.

It is imperative for Congress to continue to support existing programs and partnerships with proven track records of success. Whether it is public-private partnerships, regional collaborations or federal research grants to universities and individual researchers, none of the collaborative processes I have described occur in a vacuum. Congress has a vital role to play in continuing to advance marine observation and monitoring technologies in the private sector and academia to help federal agencies achieve their mission objectives, which ultimately benefits the American people. **ST**

Review&Forecast

A Changing Tide in Congress

By Rep. Salud Carbajal (D-Calif.)
Member
Bipartisan Climate Solutions Caucus
U.S. Congressional Oceans Caucus
U.S. House Armed Services Committee

Throughout my first year serving in Congress, I have often gotten into debates with colleagues over my belief that I represent—without a doubt—the most beautiful district in America. The Central Coast of California is a special corner of the world, and preserving our unique coastal ecosystem is a top priority of mine.

Raising my children in Santa Barbara and now watching them have children of their own, close to the natural beauty of our oceans, constantly reminds me of the urgent need to preserve and protect our natural environment.

Healthy, sustainable oceans and our nation's economic growth are not mutually exclusive. In fact, they go hand in hand. Our oceans and natural resources are renowned on the Central Coast and serve as economic hubs that generate tourism dollars, sustain our commercial and recreational fisheries and host diverse marine wildlife that is essential to preserving vital ecosystems.

The health of our oceans is not a partisan issue, and while in the minority party in Congress, I have worked with my colleagues across the aisle to advocate for commonsense solutions to protect our marine habitat. I have partnered with colleagues on work to reduce harmful NOx emissions, curb ocean acidification and strengthen our National Ocean Policy. The tides seem to be shifting in Congress, and there is a new sense of bipartisan agreement surrounding the need to act to mitigate the impacts of climate change.

Earlier this year, Congressman Mike Gallagher, a fellow Marine and a Republican representing Wisconsin, and I joined the bipartisan Climate Solutions Caucus to prioritize the need to address climate change. The caucus serves as a working group dedicated to finding solutions and advancing proposals to mitigate and reduce the impacts of climate change while continuing to grow our economy.

In this effort, I partnered with Congressman Carlos Curbelo (R-Fla.), the Climate Solutions co-chair, to introduce the bipartisan Coastal State Climate Preparedness Act. This legislation instructs the secretary of commerce to establish a coastal climate change adaptation program, as well as a response grant program to protect our coastal resources.

Additionally, I serve on the House Armed Services Committee. As a Marine Corps Reserves veteran, I am proud to support our military servicemen and women. In my role on the committee, I have met with high-ranking military officers concerned about the risk that climate change poses to our national security. On one occasion, at Elmendorf Air Force Base outside of Anchorage, Alaska, the commanding general shared with us one of his main concerns that significant Artic sea melt will mean more navigable pathways for foreign enemies.

"Ocean acidification will cost the world economy more than $1 trillion annually by 2100. In Alaska, where half of the seafood caught in the United States originates, the acidification of the cold water is endangering 70,000 jobs."

In this year's defense authorization bill, along with my colleague Rep. Jim Langevin (D-R.I.), I successfully advocated for an amendment requiring the Department of Defense (DoD) to produce a report on climate change. This report will detail the threat climate change poses to our military operations and installations, as well as requiring DoD to propose mitigation strategies.

Currently, coastal counties account for 39 percent of the United States population and produce $6.6 trillion in gross domestic product. It is important that coastal states start planning now for the harmful impacts that climate change will have on the public health of our communities and our economy.

Already, we have seen how rising sea levels are impacting coastal states such as Florida. As extreme weather events become more prevalent due to warmer temperatures, coastal states are faced with the challenge of having to adapt to this new reality—putting a strain on vulnerable communities that might not have the necessary resources.

Protecting our coastal resources and marine ecosystems makes economic sense. Ocean acidification is a concern throughout the country and globally because of its widespread impacts to our environment and our economy.

In 2014, the United Nations released a report that found ocean acidification will cost the world economy more than $1 trillion annually by 2100. In Alaska, where half of the seafood caught in the United States originates, the acidification of the cold water is endangering 70,000 jobs.

However, there is bipartisan support in Congress to act. With the support of Rep. Don Young (R-Alaska), I've introduced H.R. 845, the Ocean Acidification Research Partnerships Act. This bipartisan legislation directs NOAA to create a research grant program between the seafood industry and academia to investigate the effects of ocean acidification.

My work to combat the impacts of climate change began during my public service at the local level in Santa Barbara County government. As county supervisor, I helped initiate a program that reduces harmful NOx air pollutant emissions from vessels, as well as prevents fatal strikes on whales in Santa Barbara County. Currently, ships account for more than 50 percent of NOx emissions in this county.

After years of hard work, we reached an innovative partnership between public, private and nonprofit partners to reduce ship speeds. In 2014, the Channel Islands National Marine Sanctuary and the Santa Barbara and Ventura County Air Pollutions Control Districts, along with the Environmental Defense Center and the National Marine Sanctuary, launched a pilot program to incentivize companies to voluntarily reduce their vessel speeds in the Santa Barbara Channel to improve air quality and protect our marine ecosystem.

This was an example of what is possible when different stakeholders work together for environmental progress. It is a model for coming together and finding common ground. In Congress, I look forward to continuing this local progress at the federal level as a co-sponsor of H.R. 3682, the Blue Whales and Blue Skies Act of 2017. This legislation models the Santa Barbara Channel's successful program to increase air quality and protect marine life by reducing ship speeds.

We have many challenges ahead of us, especially as we continue to deal with the widespread impacts of climate change. Preserving our unique ocean and coastal ecosystems should not be a partisan issue. With this daunting reality, I remain encouraged by my colleagues' willingness to reach across the aisle and acknowledge that we need to find commonsense solutions to keep our oceans thriving. **ST**

Review&Forecast

A New Era of Coastal Services

By Sandro Carniel
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The increasing quality and quantity of information provided by Copernicus, the European Union program funneling Earth observation and in-situ data into a broad set of information services, offer the possibility to analyze and predict coastal meteo-oceanographic processes at an unprecedented level. A decisive step in this direction is presently being supported by the Sentinel satellite constellation launched in April 2014 and operational through 2020. The overall fleet comprises a set of six families of devices, each addressing different aspects of atmosphere, ocean and land monitoring.

The image resolution, time coverage and combinations of sensors offered by the Sentinel satellite family will provide a unique opportunity to develop the Copernicus coastal dimension and to tackle the pressures of increasing population and activities threatening the sustainability of coastal resources and infrastructures.

The combination of ocean/atmosphere/land observations made available in particular from the Sentinel 1, 2 and 3 satellites, aligned with the capabilities of an increasing number of high-resolution numerical imaging systems (specifically, coupled atmospheric, wave and current codes) within the Copernicus Marine Environment Monitoring Service (CMEMS) catalog, will enable users to get access to improved representations of the coastal environment.

This reflects a new level of understanding (e.g., wave diffraction at coastal "obstacles"), a focus on aspects related to coupling (e.g., incorporating the land discharge into the coastal sea) and will improve the overall reliability for applications (e.g., hazards for coastal navigation).

Moreover, by adding periodic bathymetric updating that may be derived from Sentinel images and incorporating new data assimilation routines, it will become possible to achieve a new level of analysis for coastal seas, with satellite oceanography constraining models and supporting downstream applications.

Overall, this would represent a tangible new step toward improved forecasting and to a new level of reanalysis, which would also translate into a benefit in the field of design/risk probability analysis for civil engineering structures at climatic scales.

These advances, once integrated into the overarching Copernicus architecture, will prove the technical feasibility of a new wealth of "coastal services" directly addressing the needs of public managers (e.g., coastal authorities) and private users (e.g., renewable energy companies) competing for the limited coastal zone space, therefore, providing the necessary resources for careful maritime spatial planning activities.

With the aim of assessing these new coastal services, the EU has recently funded the project "Copernicus Evolution and Applications with Sentinel Enhancements and Land Effluents for Shores and Seas" (CEASELESS) under the EU initiative Horizon 2020. The CEASELESS project started November 2016, under the coordination of the Polytechnic University of Catalonia (UPC) and involving several European partners: Italian National Research Council, Technical University of Denmark, Helmholtz-Zentrum Geesthacht, Danish Hydraulic Institute, Geographic Resources Analysis and Science, Natural Environmental Research Council, Met Office and the European Centre for Medium-Range Weather Forecasts.

CEASELESS highlights limits and potentialities of the new Sentinel measurements and how they can support the development of a coastal dimension in Copernicus by providing an unprecedented level of resolution/accuracy/continuity with respect to present products.

The retrieval and validation for restricted domains and for an enlarged set of combined variables will be the basis to advance the state of the art in assimilation, modeling and applications, at a level commensurate with the new Sentinel capabilities.

The mutual validation of satellite data, numerical results and in-situ observations will generate reciprocal profit for enhanced competitiveness of EU coastal industries, although the suitability for cases in poor countries opening new business opportunities for a coastal Copernicus, will be also assessed by the CEASELESS team.

CEASELESS will specifically address the wide and multiple scales coexisting in littoral areas by developing new shallow-water parameterizations, introducing them into coupled model suites (dealing with wind-wave-surge-current-land discharge) and setting new standards for coastal simulations and analyses.

The permanent database produced by the project, in addition to the modular structure of the developed models, will demonstrate the technical feasibility of a future operational Copernicus coastal service. More specifically, the data repositories (accessible via a dedicated portal), regularly updated with the evolving (satellite-derived) bathymetry, will facilitate the use/re-use of our high-resolution results, supporting a new set of Copernicus coastal applications, such as renewable energy, coastal erosion or harbor exploitation.

Generally speaking, results deriving from CEASELESS activities will be directly employed to assess and mitigate the level of conflicts that characterize the very densely populated coastal regions in the EU, where these conflicts are growing as a consequence of climate change-related impacts. Sea level rise, coastal flooding and erosion and increase of wave storms are just some of the examples that require a new level of understanding and modeling in order to provide factual and efficient support to a wide range of economic sectors taking place in the land border area.

The feasibility of such an operational coastal service will be assessed by CEASELESS on three levels: scientific (project partners), technical (project users) and operational (Copernicus providers). This approach can enhance the CMEMS coastal dimension and be integrated into the working protocols of regular users.

The general aim of CEASELESS is, thus, to achieve a high-grade analysis of coastal sea dynamics based on a superior level of information provided by Sentinel data, combined with in-situ coastal observations, and a greater wealth of processes in met-ocean numerical models that consider explicitly the land boundary condition (including the linkage to the emerged coast).

This will support an enhancement of the Copernicus coastal dimension that is timely and commensurate with the challenges faced by vulnerable coastal systems, contributing to create a weather-smart society and a variety of weather-based services. **ST**

Review&Forecast

Working Together for Improved Climate and Ocean Research

By Dr. Jose Santos
Executive Director
International CLIVAR Project Office

CLIVAR (Climate and Ocean: Variability, Predictability and Change) is the World Climate Research Programme's (WCRP) core project on climate and the ocean, and for more than 26 years it has been addressing key questions on climate variability, predictability and change.

Finding answers to these questions requires international coordination that takes into account the ongoing changes in the climate system, as well as an evolving political framework dealing with these changes. During its existence, CLIVAR has provided fundamental knowledge about the characteristics and dynamics of mechanisms of variability in the coupled climate system.

New CLIVAR Science Plan

CLIVAR's science is aligned and organized around three overarching science questions with long-lasting impacts: What are the mechanisms of climate variability, climate change and climate sensitivity; which are the fundamental processes that need to be properly represented in climate models; and how predictable is the climate on different time and space scales?

These questions are longstanding challenges that motivated CLIVAR initially, and while substantial progress has been made, important questions remain, along with newly emerging ones.

One of the expected outcomes of CLIVAR research is the development of improved predictive capability of climate and climate change for the benefit of society. During 2017, CLIVAR developed a new Science Plan in consultation with its wider community. The plan was to be finalized by the end of 2017 and will be updated on a continued basis to take into account newly emerging challenges and demands from the science community and nations worldwide.

To achieve its objectives, CLIVAR coordinates international research in climate and ocean science, facilitating cooperation among national and multinational efforts, thereby enabling global climate research beyond individual regional and institutional capabilities. Through its panels, research foci, workshops, summer schools and conferences, the CLIVAR project continues to bring together researchers from all over the world to coordinate efforts required to understand the dynamics of the coupled ocean-atmosphere system and to identify processes responsible for climate variability, change and predictability.

Conference on Regional Sea Level Changes, Coastal Impacts

After the success of the CLIVAR Open Science Conference (OSC) in Qingdao, China, September 2016, with the participation of more than 600 scientists from 47 countries, CLIVAR was involved in the organization of another important scientific event.

WCRP has established the theme "Regional Sea Level Change and Coastal Impacts" as one of its crosscutting "Grand Challenge" (GC) science questions. The GC Sea Level has designed and developed an integrated interdisciplinary program on sea level research ranging from the global to regional to coastal scales. Within this frame, WCRP, jointly with the Intergovernmental Oceanographic Commission of UNESCO, organized a five-day international conference on sea level research July 2017 at Columbia University in New York.

The conference (www.sealevel2017.org) attempted to link large-scale sea level information to coastal areas, address societal implications of those changes to coastal communities, and discuss feedback of societal actions on coastal sea level. More than 350 participants from 42 nations attended the event, after which they issued a conference statement recognizing that sea level rise has accelerated over the past 100 years due to global warming. Conference participants, which included natural scientists, social scientists, coastal engineers, managers and planners, discussed evidence indicating that sea level rise represents a major challenge for coastal societies.

They closed the conference statement by expressing that: "In summary, the present state of sea-level science provides unambiguous evidence that sea level is rising and that the increase will continue to accelerate with unmitigated emissions. This requires that scientists closely collaborate with the stakeholder community to develop plans for responding to sea-level change affecting their coasts and to implement adequate adaptation measures. Without urgent and significant mitigating action to combat climate change continued greenhouse gas emissions

will almost certainly commit the world to several meters of sea-level rise in the next few centuries."

International Conference on ENSO

For the third year in a row, CLIVAR will be involved in the organization of a large scientific event. In cooperation with the International Research Centre on El Niño (CIIFEN), CLIVAR will organize the IV International Conference on El Niño Southern Oscillation: ENSO in a Warmer Climate, to be held October 2018 in Guayaquil, Ecuador. The goal of this conference is to review the progress on the science of ENSO with a focus on examining the range of ENSO "flavors" (especially in regard to the longitudinal variations of warming), assessing the existence of possible and distinct precursors to the different flavors, and examining how the different oceanic and atmospheric processes that drive the different ENSO flavors and impact their predictability would vary in a warming world. We expect around 300 scientists from around the globe.

CLIVAR Activities for Early-Career Scientists

CLIVAR is very keen on engaging the future generation of climate scientists. Jointly with the OSC in 2016, CLIVAR successfully organized an Early Career Scientists Symposium (ECSS), hosted by China's First Institute of Oceanography (SOA/FIO). More than 120 students and early-career scientists participated in the symposium. Participants discussed the key research challenges that the scientific climate community faces at the moment and highlighted the need for international science collaboration.

In the past, CLIVAR also organized several summer schools. In 2018, CLIVAR plans to continue this tradition by offering a summer school on "Past, Present and Future Sea Level Changes," in cooperation with FIO. The objective is to provide early-career scientists and engineers specializing in sea level research with an update in observations, knowledge and understanding for the study of global and regional sea level change and their impacts in coastal areas. This summer school will cover a wide range of physical processes contributing to sea level change, from observations to modeling of the main physical processes of global and regional sea level rise and variability. In addition, there is a focus on impact studies in coastal areas.

These events will certainly help in passing on the enthusiasm for CLIVAR and its science to the next generation, whose excitement is a promise for a very bright future.

International cooperation of the type that CLIVAR fosters will continue to be indispensable to developing the human capacity and infrastructure that underpins all major scientific breakthroughs and will help society be better prepared to face the great challenges that climate change presents. **ST**

Review&Forecast

Empowering NATO's Technological Edge In the Naval Domain

By Dr. Thomas H. Killion
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Strategic Science and Technology Plans
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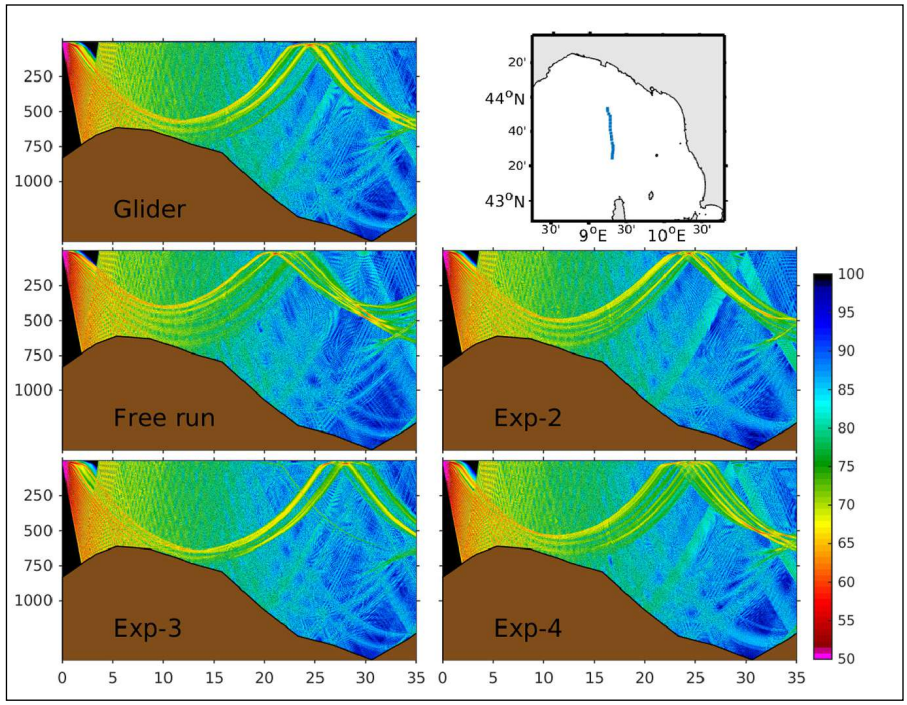
Instabilities in regions close to NATO territory are likely to remain significant for many years to come. All indications are that the Alliance will experience increasing pressure as it executes its role in helping to maintain the world's strategic balance. Global trends such as demographic and economic shifts, increasingly rapid technological advances and proliferation, pressure on scarce resources and the changing nature of conflict portend a complex geopolitical and operational environment for future NATO actions.

Maintaining the edge in defense and security will



Prediction of transmission loss as a function of depth and distance along a glider track in the Ligurian Sea off the coast of Italy in 2016. The top-left panel shows transmission loss (TL) relative to a geometry assuming a shallow sound source and using the glider observations of sound speed along the cross-section. The middle-left plot shows the TL based on a 24-hour forecast not constrained by local observations. The middle-right plot shows results using the 24-hour forecast assimilating only satellite observations. The bottom-left plot shows the ocean forecast using only the glider's past observations. The bottom-right panel displays the optimal results, combining previous glider and satellite observations to correct the 24-hour forecast. The latter shows a closer match with the results estimated by the actual observations.

therefore remain of critical importance for the Alliance and its partner nations to safeguard our freedom and shared values. Discovering, developing and utilizing advanced knowledge and cutting-edge science and technology (S&T) is of fundamental importance to continue enabling our Alliance forces to succeed across the full spectrum of operations now and in the future.

S&T within NATO

Start and Core Principles. Scientific and technological cooperation within NATO has a rich and fruitful tradition of more than six decades, starting in the middle of the last century. In those days, the North Atlantic Council (NAC) noted: "During the last decades it has become ever clearer that in modern society science and technology and their application provide the way to industrial growth and a higher standard of living. They are factors of rapidly growing importance for economic and military strength." A notion that is still fully valid today.

From the onset, S&T cooperation within NATO has been built on two complementary approaches: multinational collaborative S&T that nations and other stakeholders elect to carry out and fund in the NATO context, and in-house S&T that is carried out in a NATO-owned research establishment in predominantly the maritime domain.

Organization. Building on the experience and insights gained by several NATO organizations addressing S&T, the NATO S&T Organization (STO) was established in 2012.

The STO's mission is to: "Generate and exploit a leading-edge S&T programme of work, delivering timely results and advice that advance the defence capabilities of NATO Nations, Partner Nations, and NATO in support of collective defence, crisis management and cooperative security."

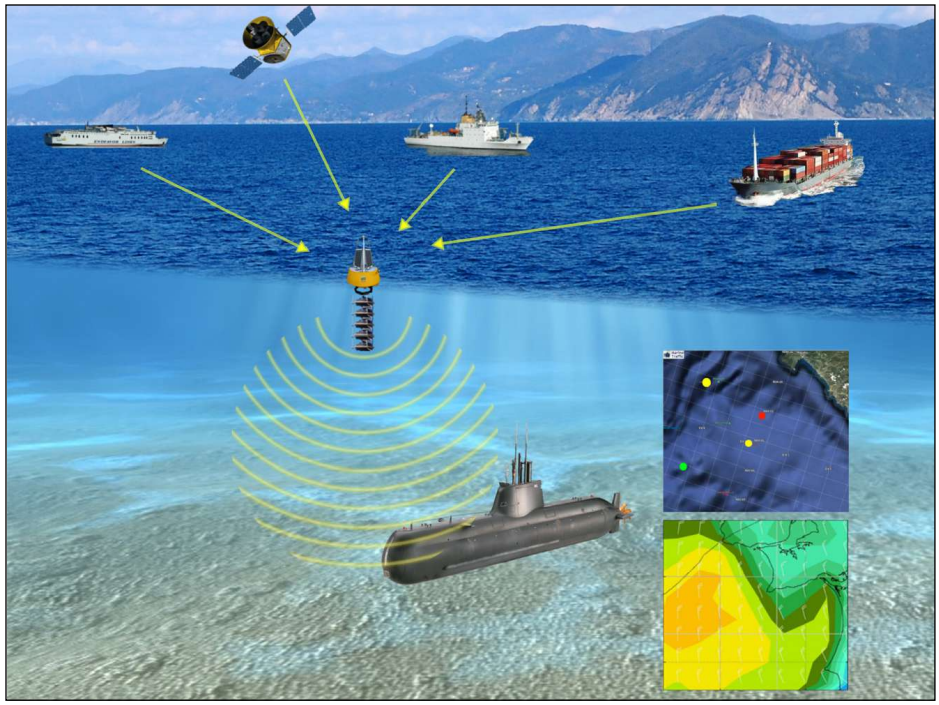
The STO achieves its mission in two ways. On the one hand, the STO nurtures a vibrant multinational collaboration network of more than 5,000 actively engaged scientists, engineers and analysts; this network draws upon a larger network of expertise of more than 200,000 scientists and engineers in the allied and partner nations, embracing a broad spectrum of scientific fields designed to address defense-relevant aspects. On the other hand, the STO encompasses the Centre for Maritime Research and Experimentation (CMRE), a customer-funded maritime S&T establishment delivering military-relevant state-of-the art S&T. The center operates two research vessels (RV), the NATO RV *Alliance* and the coastal RV *Leonardo*.

The STO is governed by the S&T board (STB), which comprises senior defense S&T leaders from allied and partner nations, as well as NATO entities. The STB is chaired by the NATO Chief Scientist, who is the STB's representative to the NAC and NATO's Secretary General. The co-vice chairs of the STB are from the armaments and military side of the NATO house, thereby underlining the connectivity of S&T with its main clients.

Highlights from the STO PoW

Maritime S&T within NATO STO's Programme of Work (PoW) has been prominent for decades. Topics include maritime situational awareness and security, cooperative anti-submarine warfare, naval mine warfare, ship signature management, unmanned autonomous vehicles, environmental knowledge and ocean engineering and underwater communications and standards.

Maritime ISR (Intelligence, Surveillance, Reconnaissance) Glider Networks and Mission Support as a Service. Robotic underwater networks can provide cost-effective and long-endurance solutions for a secure initial preparation of operating environments (IPOE) and for



AIS and METOC information being delivered to underwater assets using JANUS acoustic communication.

indication and warning (I&W) of features of interest with the underwater battlespace.

STO's CMRE has been conducting research toward developing autonomous capabilities to deliver persistent IPOE and I&W for underwater ISR in high-risk and asymmetric domains.

In sea trials, the Centre produced a persistent (two-month-long) environmental characterization, combining observations made by satellites and local robotic networks (sea gliders). Local ocean acoustic observations were integrated, evaluated and interpreted to deliver knowledge and information at different tier levels. The major focus was on underwater sound speed characterization. This work will allow for the production of high-fidelity prediction maps of operating environments that can be leveraged and complement maritime ISR systems and NATO-C2 decision systems, suited for both operational and tactical planning.

Big Data Analytics for Maritime Traffic Intelligence. Huge amounts of data overwhelm maritime situational awareness (MSA) analysts and challenge workflows. The analysts rely on summary statistics and representative patterns of life (PoL) to understand the organic behavior of maritime traffic, infer trends and extract key indicators related to safety, security, trade, regulatory compliance and port operations.

STO's CMRE developed a big maritime data analytics platform by adopting state-of-the-art big data, machine learning and information visualization techniques. The large-scale historical AIS vessel database at CMRE was leveraged to arrive at a prototype Maritime PoL information Service.

Throughout the project, NATO Shipping Centre (NSC) staff were the end-user of the prototype, evaluating it and thereby ensuring the relevance for the operational community. The prototype has been accepted by NSC, where it is impacting the day-to-day work of the maritime analysts.

Scientific Support to the NATO Naval Armaments Group's Above Water Warfare Capability Group. STO's Systems Concepts and Integration (SCI) panel is part of STO's multinational collaborative network of scientists, engineers and analysts. One of the research task groups (RTG) of the STO's SCI panel provided scientific support to improve the effectiveness, reliability and responsiveness of NATO electronic warfare (EW) assets. Specific contributions included an assessment of EW capabilities, shortfalls and resolution paths leveraged from collaborative scientific study and exploitation of NATO's annual Naval Electro-Magnetic Operations (NEMO) trials.

The SCI RTG informed NATO's Above Water Warfare Capability Group of its options to enhance the contributions of EW to military advantage, both today and in the future. Robust controls are now in place to conduct future NEMO trials while using the scientific method. The multinational collaborative RTG produced fruitful joint analyses between the radio frequency (RF) and infrared (IR) domains. NATO's EW quality will be greatly improved when scientifically informed current and future EW needs will be aligned with activities in the operational and acquisition domains.

Innovative Underwater Communications. Underwater communication capabilities are currently manufacturer specific, using proprietary digital coding technologies with no interoperable capability between modems from different manufacturers. To fill this gap, STO's CMRE has developed the JANUS (named after the Roman god of portals) modulation and coding scheme, with additional mechanisms to render it practical. It is a standard with a common format for announcing a presence, exchanging low volumes of data and creating an ad-hoc network. JANUS is in its final stages of becoming a NATO Standard-

ization Agreement (STANAG). It is the first underwater digital communications standard that can be considered a "game-changer" in terms of communication interoperability in the underwater domain.

Following scientific trials, CMRE has exercised JANUS from the perspective of real end-users. Services include "underwater AIS" and "underwater METOC" (meteorological and oceanographic) developed with the support of the Portuguese Navy. Prototype hardware for JANUS transmission and reception was installed in a modern diesel-electric submarine during an experiment at sea. The experiment delivered information vital to mission safety for a submerged submarine that is usually not available beyond periscope depth.

Summary

Maritime research, technology exploration and demonstrations are re-emerging as a key element of NATO's S&T portfolio. Work within the STO is essential to ensure that the Alliance maintains a technological edge in operational capabilities for this critical domain. **ST**

Review&Forecast

Emerging Blue Tech Improves Efficiencies, Unlocks Opportunity

By Richard Lawson
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Colleen Hahn
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Rapid progression of innovation in the areas of digital technology, material science, engineering and design has redefined the way ocean industries approach day-to-day business. Harsh conditions, extreme pressure, safety concerns and unpredictable weather are compounded by the high cost for any type of successful marine program. Technology that can address those challenges while harnessing opportunity to create value is pivotal in today's market. As offshore oil and gas, fisheries, the scientific community and other marine sectors continue to adopt and adapt these innovations into their processes, these emerging "blue" technologies have become a key driver in transforming economic value. Direct benefits have been derived in the areas of improved operations, reduced downtime, increased safety, better efficiencies and productivity and the ability to create new opportunities. The adaptive nature and flexibility of blue tech allows each individual application to be repurposed for a wide range of surface, metocean and subsea operations. No longer used as standalone or one-off alternatives, blue tech's baseline success and proven results have fast-tracked them into being specified for commercial, scientific and government contracts.

One of the key drivers for this expansion of blue tech is the quest for data. Today, a data-rich environment is no longer enough, as marine industries, scientific researchers and key stakeholders are demanding precise, measurable, high-quality, real-time data. More predictive models and better insight and engagement across the enterprise with key decision makers provide the backbone for success and impact investment, resource allocation, health, safety and environment (HSE) initiatives, and ocean exploration. The balance between the cost of acquiring accurate, precise, measurable real-time data with the ability to deliver those data inputs in the "right" format to the "right" decision maker or influencer is the game changer. If actionable data is the goal, preemptive and predictive data are the differentiator.

In the past, data acquisition has been expensive; today, blue tech innovations continue to lower those barriers by reducing costs, providing greater connectivity and delivering more robust data sets. Throughout 2017, the marine industry saw significant change in the implementation of blue tech, especially in the areas of hydrographic surveys, 3D data visualization and analytics and connectivity. With the proliferation of sensor technology, Internet-of-Things networking devices and the advancement of machine learning and AI, a second generation of blue tech is evolving. Networked, flexible and connected, these smart/intelligent solutions are not just transforming but revolutionizing (disrupting) the way marine business is conducted around the world. These new solutions unlock the unique strengths of individual products and applications and combine them through connectivity to create new "hybrid" solutions that work across verticals to solve problems, advance discovery, foster exploration and protect the resources and environment of our marine world.

This hybridization is occurring in several key areas: AUVs, autonomous surface vessels (ASVs), ROVs, drones and robotics; machine learning and AI; and an emerging area called immersive collaboration, fueled in part by the implementation of augmented reality (AR) and virtual reality (VR) solutions into the 3D data visualization and analytics workflow.

AUVs, autonomous surface vessels, ROVs, drones and robotic technology have demonstrated their value across a wide range of marine applications for some time now. The use of underwater vehicle and robotic technology has reduced human interaction in potentially hazardous situations while providing expanded capabilities via machine automation. ROVs have consistently held the greater share of the market as limitations on power, payload, connectivity and data retrieval have stalled the growth in long-range/duration, large-scale AUV, ASV and drone operations. In fact, reliable, consistent power and extended battery life has been one of the largest inhibitors to the autonomous market. With the recent advent of several commercially viable lithium-ion battery packages, those times appear to be changing. In addition, ad-

vances in material science and fabrication have provided a new series of lighter, more flexible vehicle housing and hulls that can access greater depths without compromising payload requirements. Less weight and more flexibility allow for the inherent cost of deployment to be reduced, and limitations on range, depth and power that were once the limiting factor are removed. With the addition of fly-way robotics and machine learning integrated into vehicle technology, a new form of workforce evolves. Depending on the applications, the new connectivity of ROVs, AUVs, ASVs and other robotics allows them to work alone or in tandem. Smart grids can be formed within the water column or along assets to monitor, inspect, repair and maintain them. New connectivity on the software side allows for vehicles to talk to each other, learn from each other and send messages to key resources. Using AI and robust algorithms, the power of these vehicles to connect transcends to the next level to a neural network. The ability to form smarts grids to map, collect and acquire information is an important development that will resonate with future applications like pipelines and other infrastructure inspections, biological monitoring and sampling, mapping, seismic monitoring, exploration, research and recovery, and so on.

Artificial intelligence and machine learning incorporate a wide range of digital capabilities that underpin many current subsea technologies. From data extraction and modeling to fabrication and engineering design, from ASV, AUV and robotic mechanics to marine transportation and shipping logistics, AI controls many of those activities. Machine learning is a subset of artificial intelligence in which algorithms analyze data and, based on the knowledge garnered from those results, adjust their logic on an ongoing basis to adapt to new and changing situations. Many of the recent advances in AI have originated from other sectors, university labs or the defense industry. AI's strength is built around organizing data from different sources, analyzing large-scale data sets to determine the interdependencies between data, with little or no human intervention. With the quest for actionable, preemptive data, tools that can mine it, shape it and then use it as the basis for decision making to optimize efficiencies are a clear choice in marine operations.

Immersive collaboration powered by 3D data and AR/VR technology is taking subsea, metocean, surface and atmospheric data to the next level. This emerging sector is fueled in part by two disparate technologies joined together to create a virtual reality collaboration platform that enables geographically distributed individuals to explore and experience 3D content in real time. The growth of industrial and engineering AR and VR has been slow to infiltrate many marine operations for numerous reasons. Still considered a "nascent technology," many companies have been cautious on where and how to use it in applications, especially in the current risk- and cost-averse climate. In addition, the type and quality of 3D data inputs can be a real limiter. As subsea LiDAR, optical lasers, sensors and other data collection and monitoring devices deliver more accurate, millimetric 3D data in an ASTM standardized e57 format, 3D data inputs no longer have limitations. The combination of technology creates an immersive virtual reality (VR) environment with true 1:1 3D-scale models generated using repeatable, millimetric data inputs. Now using a laptop, desktop or smart device, geographically distributed teams can collaborate within a single VR session and be present in the same scene. The ability to explore and experience 3D content as if you were actually on site with a digital representation of physical assets and the surrounding environment creates a seamless workflow environment from reality capture to virtual immersion. Actionable, insight-driven, preemptive data provides the "right" data delivered to the "right" stakeholder for greater impact.

The future for ocean technology is now as compelling in its prospects as the ocean is deep. With initiatives such as the Nippon Foundation-GEBCO Seabed 2030 Project and the Shell Ocean Discovery XPRIZE pushing the future of ocean science and technology, this is indeed an exciting time for ocean exploration and utilization. Perhaps never before have we seen a more opportune moment for collaboration between industry, the government and nonprofits. Together as we adopt these technologies we will create expanding business opportunities, stand up new industries and capture the public's imagination. Ultimately, the future ocean "enterprise" is collaborative, and to realize its potential we must seek to find that nexus of business, scientific discovery and public interest. **ST**

Review&Forecast

Exploration and Discovery of Cuba's Deep Mesophotic Coral Reefs

By John Reed
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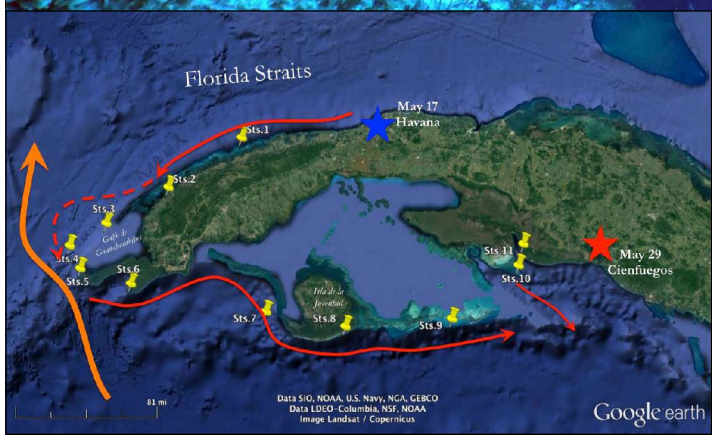
Cooperative Institute for Ocean Exploration, Research, and Technology, Harbor Branch Oceanographic Institute, Florida Atlantic University

The Cooperative Institute for Ocean Exploration, Research, and Technology (CIOERT) at Florida Atlantic University's Harbor Branch Oceanographic Institute (HBOI) recently led a joint scientific expedition with Cuban colleagues to map and characterize, for the first time, mesophotic coral ecosystems (MCEs) along the entire coastline of Cuba. MCEs are light-dependent benthic communities that occur in the "twilight zone" below shallow reefs and typically range from depths of 30 m to the bottom of the photic zone, which may extend to 150 m. Prior to this expedition, there was very little known about the extent and the health of Cuba's deep mesophotic reefs. After more than a year of planning, the 30-day research cruise circumnavigated Cuba and discovered deep coral reefs all along the shelf drop-off.

Participants

This project was jointly planned and in collaboration with organizations in Cuba and the U.S., including Cen-

Center: Giant barrel sponges (Xestospongia muta) are common in the upper mesophotic zone at San Antonio Bank. Below: Map of the survey sites (yellow pins). Broad orange arrows indicate the offshore Yucatan Current, while the red arrows indicate the shelf break countercurrents. Right: The RV Walton Smith arriving in the port of Havana at 8 a.m. on May 16, 2017. (Photo Credit: Centro Nacional de Áreas Protegidas, Cuba's Twilight Zone Reefs and Their Regional Connectivity)



tro de Investigaciónes Marinas at University of Havana (CIM-UH), Centro Nacional de Áreas Protegidas (CNAP), Instituto de Ciencias del Mar (ICIMAR), Geocuba Estudios Marinos, Guanahacabibes National Park-Sistema Nacional de Areas Protegidas (PNG-SNAP), Acuario Nacional de Cuba (ANC); and for the U.S., two NOAA Cooperative Institutes: the CIOERT and the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) at the University of Miami. The NOAA Office of Ocean Exploration and Research (OER) supported this research under a cooperative agreement with HBOI. The joint research cruise was conducted from May 14 to June 13, 2017 on the University of Miami's RV *F.G. Walton Smith* using a Mohawk ROV, operated by the Undersea Vehicle Program at the University of North Carolina at Wilmington.

Several days were spent at the western tip of Cuba where ROV dives were conducted at Banco de San Antonio and the Guanahacabibes Marine Sanctuaries. These are "Sister Sanctuaries" to the Florida Keys National Marine Sanctuary and the Flower Garden Banks National Marine Sanctuary, which were designated in a memorandum of understanding (MOU) between NOAA, the U.S. National Park Service and Cuba's CNAP. This MOU was the basis for the joint expedition.

Twenty-one scientists and technicians from both the U.S. and Cuba participated, including specialists in corals, fish, sponges, algae and physical oceanography. Total ship transit around the island covered about 2,778 km (about 1,500 nautical miles). Forty-three ROV dives at 36 stations surveyed reefs from depths of 18 to 188 m, covered 27 km and resulted in 110 hours of high-definition video. A total of 21,146 digital still images documented habitat and species and photo transects. The ship continuously recorded surface water hydrography, including near-surface temperature, salinity, florescence and dissolved oxygen, as well as water column current structure using an acoustic Doppler current profiler. Temperature, salinity and dissolved oxygen were recorded using sensors on the ROV; pCO2 and pH sensors provided data for aragonite saturation analyses.

Results

The expedition documented for the first time the deep mesophotic habitat surrounding Cuba. All 43 dives confirmed the presence of MCE habitat around the entire coastline of Cuba. Preliminary data suggest that, like the shallow reefs that fringe most of the Cuban coast, the deep reefs parallel most of the shelf edge and the various archipelagos. Topographically, the most consistently conspicuous features are the Deep Island Slope (125 to more than 150 m), Deep Fore-Reef Escarpment (the "Wall," 50 to 125 m) and Deep Fringing Reef (30 to 50 m). The Wall has the greatest diversity and density of macrobiota; nearly all vertical surfaces are covered with diverse sponges, algae, gorgonians and black corals. A total of 424 species of benthic macroinvertebrates, 124 macroalgae and 180 fish have been identified to date from the surveys and from the collected specimens. These are preliminary results, and taxonomic analyses are in progress.

Group photo of the leg two scientific party posing with the Sub-Atlantic Mohawk 18 ROV, owned by the National Marine Sanctuary Foundation and Flower Garden Banks and operated by the Undersea Vehicles Program at the University of North Carolina Wilmington.

A total of 345 mesophotic benthic samples were collected during this expedition; preliminary analyses indicate that some are new species and new records of depth or distribution. So far, there appear to be at least 10 sponge species new to science. Many sites had abundant corals, possibly some of the greatest densities in the Caribbean. For example, the mesophotic reef crest at Bahia de Cochinos (Bay of Pigs) had extensive fields of coral (*Agaricia* spp. and *Orbicella faveolata*), forming overlapping sheets on the steep slope. In general, the Cuban mesophotic corals appeared quite healthy with little signs of human impact. Only a few corals showed signs of disease; lost or discarded fishing gear was relatively uncommon and were limited to longlines and traps from artisanal fishermen. Only one station appeared heavily impacted, possibly from nutrient pollution. The biggest concern, however, is that there were relatively few large grouper. Some sites had a few grouper, but very few sites had many. The invasive lionfish was also present at most sites down to depths of 153 m, but at relatively low numbers compared to mesophotic reefs in the southeastern U.S., such as Pulley Ridge. The presence of lionfish at greater depths makes it difficult to effectively control the species and tentatively could populate reefs downstream in the U.S.

Approximately 22 percent of the Cuban shelf is designated as marine protected areas (MPAs), and many of the dives were within these MPAs. The team identified at least four sites that are not protected, but are strong candidates for MPA status. Some had dense cover of corals or populations of grouper and snapper that may indicate spawning aggregations and essential fish and coral habitat. Many of the species found in Cuba's mesophotic reefs are also present at the downstream Sister Sanctuaries in the U.S., which suggests connectivity between the sites. Further analyses of the specimens for taxonomy and genetics, along with quantitative analyses of the video and photo data, will allow for a more precise characterization of the diversity and relative abundance of the mesophotic communities of Cuba, as well as a better understanding of the connectivity of Cuban reefs with the Sister Sanctuaries in the U.S. and elsewhere in the Caribbean.

NOAA OER hosted a signature website during the entire expedition, which included 21 mission logs describing the mesophotic reef sites and discoveries, along with numerous ROV in-situ photos and highlight video. You can learn more at http://oceanexplorer.noaa.gov/explorations/17cuba-reefs/welcome.html. **ST**

Review&Forecast

Ocean Science and Technology = Security for Today and Tomorrow

By Jon White
President and CEO
The Consortium for Ocean Leadership

When I say "ocean security," what comes to mind? I'm not talking about wearing a life jacket while aboard a boat or keeping an eye on one's cellphone while splashing in the surf. What I am talking about is the merging of science and security when considering our ocean. Just as a solid foundation enables a house to withstand winds and rains, so too does a strong understanding of ocean science keep us secure–in terms of our national, homeland, food, water, energy and economic security, as well as our human health and safety.

In 2017, the Consortium for Ocean Leadership (COL) used this concept to help people understand that no matter how far they are from the coast, the ocean plays a significant role in their lives and livelihoods. Here are a few ways we did that.

Food Security. COL's annual public policy forum addressed the challenge of safely nourishing our global population. "Feeding the Future: An Ocean of Opportunity" focused on the ocean's role in a changing world with an ever-growing population. Feeding the expected 10 billion by 2050 will require doubling our global agriculture (a task that cannot be accomplished through terrestrial methods alone); sustainable fishing and aquaculture can and must play a role. Forum participants developed recommendations to improve food security (e.g., identifying core challenges) and food safety (e.g., increasing aquaculture production by determining the appropriate trophic level on which to concentrate production efforts).

Energy Security. The National Ocean Sciences Bowl (NOSB) celebrated its 20th anniversary in 2017. An ocean science-focused quiz bowl competition, the

NOSB engages high schoolers around the country, challenging their knowledge of ocean-related topics and creating a science- and ocean-literate society. The 2017 theme, "Blue Energy–Powering the Planet with our Ocean," increased awareness and understanding of the ocean's role in providing marine renewable energy, including challenges to implementation and potential impacts to ecosystems.

Economic Security. Our annual industry forum addressed economic and energy security from a different angle. "Rigs to Reality: Determining the Fate of Offshore Oil Platforms" convened cross-sector stakeholders with a shared interest in science-based decision making determining the future of decommissioned oil platforms while considering ocean environment benefits and minimizing associated costs to taxpayers and industry. Participants from industry, government, nonprofits and academia identified knowledge gaps needed to inform decision making, which will ultimately ensure the best actions (considering habitat, ecosystems and cost) are undertaken regarding these structures.

Ocean Observations. Every aspect of ocean security relies on a foundation of science, making ocean observations critical. The National Science Foundation-funded, COL-managed Ocean Observatories Initiative continues to collect and share (for free and in near real time) ocean observations through its system of arrays and platforms in the Atlantic and Pacific. Likewise, the Interagency Ocean Observation Committee (IOOC) integrates observing systems across agencies, institutions and nations through activities such as the U.S. Underwater Glider Workshop, where stakeholders discussed strategies for enhanced coordination of underwater glider activities.

In 2018, COL will continue incorporating ocean security into our work, helping to ensure a secure future for our ocean and ourselves. What COL is (and has been) doing for the last decade already aligns with this idea. What we are redoubling, however, are our efforts to make sure this is understood, so that every American, whether in California or Idaho, whether a farmer, financial analyst or member of Congress, can answer the question of why the ocean matters in his or her everyday life. I've been particularly struck by the role of technology, which relates to all facets of ocean security. Specifically, ocean transparency and ocean transmissivity and how we can advance these concepts.

Ocean transparency is our ability to see the ocean, though not just visually. Centuries ago, humans had no idea what was in the water beyond what they could see with their eyes–it was full of mystical creatures like krakens and mermaids. But as we started to explore the ocean, mythology gave way to fact–krakens were actually giant squids and mermaids were manatees. Now, we're able to see into the ocean with more than just our eyes. Satellite data along multiple spectra show the location of physical ocean features and marine life, environmental DNA identifies and quantifies organism presence based on seawater samples, and sonar and LiDAR map the seafloor. Given the ongoing, rapid advent of new sensing technology and miniaturization and low-cost replication, we can do more to make the ocean transparent, and we must ensure the ocean technology community has the resources to continue innovating.

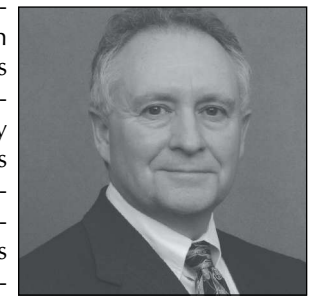
Ocean transmissivity is how we transmit information in the ocean–largely by sound, conductors and (limited-range) light. We must develop and implement the technology to build the "ocean Internet" per se. A challenging concept to be sure, but, then again, the Internet and wireless networks were largely nonexistent 25 years ago. What sort of new developments in ocean physics and technology will bring about such a revolution? Ongoing research into areas such as quantum physics and fluid particle behavior just might hold the key.

Using ocean data to improve the intensity forecasts of hurricanes; AUVs to aid in search and rescue operations in the deep sea; marine renewables to broaden the nation's available energy portfolio; ocean-based pharmacology advances to improve human health; real-time mapping to enable safe military and business operations; and sustainable recreation above, on and under the surface of the ocean are all part of ocean security that COL and the ocean science and technology community are working toward. I believe that we can't even begin to envision the highly advanced understanding and utilization of our healthy and sustainable ocean in 50 years, but I know it will only be realized through the amazing ocean science and technology we are investing in today. **ST**

Review&Forecast

The Offshore Energy Industry May Have Found Its Trump Card

By Randall Luthi
President
The National Ocean Industries Association



The National Ocean Industries Association (NOIA) and its members understand that energy improves the lives of every American every day. Thanks to the hard work and innovation of the oil and gas industry, the United States leads the world in oil and gas production. Instead of being dependent on OPEC or Russia, U.S. consumers can depend on American energy, and American values, to fill most of their energy needs.

The oil and gas industry is a bastion of American energy security and productivity, in spite of taking a beating in 2017. As oil prices hung around the $50 per barrel mark, the offshore sector continued to shed jobs. While no one knows for certain when the oil and gas market will recover, some prognosticators target 2018 for an upswing. What we do know, however, is that the current administration understands the importance of a healthy and robust offshore oil and gas industry and realizes that

cooperation and partnerships with industry are integral to achieving its goal of American energy dominance. That's good news for our industry.

So far, President Donald Trump has made good on his election promises to reduce the regulatory fiat in Washington. In its first year, the Trump Administration began implementing its America First Offshore Energy Strategy, which includes unraveling harmful regulations that placed onerous and ineffective restrictions on industry. Industry estimated the combined costs of just three Obama-era rules—well control, Arctic drilling and air quality regulations—at more than $55 billion over a 10-year period. The analysis of these rules also found they do not improve safety or provide increased environmental protections. In fact, the well control rule's provisions on drilling margins may actually increase risk, and the Arctic drilling rule does not accurately reflect current industry capabilities.

The Trump Administration is also working to increase offshore access, which was dramatically reduced by the Obama Administration. In Obama's final months in office, Arctic and Atlantic lease sales were removed from the 2017 to 2022 Five-Year Outer Continental Shelf (OCS) Oil and Gas Leasing Program, six long-awaited Atlantic OCS seismic survey permit applications were simultaneously denied, and an executive order was issued that "permanently" withdrew Atlantic and Arctic Ocean areas from future oil and gas leasing. As a result, 94 percent of the OCS is effectively closed to federal oil and gas leasing, including waters off the entire Pacific and Atlantic Coasts.

Last April, President Trump issued an executive order rescinding President Obama's offshore leasing withdrawals, and in May, Interior Secretary Ryan Zinke reversed premature blanket denial of Atlantic seismic survey permit applications through a secretarial order. These surveys are needed because existing resource estimates for the Atlantic OCS are based on data collected from seismic surveys conducted more than 30 years ago. New surveys using modern technology are vital to providing an up-to-date and scientifically accurate picture of the offshore oil and gas resources off our Atlantic seaboard. Despite the claims of anti-energy environmental groups, these surveys have been safely conducted around the world for decades. In fact, the top scientist at the Bureau of Ocean Energy Management (BOEM) during the Obama Administration said there has been zero evidence of seismic surveys harming marine life.

New surveys of the Atlantic OCS will also help inform the development of the next offshore leasing program, which the Trump Administration began work on last June by issuing a request for information (RFI). In November, based on response to the RFI, the Trump Administration unveiled the 2019 to 2024 National Offshore Oil and Gas Leasing Draft Proposed Program (DPP), which includes the most offshore acreage in history. This "All of America" plan sets the table for American energy leadership for the next generation. While the DPP guarantees nothing beyond a public conversation on our OCS energy resources, the White House, through the unprecedented amount of OCS area it included in the plan, is showing energy leadership that our nation desperately needs.

Congress has also been busy in strengthening America's energy future. Showing bipartisan leadership, House Majority Whip Steve Scalise (R-Louis.), House Natural Resources Committee Chairman Rob Bishop (R-Utah) and Reps. Henry Cuellar (D-Texas) and Vincent González (D-Texas) introduced the SECURE American Energy Act. This forward-thinking bill has the potential to unlock American energy dominance for the next generation by cutting red tape and providing a stable regulatory environment. America has long needed more policy, instead of more partisanship, and it turns out energy can be the perfect start of bipartisan growth. Congress, like President Trump, realizes that Americans, regardless of party affiliation, want the jobs, economic growth and energy security a robust domestic energy program provides.

Opening and exploring new offshore areas signals a victory for American energy security, jobs and our economy. Energy, particularly fossil fuel-based energy, is the cornerstone of our economy. Nothing moves and nothing gets made without energy. Having an administration that understands this and engages with the energy industry, instead of issuing arbitrary and harmful, politically expedient rules and regulations, is more than a comfort, it is a necessity. The oil and gas market is cyclical, and for decades, our industry has shown it can bounce back from commodity price downturns. We will do so this time as well, hopefully beginning in 2018.

As the president of NOIA, I am excited for the possibilities of 2018, including new opportunities for the offshore oil and gas industry, a critical contributor to America's economic and energy security. **ST**

Review&Forecast

Safeguarding our National Economic Security: Investing in the Information Infrastructure Required for a Thriving Marine Transportation System

By Lillian Borrone
Former Chair, Eno Center of Transportation
Member, Joint Ocean Commission Initiative Leadership Council

America's marine transportation system (MTS), and the information infrastructure on which it depends, are being challenged on multiple fronts. We need a concerted and sustained campaign that confronts these challenges to preserve a system that is central to the country's economic security.

America's wealth and prosperity have always been inextricably linked to the free flow of maritime commerce through U.S. ports. Over the last 50 years, maritime commerce has tripled. Today, activity at American seaports sustains more than 23 million jobs, generates more than $320 billion annually in tax revenues, and accounts for 26 percent of the U.S. economy. Roughly 95 percent of U.S. overseas trade flows through our seaports, supporting coastal communities and industries nationwide. Simply put, the MTS is the lifeblood of our economy.

Our MTS and economic security face numerous threats, including rising seas, more frequent coastal storms and changing global trade patterns. Congress and the Trump Administration cannot address these challenges in isolation. They must also respond to the most extensive hurricane damage in U.S. history and confront the decades of neglect plaguing America's infrastructure. To ensure the survival and growth of the marine transportation sector, the MTS must be modernized, including the information infrastructure on which it depends. This includes expanding upon the Committee on the Marine Transportation System's previous work and incorporating MTS information infrastructure into congressional and executive branch deliberations on hurricane disaster relief and national infrastructure initiatives.

Conversations about the MTS have historically focused on hard infrastructure—the channels, harbors and ports that form the essential foundation of the system. These elements not only support maritime commerce, they supplement our increasingly burdened road and rail systems. The success of our MTS depends on the integrity of *all* infrastructure, including the offshore, onshore and aerial technology that powers our understanding of an ever-changing marine environment. Without reliable science, up-to-date information and cutting-edge tools, our MTS is undermined.

While improved information infrastructure will not alleviate the need for physical infrastructure projects such as dredging, advancements in information services are a highly cost-effective way to reduce port congestion and expand the capacity of our waterways. By having a better understanding of oceanic and atmospheric conditions, we can reduce accidents, enhance trade and increase economic efficiency.

Our MTS information infrastructure tools must be expanded and modernized through renewed investment. High-frequency radar, detailed nautical charts and the National Spatial Reference System are just three examples. High-frequency radar measures the speed and direction of ocean surface currents in real time, generating up-to-the-minute surface current mapping. These maps support port and harbor navigation, search and rescue, and oil spill response. However, there are currently critical gaps in coverage, including portions of our southeastern waters. We must expand high-frequency radar coverage to accommodate increasing maritime traffic and increasing environmental variability.

Nautical charts, which alert mariners of obstructions and reduce accidents, are another essential navigation tool. Unsurprisingly, these charts are only as good as the accuracy of the information that underpins them. To meet the current and anticipated needs of mariners, NOAA requires renewed investment to better align the scale and coverage of nautical charts and to improve underlying data by conducting more frequent seafloor surveys.

NOAA's National Spatial Reference System (NSRS) provides a consistent coordinate system that defines latitude, longitude, height, scale, gravity and orientation throughout the U.S. Additionally, the NSRS defines the official national shoreline and provides navigational models and tools for all modes of transportation. The NSRS must be modernized to achieve centimeter-level accuracy and increase overall system efficiency. These changes will increase the safety of the MTS and support new economic opportunities.

Marine transportation investment needs have been, and will continue to be, a partnership between private operators/users and the public entities that own, control or regulate the system. Some of the most promising information infrastructure advancements have arisen from such partnerships. NOAA's Physical Oceanographic Real-Time System (PORTS), a cost-shared program with strong industry support, is one such advancement that improves efficiency and decreases the risk of ship groundings and collisions. PORTS provides industry with a decision support tool that integrates real-time environmental observations, forecasts and other geospatial information to help mariners make critical decisions while transiting busy seaports. Additional resources will allow NOAA to meet demand for new PORTS sites, upgrade current quality assurance and technical services, and sustain the underlying network of underwater observing systems.

To enhance maritime safety and efficiency, we need precision navigation technologies and services that enable ever-larger ships to more efficiently and safely nav-

igate busy waterways. In a 2015 precision navigation project, NOAA partnered with the Ports of Los Angeles and Long Beach to generate comprehensive data on under-keel clearance using a network of observational buoys. When navigating large 1,100-ft. vessels, a pitch of 1° causes the vessel to dip 9.6 ft.—a massive movement in channels with only 11 ft. of under-keel clearance. Prior to precision navigation, cargo had to be removed from these vessels offshore to increase under-keel clearance in waterways. Now, port operators can navigate massive ships into docks without removing cargo at sea, a change that could reduce costs by millions of dollars and encourage increased international business.

Recent appropriations have helped to sustain current systems and expand some elements. However, to achieve necessary growth, additional funds and programs will be needed, including those that capitalize on public-private partnerships. Broadening the definition of marine transportation infrastructure to include information infrastructure will help to generate new funding streams. With this definition, shipping and freight communities can encourage consistent funding through ongoing dialogs with congressional leaders, private sector financiers, and state and regional interests.

The competitiveness of U.S. industries depends on strong American ports and a thriving shipping industry. Advancements in our ability to monitor, understand and disseminate information about ocean conditions are crucial to safe and efficient maritime commerce. Providing specific funding support for information infrastructure is critical for MTS function and U.S. economic security. Including marine transportation in federal initiatives will advance U.S. leadership in technology, leverage proven public-private partnerships and incentivize state, local and private sector investments. **ST**

Review&Forecast

Ocean Acidification, Warming Waters Endanger Global Fisheries

By Brian La Shier
Policy Associate
Environmental and Energy Study Institute

Discussions about climate change typically center on the effect of greenhouse gases on the atmosphere, but those emissions have a larger footprint than many realize. Ocean acidification, primarily the result of atmospheric carbon being absorbed by the ocean and altering seawater pH levels, poses a severe threat to aquatic ecosystems. Despite acidification's relatively low profile in the public eye, it poses a grave risk to the world's fisheries and the billions of people who rely upon them for income and sustenance. Similar to the terrestrial consequences of climate change, the ocean's rapid and drastic transformation will likely have a disproportionate impact on the global population.

"For every 1° C increase in ocean temperature, the number of cholera outbreaks in humans rose by 200 percent due to the presence of* Vibrio cholera *bacteria in shellfish."

Scientists are still assessing the full scope of how acidification interacts with the ocean's complex systems, but the latest findings indicate the impacts are already being felt today and could become even more severe. The oceans currently absorb roughly a quarter of the carbon dioxide (CO_2) humans produce annually. According to the World Meteorological Organization, human activity has pushed atmospheric CO_2 concentrations to their highest levels in 800,000 years, fueling unprecedented changes in ecological systems. This excess of CO_2 has led to the oceans absorbing 560 billion tons of CO_2 over the past 250 years, making surface waters 30 percent more acidic during that span. Alarmingly, the current rate of change in ocean acidity is around 50 times faster than any known historical rate. Projections of atmospheric and oceanic CO_2 concentrations indicate that by century's end, the average surface ocean pH could reach levels not seen in more than 50 million years.

In addition to their rising acidity, ocean waters have also been growing warmer. Although the oceans are able to absorb massive amounts of heat, this process has been kicked into overdrive by anthropogenic climate change, as evidenced by an increase in global ocean surface temperatures during the past 30 years. Scientists estimate that since 1955, more than 90 percent of the excess heat retained by Earth due to atmospheric greenhouse gases has been absorbed by the oceans. Warmer ocean temperatures can alter ocean circulation patterns, which could subsequently shift the availability of nutrients, the structure of existing food webs and the location of preferred habitat temperatures for marine fish and invertebrates. As various fish species migrate to more favorable waters, resource-poor fishers and subsistence-dependent, immobile communities will be in danger of getting left behind.

An increase in seawater acidity has made it more difficult for organisms with calcium carbonate shells and skeletal components to form and maintain those essential structures. Many marine calcifying animals, including shellfish, zooplankton, coral and pteropods, are crucial parts of the marine food web. For instance, a drop in the availability of foundational food sources, like pteropods and other small marine organisms, could result in

a population decline for commercially fished herring, cod, mackerel and salmon. In addition, corals contribute to the generation and maintenance of vital reef habitats that house enormous biodiversity and sustain global fisheries valued at $6.8 billion annually. Studies show that the northeastern Pacific Ocean, including waters off the West Coast of the United States and the western Arctic Ocean, are particularly vulnerable to drastic changes in pH and calcium carbonate saturation levels, posing a significant threat to the region's calcifying organisms within the next 50 years.

Warming waters have also allowed infectious diseases to spread to regions that were previously too cold for such pathogens to survive in. Along North America's Eastern Seaboard, warm-water diseases known as MSX and Dermo have been found to wipe out 90 percent of an oyster crop when they are able to gain a foothold during mild winters. Certain species of Vibrio bacteria are expected to become more prevalent in shellfish as waters warm, presenting health risks to humans. *Vibrio vulnificus* is estimated to be responsible for 95 percent of all seafood-borne deaths, despite its historical rarity in northern waters. Likewise, a study demonstrated that for every 1° C increase in ocean temperature, the number of cholera outbreaks in humans rose by 200 percent due to the presence of *Vibrio cholera* bacteria in shellfish.

Fisheries and aquaculture are part of the livelihoods for 10 to 12 percent of the global population, with more than 90 percent of capture fishermen employed by small-scale endeavors in developing nations. The world's fisheries delivered an excess of $129 billion in exports in 2012 and accounted for 16 percent of humanity's total animal protein consumption. Although shifts in ocean temperatures and acidity may improve the production of fisheries in certain parts of the world, the regions that stand to lose the most are already among the most vulnerable to climate change impacts. Impoverished and subsistence fishers located in central and western African countries; northwestern South America; certain tropical Asian countries; and the Small Island Developing States (SIDS) are all at risk of seeing their livelihoods and key food sources vanish.

Although the United States possesses more robust food security than much of the world, more than 90 percent of all the seafood America consumes is imported. At the same time, many domestic fisheries have been struggling, in part due to climate change impacts. A 2015 assessment of the $1 billion U.S. shellfish industry identified numerous regions vulnerable to ocean acidification, including the Gulf of Mexico and the Pacific and Atlantic Coasts. Alaska's commercial fishing industry pulls in $5 billion in annual revenue and accounts for 60 percent of the overall U.S. commercial fish catch, but the region is among the most susceptible to future ocean acidification. Lobster catches from New York to New England plummeted in some states by up to 98 percent within two decades as warmer waters caused physical ailments and reproductive issues for the valuable crustaceans (meanwhile, Maine's cooler waters have experienced a boom in lobster catches). A 2016 NOAA study of 82 marine fish and invertebrate species in the Northeastern United States found that half had a "very high" or "high" vulnerability to climate change.

As climate change wreaks havoc on the world's oceans, commercial operators and subsistence fishers alike will have to adapt to the new conditions, or risk fading away. Yet, the least developed nations already face a distinct disadvantage in this arena. International institutions will face the daunting task of managing global fisheries in an equitable, sustainable and resilient manner if these shared assets are to remain viable into the next century. **ST**

Review&Forecast

Fisheries & Aquaculture: Landings Slip While Farmed Production Shows Modest Increase

By Rick Martin
Publisher
Commercial Fisheries News and Fish Farming News

Commercial landings of wild-caught fish and seafood dipped slightly last year, while U.S. production of farm-raised species showed modest gains in both marine and freshwater sectors.

Per capita seafood consumption, however, dropped by about 1/2 lb., reversing gains shown the previous year.

Commercial Landings

U.S. commercial fishermen landed 9.6 billion lb. of fish and shellfish in 2016 (the most recent year for which statistics are available). This represented a decrease of 145.6 million lb., or about 1.5 percent, compared to 2015, according to NOAA's annual report, "Fisheries of the United States 2016."

Value of U.S. commercial landings, however, was up. The value of commercial landings was $5.3 billion, up by $108.7 million, or an increase of roughly 2.1 percent versus 2015.

Imports were up in both volume and value. Imports of edible fishery products in 2016 were calculated by NOAA at 5.8 billion lb. valued at $19.5 billion. Volume increased by 90.3 million lb., about 1.6 percent, while value increased by $693 million, or 3.7 percent, compared with 2015.

Seafood Consumption

There was some slippage in per capita seafood consumption in the U.S. during 2016, breaking a three-year trend toward higher numbers.

In 2016, U.S. consumers ate 14.9 lb. of seafood per person, a decrease of 0.9 lb. from 2015's level of 15.5 lb. While the decline was fairly modest, it contradicts popular opinion that Americans are eating more fish and seafood as part of a healthy diet. Per capita seafood consumption in the U.S. remains well below the all-time record high of 16.6 lb. set in 2004.

U.S. consumers spent an estimated $93.2 billion for

fish and seafood products in 2016. Americans continue to eat most of their seafood in restaurants, spending $63.4 billion in food-service purchases (restaurants, take-out, caterers, etc.). About $29.8 billion was spent on seafood for at-home preparation and consumption.

Shrimp remained the top choice for U.S. consumers, as it has for the last several years. Salmon, canned tuna, tilapia and Alaska pollock rounded out the top five list of most popular species. Trailing pollock were pangasius (or so-called imported catfish), cod, crab, catfish and clams to complete the top 10 list.

These top 10 species, by the way, make up more than 90 percent of all the seafood Americans eat.

Aquaculture Production

U.S. aquaculture production increased slightly in 2015 (the most recent year for which statistics are available).

In 2015, estimated U.S. aquaculture production (freshwater and marine) was 627.4 million lb. with a value of $1.4 billion.

This represented an increase of about 19.6 million lb., or 3.2 percent, and an increase of about $61.5 million in value, up 4.6 percent.

While freshwater aquaculture production has been declining generally since 2009, 2013 production showed an increase of 10 percent, followed by a decline in 2014, and back up again slightly in 2015.

Marine production grew slightly as well, up by 6 million lb., about 6.6 percent, and up $7.9 million in value, about 2.1 percent.

Freshwater production is primarily comprised of catfish (317.4 million lb.), crawfish (140.4 million lb.) and trout (45.8 million lb.).

Atlantic salmon is the leading species for marine finfish aquaculture (47.5 million lb.), while oysters have the highest volume (35.2 million lb.) for marine shellfish production.

The Look Ahead

Commercial landings of wild-caught species are not expected to show significant growth going forward due to a limited resource pool and strict management measures.

While many commercial fishermen would like to have more access to the nation's fisheries, regulators would argue that current management practices are ensuring harvesting practices that are sustainable and adequately protect ocean resources.

U.S. aquaculture production, on the other hand, has the potential to see substantial growth. The U.S. currently ranks 16th among all nations in aquaculture output, despite an enormous domestic market, which is currently served largely by imports.

There are signs that could change.

Chris Oliver, the recently appointed head of NOAA Fisheries, has called aquaculture "a resource-efficient method of increasing and diversifying U.S. seafood production that can expand and stabilize U.S. seafood supply in the face of environmental change and economic uncertainty."

How that will translate into actual practice remains to be seen. **ST**

Review&Forecast

Firing Line Report

By Aileen Torres-Bennett
Managing Editor
Sea Technology *magazine*

For our latest survey on the marine industry, we received responses from around the world, reflecting the continued international mix of our readership. The majority of participants, 48.5 percent, come from the United States. The second largest group, 36.4 percent, comes from Europe. Participants from Asia made up 9.1 percent of survey respondents, and Canadians made up 6.1 percent of respondents this year.

Sales Volume

We asked participants about the volume of their sales in 2017, and 39.4 percent said 2017 sales were level with 2016, while 33.3 percent said the volume of sales decreased and 27.3 percent said sales increased compared to 2016.

Looking ahead to 2018, optimism was prevalent among survey participants: 75.8 percent expect the volume of sales to increase in the upcoming year. Those who expect sales to be level with 2017 made up 21.2 percent of respondents. Only 3 percent expected a downturn in sales for 2018.

Product Categories

Survey participants weighed in on the degrees of activity in certain product categories, and the most active category turned out to be software/data processing. Other prominent categories include acoustic sensor systems, communications/telemetry, echosounders, electrical equipment, fiber-optic systems, GPS/DGPS navigation systems, mapping/survey systems, radar systems, sensing/measuring/sampling systems, sonars and underwater vehicles.

Customers

Respondents reported that most of their customers come from academia/research institutions and military and civilian government agencies. We asked respondents to tell us which customer base has the greatest growth potential and why. One respondent pointed to increasing military budgets. Another respondent called out a growing interest in marine research in the academic realm.

"Specific clients requiring submarine cable design, analysis and predictable performance," was the description of one respondent.

"Offshore renewables, for obvious reasons," wrote another.

"Design and production of AUV/ strengthening service structure and marketing efforts," was the response of one participant.

"Other manufacturers - business seems to be picking up," wrote another.

We asked participants about the effect of current government spending on their businesses, and the majority reported moderate to significant impact from the federal budget.

Marine Renewables

In the last several years, we've been asking survey participants to report to us on the marine renewables market in order to monitor the potential of this segment. Although not currently involved in marine renewables, one respondent wrote: "I believe that this market has a strong potential due to the increasing 'activation' of states on the issues of alternative energy sources."

"Renewable energy is definitely producing an impact and the market can only go up," a respondent said.

"In Mexico you have to invest a lot in this field, water purification plants, wind energy, the potential in Mexico is huge, [but] there are not many companies that dedicate themselves to it as in other parts of the world," wrote another respondent.

As for specific market activity, respondents reported offshore wind, cameras and lights, clean tech in ship propulsion, ocean energy and wave measurement devices as active areas.

Domestic, International Outlook

Most survey participants expressed a positive mood in the marine industry in their domestic markets. The U.S., Greece and Russia were generally pegged as good for business. Those reporting a more sober mood cited the downturn in the oil and gas industry and concerns about the effect of government leadership and policy implementation.

Overall, responses ranged from "upbeat" to "cautiously optimistic" and "challenging."

As for the international marine market, responses were mostly positive, with participants calling the international mood "good," "expanding," "strong" and "optimistic."

Some of the cautious responses reported concerns with growth prospects and government issues.

The international marine industry has not been "growing larger for the last 5 years," wrote a respondent.

Another respondent is "very concerned" because "international customers do not trust or view the current administration as reliable in honoring agreements and other matters of business exchange."

On a hopeful note, one respondent believes the international marine market will expand because of new technologies. **ST**

oceanbusiness

Western Marine Electronics Has a New Owner

Founder and President of WESMAR (Western Marine Electronics) Bruce H. Blakey sold his 52-year-old business to a new owner, Roger Fellows. WESMAR started in 1965 to develop sonar for commercial fishing and has since developed the first solid state sonar and the first color radar, along with a broad portfolio of other products for commercial, noncommercial, municipal and government customers in a variety of marine industries.

Canadian Hydrographic Service Receives Autonomous System

ASV Global converted a 26-ft. hydrographic survey launch to operate autonomously using the ASView control system. The launch, which is part of the Canadian Coast Guard's fleet dedicated to the survey operations of the Canadian Hydrographic Service (CHS), will be used as a test platform for unmanned survey work.

Delivery to the CHS marks ASV Global's 10th unmanned conversion of a customer vessel using the ASView system, which interfaces with the launch's existing engine, steering and navigation systems to enable autonomous operation. The launch is connected to a remote station via IP radios that enable real-time monitoring of survey acquisition data and vessel parameters.

Nova Scotia Company Develops Arctic Technology

GeoSpectrum Technologies (GTI) announced two contracts from the Department of National Defense to develop technologies suitable for year-round Arctic deployment and capable of providing persistent surveillance and messaging over very long ranges in environmentally hostile and acoustically challenging waters.

Under the first contract, Long-Range Detection and Communications, GTI will build a very low-frequency acoustic source for long-distance underwater detection and potentially basin-scale (1,000 km) communications, as well as supporting, for example, a UUV engaged in under-ice work. Under the second contract, Low-Frequency Towed Array, GTI will develop a passive horizontal thin line array suitable for towing from a UUV.

Ballast Water Testing Approved by Saudi Aramco

Saudi Aramco announced that all ships calling at its ports and terminals are required to provide ballast water test results to show compliance with the International Maritime Organization (IMO) Ballast Water Management (BWM) 2004 convention. The Saudi Arabian Oil Co. evaluated Turner Designs' Ballast-Check 2 Handheld PAM Fluorometer and approved it as a valid ballast water sampling instrument and will accept results from certified technicians using the device.

New LNG Response Training Program Available

KVH Videotel has launched an LNG bunkering training course based on guidelines from the Society for Gas as a Marine Fuel (SGMF). It was developed in response to the increased use of LNG as a bunker fuel by operators to help them meet the low-sulphur targets required by MARPOL Annex VI.

SGMF defined "respond level" awareness as vitally important: Personnel in close proximity to bunkering operations must understand the hazards associated with LNG and respond to emergency situations. KVH Videotel's course covers composition and usage of LNG and potential bunkering methods, hazards and consequences for the individual and ship and relevant procedures for fighting LNG fires, among other LNG topics.

Jamaica Rejoins IMO Council

Jamaica has reestablished its position at the heart of international maritime rule-making following its election to the International Maritime Organization's Council, Category C membership to serve until 2019. As the largest English-speaking island state in the Caribbean, Jamaica has had a long history of involvement in maritime affairs as an integral part of the socioeconomic development of the country. Jamaica has been a member of the IMO since 1976.

Coast Guard Seeks Mariner Input For Pacific Seacoast Study

The U.S. Coast Guard (USCG) is seeking input from mariners for a study of navigation requirements in the Pacific Seacoast System. The Waterways Analysis and Management System (WAMS) study will review the short-range Aids to Navigation system that covers American waterways, from the Canadian border to the Mexican border and around Alaska, Hawaii and the Marianas Islands. In addition to the survey input, the system-wide study will cover international requirements, environmental concerns, user capabilities, available technology and available resources.

Crowley Restructures Business Units

Crowley Maritime Corp. restructured its business units to increase the company's focus on government-related business and better align vessel operations and fuel distribution services with its customers. Crowley will transition its nonliner and logistics business units into three main service lines: Crowley Shipping, Crowley Fuels and Crowley Solutions.

Rob Grune, senior vice president and general manager, will oversee Crowley Shipping, which encompasses deep-sea petroleum transportation, ship assist and escort services, offshore vessels and commercial ship management services. Under Rocky Smith, senior vice president, Crowley Fuels will include Crowley's LNG sales, distribution and engineering unit, and the company's fuel sales and distribution business in Alaska.

Todd Busch, senior vice president and general manager, will lead Crowley Solutions, which includes naval architecture and engineering through subsidiary Jensen Maritime, government vessel management and a unified government business development team. **ST**

international

Global Satellite Communications Office Opens in Ålesund, Norway

Inmarsat opened a new office at the Norwegian Maritime Competence Center (NMCC) based in Ålesund, Norway, the heart of Norway's maritime community. From the Norwegian office, Inmarsat intends to intensify work with third-party innovators and digital disrupters to exploit high-speed broadband via Fleet Xpress through its Certified Applications Provider program.

Fleet Xpress combines Inmarsat's Global Xpress high-speed data network operating on Ka-band with the ultra-reliable FleetBroadband service on L-band. Inmarsat Maritime is seeking to increase the penetration of Fleet Xpress services in the superyacht, cruise ship and offshore rig markets. Inmarsat recently signed a letter of intent to enable the Rolls-Royce Energy Management System (EMS) via Fleet Xpress, logging data in real time.

RTsys Helps Gauge the Impact Of Noise on Marine Ecosystems

RTsys measurement devices have been qualified as suitable for submarine measurements within the Marine Strategy Framework Directive (MSFD), a European collaboration to better understand the consequences of and regulate noise from human activities in the ocean.

The measurements will be made at low frequencies, concentrating on two one-third octave bands at 63 and 125 Hz, frequencies at which maritime traffic noise predominates over all other noise sources. RTsys recorders include precalculation software that directly supplies the indicators required by the MSFD, such as the acoustic pressure (SPL), the exposure level (SEL) and the third octaves. It can also emit alarms in real time in the case that the noise exceeds the thresholds determined in advance by the user.

Measurements are in progress and reports from collaborators will be delivered to Europe by summer 2018.

Ashtead Invests £1 Million in Technology

Aberdeen-based Ashtead Technology expanded its rental fleet with an investment of £1 million in navigation, positioning and imaging technology during 2017. Ashtead is currently the only rental company to offer the iXblue GAPS-NG system with the new telemetry capability, an ultrashort baseline (USBL) positioning system for locating subsea assets.

Drones Used in Ship Class Surveys

Robotics in Maintenance Strategies (RIMS) BV received a certificate as a Recognized External Specialist from ABS and RINA for remote inspection techniques using drones for surveying enclosed spaces.

RIMS was also the first company Bureau Veritas approved as a service supplier. The approval allows shipowners and managers to invite RIMS to support class surveyors by showing the objects to be inspected live on screen. **ST**

productdevelopment

For more information on any of these products, visit our website at **www.sea-technology.com/products**

Situational Modeling

Ability Marine Pilot Vision offers multiple real-time visualizations of a vessel's surroundings such as a virtual model of the ship superimposed on its surroundings. Users can switch between views to predict vessel motions and show obstacles or collision risks. ABB Marine and Ports.

Hybrid AUV/ROV

The Integra hybrid AUV/ROV can be configured with multiple sensors and maneuvered from any web-enabled device. Users can search wide areas using its untethered AUV mode and conduct detailed inspections using its ROV mode by attaching the tether for remote control. Aquabotix Technology Corp.

Miniature Ultrasonic Anemometer

The TriSonica Mini and the TriSonica Mini Weather Station are only 9.25 cm tall. The TriSonica Mini is a 3D ultrasonic anemometer that measures wind speed, direction and temperature and can report the compass heading, air density and dew point. Anemoment LLC.

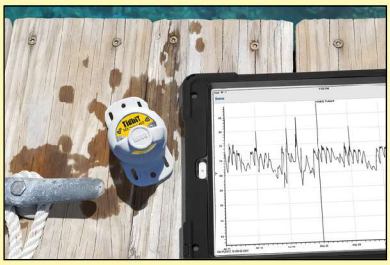
Coating Dispensing System

MIXPAC MixCoat Manual is a cartridge-based protective coating dispensing system. Components are kept separate until forced through the static mixer. Cartridges are available for 1:1, 2:1, 3:1 and 4:1 ratios. Sulzer Mixpac AG.

Synthetic Fiber Rope

Spectra HC1000 rope is made from molecular-weight polyethylene using a gel-spinning process. It has up to 60 percent greater strength than aramid fiber yet is light enough to float. The fiber is highly resistant to chemicals and ultraviolet light and provides superior abrasion resistance. Honeywell Performance Materials and Technologies.

Bluetooth Temperature Logger



HOBO MX2200 series water temperature data loggers wirelessly offload data to mobile devices with an accuracy of up to 0.2°C from 0° to 70°C. Loggers are capable of storing 96,000 measurements. The MX2202 features a built-in light sensor. Onset Computer Corp.

Environmental Compliance

A new version of the EnviroManager platform uses GPS to show regulations in force at any given position and includes all agreed national and international baselines in an updated geographic database. Version 5.4 defines discharge types including bilge water, sewage, air emissions, garbage, food waste and ballast. ChartCo Ltd.

LiDAR Option for USV

A LiDAR sensor option is available for the Z-Boat 1800RP USV that can be coupled with a multibeam echosounder to enable mapping and surveillance capabilities both above and below the waterline. Teledyne Oceanscience.

Manual Hoist

The KMX Kinetic series manual hoist is ATEX-certified for use in potentially explosive environments with spark-resistant parts and a capacity range from 0.5 to 20 metric tons. Its VH-grade load chain with an inorganic zinc coating provides optimal corrosion resistance while dip spin and powder coating provides added protection. Ingersoll Rand.

Acoustic Release Components

A line of OEM components allows customization of underwater release systems with parts such as the ORCA thermal release or OEM transducers. The OEM BART board can couple with a transducer and release control actuator for acoustic control using a PACS or 8011 surface deck box. EdgeTech.

Satellite-Based Internet Browser

Sat-Browse works via the Sat-Fi app using either Globalstar's Sat-Fi or 9600 Data Hotspot satellite devices. It offers Yippy's compression technology. Globalstar Inc.

Holographic Imagery

LISST-HOLO2 collects holographic images of fragile flocculated particles and marine organisms and can store tens of thousands of in-situ holograms, revealing some structures as small as 4 microns. The sensor has 237 GB of memory and a 25Hz continuous capture speed. Sequoia Scientific Inc.

Pile Driving Application

New software for pile driving offers GNSS positioning of the pile and uses pre-engineering information such as position and orientation as guidance during real-time operations. Teledyne RESON.

UXO Detection System

Magsense is a vertical gradiometer array to record data in magnetically noisy subsea environments. 3D steering decreases the amount of infill and the launch-and-recovery system minimizes manual handling. N-Sea Group. **ST**

Getting Ready for the Next Wave: The Digital Future—*Stuart Nicholls*

Stuart Nicholls is the CEO of StratumFive, a hi-tech software company providing international shipowners with innovative vessel monitoring software.
A former deep-sea master before coming ashore as an entrepreneur, Nicholls founded StratumFive to combine his operational experience with a passion for technology, realizing the transformative power of big data. He is a fellow of the Nautical Institute.

In a recent report, McKinsey looked at the prospects for the next 50 years of cargo shipping, marking 50 years since it first reported on the potential impact of shipping containers on the industry. The new report predicts that digitalization and the use of big data in shipping will be just as disruptive to the market as the introduction of containers was in 1967: "Advances in the use of data and analytics will bring further step changes in productivity. Shipping companies could heed the example of today's state-of-the-art aircraft, which generate up to a terabyte of data per flight. Coupled with the introduction of more sensors, the better usage of the data that ships and containers generate would allow enhancements such as optimizing voyages in real time (by taking into account weather, currents, traffic and other external factors), smarter stowage and terminal operations and predictive maintenance. Data could also improve the coordination of arrivals at port—a major benefit, since 48 percent of container ships arrive more than 12 hours behind schedule, thus wasting the carriers' fuel and underutilising the terminal operators' labour and quay space."

The shipping industry is keenly aware of the need for digitalization, and the potential risks for those who fail to keep up. Recently, ex-DVB bank shipping boss Dagfinn Lunde warned that there is a "digital tsunami" on the horizon that threatens to "wipe out" owners and banks who ignore the effect of digitalization on the maritime industry. This state of affairs can lead to a rush for some to digitize everything possible—and others to bury their heads in the sand and hope it all goes away.

Instead, we at StratumFive argue that while it's necessary to embrace digitalization, there's no need to rush blindly toward it. What's needed is a pragmatic approach. One that looks at maximizing the benefit to seafarers and to the owners and operators who support them, and focusing on the elements that make the biggest difference to the voyage, e.g., voyage monitoring systems that provide weather, security and navigational data. Such systems give owners, operators and shore crew the most accurate picture of where their ship is and what it's doing. This minimizes the risk from adverse situations, such as storms or piracy, and makes sure the voyage is as efficient and safe as possible.

Companies looking to capitalize on digitalization should focus on giving users the biggest "bang for their buck," delivering the most value in terms of the impact of the data available for analysis. Weather and navigation are among the biggest factors here. No matter how well optimized a vessel's engine or trim might be, if you can't avoid adverse weather or risky situations, this becomes obsolete. Systems that allow hyperaccurate monitoring and analysis of the minutiae of vessel performance are important, but to answer the most pressing questions that seafarers and shipowners have, we need to focus on the bigger picture.

The next phase in the development journey should be to use data sets to build predictive models, using machine learning techniques, based on analytics and data from past voyages. We can already see the examples of this analytical ability in the field of security. One such example is interactive heat maps that highlight the relative risks of piracy in different areas. Using this methodology can find relationships that might otherwise seem counter-intuitive. For instance, one might guess that light levels, speed and weather will play a part—but not the day of the week. As it turns out, the risk of piracy is actually higher on certain days. In Somalia, Fridays are days of prayer. Pirates can be divided into two groups: less experienced, opportunistic "part-time" pirates and hardened "professional" pirates. The former group will observe their holy days, while the latter will venture out regardless. So, if a pirate attack occurs on a Friday, it is more likely to result in a hijacking.

This exemplifies a crucial advantage of big data and machine learning. As in all things in shipping, data platforms need to expect the unexpected. The goal should be to create open solutions that can efficiently index and leverage data from a variety of sources. This means we can find and use links between departments and data sets that might not be obvious at the outset, bringing together more data sets to come up with new solutions. This requires us to be bold and adventurous when working with partners. We need to share data. In reality, maintaining a data silo for fear of the competition benefits no one, and, in fact, can have a negative impact on commercial success. With a collective experience that spans decades at sea, and in the fields of meteorology, software development and data science, it's clear we need to work in a way that enhances good seamanship. At the outset, digital solutions providers need to listen; to ask what shipping and seafarers need to know, rather than creating solutions in search of problems. Through listening, and adopting a pragmatic approach, shipping can master big data and digitalization, rather than drown in their wave. **ST**

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