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Members are encouraged to submit copy highlighting 1) Chapter Events, 2) People & Company News, 3) Student & Young Professional News, 4) Technology Updates, or 5) other material of broad interest to the OES. Please send to Beacon Editor-in-Chief, Harumi Sugimatsu <harumis@iis.u-tokyo.ac.jp>. Word format, 1-1/2 space; Photos (always encouraged): jpg, 300 dpi preferred. Material becomes property of IEEE-OES. Please send e-mail or physical address corrections or updates to the EIC.

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From the OES BEACON Editors

Harumi Sugimatsu and Robert Wernli

Welcome to the December 2018 issue of the Beacon. And, once again we open and close this article with the same comments. Again, we'd like to thank all of the contributors to our quarterly newsletter. As you can see by the content, this is your newsletter, and we try to cover all aspects of the society activities from our workshops, symposia and conferences to what our individual members, chapters and committees are up to. And, don't forget, all issues of the Beacon are available on the OES website.

Our last issue featured a report on the very successful OCEANS'18 MTS/IEEE Kobe / Techno-Ocean 2018 (OTO'18) conference including activities there by our Young Professionals attending under our YP-BOOST program and the results of our Student Poster Competition. Also included were AUV competition results, upcoming events and a large number of member, committee and chapter reports. And this issue will continue providing you with the latest OES activities and opportunities for our members, including announcing our newly elected ExCom officers.

Of particular interest in this issue is the report on the very successful OCEANS 2018 Charleston conference including two amazing plenaries. A significant event at all OCEANS conferences is the Student Poster Competition. Enjoy the article on all the participants and winners, along with the winning paper. And, you will also find an article that provides the results of our OES awards to those who have served the society so well. Such support is also reflected in this issue's Blast from the Past. Thanks to all our volunteers.

Chapter activity continues to accelerate as reported by the Australia, Malaysia, Providence, Seattle, Singapore chapters and the newly created Ecuador chapter. We have excellent articles that range from navigating the Tonga waters to doppler oceanography from space. Also, see our many ads that provide details on upcoming conferences and events that you may wish to attend.

There is a wealth of other information and articles in this issue that we hope you enjoy. And, as always, we'll close by inviting you to participate in your society. Submit articles and material for the Beacon. Or . . . volunteer for other society activities as a participant or an elected officer. There are also many opportunities for students and Young Professionals, some that include financial support. It's your society and it is here to help you reach your professional goals. Enjoy.

Harumi on the AUVs cruise.

Your editors documenting the birthday celebration of Tamaki Ura at OCEANS '18 Kobe.

Member Benefits—Did You know?

Your Action Required

As an OES Member, You Must "Opt-In" to Continue Receiving Your Paper Copy of the OES Beacon Newsletter

The OES Beacon newsletter is published on the OES website in both pdf and Html form. This will continue and you will be notified when each issue is on line. However, if you wish **to retain your paper copy of the Beacon you must take one of the following actions**.

1) When renewing your membership and to **"opt-in" to retain the print edition** of the OES Beacon, please select "Customize Options" in the Cart and check the box for print.
2) If you have **auto-renew** of your membership, it is suggested that you go on line and renew manually so that you can access the publication options and **opt-in to the print version**. Or, you can follow the instruction in the third option below.
3) If you renewed and did not opt-in to retain the paper copy, or if you have a problem doing so, you can **call the contact** center and ask them to provide the print copy and they will do it. Below is the information for the contact center and support center.
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From the Journal Editor's Desk: IEEE Journal of Engineering Early Access Papers

Mandar Chitre, Journal Editor-in Chief

Congratulations to the authors of our most recently approved papers for the IEEE JOE. The following papers were published as Early Access papers online on IEEE Xplore and will appear in regular issues soon. You'll find these papers now:

- "Experimental Research on Seafloor Mapping and Vertical Deformation Monitoring for Gas Hydrate Zone Using Nine-Axis MEMs Sensor Tapes" by C. Xu; J. Chen; H. Zhu; H. Liu; Y. Lin
- "A High-Gain Observer-Based Approach to Robust Motion Control of Towed Underwater Vehicles" by A. Minowa; M. Toda
- "Marine Animal Classification With Correntropy-Loss-Based Multiview Learning" by Z. Cao; S. Yu; B. Ouyang; F. Dalgleish; A. Vuorenkoski; G. Alsenas; J.C. Principe
- "Unsupervised Local Spatial Mixture Segmentation of Underwater Objects in Sonar Images" by A. Abu; R. Diamant
- "Topology Optimization of Long-Thin Sensor Networks in Under-Ice Environments" by S. Liu; A. Song; C.-C. Shen
- "Single Underwater Image Restoration Based on Depth Estimation and Transmission Compensation" by H.-H. Chang; C.-Y. Cheng; C.-C. Sung
- "Three-Dimensional Reconstruction of a Marine Floating Structure With an Unmanned Surface Vessel" by J. Han; J. Kim
- "Launch and Recovery of an Autonomous Underwater Vehicle From a Station-Keeping Unmanned Surface Vehicle" by E. I. Sarda; M.R. Dhanak
- "Analytical and Numerical Propagation Loss Predictions for Gradually Range-Dependent Isospeed Waveguides" by H. Ö. Sertlek; M.A. Ainslie; K.D. Heaney
- "A No-Reference Video Quality Assessment Model for Underwater Networks" by J.-M. Moreno-Roldán; J. Poncela; P. Otero; A.C. Bovik
- "Reference-Point Algorithms for Active Motion Compensation of Towed Bodies" by C. Calnon; R.J. Bauer; R.A Irani
- "A Study on the Effects of Wave Spectra on Wave Energy Conversions" by J. Prendergast; M. Li; W. Sheng
- "Multimodal Sensor Fusion for Robust Obstacle Detection and Classification in the Maritime RobotX Challenge" by L. Stanislas; M. Dunbabin
- "Smart Surrogate Munitions for Nearshore Unexploded Ordnance Mobility/Burial Studies" by B. Bruder; D. Cristaudo; J.A. Puleo

- "Experimental Comparison of Two Composite MRAC Methods for UUV Operations WIth Low Adaptation Gains" by C.D. Makavita; S.G. Jayasinghe; H.D. Nguyen; D. Ranmuthugala
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Obituaries of Three OES Colleagues

We have lost three OES colleagues in September 2018. Jean-Pierre Hermand, Edmund Sullivan and John E. Ehrenberg. The following obituaries for them were prepared by their families and friends.

Obituary of Professor Jean-Pierre Hermand

James V Candy, Patricia Candy, John Potter and Mal Heron

Professor Jean-Pierre Hermand.

JEAN-PIERRE HERMAND passed away suddenly on September 3, 2018. He was a father, professor, mentor, colleague and a dear friend. He leaves behind three children and his beloved wife, Dominique. As a professor at the Université libre de Bruxelles (ULB), Belgium, he was always willing to share his deep knowledge of ocean acoustics ranging from propagation theory and practice to the signal processing of truly challenging problems. As a mentor, he willingly provided any information through his experience as the lead investigator on many oceanic projects while he was at the NATO STO Centre for Maritime Research and Experimentation (CMRE) in La Spezia, Italy. He was also Principal Investigator as Researcher/Director at the Environmental HydroAcoustics Laboratory (EHL) of the university.

Educationally, he received his Master's degree in Electrical and Mechanical Engineering and a Ph.D. degree in Applied Sciences from ULB in 1981 and 1994, respectively.

As a Professor of Acoustics at ULB, he founded the EHL in 2001, which merged in 2012 to form the Laboratories of Image, Signal processing and Acoustics (LISA) where he was the Director of Research.

Professor Hermand was both a Fellow of the IEEE, conferred in 2009, as well as a Fellow of the Acoustical Society of America (ASA), conferred in 2007. Additionally, he was a Distinguished

Lecturer for the IEEE Oceanic Engineering Society (OES) where he provided many enlightening lectures throughout the world on his passion of geoacoustic inversion and acoustical signal/image processing. A recent survey showed that Jean-Pierre was the most active Distinguished Lecturer on the OES roster.

Professor Jean-Pierre Hermand was the Chair of the Ocean Signal and Image Processing Technology Committee of the OES as well as the Leader of, and POC for, the 'Acoustics and Signal Processing' Technical Committee Affinity Group. From 2011 to 2016, he served as an elected Administrative Committee member. Professor Hermand pioneered the OES sponsorship of the biannual "Rio Acoustics Conference" as well as motivating many collaborative efforts in Latin America, Australia and China. He organized the First and Second Workshops on Experimental Acoustic Inversion Methods for Exploration of the Shallow Water Environment in 1999 and 2004. In 2013, he co-created the Latin American and the Caribbean IEEE/OES Acoustics in Underwater Geosciences Symposium which was also held in 2015 and 2017.

Historically, Professor Hermand has held several positions at the CMRE, formerly known as the SACLANT Undersea Research Centre (SACLANTCEN). He conducted experimental and theoretical research in underwater acoustics and electromagnetics, mostly on inverse problems. In 1991, he became the Principal Investigator of a grant from the US Office of Naval Research to develop environmentally adaptive sonar processing at the Naval Underwater Systems Centre, New London, CT. In 1993, he was appointed by the SACLANTCEN Environmental Research Division to lead research on acoustic sensing and inversion techniques for the characterization of shallow marine sediment. He has taught image processing at the Free University of Nuoro, Sardinia, and acoustical oceanography at the Ca' Foscari University of Venice, Italy. He has received grants from research funding agencies and government institutions of France, The Netherlands, The United States of America and Australia to carry out advanced studies. These have included adjoint modelling, Bayesian filtering, acoustic particle velocity measurement, the application of ambient noise for ocean tomography and geoacoustic inversion, and the acoustics of kelp forests and seagrass meadows. He has been a consultant to industry and government on acoustic systems for environmental assessment and a group leader in multidisciplinary projects of the European Commission Framework Programme (Integrated Project, Network of Excellence, International Research Staff Exchange Scheme, Cooperation).

Besides his own field research projects, he has been involved in a variety of campaigns in the Mediterranean, Australia, West Africa and Latin America dealing with marine ecology, fisheries, sediment transport and cultural heritage. Over the course of his career, he has served as Chief Scientist on over thirty scientific cruises. He is also the author of over 250 publications and co-editor of two books. Professor Hermand has served on scientific and technical committees for the ASA, the IEEE OES, the European Optical Society, the European Conferences on Underwater Acoustics, the International Conferences on Theoretical and Computational Acoustics, the Pacific Rim Underwater Acoustics Conference and the Underwater Acoustics Conferences and Exhibitions, where he has co-organized structured sessions.

Special place—special bike—special guy!

As a friend, "JP" was always joyful and supportive. The glimmer in his eyes and his mischievous smile could easily illuminate a room and bring great joy to those around him. If he could have traveled at the speed-of-light he would have, but instead he took his special bicycle everywhere. Jean-Pierre will be sorely missed by many. He departs this world, but will always remain in our hearts!

Obituary of Dr. Edmund J. Sullivan

James V Candy

EDMUND J. SULLIVAN, 83, passed away on September 15 2018 after a battle with cancer. He was a father, mentor, colleague and a dear friend. Ed was a Co-Chair of the Ocean Signal Processing and Statistical Learning Technical Committee of the IEEE Oceanic Engineering Society as well as an associate editor for the IEEE Journal of Oceanic Engineering for nine years. He will be greatly missed, his curiosity, his insight into complex technical problems, his mastery of foreign languages, his conversations and sound arguments, his love of daily puzzle-solving, but most importantly—his wonderful sense of humor and jokes!

Dr. Edmund J. Sullivan.

Dr. Edmund Sullivan received all of his degrees from the University of Rhode Island with a Bachelor's in Science in

Electrical Engineering in 1965, a master's degree in Electrical Engineering in 1967 and a Ph.D. in Physics in 1970. He was truly an "oceanic signal processor" possessing a deep knowledge and understanding of both ocean dynamics and processing techniques. Most known for his work on passive synthetic aperture towed array processing culminating in his recent textbook entitled *Model-Based: Processing for Underwater Acoustic Arrays* (Springer Briefs in Physics, ASA Press, 2015).

Dr. Sullivan's contributions to acoustics might be considered somewhat of an anomaly at first glance. Ed had a wealth of technical publications and awards in acoustics. He was well-known in the underwater acoustics community as an array designer, acoustics modeler, torpedo analyst/designer, tracking algorithm specialist, educator, advisor, mentor and father of the modern passive synthetic aperture processor. Perhaps all of these contributions can be surmised in one catchall identifier—Ed was a "model-based signal processor" combining his knowledge of the underlying acoustic phenomenology with oceanic measurements to create a model-based processor.

Ed's career was international, most notably evolving first as a staff scientist for the Physics and Technology Division at the Naval Undersea Warfare Center (NUWC), then next as leader of the Signal Processing Group at the SACLANT Undersea Research Centre in La Spezia Italy until 1988 returning again to NUWC.

Technically, Dr. Sullivan published a wealth of papers and was extremely well-known in acoustic signal processing. In recognition of his achievements and contributions to model-based acoustic array signal processing, he was elevated to the grade of Fellow of *both* the Acoustical Society of America and the IEEE (Oceanic Engineering Society), a rare distinction. He received NUWC "Excellence in Science" Award, both in 1978 and 1991. Further honors followed with the IEEE Distinguished Technical Achievement award in 1994 and the inaugural Acoustical Society of America's Silver Medal for Signal Processing in Acoustics in 2010.

Ed Sullivan was a wonderful scientist, a man of high integrity and a great friend and colleague. He will be greatly missed!

Obituary of Dr. John E. Ehrenberg

Tracey Steig

The following obituary for John Ehrenberg was prepared by his family. The photo below was added for the Beacon. John Ehrenberg was a Life Senior Member of the IEEE Oceanic Engineering Society. He served as an Associate Editor for the IEEE Journal of Oceanic Engineering from July 1982 to January 2005. He was Editor of a special issue of the Journal devoted to "Ocean Acoustic Remote Sensing" V.11(1), 1986.

John Ehrenberg, age 74, passed away at home on September 27, 2018 after a short but robust struggle with pancreatic cancer. John was born in Spokane, worked most of his adult life in Seattle and returned to live part-time in eastern Washington in 2001. He rebuilt a cabin in his much loved Methow Valley, enjoyed skiing and hiking and had a keen and grateful appreciation for the Methow Valley Chamber Music Festival. He enjoyed sailing, was an avid traveler for business and pleasure and a brilliant finish carpenter. John loved his friends and nieces and nephews who were a wonderful support for him during his illness. He was a devoted and loving husband to his wife of 51 years Kathleen, father to his daughter Shannon and his son David, and grandfather to Riley.

Dr. John E. Ehrenberg

Beginning at the University of Washington in the 1970's and continuing over the past 45 years, Dr Ehrenberg did seminal work in the advancement of fisheries acoustic research. In 2016 he was awarded the IEEE Oceanic Engineering Society (OES) Distinguished Technical Achievement Award for the invention of the dual beam and split-beam scientific echo sounders and for contributions to the use of miniature acoustic tags in fisheries and predation research.

Dr. Ehrenberg received his PhD in Electrical Engineering from the University of Washington in 1973, his MS in Electrical Engineering from the Massachusetts Institute of Technology in 1968 and his BS in EE from Seattle University. From 1973 to 1983 John was Research Faculty and Principal Engineer at the University of Washington Applied Physics Research Lab and went on to become a Research Professor in Electrical Engineering at the UW and then an Affiliate Faculty member at the University. Dr. Ehrenberg's students and younger colleagues continue to do stellar research in echo statistics.

From 1989 to 2007 Ehrenberg was Director and then acting Vice President of Information Electronics and Avionics Technology for Boeing Phantom Works. He directed research and development on advanced modulation and coding techniques for digital communications systems, adaptive processing algorithms and custom architectures for high speed signal processing. John was impressed by and grateful for the brilliance of the scientists and support staff he worked with while at Boeing.

In 1989 Dr. Ehrenberg was brought on by the founding partners of the hydroacoustic consulting firm Hydroacoustic Technology Inc. to develop an engineering and manufacturing division. From 2007 until 2016 John Ehrenberg was President of HTI as they pioneered new techniques in fish assessment throughout the Pacific Northwest and the world. Using acoustic principles, John pioneered chirp signal processing and matched filter technology in the design of off-the-shelf echosounders available from HTI since 1992. From 2016 until the present Dr. Ehrenberg has been Chief Scientist of HTI-Vemco USA. The company has given many young engineers and fishery biologists the opportunity to work for the protection of our resources and the environment.

John, the grandson of Swedish immigrants who came here on their own as teenagers, worked all his adult life to insure everyone had the same opportunities his family did. (In the 1960's he joined the already decades long struggle for open housing in Seattle. In the 1970's John joined the campaign against

Initiative 13; marched in the first AIDS Walk in 1986; and campaigned for Gay Rights for the rest of his life. Most recently he joined the struggle against the inhumane treatment of immigrant children and worked to protect the civil rights of his Muslim students and their families.) John was a happy man. He led a good life.

At John's request, there will not be a funeral. In early June of 2019 a celebration of John's life will be held in the Methow Valley. If you would like to make a gift in John's memory, you may contribute to the Ehrenberg Endowed Scholarship in Electrical Engineering, University of Washington Foundation, College of Engineering, 371 Loew hall, Box 352180, Seattle, WA 98195.

"We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time." T.S.Elliot.

OES Society Awards

Photos by Stan Chamberlain

The OES Society Awards Ceremony was held during the Wednesday Plenary at OCEANS 2018 Charleston. We are honored to introduce the following 2018 OES award recipients. Congratulations!

2018 Distinguished Technical Achievement Award: Martin Klein

Martin Klein is presented the DTA award for the design and development of the first commercial dual-channel side scan sonar and contributions to new techniques in ocean exploration.

Mr. Martin Klein is Founder and former President of Klein Associates, Inc., now Klein Marine Systems. A Massachusetts Institute of Technology (MIT) graduate (Class of 1962), Mr. Klein was Program Manager for Sonar Systems at E.G.&G. International (1962–1967) where he developed the first commercial dual-channel side scan sonar, establishing a lineage of seabed mapping systems that continues to evolve and to be used to this day. In 1968 he founded Klein Associates, Inc., where he improved and diversified the product, distributed the first dual-frequency system, and developed the first combined side scan and sub-bottom profiling sonar. These systems have seen worldwide use in surveys for the offshore commercial sector, for resource management, maritime archeology, as well as for military applications. The Klein Side Scan Sonar was one of the iconic objects selected for the MIT150 Exhibition, commemorating the 150th anniversary of the founding of MIT.

Martin Klein receives the Distinguished Technical Achievement Award from OES president Christian de Moustier.

Klein's sonars have been used to help find numerous shipwrecks that include the Titanic, the Lusitania, the Edinburgh, the Hamilton and Scourge, the Lake George Radeau (oldest warship in the U.S.), and the HMS Erebus. In the 1960s Mr. Klein helped design, install and operate the first deep side scan sonar, and up-down and navigation sonar for the Bathyscaph Trieste during the search for the lost submarine USS Thresher. In the 1970s Mr. Klein worked with the Academy of Applied Science and the Loch Ness Investigation Bureau using his side scan sonar instruments to show the existence of caves in the steep walls of the Loch, locate cultural artifacts, and assess the fauna of that storied body of water. He participated in dives of several research submersibles, including a 5000- foot dive in the ALVIN with a team from the Woods Hole Oceanographic Institution in which he made the first sub-bottom profile from a deep submersible.

Mr. Klein is the author of numerous patents and publications. He is a Life Member of the IEEE, a fellow of the Explorers Club, and a fellow and former Director of Budget and Finance for the Marine Technology Society. Mr. Klein was elected to the National Academy of Engineering, is recipient of the Order of Excellence Award from the Alliance for Maritime Heritage Conservation and the Compass Distinguished Achievement Award sponsored by Sea Technology Magazine, and in 2018 received the Lifetime Achievement Award at the Oceanology International Conference in London. Currently Mr. Klein serves on the Advisory Board of the MIT Sea Grant Program and the Stellwagen Bank National Marine Sanctuary, and serves as a judge and mentor for the Marine Advanced Technology Education (MATE) ROV Competition.

2018 Distinguished Service Award: Jerry Carroll

Jerry Carroll is presented the DSA for contributions to the governance of the Society as an elected member of the Administrative and Executive Committees, for service as Treasurer (2005–2008), President (2009–2012), Junior Past President (2013–2016), and Senior Past President (2016–2018).

Jerry Carroll attended Oklahoma State University majoring in geophysics. Before graduating, he worked for Petty Geophysical Co. performing seismic survey, and for Phillips Petroleum Co.

Jerry Carroll receives the Distinguished Service Award from OES president Christian de Moustier.

After graduating he began his career with NAVOCEANO in Washington D.C. During his career in Oceanography, he served as Special Advisor to the Naval Meteorology and Oceanography Command, concerning Oceanography Programs from 1996 to 2008. While at the Naval Oceanographic Office, he was the Director of the Oceanography Department from 1981 to 1990 and Director of the Operations Directorate from 1991 to 1996, responsible for over 650 civilians, 100 military personnel and a fleet of oceanographic ships & aircraft. He developed a system at NAVOCEANO to find a major wreck off the Aleutian Islands that was set to create a nuclear explosion, but the threat was neutralized. His experience in the Navy Department was very valuable for involving Navy participation, organizing conferences and symposia for the OES, and expanding OES international participation. He was very influential in developing technical sessions with Navy participation for OES conferences and symposia.

He received numerous awards, including the Navy's Meritorious Civilian Service Award and the Secretary of the Navy's Hispanic 5 Point Award. He was very active in the Navy's International Programs, establishing contacts in many countries. Mr. Carroll has been active in Professional Societies most of his career. As a member of the American Geophysical Union he helped organize Oceanographic Conferences in New Orleans. He is a Fellow in the Marine Technology Society and served as Vice-President for the MTS Southern Region. He was also a member of the Society of Exploration Geophysicists and GRSS. He was affiliated with the University of Mississippi as a Research Scientist and a member of the Gulf Coast Gas Hydrate Consortium.

As OES President and Treasurer of IEEE/OES, Jerry strengthened OES policy for controlling finances for conferences and symposia. He provided leadership and promoted new international symposia in South America, the Baltic and S.E. Asia.

Mr. Carroll is a Senior Past President of the IEEE Oceanic Engineering Society and served more than 10 years providing OES leadership in the administrative and executive committees. He served as OES Treasurer from 2005 to 2008 and as OES president from 2009 to 2012.

In his term of office, he pioneered initiating international programs in South America, and initiated a series of symposia in the Baltic region. Mr. Carroll was successful in getting prominent speakers from the Navy Department and financial support from the Office of Naval Research Global whose responsibility included providing conference support for foreign universities. In 2006, Mr. Carroll played a major role in inviting Russian participation, including bringing a prominent Russian oceanographic ship into Klaipeda Harbor; inviting ship tours and an onboard reception. This was the first time that a Russian ship from neighboring Kaliningrad was allowed entry in the port of Klaipeda. Russian participation enabled exchange of ocean technology which was previously limited. He brought about discussions of very sensitive and new topics on marine activities in the Baltic such as obtaining valuable information on World War II ordinance disposal and monitoring, and the introduction of the gas pipeline from Russia along the Baltic floor. The disposal of World War II ordinance, including unexploded mines bearing dangerous chemicals, posed serious environmental problems.

Mr. Carroll played a leading role in establishing symposia and workshops in South America. This represented the first OES penetration in South America. The symposia proved to be very successful. In Chile and Argentina, academic and naval organizations and their leadership were invited in responsible roles in symposia participation. Mr. Carroll played a leading role in planning and organizing the South American symposia and in particular, getting financial support. The symposia in Vina Del Mar, Chile and Buenos Aires, Argentina were very successful in providing OES South American participation. Mr. Carroll also participated in launching a new series of Underwater Technology (UT) symposia in Tokyo Japan which later led to the UT symposia in Taiwan, China and India.

2018 Institution Award: Brest Métropole

Brest Métropole is presented the Institution Award for its enduring support and contributions to the goals of the Society and their promotion during the biennial Sea Tech Week event since 2010.

Sea Tech Week—the international marine science and technology conference—is organised every two even years in Brest, in the framework of "Campus mondial de la mer" by Brest Metropole city council and Technopôle Brest-Iroise, with the support of the European Union and the Brittany region.

René Garello receives the OES Institution Award on behalf of Brest Metropole.

Sea Tech Week was first launched in the 2000s. For Brest metropole, the idea was to offer the region's stakeholders a showcase to raise the profile of all research as well as innovation-generating companies.

The conference represents over one thousand participants, researchers, industrialists and decision-makers and it offers also a unique opportunity to develop business relationships in taking part in the exhibition and face-to-face meetings.

Since 2009, the Brest event is supported by IEEE/OES through a memorandum of understanding which organizes a crossed promotion between Sea Tech Week, the even years, and the OCEANS conference held in Europe the odd years.

2018 Presidential Award: Venugopalan Pallayil

Venugopalan Pallayil is presented the Presidential Award with appreciation and thanks for his outstanding service to the Society.

Venugopalan Pallayil is a Senior Research Fellow and Deputy Head at the Acoustic Research Laboratory, Tropical Marine Science, National University of Singapore. He holds a Master's degree in Physics and PhD in microwave electronics from Cochin University of Science and Technology. His research interest includes ambient noise measurement and imaging, underwater sensor system development and seabed characterization. In 2004, the project ROMANIS, a second generation ambient noise imaging system, won the Defence Technology Prize for best group project. He has published widely in many international journals and conferences. He has participated, on invitation, in three international research cruises in collaboration with U.S. universities towards understanding acoustic interactions with the seabed. Prior to moving to Singapore, he spent about 11 years at the Naval Physical and Oceanographic Laboratory, Cochin, as an R&D Scientist where he worked on airborne ASW sensor systems.

Venu has been a member of IEEE for the past 21 years and is a senior member since 2007. He is also a Member of Acoustical Society of America and Society of Acoustics, Singapore. He serves as a reviewer for many international journals and conferences. He served on the AdCom for IEEE Oceanic Engineering Society in 2016 as a nominated member and was again elected to serve for the period 2018-2020. He was one of the founding members of IEEE OES Singapore Chapter and served it in different capacities such as treasurer and Chair. As a leading member of the committee which initiated The Singapore AUV Challenge, an international student competition, he supported its activities in many capacities including its chairmanship. He has been the Chair for sponsorship for this event since 2013 and generates on an average $35K for running this competition. Venu was associated with the IEEE OES programme sub-committee for OTC Asia since 2014 and served as its Chair in 2018. In 2006 he served as the Chair for Finance for the OCEANS conference held in Singapore. He will be the General Chair for OCEANS 2020 Singapore.

Venugopalan Pallayil receives the Presidential Award from OES president Christian de Moustier.

2018 Emeritus Award: Daniel Alspach

Daniel Alspach is presented the Emeritus Award with appreciation and thanks for his outstanding service to the Society as an elected member of the Administrative and Executive Committee.

Dr. Alspach, a company founder in 1973, served as Vice President/Technical Director till 1980 and has been President of ORINCON Corporation since 1980. As of July 1, 2000, Dr. Alspach was Chairman, President and CEO of ORINCON, Industries, Inc., the parent company. Using his 30+ years of technical and management experience, he has guided ORINCON in its mission of bringing quality systems analysis and software development skills to bear on real-world technical problems.

As President of ORINCON Corporation, Dr. Alspach oversaw all corporate activities while maintaining a strong interest in ORINCON's technical work. Under contracts to DARPA, the U.S. Navy, and other Government customers, he has led many company efforts, particularly inter-array processing and multiple coherence for ocean surveillance, designed and led the implementation effort for the SOSUS tracker, and the company's first multi-target/multi-sensor tracking system. He led a DARPA-sponsored technology assessment of key issues in development of antiballistic missile concepts for the Strategic Defense Initiative.

Dr. Alspach is a Fellow Member of the IEEE and past President of the IEEE Oceanic Engineering Society and was a member of the Executive Board. He was a founding member of the OES and was on the Council of Oceanic Engineering from its inception in 1976. He was also on the Board of Directors for the Small Business Technology Coalition. Dr. Alspach has held faculty positions at the University of California at San Diego and at Colorado State University. Prior to founding ORINCON, he investigated spin-off concepts for the ORION nuclear-powered space vehicle at the General Atomic Division of General Dynamics and performed navigation and control studies of manned spacecraft at Honeywell, Inc., in the Advanced Space Flight Systems Division.

Dr. Alspach received his B.S./M.S. in Physics from the University of Washington, 1962 and 1966, respectively, and his Ph.D. in Engineering Sciences from the University of California at San Diego in 1970.

OES Young Professionals at OCEANS 2018 Charleston

Shyam Madhusudhana and Fausto Ferreira, IEEE OES Young Professionals BOOST Program Members

Not so far on the heels of an excellent experience during OCEANS'18 Kobe, we were now headed to Charleston, SC with renewed excitement and enthusiasm to partake in our second stint as Young Professional (YP) BOOST Program members at an OCEANS conference. Having been spared from the wrath of hurricane Florence and the looming threat of hurricane Michael, Charleston, a city steeped in history and Southern charm, welcomed us with exceedingly pleasant weather.

As YP-BOOST members, we were invited to the Presidential dinner, on the evening before the first day of the conference. It was a fabulous opportunity to not only catch up with the AdCom folks but also to meet the spouses of some of the members. Frédéric Maussang, the OES YP chair, who was unable to attend the previous OCEANS conference in Kobe, Japan, was present at the dinner and we were glad to finally meet him in person.

The AdCom meeting, on the following day, progressed with much gusto, amidst occasional lighthearted infusions from several of the members. Numerous motions were raised and passed throughout the day and as we continued to witness the proceedings and the ensuing deliberations, we developed a much better appreciation for the YP BOOST initiative and a stronger sense of purpose in OES. As the meeting neared its end, we were thrilled to find out that our roles within the society were being considered for elevation, i.e., for induction into the AdCom to fill two recently opened positions. When the meeting finally ended, there was just one thing on our minds - the yearning to hear the 'clinking' of glasses and to gulp the celebratory sip. So, in 2019, besides continuing to fulfill our existing duties and helping with the initiation of the next batch of YP BOOST Program members, we will also be stepping into a larger role in the AdCom.

Of our duties as YP BOOST Program members, the most exciting one has been to serve as judges in the Student Poster Competition (SPC). In comparison to the SPC at OCEANS'18 Kobe, the number of participants had increased this time. This meant that our schedules were going to be a bit more packed. Nonetheless, we were very happy to find out that it was not just an increase in quantity but also in the quality of the research presented. Choosing the winners was quite hard as there were several high caliber participants presenting excellent studies.

Social media reporting, led by Brandy Armstrong, witnessed increased participation of volunteer reporters this time, which provided excellent coverage of the event. The coverage also included short videos with main sponsors as well as live streaming of the Career panel and Women in Engineering (WIE) panel discussions. We are still improving and enlarging this initiative but the results have been encouraging and it is a pleasure to contribute to this.

Besides all the commitments, we fortunately had time to share many joyous moments with several of the society members like William (Bill) Kirkwood, Christopher Whitt, Marinna Martini, João Alves, John Watson and Philippe Courmontagne who, on numerous occasions, amused us with several of their captivating anecdotes. It is great that we had the time to 'hang out' with other AdCom members, as they continued to integrate us in the society. This is not only encouraging for us given our impending involvement in AdCom but is also attractive for potential future candidates considering participation in the YP BOOST Program. We are eager to find out what else is in store for us going forward as we take on bigger responsibilities within the society and contribute to shaping the future at AdCom meetings.

We are very much looking forward to OCEANS'19 Marseille. See you in France! *Au revoir!*

Photo credit: Stan Chamberlain

YP BOOST Program members Fausto Ferreira (center) and Shyam Madhusudhana (third from right) … (can you find the YP?) … along with Frédéric Maussang (second from left), Christopher Whitt (second from right) and Brandy Armstrong (extreme right) during the YP meeting at OCEANS'18 Charleston.

Chapter News

Submit Chapter News to Beacon Co-Editors and OES Chapter Coordinator

Australia Chapter Antarctic and Southern Ocean Forum (ASOF)—for Engineering Science and Technology

Reported by Mal Heron

General Chair Andreas Marouchos was kept very busy all week.

ASOF was hosted by the OES Australia Chapter in Hobart, 14–17 August 2018. It was a single-track workshop co-sponsored inside IEEE by OES and GRSS, with CSIRO an external sponsor. Andreas Marouchos, who is Chair of the Polar Oceans OES Technology Committee, was the General Chair, ably assisted by Shona Lyden from CSIRO. Hobart is the smallest capital city, in Australia's smallest state, with the biggest aggregation of oceanography and Antarctic science. Because Hobart is the supply base for Australia's Antarctic activities, it has a large group of technology and engineering support personnel. The CSIRO research vessel RV Investigator was in port and the ice-breaker RSV Aurora Australis was preparing for the coming season in Antarctica. The ASOF program included a tour of the RV Investigator; but we did not manage to have the ice-breaker on the ice-breaker. The main signature of the Forum was the confluence of science and technology in the delegates and in the presentations. Perhaps it is the extreme conditions that people are working under in the Southern Ocean and the Antarctic Continent, or perhaps it is the close proximity of science and the supporting infrastructure in Hobart, but whatever the reason, the presentations in ASOF went all the way from lost moorings through to the highest aspirations for the planet. We heard about the science challenges as well as the issues in deploying and maintaining research instruments in this environment. Comment and discussions on presentations sometimes encroached on coffee break time. This came into focus when several feedback comments suggested that more time be allocated for structured discussion in future ASOFs. In the discussion at the end of the event there was a consensus that ASOF should be repeated in 2020, and the most significant take-home message was the

Aft deck of RV Investigator.

Damien Guihen (L) and Craig McPherson (R) interacting with Celeste Fraser at the conference dinner.

The CSIRO Auditorium was an ideal venue.

success of the interactions between technologists, engineers and scientists. This was a most successful Forum in many respects.

Providence Chapter a Summary of the Four Technical Meetings

Reported by Sandy Williams

James Michaelson, June 4, 2018

The first speaker was Dr. Jim Michaelson from Harvard Medical and Visiting Scientist at Woods Hole Oceanographic Institution. His topic was Micro CT Imaging, a technique most recently employed on clam shells and oceanic bird ears. The resolution of the CT scan is millimeters to microns, based upon a very intense and bright x-ray source. The application to surgery is where it has been most beneficial; permitting a surgeon removing a tumor to determine in minutes whether the excised material shows clean margins and if not the surgeon can extend the excision while the patient is still in the operating room, rather than returning a week later for a second procedure. Micro CT imaging was first employed in metallurgy but now has spread to other fields. The talk was presented at U. MASS. Dartmouth on June 4, 2018 at 6 PM. Because of the biological aspects of the subject it was advertised jointly with the Providence EMBS Chapter. The location between Woods Hole and Providence was convenient for all to attend.

Prof. John Buck, our host at U. MASS. Dartmouth is reading the CV (or possibly the menu after the talk) where Jim Michaelson at the right gave us a lecture on Micro CT Imaging June 4, 2018. The talk was attended by 7 IEEE members and 7 guests.

Dr. Latha, June 25, 2018

On June 25, 2018, we had a guest from NIOT in Chennai, India—visiting Prof. Gopu Potty at URI. After Dr. Latha saw URI, she came with Gopu to Woods Hole Oceanographic Institution to speak with acousticians there and gave us a Chapter talk on Real Time Monitoring of Ocean Noise. The talk was very interesting. Dr. Latha started out by briefly summarizing the acoustics related activities her group at National Institute of Ocean Technology is involved in. This included

- Ambient noise measurements in shallow waters off the coast of India
- Noise measurements being carried out in the Arctic
- Geoacoustic inversion using ambient noise measurements made on Vertical Line Array in collaboration with URI.
- State of the art calibration facilities at NIOT in collaboration with NPL (UK), WTD (Germany) and VNIIFTRI (Russia).
- Humpback whale studies in shallow waters off Cochin, India in collaboration with WHOI.

Dr. Latha of National Institute of Ocean Technology in Chennai, India presenting an OES Chapter talk, June 25, 2018 to an acoustics audience at Woods Hole Oceanographic Institution. Five were IEEE members and there were six guests.

The major topic covered in the talk was *Real time monitoring of ocean ambient noise in Indian seas*. She discussed the features of the autonomous passive acoustic measurement system with real time transmission, which has been developed for shallow water applications and operated in the open ocean at different sites off the Indian coast. The performance of the system in severe weather conditions, during multiple cyclones, was highlighted. Current efforts to develop a vector sensor array for passive noise monitoring were also discussed.

A lively discussion followed the talk on various topics covered in the talk especially related to the mooring design, telemetry aspects, and the marine mammal studies.

Milestone Event, September 6, 2018

On September 6, 2018 a Milestone event was held in Orleans, MA at the French Cable Station Museum. This was co-sponsored by the Providence Section and the Providence OES Chapter.

Joe Manas, President of the French Cable Station Museum in Orleans, MA is standing in front of the Museum bronze plaque in English and the Milestone plaque in French provided by the Providence OES Chapter on September 6, 2018. About 40 attended the Milestone celebration, about 10 IEEE members including Jeff Jefferies, IEEE President.

Jake Lacourse is explaining the Lean Manufacturing philosophy used at Onset Computer, Inc. in their selection of product, design, testing, and manufacturing. The Chapter technical meeting at the factory in Bourne, MA on September 27, 2018 was followed by pizza and informal discussion with every part of the facility available for inspection. There were 6 IEEE members and 11 Guests.

Rene Garello, a principal speaker at the event, has already reported on it so it will not be commented upon here except to say it was a very interesting and rewarding event. The two sponsors each bought a bronze Milestone plaque, the OES plaque was in French, to copy one of the corresponding Milestone plaques in Brest, France at the other end of the 1889—1956 operating telegraph cable, first to connect Europe to the United States directly. Attendance was about 40 persons with about 10 IEEE members.

Mal Heron, September 7, 2018

Our September 7, 2018 Distinguished Lecturer, Mal Heron, presented an OES Chapter talk on HF Radar in the Next Decade, held at Woods Hole Oceanographic Institution.

Distinguished Lecturer, Mal Heron from Jamestown University in Queensland, Australia, gave the OES Providence Chapter a presentation on HF Radar in the Next Decade. He provided both background on the discovery and development of HF Radar as used for measuring ocean current remotely and the new ramifications of the use of Radar, even in the X-band, for surface current and waves. We benefited in his availability in Woods Hole, MA due to his position on OES ExCom, which held its late summer meeting on Cape Cod. This talk was on September 7, 2018 and was attended by 11 IEEE members and 3 Guests.

Onset Computing, Inc., September 27, 2018

In the interest of also representing manufacturing and industry in Chapter talks, a technical meeting was held on September 27, 2018 at Onset Computer, Inc. in the Bourne, MA factory. Jake Lacourse, Director of Hardware Engineering, and Jamie Pearce, VP of Marketing and Business Development, gave a series of presentations as well as a factory tour. Onset has a staff of 140 and all work, from product definition to assembly and shipping is done in this facility. It was a very interesting glimpse into an essential aspect of engineering. My personal interest in Onset arose from their data loggers, the Tattletale family, that I have used in my underwater instrumentation since their earliest days in about 1981.

Malaysia Chapter—Meeting Report and Activities

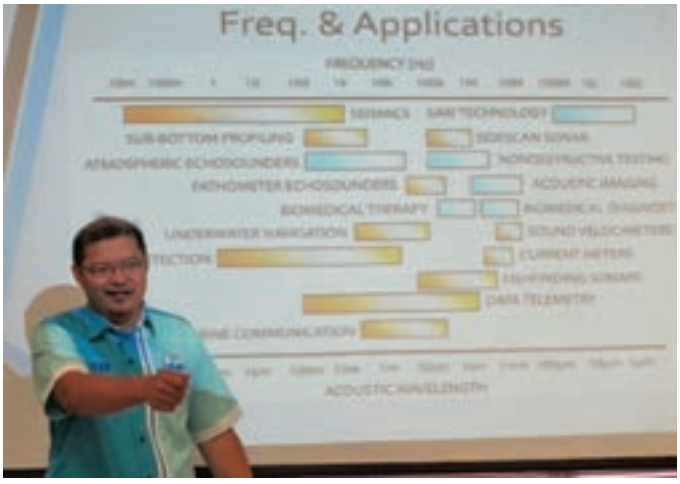
Reported by Rosmiwati Mohd Mokhtar, Mohd Rizal Arshad and Zainah Md Zain

Chapter Meeting

As of October 2018, the IEEE OES Malaysia Chapter has conducted four chapter meetings for the year.

Date	Meeting
6 Apr 2018	20th IEEE OES MY Meeting (MJIIT, UTM, Kuala Lumpur)
29 June 2018	21st IEEE OES MY Meeting (MJIIT, UTM, Kuala Lumpur)
28 Aug 2018	22nd IEEE OES MY Meeting (FKE, UTeM, Melaka)
27 Sept 2018	23rd IEEE OES MY Meeting (Meeting Room, UMP, Pahang)

Photo taken during one of the Chapter Meetin.



Dr. Ikhwan while conducting the talk.

Experimental test in the lab tank.

Technical Workshop on Underwater Acoustics Sensor Design

On 27th and 28th August 2018, the IEEE OES Malaysia Chapter organized a two day workshop on underwater acoustics sensor design. The workshop was jointly organized by the Center for Robotics & Industrial Automation (CeRIA), Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka (UTeM). The speaker of the workshop was Dr. Mohd Ikhwan Hadi Yaacob from Universiti Pendidikan Sultan Idris (UPSI), Tanjung Malim, Perak. The aim of the workshop was to give an overview and exposure of underwater acoustics sensor to researchers. During the event, participants were given opportunity to design a simple acoustics sensor for underwater application.

On the first day, the workshop focused on underwater acoustics basics and essentials, underwater acoustics sensor architecture, material selection and design consideration. It was also included with hands-on design of a simple underwater acoustics sensor. More experimental work was conducted on the second day. The designed underwater acoustics sensor was tested in the big tank, which was available in the lab. The conducted workshop has indeed promoted the research related to this underwater field and that has also provided the participants an opportunity to experience designing an acoustics sensor for underwater application. This has improved in terms of their development skills in the associated technologies.

In conjunction with the workshop, the visit to underwater technology research lab at the Universiti Teknikal Malaysia Melaka was also made. The participants had the opportunity to see the ocean engineering research activities that are conducted at the university. This activity has allowed the members to share ideas and knowledge and to discuss on further direction and future expectation of ocean engineering and technology in Malaysia.

National Seminar on Underwater System Technology 2018

The 10th National Technical Seminar on Underwater System Technology 2018 (NUSYS'18) was organized by the Faculty of Electrical & Electronics Engineering, Universiti Malaysia Pahang (UMP) on the 26–27 September 2018 at the UMP Library, Pekan Campus. With a theme "Deeper Discoveries," NUSYS'18 was jointly organized by IEEE OES Malaysia Chapter, Malaysian Society for Automatic Control Engineers (MACE), and Institute of Engineer Malaysia (IEM) Marine Engineering and Naval Architecture Technical Division (MNATD). The objectives of the seminar were;

- To accommodate a medium to discuss wide range of underwater system technology between universities and industries.
- To disseminate the latest technology in the field of underwater engineering.
- To provide an opportunity for researchers to present their paper in electrical & electronics engineering and underwater system technology area.

NUSYS'18 was officiated by the Deputy Dean (Academic) Faculty of Electrical and Electronics Engineering, UMP, Assoc. Prof. Dr. Hamdan Daniyal. 57 papers were presented by authors during the technical sessions. In addition, 3 distinguish speakers delivered their keynotes during the event. Those were,

- Assoc. Prof. Dr. Aidy @ Mohamed Shawal M. Muslim, the Director of Institute of Oceanography and Environment (INOS), Universiti Malaysia Terengganu—*Exploring Application of Remote Sensing in Underwater Mapping.*

NUSYS'18 committees with the keynote speakers.

Assoc. Prof. Dr. Aidy @ Mohamed Shawal M. Muslim.

Mr. Mirza Iryawan Hamza.

Assoc. Prof. Dr. Mohd Farid Muhamad Said.

- Mr. Mirza Iryawan Hamza, Technical Director of Temasek Hidroteknik Sdn. Bhd. (Survey Division) & Temasek Allied Engineering (Instrumentation Division)—*Autonomous Underwater Vehicle (AUV) for Coastal Hydrographic Surveys.*
- Assoc. Prof. Dr. Mohd Farid Muhamad Said, Senior Lecturer at Dept. of Aeronautic, Automotive & Ocean Engineering, School of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia—*Development of an ROV: Antarctic Expedition and Underwater Observation for Industry Application*.

The OES membership drive was also conducted during the event. This is made to give an overview about the IEEE OES Chapter with the aim that more people will join the Chapter in the future.

Singapore Chapter—Meeting Report and Activities

Reported by Hari Vishnu and Venugopalan Pallayil

IEEE OES Singapore has been active this year in organizing many technical talks for its members. On the 1st of February, Eric de Trétaigne from Alseamar delivered a talk touching upon aspects of the SeaExplorer Glider system.

After our flagship underwater robotics event (The Singapore AUV challenge), we followed it up with a talk later in March by Dr. James Bellingham. Dr. Bellingham is the founding director of Center of marine robotics at Woods Hole Oceanographic Institution and the co-founder of Bluefin Robotics. His talk dealt with the current state of the art in autonomous marine systems, and the future of research in this field. The talk was titled "Ocean Science in the Age of Marine Robots," and saw quite a bit of audience engagement and discussion on marine robotics.

Dr. Bellingham in an engaging discussion on marine robotics at the Tropical Marine Science Institute, National University of Singapore.

Dr. Christian de Moustier, President of IEEE OES, with the attendees of his talk at National University of Singapore.

Dr. Dajun Tang's talk on "Acoustic Transmission Loss: a practical consideration" in progress.

U.S. Coast Guard Cutter HEALY.

Dr. Christian de Moustier, who is the founder of 10 dBx LLC, and also the President of the IEEE Oceanic Engineering Society, visited Singapore in May 2018 and a technical talk by him was organised by the local Chapter. His talk focused on advanced post-processing of sonar data. The talk was titled "In-situ beam pattern estimation for seafloor acoustic backscatter measurements."

Dr. Dajun Tang gave a talk on "Transmission Loss: a practical consideration" on the 28th of September. He is a Principal Senior Oceanographer at Applied Physics Laboratory, University of Washington. Dajun's talk covered the definition, measurement, modeling, and application of underwater transmission loss through real data collected in some recently conducted experiments, and touched upon practicalities associated with predicting and measuring transmission loss. The talk was followed by an involved technical discussion along with a networking barbeque dinner held at the premises of the Acoustic Research Laboratory in the National University of Singapore.

In summary, we have had a range of talks focusing mainly on acoustics and marine robotics this year. We plan to round up this year with an annual year-end workshop complete with technical talks, mostly focusing around marine biology and bio-acoustics. We expect strong participation from students, industry and academia. The details of this event will be reported in a later BEACON article.

Seattle Chapter Technical Meetings

Reported by John Hager, Secretary, Seattle Chapter

USCGC Healy Tour

The monthly meeting for January, 2018, was a tour of the U.S. Coast Guard's newest icebreaker, the USCGC Healy (WAGB-20), launched in 1997. At an overall length of 420 feet and beam of 82 feet the 16,000LT displacement ship can break 3-1/2 foot thick ice at a speed of 3 knots and ice up to 8 feet thick by backing and ramming. The vessel was designed to also conduct extensive science missions in the arctic. The ship features more than 4,200 square feet of scientific laboratory space, an array of oceanographic handling gear including multiple winches loaded with mechanical-optical cable, and a suite of sensor systems. The vessel can accommodate up to 50 scientists. The tour was conducted by two Ensigns, recent graduates of the U.S. Coast Guard Academy, each now with arctic cruise experience. These two ladies lead the group from the bridge, through the length of the ship, down to the engine level, providing a wealth of technical information at each station. The stations included not only the piloting, navigation, logistics, mechanical, electrical, and propulsion, but also the laboratory rooms and equipment, the high-bay hanger for research vans, equipment, and vehicles, and the gargantuan oceanographic winches (one loaded with 30,000 feet of mechanical-optical cable) on the lowest deck. Perhaps most impressive, beyond the deep knowledge of the ship's specifications and capabilities, was the enthusiasm displayed by the two Ensigns. They regaled the group with stories of their physical training (damage control, fire-fighting, scuba diving), and their arctic cruise experiences piloting the ship through ice (and getting stuck, briefly),

Tour welcome and orientation.

Healy Control Center.

Business wrap-up.

ROV SuBastian.

Let the presentation begin.

Q & A with Mr. Eric King.

and supporting arctic oceanographic research. The education, training, experience, and eagerness which they displayed was impressive and inspirational.

Heave and Motion compensation

At the monthly meeting for February, 2018, Mr. Joseph Sabbia from Bosch Rexroth Corp. discussed "Calm Waters-Wait or Create? Active Heave and Motion Compensation." The effects of wave motion can have significant safety and cost impacts on marine operations when handling heavy loads and sensitive oceanographic equipment. Maximizing up time can be achieved by using heave and motion compensating technologies which counter the wave actions. Active compensation solutions have been implemented in many aspects of marine operations from roll compensated helicopter landing platforms to deep water handling systems to 3 degree of freedom compensated platforms. Mr. Sabbia discussed his extensive work at Bosch Rexroth in the area of motion compensation where they have been able to deliver both hydraulic and electric driven compensation solutions from one to six degrees of freedom. He presented an overview of application examples for heave and motion compensated machines that Bosch Rexroth has delivered to the market and discussed the technology behind these systems including the differences between passive heave compensation and active heave compensation. Energy storage and recovery also was discussed along with state-of-the-art systems for multi-axis compensation.

Schmidt Ocean Institute's ROV SuBastian

At the monthly meeting for March, 2018, Mr. Eric King from Schmidt Ocean Institute (SOI) discussed the rapid development and completion of the 4,000 m ROV SuBastian: "18 Months from Concept to Mission Ready." In 2016 SOI added a pivotal ocean science resource to its suite of systems offered aboard the foundation's 275 foot privately owned research vessel Falkor. SOI recognized the need for a dedicated remotely operated vehicle that could live aboard the ship. This vehicle, with some of the same capabilities as NSF's ROV Jason and CSSF's ROV ROPOS, would become a primary robotic tool available to scientists and researchers during collaborative expeditions. As a no-cost platform to the greater community of users, SOI is committed to continuously improve the vehicle's specifications and enhance its plug-and-play features. Mr. King discussed how the project developed from concept to operational readiness, including the back story of SOI's initial initiative to build an 11,000 m hybrid ROV. He also highlighted several recent missions where ROV SuBastian has been used off of Guam, the Republic of Kiribati, and the Kingdom of Tonga, along with upcoming 2018 projects off the Pacific Northwest coast in the vicinity of Hydrate Ridge. Of significance is the potential for low cost at-sea support of small oceanographic research projects through SOI. The Schmidt Ocean Institute is a 501(c)(3) private non-profit operating foundation established to advance oceanographic research, discovery, and knowledge, and catalyze sharing of information about the oceans.

2018 First Congress on Ocean Technology: Providing an Atmosphere of Cooperation between those who Work, Study and Research the Oceans—Belgium, Brazil, Japan, Venezuela and Ecuador.

Lady Nicole Macas Mende

This article is dedicated to the memory of Jean-Pierre Hermand, Ph.D. the greatest inspiration for the creation of the IEEE OES ESPOL chapter in Ecuador as well as a great mentor and friend.

The newly created OES-ESPOL chapter in conjunction with the main branch IEEE-ESPOL organized the first congress on "Ocean Technology" which addressed the various ways in which technology is related to marine sciences, and to the demand of students, professionals and researchers in Ecuador. It brought together 8 speakers, 80 students, 30 professionals and 10 representatives of the main marine science organizations and authorities of "Escuela Superior Politécnica Del Litoral (ESPOL)" ESPOL, on Saturday, September 1, 2018 from 0900 to 1700. The event took place at the STEM auditorium of ESPOL, Guayaquil, Ecuador's main economic engine.

The main topics included development of technology and use of tools for underwater exploration such as "The development of submarine robots for Antarctic exploration" presented by Arturo Cadena, M.Sc. a research professor at the Faculty of Marine Sciences at Universidad Peninsula de Santa Elena (UPSE) and the director of the Research Project on Submarine Robotics. Arturo is the author of 11 publications on Scopus and participates in international robotics conferences held in the United States, Russia, Argentina and New Zealand. He has also participated in Ecuadorian Expeditions to the Pedro Vicente Maldonado Station in Antarctica.

Another spearker described a proposal called "Blue Ocean" made by the company Yaku, focused on the creation of an automatic vehicle to search and collect garbage in the ocean. Wilmer Acosta, a networks and operating systems professional, along with Allison Brito, a computer engineering student, won the 1st place of the contest "Entrepreneurship seed" of Fundación Telefónica and Fundación Junior Achievement Ecuador using this initiative.

Acknowledging that underwater acoustics is an interdisciplinary branch of physics that allows to study diverse topics such as resources exploration, geological studies of the seabed, signal processing and its importance for marine conservation, OES ESPOL invited Jean-Pierre Hermand, Ph.D., an important scientist in the field of underwater acoustics, who had over 250 publications, was chairman of the IEEE OES Technical Committee on 'Oceanic Signal Processing and Statistical Learning', a member of the Acoustical Society of America (ASA) and co-creator of the "Latin American and the Caribbean IEEE/ OES Acoustics in Underwater Geosciences Symposium." As a Distinguished Lecturer, Jean Pierre gave a speech on "Acoustics and Acoustic Ecology of Marine Habitats" which focused on the application of acoustics on marine algae studies and conservation.

We also had the presence of Arthur Ayres Neto, Ph.D. a professor at the Fluminense Federal University (UFF) in Brazil, whose work focuses on the characterization of the

Attendees and exhibitors of the First Congress on "Ocean Technology"

Ayres, Ph.D. and Hermand together with the board of directors of the IEEE/OES ESPOL chapter and ESPOL´s Faculty of Maritime Engineering, Biological, Oceanic and Natural Resources Sciences (FIMCBOR) subdirector.

Ayres, Ph.D. and Hermand, Ph.D. with a representative of the Ecuadorian Antarctic Institute (INAE), Ruth Ramos, B. Sc.

Hermand, Ph.D. during his lecture "Acoustics and Acoustic Ecology of Marine Habitats."

seabed by acoustic attributes. His talk, "Relationship between Geoacoustic Properties and Chemical Content of Submarine Polymetallic Crusts from the Brazilian Continental Margin," highlighted the importance of geoacoustics in prospecting metals.

Finally, Robert Llanos, M.Sc., a representative and officer of the Ecuadorian Navy, presented his work on "Characterization of two marine areas of the Ecuadorian coast for the design of a submarine acoustic laboratory," which showed other professionals and students how acoustics can be realized in Ecuador.

Some of our chapter student members and volunteers study Aquaculture so we included speaker Jormil Revilla, M. Sc. in Fisheries Engineering, with 8 years of experience in the area of design, construction and installation of structures for the experimental culture of aquatic organisms, as well as in strategies for culturing mollusks and marine fish of commercial interest in the Caribbean and tropical Eastern Pacific regions. His lecture, "Design and operation of mini farms for the production of bivalve seeds," aroused the interest of those seeking a commercial application to their knowledge in species and in the application of new technologies to increase efficiency of production.

The talk given by Roberto Aguilera, M.Sc. in Geography and Environment, geomatics, expert in the use of geographic information systems, remote sensing, analysis and digital processing of satellite images, was about "Interpretation of seabed coverage through the use of satellite images." The innumerable applications, ease of learning and use of tools presented caused a positive impact on the audience.

Finally, Mikio Naganobu, Ph.D., a National Fisheries Institute of Ecuador representative and volunteer of the Japan International Cooperation Agency (JICA), gave the conference "Coherent Approach on Ecocline in the Antarctic Ocean and its strong Correlation with the Ecuadorian Ocean," contributing to our perception of the Antarctic Ocean influence on Ecuadorian waters.

The congress' diverse topics facilitated the exchange of interdisciplinary knowledge among the attendees and provided an atmosphere of cooperation between those who work, study and research the oceans. Unfortunately Jean-Pierre Hermand, Ph.D. died a few days after the end of the congress. He was the greatest inspiration for the creation of the IEEE OES ESPOL chapter in Ecuador as well as a great mentor and friend; in his honor we want to continue his legacy, making events that encourage student and professionals that build a strong Ocean Engineering network that encourages ocean conservation in the region.

The event was transmitted from start to finish through our social *Ayres, Ph.D. and Hermand, Ph.D. with a representative of the Ecuadorian Antarctic Institute (INAE), Ruth Ramos, B. Sc.*media networks which can be viewed at :https://www.facebook.com/oesEspol/videos/1855604324494867/

UT'19 Kaohsiung

Pathway to Get Green in Deep Blue

Undersea Tecnology

Dear Sir/Madam,

We are pleased to invite you to participate UT'19 Kaohsiung, which will be hosted by five organizers and institutes, IEEE Oceanic Engineering Society (IEEE/OES), IEEE/OES Japan Chapter, IEEE/OES Taipei, Taiwan Chapter, Taiwan Ocean Research Institute, and National Sun Yat-sen University. The symposium will be held from 16-19 April 2019 at National Sun Yat-sen University (NSYSU) in Kaohsiung, the third largest city in Taiwan.

NSYSU is known for the natural fortress in the campus. Sitting along the side of Kaohsiung Harbor, the NSYSU is surrounded by mountains and faces the crystal blue water of Taiwan Strait. The beautiful Sizihwan beach in the campus makes NSYSU to be one of most valuable universities to visit in Taiwan.

We cordially invite researchers from all participating countries to attend our upcoming UT symposium and look forward to welcoming you in Taiwan in April 2019!

Sincerely,

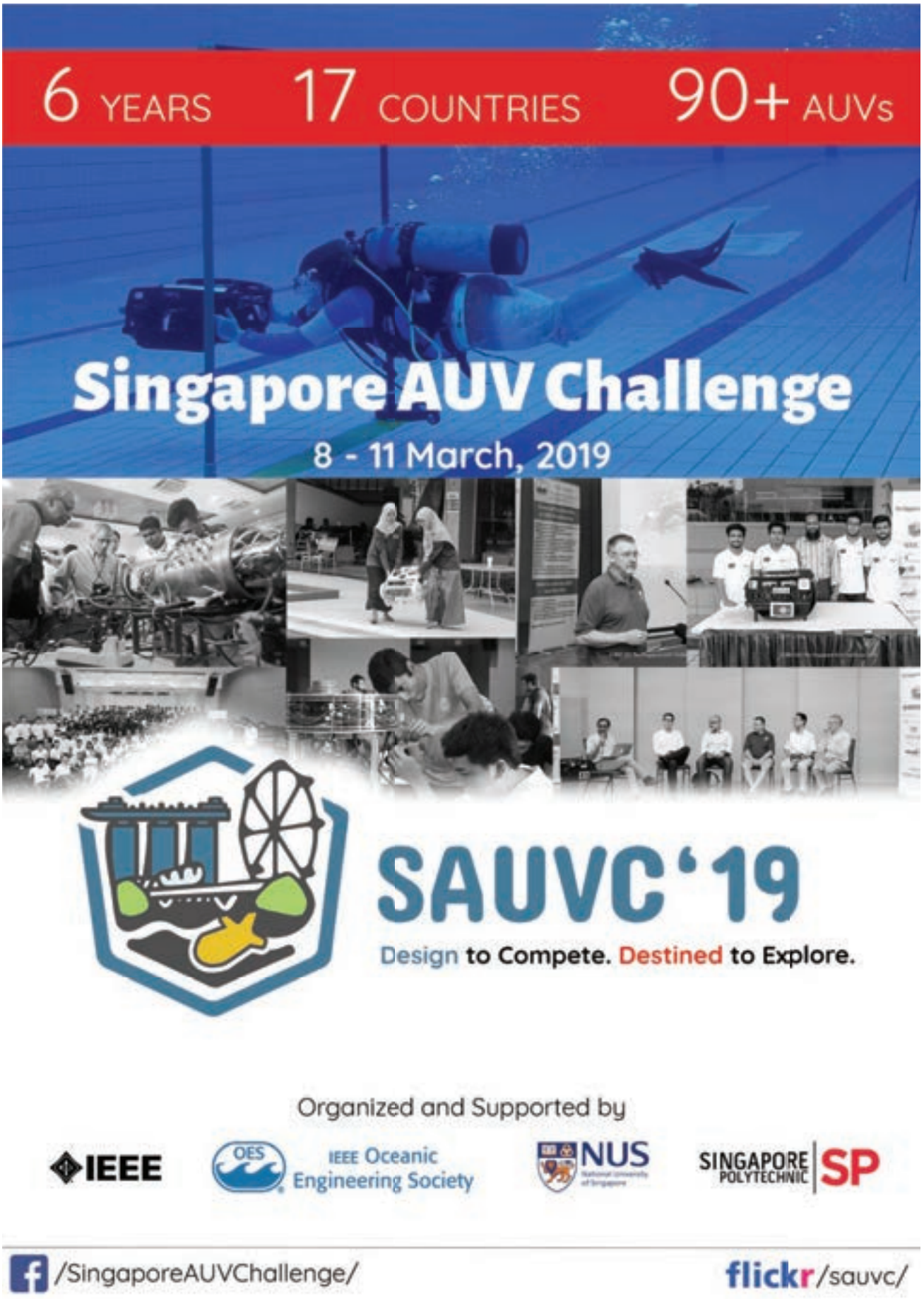
UT'19 Kaohsiung Co-Chairs

Robert L. Wernli
President at First Centurion Enterprises, USA

Tamaki Ura
Professor of Kyushu Institute of Technology, Japan

Forng-Chen Chiu
Chairman at Ship and Ocean Industries R&D Center, Taiwan

For further information about UT'19 Kaohsiung please contact:
Email: info_ut19@narlabs.org.tw
http://ut19.tori.org.tw/


6 YEARS
17 COUNTRIES
90+ AUVs
Singapore AUV Challenge
8 - 11 March, 2019
SAUVC'19
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The Fourth IEEE OES Underwater Communications and Networking (UComms18) Conference

João Alves and John Potter (UComms18 General Chairs and OES AdCom members)

Introduction

The coastal town of Lerici, just south of La Spezia at the southern tip of the Italian Riviera, once again hosted the Underwater Communications and Networking conference (UComms) this year, UComms18, on 28th–30th of August.

UComms18 was the fourth in a series of biennial, international events organised by the NATO STO Centre for Maritime Research and Experimentation (CMRE), this year co-chaired by João Alves & John Potter. The conference aims to bring together key contributors in Under Water (UW) wireless communications and networking to review the state-of-the-art and share understanding of performance constraints and trade-offs with a view to catalysing consensus on standards for interoperability. Key distinguishing features of the conference series include the rigorous review process, designed to accept only the highest-quality innovative papers for presentation in a single-track format, and the high proportion of networking and discussion time allocated. UComms is also known for providing elegant spaces and memorable gastronomy, designed to raise the bar on the quality of the experience and encourage relaxed, meaningful, discussion.

This year, we again staged the conference at the Villa Marigola congress centre, a traditional venue for CMRE conferences and one that continues to delight attendees with its spectacular views and elegant environment, conveniently close to a range of hotels and tourist attractions.

Conference Topics and Format

UW communication capabilities have progressed rapidly in the past decade and are now appreciated as a key enabling technology for maritime autonomous futures, a huge growth area and arguably the hottest topic in maritime science and engineering at the moment. A glance around the exhibitor stands, or paper sessions, at recent OCEANS conferences is enough to demonstrate that autonomous and hybrid vehicles, singly and in teams, are at the core of current disruptive technology developments in ocean engineering.

The progress in UW communications has been achieved both through the development of advanced coherent modulation, demodulation and coding techniques and by moving from point-to-point systems to multi-hop networks. At higher communication stack layers, above the physical layer, there have been significant advances in developing effective Medium Access Control (MAC), routing and other protocols to establish efficient and reliable communications. It has also become clear that the UW bandwidth is, in general, so limited that it is highly unlikely that a 'one-size-fits-all' solution can emerge. Systems will need to adaptively reconfigure themselves to the (continuously changing) network topology, environment and application. This is leading the field towards intelligent cognitive approaches with a high degree of cross-layer connectivity, closely integrated with the intelligent adaptive mission capabilities being developed on vehicles.

Figure 1. Group photo of UComms18 participants in the gardens of the Villa Marigola congress centre.

In stark contrast to the successful model adopted in the Radio Frequency (RF) world for WiFi and cellular telephone networks, the world of UW communications lacks standards on almost every front. Only very recently (March 2017) has the UW communications community seen the acceptance and promulgation of the first standard for digital data exchange, the NATO standard 'JANUS', in which UComms played a significant role. The first peer-reviewed draft specification for JANUS was published in the 2014 edition of UComms, following development in close cooperation with the community of interest, in large part represented over the years in the UComms series of conferences since 2012. JANUS is a first step in breaking the interoperability barrier, at the physical level. We hope that UComms continues to engender productive exchanges that will lead to further standards, also in higher levels of the communication stack, and further interoperability gains.

The UComms conferences are organised as a series of structured sessions, coordinated by key researchers in the field who act as session chairs and organisers, attracting top-quality contributions with the intention to generate a vibrant exchange of knowledge and develop a common understanding of the state-of-the-art. The multiple sessions are handled in a single track, giving the opportunity to all participants to follow all the talks and take part in all discussions. This helps break down tendencies to take a 'stove-piped' approach to the field and encourages a more holistic appreciation of the challenges, opportunities, solutions and developments.

The session organisers invited contributions from key innovative researchers and, adding in the contributed papers, managed the reviews, ranked and selected the final presentations in coordination with the general chairs and conducted their session at the conference. The session chairs also took in hand the task of engaging the delegates in productive dialogue following each presentation. For each edition of UComms, the focus of the sessions is guided by the nature of the invited and contributed submissions, so that the conference truly reflects the hot-topics of the moment, as perceived by the community, rather than being driven only by the perceptions of the organisers.

For UComms18 a total of nine sessions were convened:

- "Applications and requirements" had the objective to expose a wide range of communication requirements, not all strictly UW, from an end-user point of view to feed back into basic research.
- "Physical Layer in Acoustic Communications" tackled all aspects of the acoustic communications physical layer, from acoustic propagation to channel equalisation and signal modulation.
- "Networking, Localisation and Scheduling" addressed the upper layers of the communications stack as well as network-based services.
- "Simulation, Models and Test Beds" considered the development of models, simulation work and experimental testbeds.
- "Interoperability and Standards" looked at this critical enabler for interoperability, in which underwater communications lags far behind in-air RF communications.
- "Non-Acoustic Communication Modalities" explored the hot topic of optical modalities for UW communications.

Figure 2. A view of the town of Lerici and the "Golfo dei Poeti".

Figure 3. The magnificent gardens of the Villa Marigola congress facility with views over the "Golfo dei Poeti".

Figure 4. The exhibit area in the Villa Marigola congress centre.

- "Communication Architectures and Novel Stacks" gathered contributions on the development of non-traditional communications architectures and protocol stacks that are better tailored to the UW communications environment.
- "Communications in challenging environments" addressed the challenges of communicating in particularly harsh conditions such as under-ice and in the presence of air bubbles.

Sixty-four manuscripts (ms.) were submitted in response to the call for papers.

Figure 5. Prof. Arthur Baggeroer delivering his invited talk.

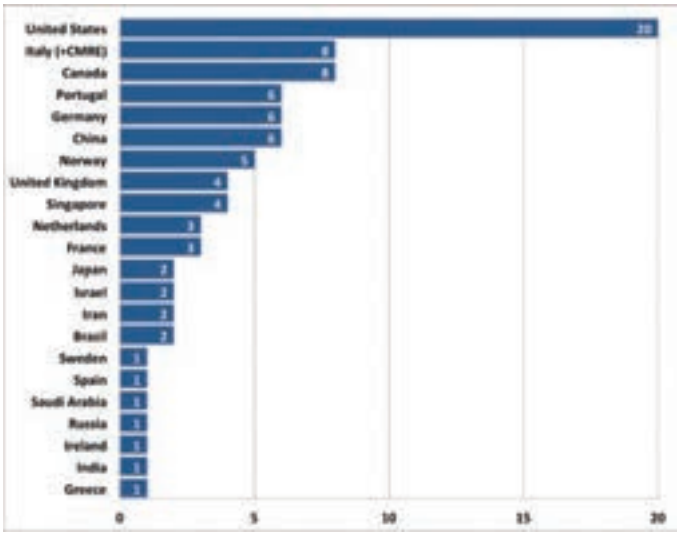

Figure 6. Number of papers including at least one author affiliated with an institution of a given Country.

Figure 7. Lunch break in the gardens.

Figure 8. Time to raise the glass to UComms during the social dinner.

Fig. 6 shows the geographic distribution of author affiliations for the submitted ms., illustrating that UComms is indeed a truly international venue, with 30% coming from North America, 40% from Europe and 30% from Asia and elsewhere.

After a very strict review process (where each ms. was independently and blindly reviewed by at least three reviewers), thirty-seven (58%) were selected for presentation and publication in IEEE Xplore. In addition to the regular sessions for presentations, this year we also added two round-table style discussions where the whole floor was invited to participate and contribute.

The conference was opened by the chairs with a very brief introduction, followed by an institutional welcome by CMRE's Director, Dr. Catherine Warner. We had the pleasure to include two invited talks in the program of the conference. These were delivered by our distinguished guests Prof. Mandar Chitre (NUS Singapore, OES JOE EiC) and Prof. Arthur Baggeroer (MIT).

Prof. Chitre provided the technical "kickoff" for the conference. He delivered a very timely keynote where he shared with the participants his plans as Editor in Chief for the Journal of Oceanic Engineering (JOE) and how they tie in with his vision to facilitate cooperation and to democratize access to the field. He made a compelling proposal that emphasises the publication of reproducible results and the sharing of code and data as an integral part of scientific publication. His ideas open up a new aspect to peer-reviewed science and strongly resonated with the audience. Now that the JOE supports the publication of papers that include code and data sets, we expect to see an increase in such contributions, that without doubt have an enhanced potential to be long-lasting and high-impact.

On Wednesday the 29th, Prof. Baggeroer delivered his invited talk on the topic of directionality for UW communications. With a thought-provoking presentation, he highlighted several advantages that can be derived with directional UW communication systems, such as performance benefits and increased security.

A total of ninety-five delegates participated in UComms18, representing institutions from seventeen different countries. This continues the trend over the years of an increased diversity in the UComms community. The 37 papers presented at UComms18 have already been published online in IEEE Xplore. We invite everyone to browse through them, get updated on the latest in underwater communications and discover a (little) bit of what UComms is all about.

As in previous years, a Special Issue (SI) of the IEEE JOE, with expanded versions of the best papers presented during UComms, is now being prepared and is planned for publication in 2019. All papers presented at UComms are eligible for submission to the SI.

The Editorial Board for the SI consists of the UComms18 general chairs João Alves and John Potter, joined by Milica Stojanovic (Northeastern University).

Besides the IEEE OES sponsorship, the 2018 edition of UComms had patron support from the following commercial and non-commercial institutions: NATO Allied Command Transformation (ACT), ONR, ONR-Global, ASA, ATLAS Elektronik, Kongsberg Maritime, and Evologics. These are the organisations and people who enable us to keep the technical quality standard very high, and the registration cost reasonable. Thanks to our sponsors and patrons, UComms does not need to increase acceptance rates from the pressure of financial motivation. This way we can keep UComms single track, high-quality and capable of attracting the best of the field to participate.

Participant Feedback

A key aspect that shapes the evolution of UComms is gathering feedback from participants through an anonymous online survey. This is a practice that was initiated with the first edition in 2012 and which we have continued ever since.

The fifty-one responses collected to date (curiously, the exact same number we collected for UComms16) show us that UComms18 was a resounding success, and specifically that:

- 77% of participants were "extremely satisfied" with the conference while 23% were "Moderately satisfied". No participant expressed dissatisfaction with the conference.
- 82% found the technical content to be either "extremely strong" or "very strong".
- 92% found the networking opportunities to be "extremely useful" or "very useful".
- Concerning format, schedule and periodicity, the vast majority agrees with keeping it a biennial event, single track, with 25 minutes per presentation to accommodate discussions over 3 days, which means maintaining the size at around 42 papers regardless of the number of submissions.
- As per when, in the year, UComms should take place, the last week of August is the period that gathers the most support.

Future UComms Conferences

UComms has been gaining credibility as a top quality international event, bridging Europe and the Americas, since the first edition in 2012, going from strength to strength with every edition. We hope and expect to continue enjoying the support of our sponsors and patrons as we strive to make them proud of our work and achievements, made possible by the enthusiastic engagement and quality contributions of the community. There is an ambition to issue a first call for sponsorship in the spring of 2019 for UComms 2020. The call for papers will be issued in the fall of 2019.

The mission for the fifth UComms will remain one of delivering a top quality conference, where leading scholars of the field want to engage. We plan to explore ways to match this with an increased student and industrial participation. See you in 2020!

The Fifth Artic Technology Conference (ATC)

Jerry Carroll, OES Senior Past President, OTC Board Member

The fifth Artic Technology Conference (ATC) was held in Houston, 5-7 November 2018, under the direction of Peter Noble, ATC Program Committee Chair. Jim Barbera served as OES Oversight Committee Representative and Jerry Carroll, Chair of the OES Technical Program Committee. Our VP of Technical Activities, Mal Heron, attended and helped chair sessions and the exhibit booth. The Conference was held at the Hilton America's Hotel, which presented an excellent venue with facilities very close and adjacent to the hotel. The receptions and coffee breaks were held in the exhibit hall. There were excellent technical papers presented at the conference by very skilled and professional presenters. Alaska is the United States' frontier for the Arctic and will represent most of the U.S. activities. The Prudhoe Bay Field, which is the countries' third largest producer of oil and gas, will be shipping LNG to the Asian countries. The possibility exists that when the Arctic Ocean is open, LNG may be shipped to the European Countries by the Northern Route. This will represent a major interest of the U.S. in the Arctic Ocean. The OTC Board and the ATC Program Committee will be discussing when and where the next ATC will be held.

Doppler Oceanography From Space (DOfS) Meeting in Brest, October 10–12 2018

Fabrice Ardhuin, and Charles Peureux (Ifremer), René Garello (IMT Atlantique/OES)

Context

Remote sensing has revolutionized oceanography, starting from sea surface temperature, ocean color, sea level, winds, waves, and the recent addition of sea surface salinity. Now the oceanographic community is at the doorstep of yet another revolution with the direct measurement of surface velocities related to currents, winds and waves. After demonstrations using pairs of interferometric synthetic aperture radars (InSAR) and the Doppler centroid from single SARs, Doppler Oceanography from Space has demonstrated its feasibility, and a global monitoring mission concepts, SKIM (Sea surface KInematics Multiscale monitoring: an ESA* satellite mission - https://www.skim-ee9.org/) is at detailed design and proposal stages for ESA and NASA**. It is also possible to use today's SAR data for measuring a single component of this velocity vector.

Meeting

A meeting held in Brest, France, on October 10 to 12, 2018, gathered 100 international participants from academia, industry and space agencies. The event was technically co-sponsored by the IEEE Oceanic Engineering Society (OES) and with the support of ESA, CNES***, Brest Metropole (Sea Tech Week), IFREMER, IUEM****, Labex Mer***** and LOPS (Laboratoire d'Océanographie Physique et Spatiale). The workshop was organized around 24 oral presentations and 15 posters. It reviewed the gaps in the observation capabilities of currents, winds and waves, recent developments in radar technology, processing and the understanding of Doppler data. The meeting was recorded live on https://www.youtube.com/channel/UCG9o60slGCjji-jOFOngYgw or Facebook https://www.facebook.com/SKIM4EE9/.

Physical Oceanography Background

Gaps are particularly important for tropical currents, high latitudes, extreme winds, and high-resolution currents. Today's tropical currents are estimated from near-surface drifters or the surface drift of Argo floats, with a very poor spatial coverage for the first (> 2000 km), and a very poor temporal coverage for the latter (30 minutes every week). Estimates of surface currents are otherwise made by combining satellite altimetry and wind from models or scatterometers. At the equator, even for time scales longer than 30 days, these estimates are very poorly correlated with drifter data (Sudre et al. 2013, see figure below for V component), so that we basically know better the winds on Mars than the surface currents at the equator of our own planet. This severely limits our understanding of the heat balance in the equatorial cold tongues and the forecasting capabilities of patterns such as the African monsoon.

At high latitude, sea ice is hiding most of the dynamics from the measurement capabilities of satellite altimeters, and where the sea ice is receding, the structures are too small to be resolved. Doppler radars can come in to measure near-ice current jets and the mesoscale of the emerging Arctic, which play a dominant role in defining the dynamics of the ice edge and transporting freshwater in the Arctic basin and around Greenland, both hugely important in global ocean circulation and its role in regulating the climate and weather.

Another area of great science and applications opportunities is opened when waves and currents, or winds and currents are measured simultaneously. This would allow a better understanding of extreme sea states and extreme waves, and a better understanding on the ocean energy cycle, from the wind-work to the energy cascade in the ocean circulation.

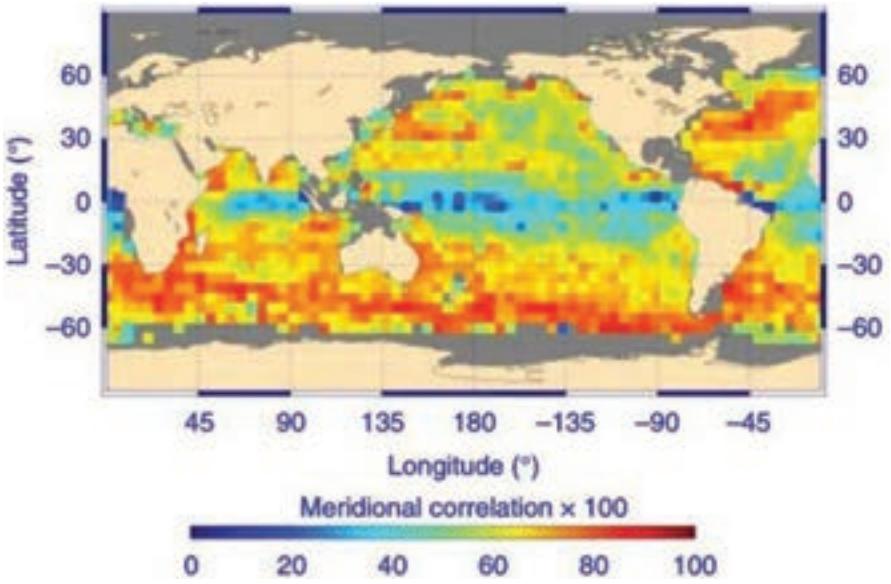

Figure 1. Reproduced from Sudre et al. (2013): correlation of V-component of current estimated from satellite data (filtered for time scales > 30 days) with in situ drifter measurements.

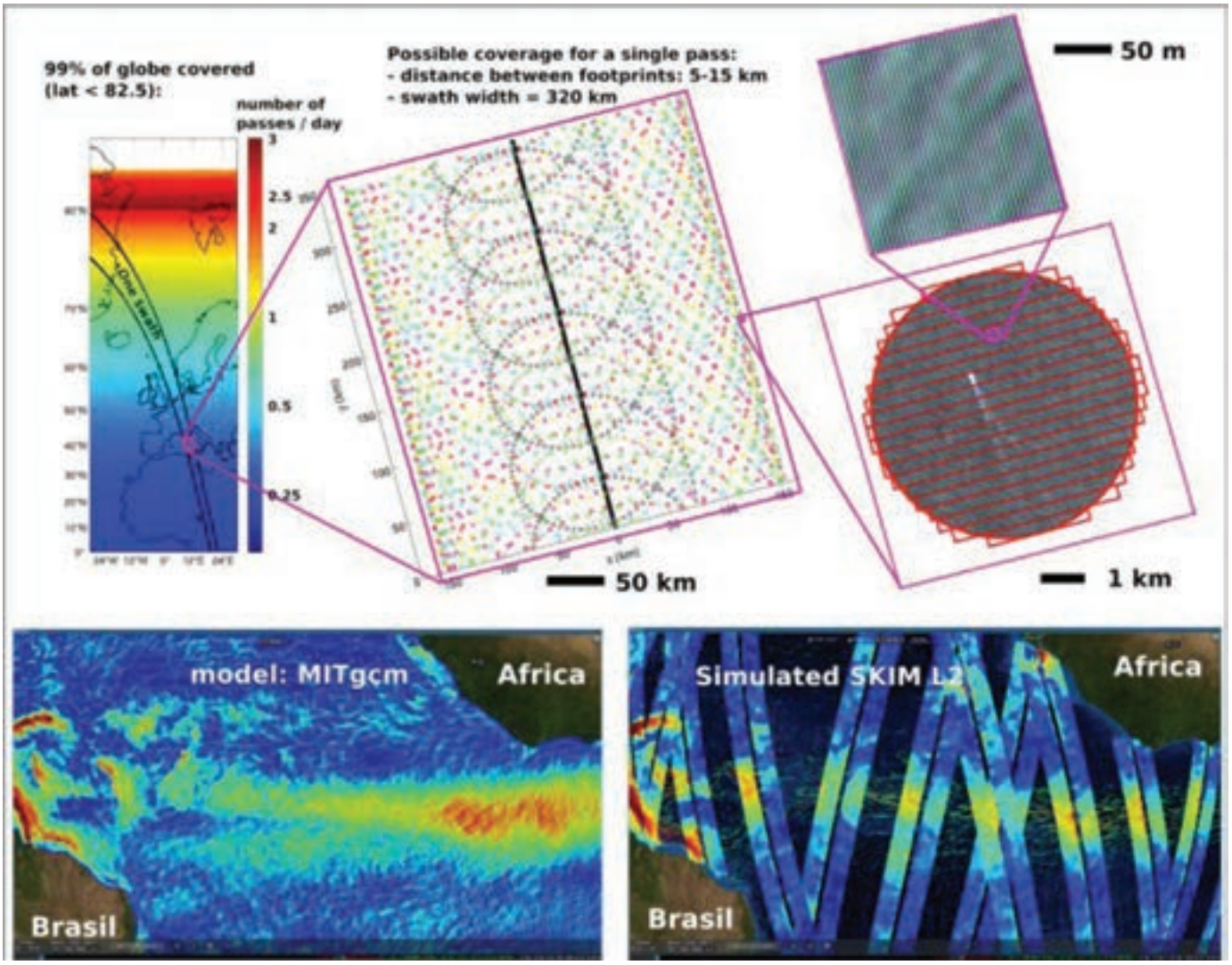

Figure 2. Top panels show the particular sampling of the SKIM concept, from 4 m resolution in range and 300 m in azimuth within footprints distributed across a 300 km wide swath. The bottom panels show simulated currents (with the MITgcm model) and their sampling in 3 days over the tropical Atlantic, for a particular choice of orbit.

Technical Background

Most of these scientific requirements are easily achievable by recent technical developments in radar technology and our understanding or Doppler properties of radar backscatter from the ocean. Exploring ocean currents, winds and waves from space can now use mature Doppler radar technology, in particular SKIM will fill two important blind spots: in the tropics and in the marginal ice zone, and expand the effective space and time resolution of the altimeter constellation by a factor 2 or more. The novel direct measurement of surface currents in the top two meters will produce the first maps of the equatorial upwellings that are critical for understanding and forecasting the heat budget at the equator with far-reaching weather and climate consequences, for example on the African monsoon. OSCV (Ocean Surface Current Velocity) maps will also allow the first monitoring of the highly dynamic currents at the ice edge. Adding this new and fundamental variable to Earth Observation capability together with high fidelity measurements of wave spectra will allow scientists to address a wide range of questions, including:

- How OSCV and waves influence upper ocean mixing and large-scale circulation?
- How do OSCV and waves influence the dynamics of the ice edge in the Arctic and Antarctic?
- What are the roles of eddies, wind-driven flows and waves in setting the surface concentration of marine litter and shaping marine ecosystems?

Notes

*ESA: European Space Agency

**NASA: National Aeronautics and Space Administration

***Centre National d'Etudes Spatiales (the French Space Agency)

****IUEM: Institut Universitaire Européen de la Mer (part of the Brest University)

*****Labex Mer is a "Laboratory of Excellence" for the sea (la mer)


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OCEANS 2018 Charleston

Jeffrey L. Payne, Ph.D. and John Flynn

OCEANS
CONFERENCE & EXPOSITION

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October 22–25, 2018
Charleston South Carolina

Healthy Oceans, Resilient Coasts, Robust Commerce… Strong Nations
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Over 1,242 scientists and technologists and over 100 technology exhibitors attended OCEANS 2018 Charleston, South Carolina to learn about protecting our communities and preserving our oceans. In addition, nearly 450 technical presentations, multiple special sessions and panels, a competitive and non-competitive student posters, and professional development opportunities supported participants' understanding and education about the state of marine and coastal science and technology during the conference. Charleston's history, economy, and experience in living with the ocean made it an ideal location for learning about and discussing ocean processes and health, coastal community resilience to hazards, and sustainable commerce.

OCEANS 2018 ensured that science leads the way, especially when solving difficult local problems around flooding and energy. And, making technology simpler, cheaper, and more accurate means we can more thoroughly inform local leaders and scientists. Co-sponsored by the Marine Technology Society and the IEEE Oceanic Engineering Society, OCEANS 2018 Charleston is the 63rd installment of the international biennial OCEANS conference. Participants included 1242 global marine technologists, scientists, engineers, students, government officials, and lawyers. Consistent with the conference theme, "Healthy Oceans, Resilient Coasts, Robust Commerce…Strong Nations," the technical program focused on innovations and

"ISS Live Simulcast". RADM Michael J. Silah, Director, NOAA Office of Marine and Aviation Operations, Director NOAA Corps, speaks via simulcast with NASA Astronaut Serena M. Auñón-Chancellor (MD) about her work on the International Space Station.

"Local Regional Panel." Mark J. Wilbert, City of Charleston; David E. Rivers, M.A., DHL, Medical University of South Carolina; The Honorable Joseph P. Riley, Jr., College of Charleston and The Citadel; Dr. Anne D. Cope, Ph.D., P.E., Insurance Institute for Business and Home Safety; Brigadier General Stephen A. Cheney, USMC (Retired), American Security Project; Dr. Paul A. Sandifer, College of Charleston (left to right).

Arthur Ravenel Jr. Bridge.

"Plenary Auditorium". Dr. Jeffrey Payne, Director NOAA's Office for Coastal Management, and co-chair of the Local Organizing Committee, welcomes participants to OCEANS 2018 Charleston.

advances across more than 128 sessions, more than 450 speakers, and numerous special sessions.

Although all of the plenary sessions contributed to the conference objectives, four were especially interesting. In one, Rear Admiral (RDML) Timothy Gallaudet addressed the question, "How is research via ships helping us learn and change things for our communities?" Through a hosted remote conversation among the crew aboard the NOAA ship Okeanos Explorer and the Research Vessel Atlantis, RDML Gallaudet led a discussion with researchers about ocean exploration, what we're learning, and how it's helping our communities. (RDML Timothy Gallaudet, Ph.D. USN Retired is Assistant Secretary of Commerce for Oceans and Atmosphere and Acting Undersecretary of Commerce for Oceans and Atmosphere.)

"ROV Tank Competition". Participants compete to operate a remotely-operated vehicle.

Dr. Peter Haugan addressed the question, "How are oceans changing the world and what is the future for our oceans from an international perspective?" Dr. Haugan, Chair of the Intergovernmental Oceanographic Commission, ensured that the discussion addressed questions about community changes in the immediate future and about the longer-term challenges and opportunities as oceans change our world.

Dr. Anne Cope (MD, PE) considered, "How do we apply scientific research to address regional and local coastal resilience challenges?" Dr. Cope also considered the performance of full-scale homes and commercial structures, building materials and construction practices during natural catastrophe conditions such as hurricanes, as well as ongoing efforts to implement solutions in real-world communities to make them more resilient.

Finally, Rear Admiral Michael Silah, led a discussion about the role of space in ocean research. Rear Admiral (RADM) Silah, Director of the NOAA Commissioned Officer Corps and NOAA Office of Marine and Aviation Operations, addressed questions about information from satellites and from the research conducted on the International Space Station. He also moderated a live discussion with NASA astronaut Serena Auñón-Chancellor (MD), who is currently stationed on the International Space Station and is studying our oceans from space.

As Christian de Moustier, president of the IEEE Oceanic Engineering Society, wrote in the press release, "As coastal communities in the Carolinas and the Florida panhandle strive to recover from 2018 hurricanes Florence and Michael, OCEANS 2018 Charleston provides a timely and critical opportunity for marine scientists and engineers and policymakers to assess our knowledge and understanding of our ocean planet."

The Student Poster Competition at OCEANS 2018 Charleston

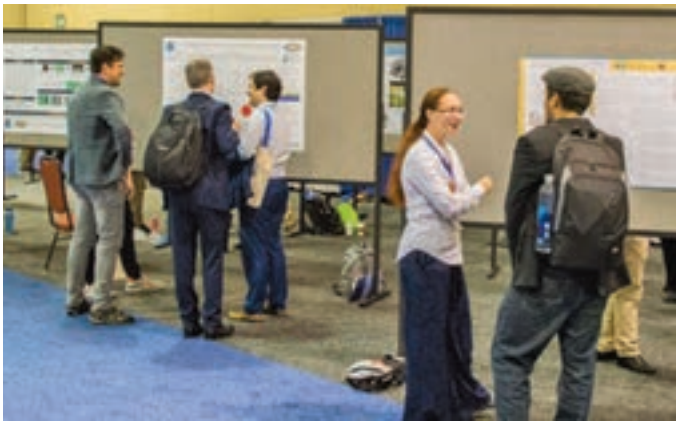
John Watson, OES Student Poster Competition Chair,
Photos by Stan Chamberlain (OES)

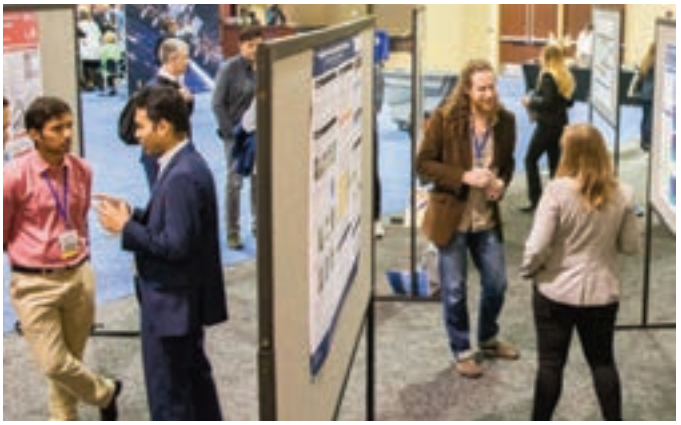
A Flagship event of any MTS/IEEE OCEANS conference is the Student Poster Competition (SPC) in which a selection of students are invited, on the basis of their abstract submission, to attend the conference at no expense to them, and present a poster of their work. They also have the opportunity to win a monetary prize offered to the three posters judged to be the best, by an independent panel. The latest occurrence of the SPC was held during OCEANS 2018 Charleston on the 23th and 24th of October, 2018.

The SPC program was funded by grants from the Office of Naval Research (ONR) and National Oceanic and Atmospheric Administration (NOAA), and to them we offer our sincere appreciation; without their support the competition could not go ahead. For this edition of the SPC, 18 students were selected to attend in Charleston out of more than a hundred submissions from around the world. Selecting the best abstracts is not easy given the quality of the abstracts submitted, but eventually what were judged to be the best 18 were selected.

The posters were on display in the Exhibition Hall of the Charleston Area Conference Centre for two days. Like previous Student Poster Competitions, the posters on display described the work carried out by the students and, as is rapidly becoming the norm, were of a very high standard. The posters were judged by a team of judges who read and discussed the work

SPC presenters.





Discussions during the poster sessions.

with every student; a very difficult, time consuming and intensive task over a two-day period and our thanks and appreciation goes out once again to the judges. The students enthusiastically described their work to the judges and to any delegates who dropped by over the two day period.

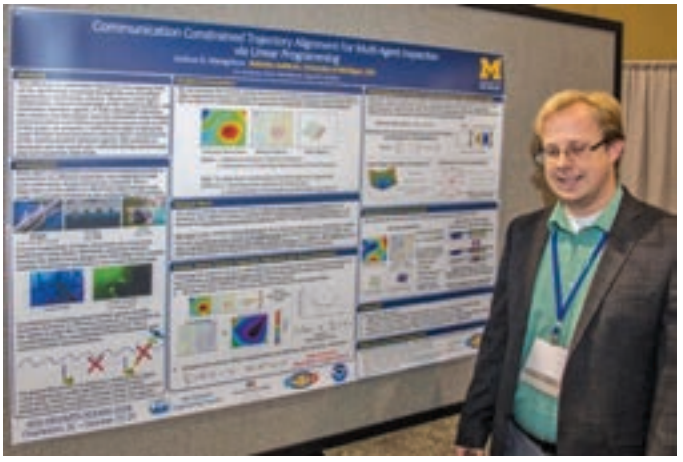
Each participating student was awarded a Certificate of Attendance and the top three posters were awarded a specially designed trophy and a monetary prize. The Award Ceremony took place during lunchtime in the Convention Centre on Thursday, October 25th. The ceremony began with a few words from Liesl Hotaling, the MTS SPC Chair and Local Organizing Committee SPC Chair, followed by a presentation of awards by John Watson, the OES SPC Chair. The winner of the SPC is awarded the Norman Miller Prize. Many will know that Col. Miller inaugurated the first SPC in 1989 and enthusiastically championed it until he passed away in July 2015. The First Prize is named in his honour.

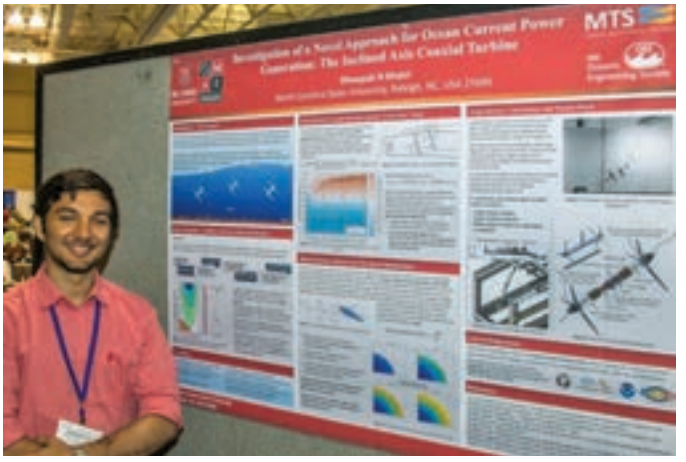
The full list of 18 participants and prize winners together with their affiliation, poster title and an abstract of their poster is given below.

First Prize and Norman Miller Award (Trophy, certificate and $3000 prize)

Joshua Mangelson, University of Michigan, USA, *Communication Constrained Trajectory Alignment for Multi-Agent Inspection via Linear Programming.*

Abstract—This paper reports on a system for estimating the alignment between robotic trajectories under constrained communications. Multi-agent collaborative inspection and navigation tasks depend on the ability to determine an alignment between robotic trajectories or maps. The properties of the underwater environment make determining such an alignment difficult because of extreme limitations on communication and the lack of absolute position measurements such as GPS. In this paper, we propose a method that takes advantage of convex relaxation techniques to determine an alignment between robotic trajectories based on sparse observations of a low-dimensional underlying feature space. We use a linear approximation of the l2-norm to approximately enforce that the estimated transformation is an element of SO(2). Because the relaxed optimization problem is

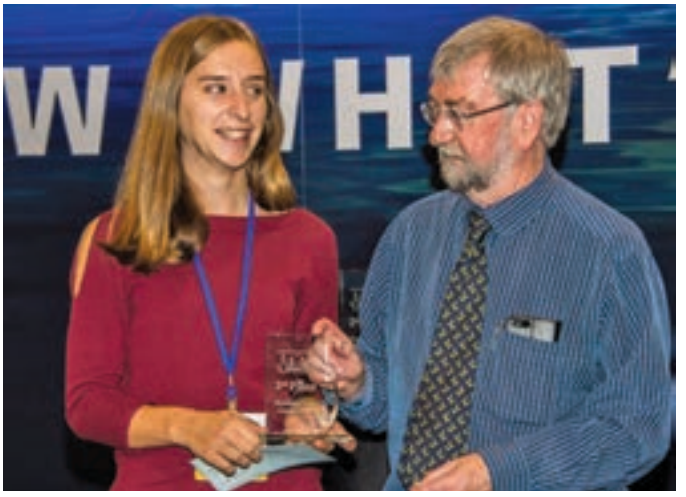




linear, we can take advantage of existing convex optimization libraries, which do not require an initial estimate of relative pose. In addition, because the proposed method does not need to perform data association, we can align trajectories using low-dimensional feature vectors and can thus decrease the amount of data that must be transferred between agents by several orders of magnitude when compared to image feature descriptors such as SIFT and SURF. We evaluate the proposed method on simulated datasets and apply it to real-world data collected during autonomous ship hull inspection field trials.

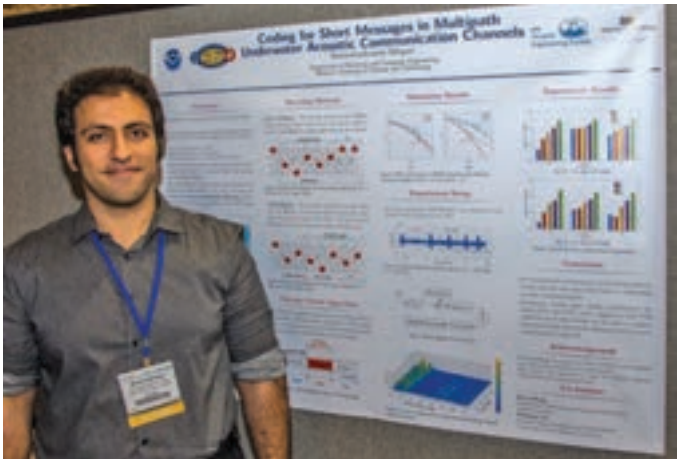
Second Prize (Trophy, certificate and $2000 prize)
Dheepak Nand Kishore Khatri, North Carolina State University, USA, *Investigation of a Novel Approach for Ocean Current Power Generation: The Inclined-Axis Coaxial Turbine.*
Abstract—The feasibility and performance of a tethered coaxial system is investigated to understand changes in power production with perturbation. Our results suggest that the power extracted from an ocean current by a tethered coaxial system is insensitive to attitude perturbation within a range of inclination to the flow. Flow domains and design parameters have been optimized to come up with a wide range of operating parameters resulting in a higher power extraction compared to a traditional horizontal axis single rotor system. We report our results and suggest future work.

Third Prize Winner (Trophy, certificate and $1000 prize)
Sara Cardigos, University of Aveiro, Portugal, *Using LAUVs in highly dynamic environments: influence of the tidal estuarine outflow in the thermocline structure.*



Abstract—Obtaining in situ data from highly dynamic tidal environments such as estuarine outflows is a challenging task. In the last few years technological development of submarine robotics has been key to oceanographic research. Due to the high spatial and temporal resolution provided and the exceptional maneuverability, LAUVs (Light Autonomous Underwater Vehicles) are instruments with the characteristics required to accomplish the task at hand. The purpose of this study is to demonstrate the use of in situ data, collected by LAUVs, to characterize the Sado estuarine outflow in terms of its vertical thermohaline structure and changes over a semi-diurnal tidal cycle. Results show that water temperature distribution is both dependent on ebb/flood cycle and diurnal radiation, generating a temporary thermocline. However, the vertical water temperature structure presents significant spatial differences along the transect monitored by the LAUVs.

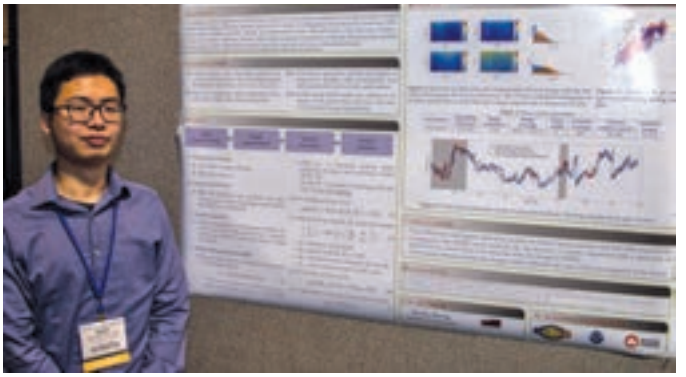
Mohammad Hossein Behgam, Missouri University of Science and Technology, USA, *Coding for Short Messages in Multipath Underwater Acoustic Communication Channels.*



Abstract—This paper applies the full tail-biting (FTB) convolutional codes to short data packets and evaluates their performance in underwater acoustic communication by computer simulation and an ocean experiment. The simulation results for AWGN channels show that the FTB codes achieve the similar bit error rate (BER) performance as the zero-tailing convolutional (ZTC) codes regardless of block lengths, while the direct-truncate convolutional (DTC) codes suffer from BER degradation, especially with short block lengths. Both simulation and ocean experimental results demonstrate that the FTB codes are excellent candidates for underwater acoustic communication systems where short data blocks and strong error correction codes are needed.

Xinwei Chen, Memorial University of Newfoundland, Canada, *Gaussian Process Regression for Estimating Wind Speed from X-band Marine Radar Images.*

Abstract—A Gaussian process regression (GPR) based method for estimating wind speed from X-band marine radar images is proposed. The dependence of histogram pattern of radar images on wind speed and rain condition is first observed. Then the feature vectors based on bin values of histograms are extracted.

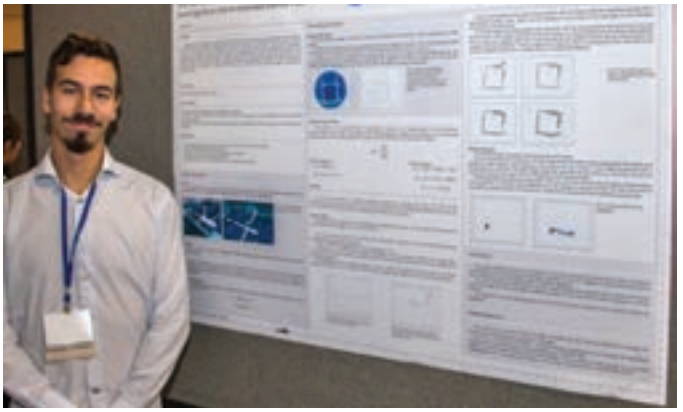


Two models, which estimate wind speed from rain-free and rain-contaminated images respectively, are trained using GPR algorithm. Radar and anemometer data collected from a sea trial near Halifax, Canada are used for validation. Compared to the ensemble empirical mode decomposition (EEMD) based methods, the accuracy of wind speed estimation is further improved with a reduction of about 0.13 m/s for rain-free images and 0.18 m/s for rain-contaminated images in root mean square deviation (RMSD).

Fábio Cruz, University of Minho/ISISE, Portugal, *Structural design of an innovative multifunctional artificial reef.*

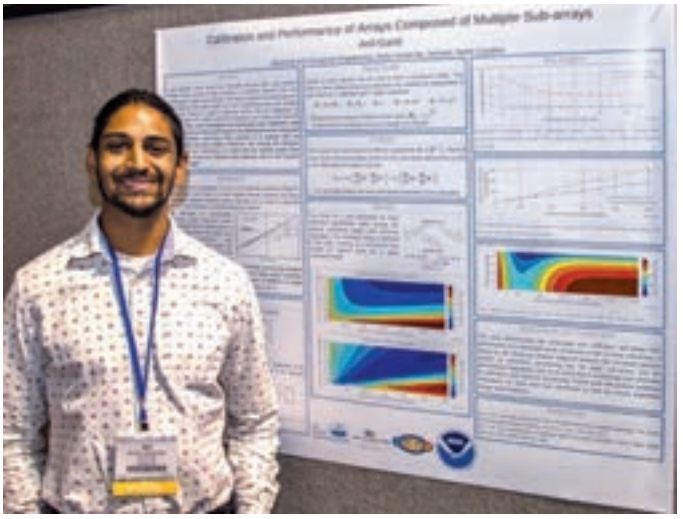
Abstract—Marine resources are essential to support an ever growing world population and approaches that can foster the growth and survival rates of habitats and promote the sustainability of human activities are seen as urgent. Artificial reefs (AR) or multifunctional artificial reefs (MFAR) are considered promising and viable solutions to increase the number of marine populations, prevent erosion and produce energy. As a consequence, there have been several attempts to design these structures in recent years. Several challenges still exist, related to the design approaches, materials used, durability requirements, hydrodynamic behaviour and interaction with the environment (fluid), among others. Thereby, the aim of this research is to discuss the structural behaviour of a concrete and steel complex, modular, slender and reticulated MFAR and to develop its design, by using numerical analysis. In order to do that, computational fluid dynamics models (CFD) and fluid-structure interaction (FSI) are considered. This analysis shows great complexity and the results show that the design of these innovative structures is both challenging and promising.

João Fula, University of Porto, Portugal, *AUV self-localization in structured environments using a scanning sonar and an extended Kalman filter.*



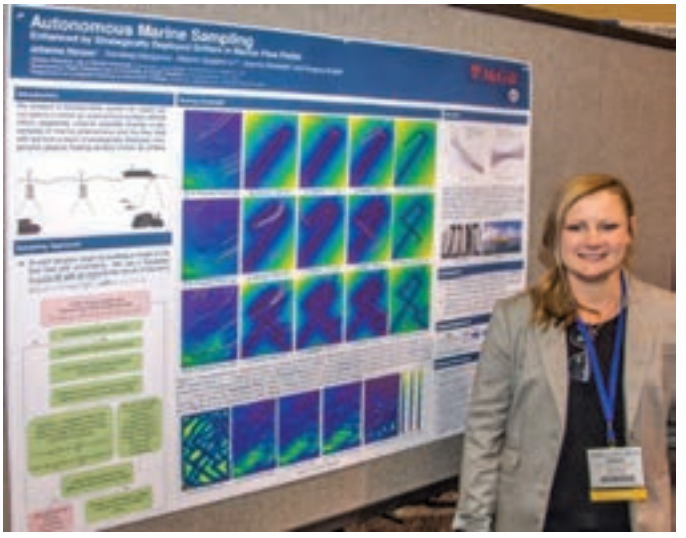
Abstract—Autonomous Underwater Vehicles (AUV) are growing in importance for their many underwater applications, due to their characteristics and functionalities. Making use of a imaging sonar, it is possible to acquire the AUV's distance to existing obstacles. Then, through an implementation of a feature detection algorithm and an estimator, it is possible to interpolate the vehicle's relative position. This paper proposes a localization method for structured environments employing a mechanical scanning sonar feeding an extended Kalman filter. Some tests were then run in two different water tanks in order to verify the effectiveness of the solutions. These tests were performed in two different phases. For the first one, all the readings were taken with the vehicle steady and immobile. The second phase was executed with the vehicle in motion. The results are presented and compared against ground-truth measurements.

Anil Ganti, Duke University, USA, *Calibration of Sonar Arrays Composed of Multiple Sub-arrays.*



Abstract—Distributed sonar arrays are promising in achieving high resolution acoustic imaging. For such arrays, however, the array manifold must be estimated from observations using calibration sources. This paper investigates the performance bounds on jointly estimating the manifold parameters of a distributed array as well as the direction of arrival of an unknown target. Simulations use two calibration sources with known bearings and a single target with an unknown bearing. It is shown that for a system of two uniform linear arrays in channels with exponentially decaying spatial coherence, there are predictable optimal separations between the sub-arrays. Furthermore, the optimal separation is shown to be nearly invariant to source calibration and target parameters.

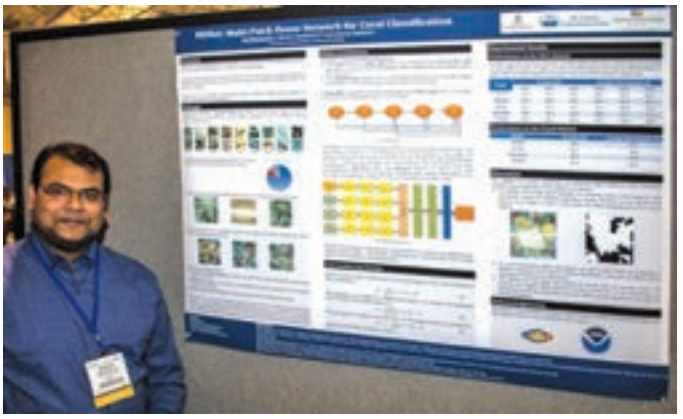
Johanna Hansen, McGill University, Canada, *Autonomous Marine Sampling Enhanced by Strategically Deployed Drifters in Marine Flow Fields.*



Abstract—We present a transportable system for ocean observations in which a small autonomous surface vehicle (ASV) adaptively collects spatially diverse samples with aid from a team of inexpensive, passive floating sensors known as drifters. Drifters can provide an increase in spatial coverage at little cost as they are propelled about the survey area by the ambient flow field instead of with actuators. Our iterative planning approach demonstrates how we can use the ASV to strategically deploy drifters into points of the flow field for high expected information gain, while also adaptively sampling the space. In this paper, we examine the performance of this heterogeneous sensing system in simulated flow field experiments.

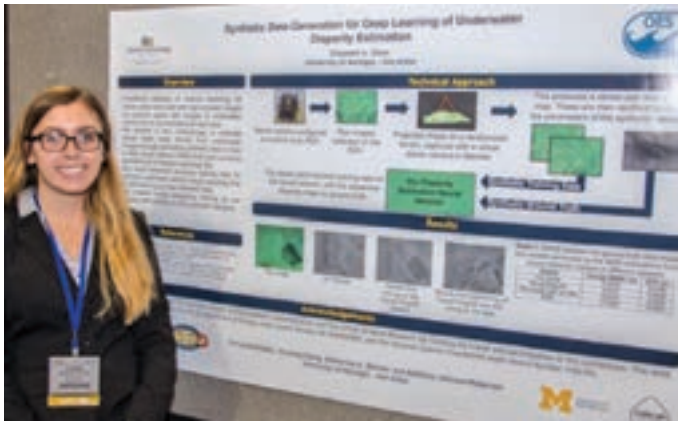
Md Modasshir, University of South Carolina, USA, *MDNet: Multi-Patch Dense Network for Coral Classification.*

Abstract—Classifying coral species from visual data is a challenging task due to significant intra-species variation, high interspecies similarity, inconsistent underwater image clarity, and high dataset imbalance. In addition, point annotation, the labeling method used for coral reef images by marine biologists, is prone to mislabeling. Point annotation also makes existing datasets incompatible with state-of-the-art classification methods which use the bounding box annotation technique. In this paper, we present a novel end-to-end Convolutional Neural



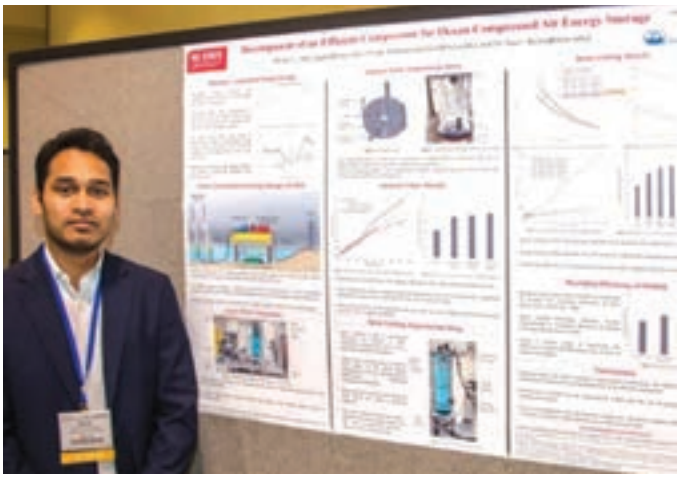
Network (CNN) architecture, Multi-Patch Dense Network (MDNet) that can learn to classify coral species from point annotated visual data. The proposed approach utilizes patches of different scale centered on point annotated objects. Furthermore, MDNet utilizes dense connectivity among layers to reduce over-fitting on imbalanced datasets. Experimental results on the Moorea Labeled Coral (MLC) benchmark dataset are presented. The proposed MDNet achieves higher accuracy and average class precision than the state-of-the-art approaches.

Elizabeth Olson, University of Michigan, USA, *Deep Learning for Disparity Estimation of Underwater Images with Synthetic Data.*



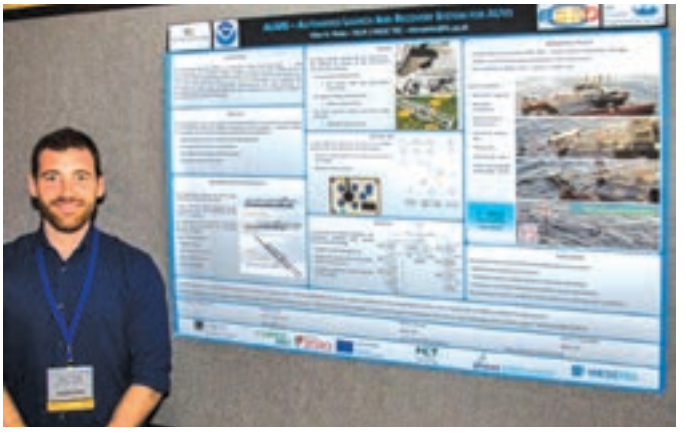
Abstract—In this paper, we present a new methodology to generate synthetic data for training a deep neural network (DNN) to estimate depth maps directly from stereo images of underwater scenes. The proposed method projects real underwater images onto landscapes of randomized heights in a 3D rendering framework. This procedure provides a synthetic stereo image pair and the corresponding depth map of the scene, which are used to train a disparity estimation DNN. Through this process, we learn to match the underwater feature space using supervised learning without the need to capture extensive real underwater depth maps for ground truth. In our results, we demonstrate improved accuracy of reconstruction compared to traditional computer vision feature matching methods and state-of-the-art DNNs trained on synthetic terrestrial data.

Vikram Patil, North Carolina State University, USA, *Development of an Efficient Compressor for Ocean Compressed Air Energy Storage.*



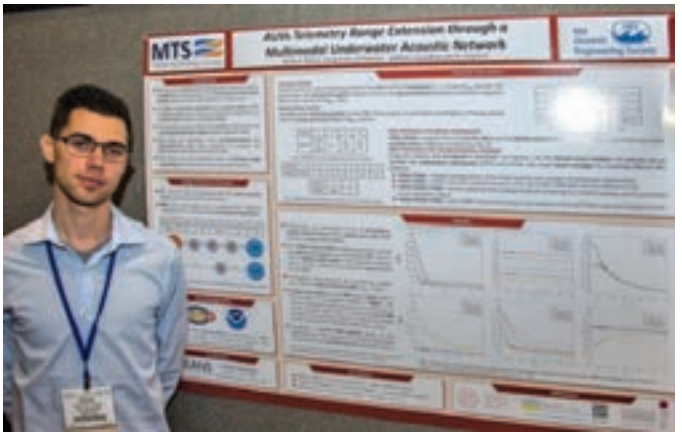
Abstract—Utilization of intermittent ocean energy resources can be improved by integrating them with an energy storage system. Ocean compressed air energy storage (OCAES) is a promising large-scale energy storage system in the proximity of ocean energy resources. Efficient compressors and expanders are needed to achieve a high roundtrip efficiency of OCAES systems. In this paper, the development of an efficient liquid piston compressor is discussed. Heat transfer enhancement techniques such as aqueous foam and spray cooling are tested in a liquid piston compressor to achieve a highly efficient near-isothermal compression. It is observed that both aqueous foam and spray cooling are highly effective in abating the rise of air temperature during compression and improve the isothermal efficiency of compression. The use of aqueous foam in a liquid piston compressor shows an isothermal efficiency up to 91% whereas spray cooling results in an isothermal efficiency up to 96%. Efficiency analysis of liquid piston based OCAES systems with aqueous foam and spray cooling indicate the potential improvement of 4-14% in roundtrip efficiency of OCAES with the use of aqueous foam and 10-20% improvement with the spray cooling.

Vítor Pinto, FEUP / INESC TEC, Portugal, *An Automated Launch and Recovery System for AUVs.*



Abstract—Underwater sensing and mapping operations using autonomous vehicles are becoming widely used. This article describes an automated system to launch and recover an AUV. It can operate in any host platform and can transport any torpedo-shaped vehicle with 0.2 meters of diameter, length up to 3 meters and weight up to 1000 N. The system ensures a restrained transportation of the vehicle and guarantees that it performs a smooth entrance in the water. It was instrumented for continuous status remote monitoring, using linear and angular motion sensors, as well as enables to remotely take control over the operation. Experimental results carried out within the XPRIZE competition demonstration scope are presented.

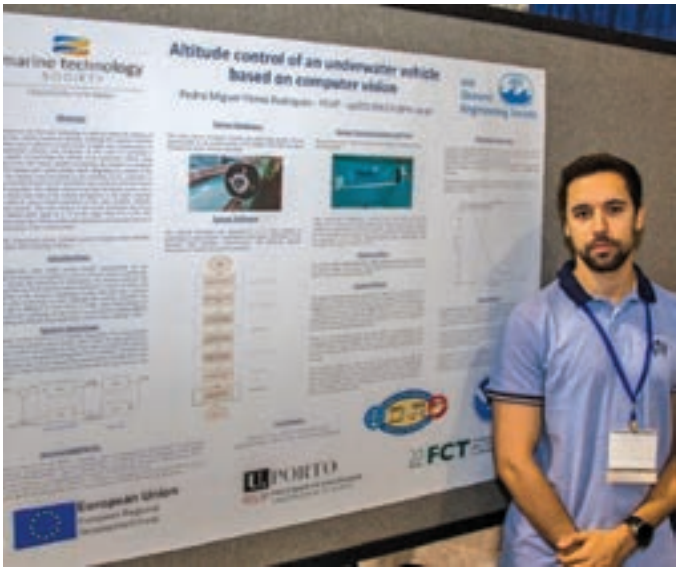
William Rizzo, University of Padova, Italy, *AUVs Telemetry Range Extension through a Multimodal Underwater Acoustic Network.*



Abstract—In this paper, we describe an underwater multihop network scenario based only on acoustic modems operating at different frequencies. The idea is to remotely control an Autonomous Underwater Vehicle (AUV) and verify whether it is able to follow the path sent by a control station (CTR) in the form of consecutive waypoints. The AUV sends back packets that can be monitoring or control information. We tested by simulation different MAC layer protocols to compare their performance in terms of throughput and packet delivery delay, in particular focusing on both contention-free (TDMA-based) and contention-based (CSMA-based) protocols, to analyze which solution performs better in different network conditions varying the amount of traffic generated by the AUV during its mission.

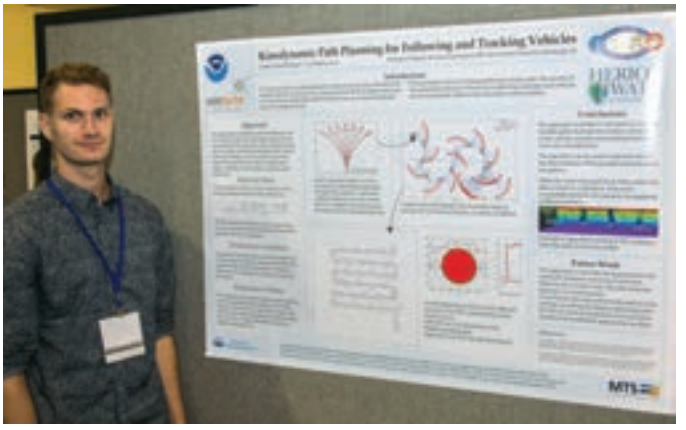
Pedro Rodrigues, FEUP, Portugal, *Altitude control of an underwater vehicle based on computer vision.*

Abstract—It is common the use of the sonar technology in order acquire and posteriorly control the distance of an underwater vehicle towards an obstacle. Although this solution simplifies the problem and is effective in most cases, it might carry some disadvantages in certain underwater vehicles or conditions. In this work it is presented a system capable of controlling the altitude of an underwater vehicle using computer vision. The sensor capable of computing the distance is composed of a CCD camera and 2 green pointer lasers. Regarding the control of the vehicle, the solution used was based on the switching of two controllers, a velocity controller (based on a PI controller), and a position controller (based on a PD controller). The vehicle chosen to test the developed system was a profiler, which main task is the vertical navigation. The mathematical model was obtained and used in order to validate the controllers designed using the Simulink toolbox from Matlab. It was used a Kalman filter in order to have a better estimation of the state variables (altitude, depth, and velocity). The tests relative to the sensor developed responsible for the acquisition of the altitude showed an average relative error equal to 1 % in the range from 0 to 2.5 m. The UWsim underwater simulation environment was used in order to validate the integration of the system and its performance.



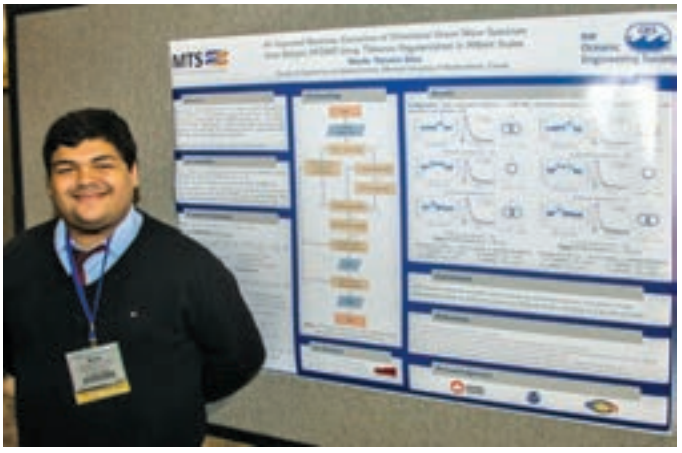
Jonatan Scharff Willners, Heriot-Watt University, UK, *Autonomous Maritime Vehicle Planning and Tracking under Kinodynamic Constraints.*

Abstract—This paper presents a novel approach to planning vehicle paths under kinodynamic constraints in a leader follower scenario where the follower vehicle has to track and follow the leader. This problem is important in the maritime domain where



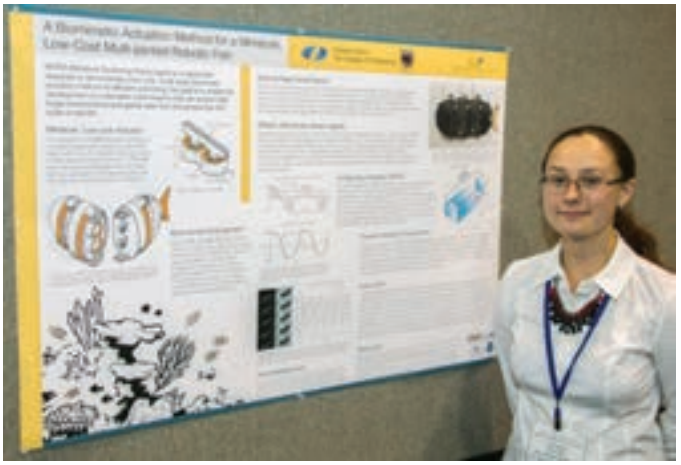
Autonomous Underwater Vehicles (AUVs) can greatly benefit from an Autonomous Surface Vehicle (ASV) acting as a Communication Relay (CR) and/or a Navigational Aid (NA), typically using acoustic communication. The proposed approach is an extension of Hybrid-A* (HA*), a hybrid version of A* which enables the derivation of paths that are obstacle free and feasible by the vehicle. The proposed algorithm finds a solution, if it exists, for scenarios where the leader and the follower operate under the same kinematic constraints as well as when they differ. Various simulations using multiple configurations and scenarios are presented to validate the approach. Whilst the work presented here has a focus on the maritime environment, the algorithm is applicable to other domains.

Murilo Silva, Memorial University of Newfoundland, Canada, *An Improved Nonlinear Extraction of Directional Ocean Wave Spectrum from Bistatic HFSWR Using Tikhonov Regularization in Hilbert Scales.*



Abstract—The present work proposes the use of a non-linear inversion technique for the extraction of the directional ocean wave spectrum from bistatic High-Frequency Surface Wave Radar (HFSWR) Doppler data. The extraction method is combined with empirical expressions, solely based on the Doppler data, to retrieve wind speed and direction. Once the initialization parameters have been defined using these empirical expressions, a blind iterative algorithm based on Tikhonov regularization in Hilbert Scales is used to extract the non-directional spectrum. The extracted spectrum is then used to determine the directional factor, which is assumed to be described by a cosine-power model. The proposed method yields good results with synthetic noise-contaminated HFSWR data with a priori regularization parameters.

Katerina Soltan, Olin College, USA, *Characterization of Miniature Underwater Actuator for Biomimetic Propulsion.*



Abstract—This paper presents the Miniature Oscillating Robot Agent (MORA). MORA is a small (12 cm) and low-cost (~$100) robotic fish which was designed to demonstrate a biomimetic actuation method for efficient swimming. Our goal is to enable the development of underwater robot swarms that can access tight, fragile environments and gather data from the perspective and scale of real fish. Conventional actuation methods are often too large, expensive, or mechanically complex to use in collective behavior applications, which to be practical must be easy to manufacture, low-cost, and small. We arranged six magnet-incoil (MIC) actuators, at $1/unit, in a multi-jointed configuration of three independently controlled joints. Oscillating the joints in a sinusoidal waveform allowed us to replicate the efficient undulatory body motion seen in fish. to replicate the efficient undulatory motion seen in fish. In initial straight-line swimming experiments, MORA achieved a speed of 0.37 BL/s with the potential for faster and more coordinated movement with further experimentation of MIC control settings.

Winning Poster Paper

Communication Constrained Trajectory Alignment For Multi-Agent Inspection via Linear Programming

Joshua G. Mangelson, Ram Vasudevan, and Ryan M. Eustice

***Abstract*— This paper reports on a system for estimating the alignment between robotic trajectories under constrained communications. Multi-agent collaborative inspection and navigation tasks depend on the ability to determine an alignment between robotic trajectories or maps. The properties of the underwater environment make determining such an alignment difficult because of extreme limitations on communication and the lack of absolute position measurements such as GPS. In this paper, we propose a method that takes advantage of convex relaxation techniques to determine an alignment between robotic trajectories based on sparse observations of a low-dimensional underlying feature space. We use a linear approximation of the l2-norm to approximately enforce that the estimated transformation is an element of SO(2). Because the relaxed optimization problem is linear, we can take advantage of existing convex optimization libraries, which do not require an initial estimate of relative pose. In addition, because the proposed method does not need to perform data association, we can align trajectories using low-dimensional feature vectors and can thus decrease the amount of data that must be transferred between agents by several orders of magnitude when compared to image feature descriptors such as SIFT and SURF. We evaluate the proposed method on simulated datasets and apply it to real-world data collected during autonomous ship hull inspection field trials.**

I. Introduction

Multi-agent underwater inspection and mapping tasks depend on the ability to determine an alignment between multiple robot maps or trajectories. This is challenging in underwater environments where global positioning systems are unavailable and where acoustic positioning systems require extensive setup and calibration [1]. Moreover, in fully submersed scenarios, communication is limited to a few bits per second making data transfer a significant system constraint [2].

Existing methods for estimating this alignment rely on the matching of discrete feature points observed by multiple robotic vehicles [3]. However, performing this data association requires that feature points transfer-ed between agents be uniquely identifiable. This is usually accomplished through the transfer of high dimensional feature descriptions that often surpass the throughput available in the underwater environment.

This paper proposes a method that efficiently estimates the rigid body transformation between reference and query robot trajectories based on a sparsely sampled underlying feature space. Because we formulate the problem as a convex optimization problem, our method avoids performing data association and decreases the amount of data that needs to be transferred between robotic vehicles by several orders of magnitude. In addition, because our formulation is convex, our proposed method is not dependent on initialization and does not require a prior estimate of the relative transforma-

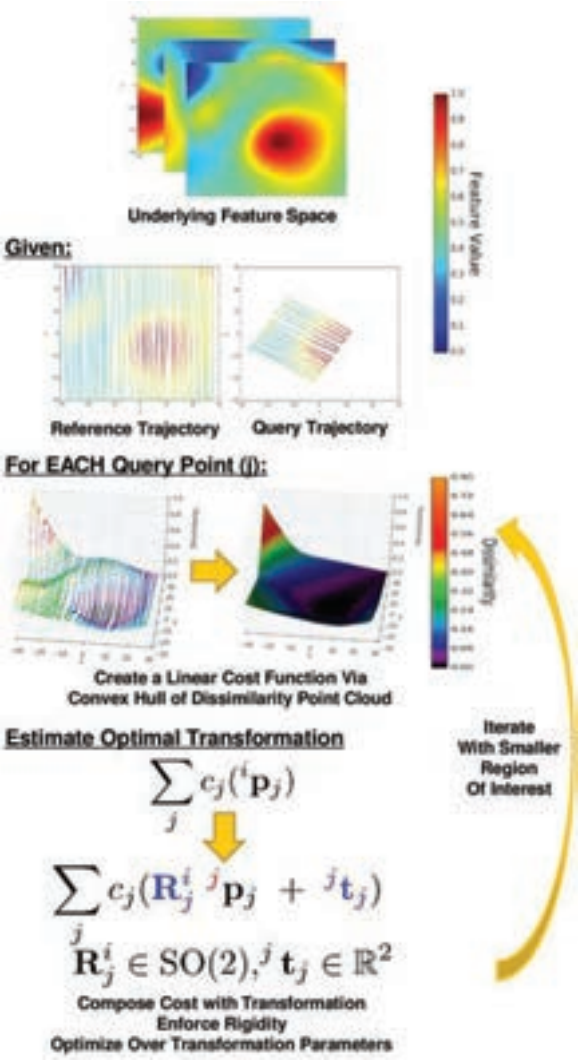


Fig. 1: An overview of the proposed trajectory alignment algorithm. Given sparse observations of an underlying feature space, we formulate a linear optimization problem that seeks to align a query trajectory with a reference trajectory. We do this by iteratively creating a linear cost that minimizes feature distance and optimizing over the transformation that minimizes that cost.

*This work was supported by the Office of Naval Research under award N00014-16-1-2102;

J. Mangelson, R. Vasudevan, and R. Eustice are with the Robotics Institute at the University of Michigan. R. Vasudevan is also with the Department of Mechanical Engineering and R. Eustice is with the Department of Naval Architecture and Marine Engineering. {mangelso, ramv, eustice}@umich.edu.

tion between trajectories. Finally, our method is parallelizable and takes advantage of existing commercial optimization libraries to increase the efficiency of the optimization process.

The contributions of this paper include the following:

1) The development of a system for alignment and localization of robot trajectories that:
   i) Relies only on low-dimensional feature observations.
   ii) Avoids performing data association.
   iii) Does not require an initial alignment estimate.
2) A novel linear approximation based method for approximate optimization over $\mathrm{SO}(2)$.
3) A parallelized implementation of the proposed method.

The remainder of this paper is organized as follows: In §II, we provide an overview of related areas of work. In §III we formalize the trajectory alignment problem. In §IV, we present a method that takes advantage of convex relaxation techniques to generate a linear cost function that is minimized when query feature points are placed near reference feature points with similar value. In §V, we present a novel method that uses linear programming to approximately optimize over $\mathrm{SO}(2)$. In §VI, we provide an outline of the full system and our released implementation. We evaluate the proposed algorithm on simulated datasets in §VII and apply it to multi-agent ship hull inspection in §VIII. Finally, we conclude in §IX.

II. Related Work

Multi-agent collaborative mapping has been heavily researched and a variety of methods have been developed for estimating the relative transformation between robot coordinate frames. Early methods assumed that vehicles were able to observe one another directly [4–6]. These methods relied on a single direct observation to determine the relative pose (position and orientation) of the two agents. Later, maximum likelihood based simultaneous localization and mapping (SLAM) methods enabled the use of multiple observations by estimating the most likely alignment and map given all the observed measurements [7–11]. These methods often relax the assumption that vehicles must be able to observe one another directly. Instead, features present in the environment observed by both vehicles are co-registered and used to relate the pose of the two vehicles. Most recent methods for determining multi-agent alignment are based on co-registering data in this way [3, 12–14]. While co-registering observed data works well in many cases, it depends on the ability to transmit large amounts of data between vehicles. This work focuses on developing methods that minimize the amount of data that must be transmitted between agents.

Our work is also related to research in the area of terrain based navigation [15–17]. In the underwater environment, this refers the use of a known bathymetric map of the seafloor to improve navigation estimates. These methods, however, are more focused on improving the estimate of a single robot's trajectory than on determining the alignment between multiple trajectories. In addition, these methods require an a prioi map of the environment, while our ultimate goal is to directly align the trajectories of two robotic vehicles that are simultaneously performing an inspection/mapping task in a potentially unknown environment.

There has also been significant recent interest in the SLAM and computer vision communities in developing estimation algorithms that leverage convex optimization techniques to avoid the need for an initial guess [14, 18–21]. This is especially useful in the underwater environment where global positioning system (GPS) is not available and global measurements of position can be hard to come by. In 2014, Li et al. [21] proposed a method that uses the convex hull of a set of dissimilarity points to estimate the affine transformation that must have occurred to transform a set of points observed in one image to a similar set of points observed in another. Their proposed method results in a linear (convex) cost function that can take advantage of existing optimization libraries and does not require an initialization. However, to apply their method to the trajectory alignment problem, we need to ensure that the estimated trajectory is rigid as opposed to affine.

Optimization over the group of rigid body transformations is generally non-convex making it hard to guarantee the true optimum. Recent works have investigated convex relaxation based methods for performing optimization over the group of rigid body transformations (the special euclidean group $\mathrm{SE}(d)$) [18, 19]. Specifically, these methods relax optimization over the set of valid rotation matrices $\mathrm{SO}(d)$ to optimization over the convex hull of $\mathrm{SO}(d)$. These methods work well in many cases. However, they fail to enforce that the estimated transformation be a valid rigid body transformation. The optimization problem used in our method also takes advantage of convex relaxation techniques, however, we use a linear approximation of the $\ell 2$-norm to add an additional set of constraints to the optimization that collectively enforce that the estimated transformation be approximately rigid. This results in more accurate transformation estimates than optimization over the convex hull of $\mathrm{SO}(d)$.

III. Problem Formulation

In this section, we outline the need for communication constrained trajectory alignment in underwater inspection and then formalize the trajectory alignment problem.

A. Trajectory Alignment w/o Data Association

In multi-agent inspection tasks, multiple vehicles navigate through the environment collecting information and estimating a map of the structure or scene they are inspecting. Some form of these local maps are then transmitted between vehicles allowing the agents to use the data collected by other vehicles for navigation, path planning, or global map generation. However, before an agent can use the data collected by another agent, it must first determine an alignment between its own local trajectory/map and the trajectory/map received from the other agent. Traditionally, this alignment is determined by matching locations in the environment observed by both agents [4–6].

However, communicating large amounts of data such as point clouds or high-dimensional image feature vectors between vehicles is often not practical in the underwater domain. While one approach is to limit data transfer by prioritizing data that is most likely to be useful, our approach is to cut out the transfer of this high-dimensional data completely. Instead, we take a descretized version of the robot trajectory and summarize information observed near each individual robot position using a small low-dimensional feature vector. We then align the robot trajectories by trying to find a rigid body transformation that places poses with similar descriptions near one another, without trying to match individual features. Taking this approach allows us to limit the data that must be transferred between vehicles to the discretized set of positions and the associated set of low-dimensional feature vectors.

B. Convex Trajectory Alignment

Formally, our goal is to align a query trajectory with a reference trajectory based only on low dimensional feature vectors describing the environment at each position visited by the two trajectories.

We denote the positions visited by the reference trajectory by $\{\mathbf{p}_1^a, \cdots, \mathbf{p}_{n_a}^a\}$ and the associated feature vectors by $\{\xi_1^a, \cdots, \xi_{n_a}^a\}$, indexed by i. Similarly, the query trajectory positions and feature vectors are denoted by $\{\mathbf{p}_1^b, \cdots, \mathbf{p}_{n_b}^b\}$ and $\{\xi_1^b, \cdots, \xi_{n_b}^b\}$, respectively, indexed by j. We then frame the trajectory alignment problem as an optimization that seeks to find a transformation that transforms positions in the coordinate frame of the query trajectory into the coordinate frame of the reference trajectory, such that when the points $\{\mathbf{p}_1^b, \cdots, \mathbf{p}_{n_b}^b\}$ are transformed they lie nearby points in $\{\mathbf{p}_1^a, \cdots, \mathbf{p}_{n_a}^a\}$ with similar feature values. Thus, the feature vectors ξ only need to describe the local environment as opposed to uniquely identify a specific point and can, as a result, have a much lower dimension.

Using a formulation similar to [21], we define a transformation function $T_j^{ab}(\mathbf{\Theta}) : \mathbb{R}^n \mapsto \mathbb{R}^d$ that maps the j-th query point, $\mathbf{p}_j^b$, to a position represented with respect to the reference trajectory coordinate frame. Specifically, we define $T_j^{ab}(\mathbf{\Theta})$ as

$$T_j^{ab}(\mathbf{\Theta}) = \mathbf{R}^{ab}\mathbf{p}_j^b + \mathbf{t}^{ab}, \tag{1}$$

where $\mathbf{\Theta} = (\mathbf{R}^{ab}, \mathbf{t}^{ab})$ are the parameters of the function. Together, $\mathbf{R}^{ab} \in \mathrm{SO}(d)$ and $\mathbf{t}^{ab} \in \mathbb{R}^d$ parameterize a global rigid body transformation relating the local coordinate frames of the two vehicles. The points $\mathbf{p}_j^b$ are fixed in the function T_j^{ab} and we thus define n_b transformation functions, one for each feature in the query trajectory.

We also define a function $c_j : \mathbb{R}^d \mapsto \mathbb{R}$ that takes a position represented in the reference trajectory coordinate frame, $\mathbf{p}^a \in \mathbb{R}^d$, and calculates the feature dissimilarity between ξ_j^b and the given position. As before, because there are n_b query feature points, we define n_b different dissimilarity functions $c_j, j = 1, \cdots, n_b$. §IV provides more detail on how these functions are defined.

With these definitions, we can formulate the final overall objective function as follows:

$$\underset{\substack{\mathbf{R}^{ab}\in\mathrm{SO}(d)\\ \mathbf{t}^{ab}\in\mathbb{R}^d}}{\text{minimize}} \sum_{j=1}^{n_b} c_j(T_j^{ab}(\mathbf{\Theta})) \tag{2}$$

where $c_j(T_j^{ab}(\mathbf{\Theta}))$ is the dissimilarity between the feature vector ξ_j^b and its new transformed position in the reference trajectory coordinate frame. Solving this optimization problem would allow us to find the transformation that minimizes the dissimilarity between query feature points and their associated positions in the reference trajectory coordinate frame.

Note, that while our formulation is based on that of [21], their method assumes the transformation is affine, while we restrict it to be an isometric (or rigid body [22]) transformation. This assumption on their part, results in the associated terms of their cost function being affine and the resulting optimization problem being convex. However, when dealing with physical transformations between coordinate frames, an affine transformation does not represent reality and a rigid body transformation must be used. This makes our resulting optimization problem non-convex and more difficult to solve. In §V we explain a novel method to approximately optimize over $\mathrm{SO}(2)$.

IV. Convex Transformation Estimation via the Lower Convex Hull

In this section, we discuss the formulation of the dissimilarity functions $c_j,\ j = 1, \cdots, n_b$ that measure the feature dissimilarity of the feature vector ξ_j^b and a position in the reference trajectory coordinate frame. We then compose the dissimilarity functions c_j with the transformation function (1) so that we can optimize over the transformation parameters as opposed to individual pose positions. There are two cases that we cover:

1) The 2D case where both maps lie in a 2D world($d = 2$)
2) The known depth case where both maps lie in the 3D world($d = 3$), but one coordinate is known.

We first cover the 2D case which follows directly from [21]. We then generalize this to the case with known depth.

A. Convex Dissimilarity Function Definition in 2D

Following [21], we denote the feature dissimilarity between ξ_i^a and ξ_j^b by C_{ij}^{ab}. If we use every possibly pairing, there are $n_a \times n_b$ of these values and they can be calculated before performing registration via an arbitrary dissimilarity function. However, because we want to find a transformation as opposed to a discrete matching, we create n_b continuous and convex feature dissimilarity functions $c_j,\ j = 1, \cdots, n_b$. Each c_j takes a position represented with respect to the reference trajectory coordinate frame and returns a predicted lower bound on the dissimilarity of that position with respect to the feature vector ξ_j^b. We derive this function by taking

the lower convex hull of the following point cloud:

$$\begin{bmatrix} x_1^a & y_1^a & C_{1j}^{ab} \\ x_2^a & y_2^a & C_{2j}^{ab} \\ \vdots & \vdots & \vdots \\ x_{n_a}^a & y_{n_a}^a & C_{n_a j}^{ab} \end{bmatrix}. \tag{3}$$

For a given feature vector ξ_j^b with $d = 2$, the point cloud (3) defines discrete points in a space that relates 2D positions in the reference trajectory coordinate frame to their associated dissimilarity value with respect to ξ_j^b. Because this space is 3D, we can calculate the convex hull of these points using an algorithm like [23]. The lower convex hull with respect to the dissimilarity value dimension is made up of a set of planes (facets) that represent lower bounds on the discrete dissimilarity values C_{ij}^{ab} for a given fixed j. These planes can be found by selecting the planes that have normal vectors with a negative component in the dimension corresponding to dissimilarity. Assuming there are M_j planes in the lower convex hull for feature ξ_j^b, we can define these planes using the equations $a_m x + b_m y + c_m C_m + d_m = 0$, for $m = 1, \cdots, M_j$, where x and y correspond to the position dimensions and C_m corresponds to the dissimilarity dimension in the point cloud (3). We then rearrange these equations to arrive at the plane functions $C_m = r_m x + s_m y + t_m$, for $m = 1, \cdots, M_j$ that calculate the predicted dissimilarity given a specified feature position. Finally, we can now define the feature dissimilarity function c_j as

$$c_j([x, y]^\top) = \max_m (r_m x + s_m y + t_m), \quad m = 1, \cdots, M_j. \tag{4}$$

This function is both continuous and convex and its minimization can be transformed into an equivalent linear program [24]:

$$\begin{aligned} \underset{u_j, x, y}{\text{minimize}} \quad & u_j \\ \text{subject to} \quad & r_m x + s_m y + t_m \leq u_j, \\ & m = 1, \cdots, M_j. \end{aligned} \tag{5}$$

Using the dissimilarity function (4) and the linear program (5) enables us to efficiently solve for an arbitrary 2D position $[x, y]^\top \in \mathbb{R}^2$ that minimizes the dissimilarity with respect to ξ_j^b for a given value of j. The next section describes how to compose $c_j(\cdot)$ with the transformation $T_j^{ab}(\mathbf{\Theta})$ which enables us to optimize over the parameters $\mathbf{\Theta} = (\mathbf{R}^{ab}, \mathbf{t}^{ab})$.

B. Composition with the Transformation Function

Our goal is to estimate the rigid body transformation between respective trajectories. As such, rather than estimate the individual locations of points, we estimate the parameters of the transformation, $\mathbf{\Theta}$, or more specifically the parameters $\mathbf{R}^{ab}$ and $\mathbf{t}^{ab}$. We do this by minimizing $c_j(T_j^{ab}(\mathbf{\Theta}))$, for all $j = 1, \cdots, n_b$, as opposed to $c_j([x, y]^\top)$ directly.

Remembering that $T_j^{ab}(\mathbf{\Theta}) \in \mathbb{R}^d$ represents the transformed coordinates of $\mathbf{p}_j^b$, we represent the function that calculates the first coordinate of $T_j^{ab}(\mathbf{\Theta})$ by $f_j(\mathbf{\Theta})$ and the second coordinate by $g_j(\mathbf{\Theta})$. Specifically, define

$$f_j(\mathbf{\Theta}) = \mathbf{R}^{ab(1)} \mathbf{p}_j^b + \mathbf{t}^{ab(1)} \tag{6}$$

and

$$g_j(\mathbf{\Theta}) = \mathbf{R}^{ab(2)} \mathbf{p}_j^b + \mathbf{t}^{ab(2)}, \tag{7}$$

where the notation $^{(i)}$ denotes the i-th row of the given matrix or vector and again $\mathbf{p}_j^b$ is fixed for both f_j and g_j.

Using this, we can rewrite (5) to be a minimization of $c_j(T_j^{ab}(\mathbf{\Theta}))$ over $\mathbf{\Theta}$ as

$$\begin{aligned} \underset{\substack{u_j \in \mathbb{R} \\ \mathbf{R}^{ab} \in \mathrm{SO}(2) \\ \mathbf{t}^{ab} \in \mathbb{R}^2}}{\text{minimize}} \quad & u_j \\ \text{subject to} \quad & r_m f_j(\mathbf{\Theta}) + s_m g_j(\mathbf{\Theta}) + t_m - u_j \leq 0, \\ & m = 1, \cdots, M_j. \end{aligned} \tag{8}$$

If the elements of the matrix $\mathbf{R}^{ab}$ are treated as individual elements in $\mathbf{\Theta}$, then both $f_j(\mathbf{\Theta})$ and $g_j(\mathbf{\Theta})$ are affine functions of $\mathbf{\Theta}$ and $r_m f_j(\mathbf{\Theta}) + s_m g_j(\mathbf{\Theta}) + t_m - u_j$ is also an affine function of $\mathbf{\Theta}$ and u_j. This was noted in [21]. However, in our case the resulting problem (8) is non-convex because of the implicit constraint that $\mathbf{R}^{ab} \in \mathrm{SO}(2)$. §V proposes a solution to this problem.

The next section explains how this can be generalized to three dimensions when depth is known.

C. The Known Depth Case

The prior section is defined with a planar world in mind. However, the real world exists in three dimensions. Although the prior section can be generalized to three dimensions, in the underwater domain we can take advantage of the fact that we can accurately measure depth and just estimate translation in the xy-plane and rotation about the z (vertical) axis. Under these assumptions, we can restrict T_j^{ab} to the following:

$$T_j^{ab}(\mathbf{\Theta}) = \begin{bmatrix} \mathbf{R}_z^{ab} & \mathbf{0} \\ \mathbf{0} & 1 \end{bmatrix} \mathbf{p}_j^b + \begin{bmatrix} \mathbf{t}_z^{ab} \\ 0 \end{bmatrix}, \tag{9}$$

with $\mathbf{R}_z^{ab} \in \mathrm{SO}(2)$, $\mathbf{t}_z^{ab} \in \mathbb{R}^2$, and $\mathbf{p}_j^b \in \mathbb{R}^3$. This restriction simplifies the problem and enables us to work on $\mathrm{SO}(2)$ as opposed to $\mathrm{SO}(3)$ when relaxing the optimization problem.

In addition, if the feature value varies with depth, then we can limit the reference trajectory feature points that need to be paired with each query feature ξ_j^b to those with a depth within a threshold γ of the estimated depth of $\mathbf{p}_j^b$. This allows us to decrease the size of the point cloud (3) and tighten the lower bounds defined by the planes in the lower convex hull.

V. Ensuring the Transformation is Rigid

The ultimate optimization problem we want to solve, (2), is non-convex because of the implicit constraint that $\mathbf{R}^{ab}$ (or equivalently $\mathbf{R}_z^{ab}$) $\in \mathrm{SO}(d)$. This makes it difficult to ensure that the solution obtained is globally optimal without a good initialization. However, this constraint is essential because it ensures that the estimated transformation is rigid as opposed to affine. A general affine transformation allows scaling and distortions of the object in addition to rotation

and translation. Physical rigid body transformations on the other hand preserve distance between points and thus do not allow scaling or distortions [22].

A. Definition of $SO(2)$ and $\operatorname{conv} \mathrm{SO}(2)$

Formally, $\mathrm{SO}(d)$ is defined as follows:

$$\mathrm{SO}(d) = \left\{ \mathbf{R} \in \mathbb{R}^{d \times d} : \mathbf{R}^\top \mathbf{R} = \mathbf{R}\mathbf{R}^\top = \mathbf{I}, \det \mathbf{R} = 1 \right\}. \tag{10}$$

In the two dimensional case, an alternative definition for (10) is:

$$\mathrm{SO}(2) = \left\{ \mathbf{R} = \begin{bmatrix} c & -s \\ s & c \end{bmatrix} \in \mathbb{R}^{2\times 2} : c^2 + s^2 = 1 \right\}. \tag{11}$$

A variety of recent papers have investigated the use of the convex hull of $\mathrm{SO}(d)$ [18, 19]:

$$\operatorname{conv} \mathrm{SO}(2) = \left\{ \tilde{\mathbf{R}} = \begin{bmatrix} c & -s \\ s & c \end{bmatrix} \in \mathbb{R}^{2\times 2} : \begin{bmatrix} 1+c & s \\ s & 1-c \end{bmatrix} \leq \mathbf{0} \right\}. \tag{12}$$

These methods relax optimization over $\mathrm{SO}(d)$ to optimization over the smallest convex set of matrices containing it. In this case the set of valid rigid body transformations lies on the border of the convex hull. However, if the minimum of the cost function lies within that convex hull as opposed to outside it or on its border, then these methods still return a transformation that scales and/or distorts the transformed trajectory. While rounding to the nearest rigid body transformation is possible, if the estimated transformation is no where near valid then the rounded solution tends to be inaccurate.

Instead of using the convex hull of $\mathrm{SO}(2)$, we break the problem up into linear sub-problems, within which we can use a linear approximation of the $\ell 2$ norm [25] to enforce that $c^2 + s^2 \approx 1$ and thus that the transformation be approximately rigid.

B. Linear Approximation of $\ell 2$

Celebi et al. [26] evaluate several potential linear approximations of the $\ell 2$-norm. According to their evaluation, the approximation presented by Barni et al. [25] has the lowest maximum error. This approximation states that given a vector $\mathbf{x} = [x_1, x_2, \cdots, x_n]^\top \in \mathbb{R}^n$,

$$||\mathbf{x}||_2 \approx \delta^* \sum_{i=1}^{n} \alpha_i^* x_{(i)}, \tag{13}$$

where $(x_{(1)}, x_{(2)}, \cdots, x_{(n)})$ is a permutation of $(|x_1|, |x_2|, \cdots, |x_n|)$ such that $x_{(1)} \geq x_{(2)} \geq \cdots \geq x_{(n)}$, and δ, α_i are parameters optimally given by (See (20) and (21) in [25]):

$$\alpha_i^* = \sqrt{i} - \sqrt{i-1}, \quad \delta^* = \frac{2}{1 + \sqrt{\sum_{i=1}^{n} \alpha_i^{*2}}}. \tag{14}$$

In the two dimensional case, $\alpha_1^* = 1$, $\alpha_2^* = \sqrt{2} - 1$, and $\delta^* = \frac{2}{1+\sqrt{1+(\sqrt{2}-1)^2}} \approx 0.96044$. In addition, in the two dimensional case, the sorting of $(|x_1|, |x_2|)$ can be

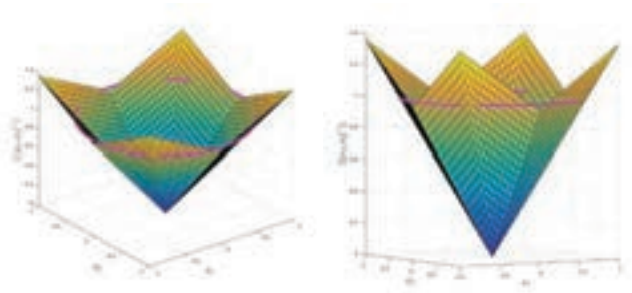


Fig. 2: The planes in these plots represent a piece-wise linear approximation of the $\ell 2$-norm of $\mathbf{x} = [x_1, x_2]^\top$ (16). The pink circle represents where the $\ell 2$-norm is one, $||\mathbf{x}||_2 = x_1^2 + x_2^2 = 1$.

implemented via a maximization term, and (13) can be rewritten as

$$\begin{aligned} ||\mathbf{x}||_2 \approx \delta\alpha_1 \max(|x_1|, |x_2|) \; + \\ \delta\alpha_2(|x_1| + |x_2| - \max(|x_1|, |x_2|). \end{aligned} \tag{15}$$

Implementing $\max$ and absolute value in convex optimization problems is not always possible. Instead of actually evaluating the $\max$ and absolute values, we can enumerate the possible values and rewrite (15) as:

$$\begin{aligned} ||\mathbf{x}||_2 \approx \max(&\delta(\alpha_1 x_1 + \alpha_2 x_2), \\ &\delta(\alpha_1(-x_1) + \alpha_2 x_2), \\ &\delta(\alpha_1(-x_1) + \alpha_2(-x_2)), \\ &\delta(\alpha_1 x_1 + \alpha_2(-x_2)), \\ &\delta(\alpha_1 x_2 + \alpha_2 x_1), \\ &\delta(\alpha_1(-x_2) + \alpha_2 x_1), \\ &\delta(\alpha_1(-x_2) + \alpha_2(-x_1)), \\ &\delta(\alpha_1 x_2 + \alpha_2(-x_1))) \end{aligned} \tag{16}$$

This function is shown plotted in Fig. 2.

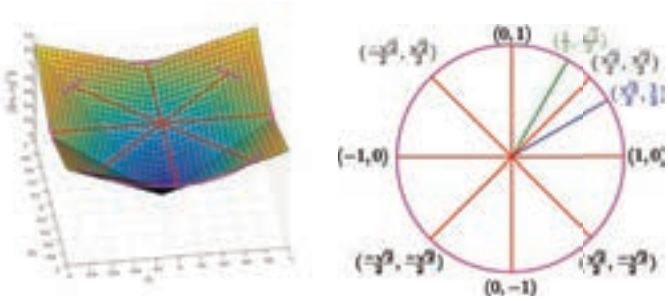
C. Breaking the Optimization into Linear Sub-Problems

Using (16) to enforce unit norm is still difficult because enforcing the $\max$ operation requires simultaneous minimization and maximization, instead, we split the problem into eight sub-problems in a way that enables us to ignore the $\max$ operation. Each of the eight terms in (16) correspond to a single plane in Fig. 2. Additionally, each term is maximal only when the signs and relative values of x_1 and x_2 meet certain conditions. These conditions correspond to sections of the unit circle (Fig. 3(b)) and can be enforced with linear constraints on x_1 and x_2.

Specifically, we can enforce that $\mathbf{x}$ lie within any given section by adding the corresponding choice of the following constraints to the optimization problem:

$$\begin{aligned} x_1 \leq x_2 \quad &\text{or} \quad x_2 \leq x_1 \\ x_1 \leq 0 \quad &\text{or} \quad x_1 \geq 0 \\ x_2 \leq 0 \quad &\text{or} \quad x_2 \geq 0. \end{aligned} \tag{17}$$

Within a given section, only a single plane is maximal and the approximation of $\ell 2$ becomes linear (Fig. 3(a)). Thus, we



(a) Division into Sections **(b)** Unit Circle

Fig. 3: By dividing the optimization into eight sub-problems, we no longer need to execute the max operation in (16) and each sub-problem then becomes convex. The red lines in (a) demonstrate where this division takes place. These divisions correspond to the unit circle (b) and the enumerated sign/max combinations in (16).

can enforce that our solution be close to unit norm by adding the following linear constraint to the problem:

$$\delta(\alpha_1 x_p + \alpha_2 x_q) = 1 \tag{18}$$

where x_p and x_q represent the appropriately selected elements of $\{x_1, -x_1, x_2, -x_2\}$, such that they match the respective maximal term in (16). The maximum error of this approximation (18) is related to, but likely slightly higher than ϵ_{max} as defined in (4) and Table 3 of [26].

Formulating the problem in this way makes each sub-problem a linear program, and so we can take advantage of existing efficient optimization libraries to solve each sub-problem to a global minimum [27]. In addition, because the sub-problems divide the space and optimize over the same linear cost function, the solution to the sub-problem with lowest optimal value is identical to what the solution would be if we were able to constrain (16) to be equal to 1. Finally, the sub-problems are independent and thus can be parallelized.

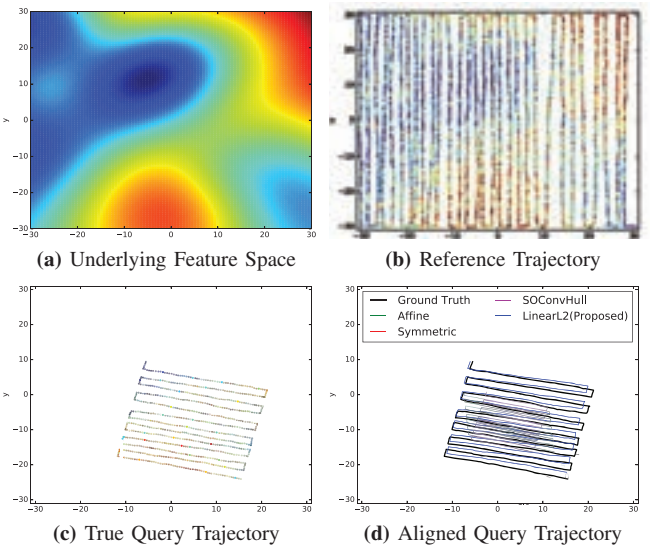
VI. The Full System

We are now able to create a general system for aligning robot trajectories.

A. The Final Optimization Problem

We can rewrite the optimization problem (2), by combining (8), (17), and (18).

$$\begin{aligned}
\underset{\substack{u_j \in \mathbb{R} \\ c,s \in \mathbb{R} \\ \mathbf{t}^{ab} \in \mathbb{R}^2}}{\text{minimize}} \quad & \sum_{j=1}^{n_b} u_j \\
\text{subject to} \quad & r_{m_j} f_j(\mathbf{\Theta}) + s_{m_j} g_j(\mathbf{\Theta}) + t_{m_j} - u_j \leq 0, \\
& \qquad m_j = 1, \cdots, M_j, \quad j = 1, \cdots, n_b \\
& \mathbf{R}^{ab} = \begin{bmatrix} c & -s \\ s & c \end{bmatrix} \\
& c \leq s \quad \text{or} \quad s \leq c \\
& c \leq 0 \quad \text{or} \quad c \geq 0 \\
& s \leq 0 \quad \text{or} \quad s \geq 0 \\
& \delta(\alpha_1 x_p + \alpha_2 x_q) = 1,
\end{aligned} \tag{19}$$



(a) Underlying Feature Space **(b)** Reference Trajectory

(c) True Query Trajectory **(d)** Aligned Query Trajectory

Fig. 4: The feature space for a sample simulated trial is shown in (a). The reference and query trajectories are then generated as shown in (b) and (c). To simulate the fact that the relative transformation between trajectories is unknown, we then randomly rotate and translate the query trajectory and use the proposed and evaluated methods to estimate the inverse of the random transformation. The resulting trajectories are shown in (d).

where the inequality constraints and x_p and x_q are chosen according to the specific sub-problem.

Enumerating the possible combinations of these constraints results in eight sub-problems. Solving all eight sub-problems and then selecting the solution with lowest cost enables us to estimate a transformation to align the two trajectories without an initial estimate of alignment. In addition, this method enables us to avoid performing data association and thus perform alignment based on relatively indistinct, low-dimensional, feature observations. We then iterate over this process with consecutively smaller regions of interest, as explained in Section 4 of [21], to decrease the number of reference trajectory points used to create the cost function and thus increase accuracy.

B. Parallel and Feature Agnostic Implementation

We implemented the proposed system in c++. The released implementation uses MOSEK [27] and multiple threads to efficiently solve the linear sub-problems in parallel. The released code can be found at the following link: https://bitbucket.org/jmangelson/cte.

Our implementation and method are agnostic to the underlying feature space. When specifying a problem to be solved, the user provides feature point positions and a function that calculates the feature dissimilarity of a given pair of points. As such, the specifics of the feature space being used and the dissimilarity function are free to be chosen by the user.

In addition to our own proposed method for approximate optimization over $\mathrm{SO}(2)$, we also implemented functionality for estimating affine and symmetric transformations [21], as well as rigid body transformations via $\mathrm{conv}\,\mathrm{SO}(2)$ [19] for comparison.

TABLE I: Comparison of the proposed linear programming based method with other convex transformation estimation algorithms. Standard deviation shown is after removing outliers outside 1.5*IQR, IQR=Inter-Quartile-Range.

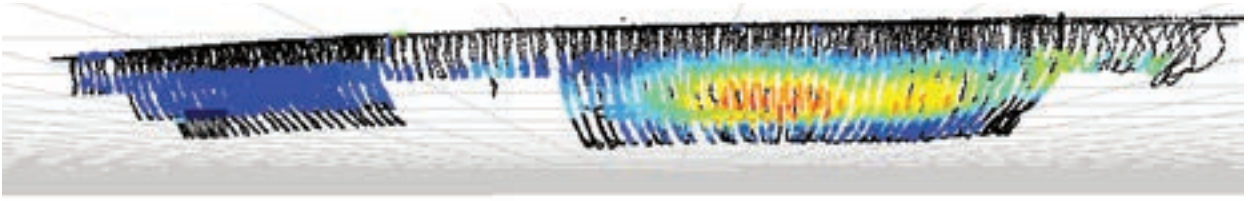
	Proposed	SOConvHull [19]	Symmetric [21]	Affine [21]
Rotation Median SE	**0.011**	0.039	0.042	0.338
Rotation Stddev SE	**0.017**	0.096	0.095	0.498
Trans. Median SE (m^2)	**4.796**	10.974	11.601	32.582
Trans. Stddev SE (m^2)	**6.770**	18.219	20.318	57.370
% Approx. Valid Rotations	**100.0**	37.0	25.5	1.0
Avg Runtime (s)	41.444	29.527	25.416	**23.926**

VII. Comparison With Existing Convex Optimization Methods

To provide quantitative results, we generated 200 synthetic worlds with smoothly varying feature spaces. We then simulated both a reference and a query lawn-mower trajectory within that space and randomly rotated and translated the query trajectory. Finally, we compared the alignment results from a variety of convex alignment methods formulated as in §IV but with different types of transformation constraints. Specifically, we compared our proposed linear programming-based approach to methods based on [21] that allowed either affine or symmetric transformations as well as a method that enforced that the estimated transformation lie within the convex hull of $\mathrm{SO}(2)$ [19]. Fig. 4 shows a sample simulated trajectory and associated alignment results. The nominal trackline width for this dataset was two meters and the feature vector dimension was three.

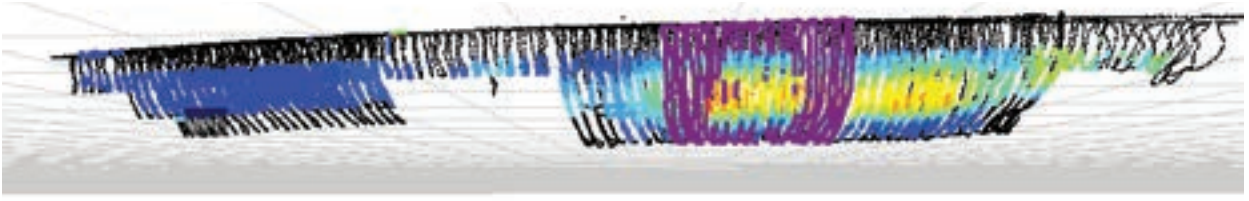
Table I provides a summary of the comparison results. Our proposed method outperforms other methods in all metrics except for runtime. Note that the median translation squared error for the proposed method is 4.796 meters squared while the resolution of the tracklines simulated was two meters, meaning that the median error is only slightly higher than the resolution of the input data.

The current implementation uses four threads that independently solve two linear programs each via the optimization library Mosek [27]. However, the speed of the algorithm can be additionally improved by increasing the number of cores or by using a faster convex optimization library.



(a) Trajectory 1 Colored by Curvature

(b) Trajectory 2 Colored by Curvature



(c) Alignment Based on Hull Curvature Alone

(d) Ground Truth

Fig. 5: Two trajectories colored by estimated curvature are shown in (a) and (b). The estimated alignment of these two trajectories is shown in (c). The groundtruth alignment is shown in (d). This data was collected during field trials inspecting the hull of the USCGC Spencer in Boston, MA.

VIII. Application to Multi-Agent Autonomous Ship Hull Inspection

We also tested this method on real-world field data collected using a Hovering Autonomous Underwater Vehicle (HAUV) performing autonomous ship hull inspection. We used the sparse range returns of the Doppler velocity log (DVL) to estimate the curvature of the hull. Then, by treating the local curvature of the ship hull as a feature vector, we are able to re-localize to an earlier trajectory using only the DVL. Fig. 5 shows an alignment using this method.

Using the proposed alignment method limits the information that needs to be passed between vehicles to six fixed or floating-point values for each position visited by the agent (including three position coordinates and three curvature feature values), while the throughput needed to transfer image features between agents would be on the order of 1000-10000 fixed or floating-point values per position. Thus, the proposed method results in a decrease in required throughput of approximately 3-4 orders of magnitude.

The final accuracy of the alignment is dependent on the distinctiveness of the features being observed as well as the sampling resolution inherited from the reference trajectory. However, as formulated, the proposed method is independent of the specific feature and thus can be applied to whatever feature set is most distinctive in a given environment, subject to the communication bandwidth available. In addition, alignment can be further refined if desired using higher dimensional data such as imagery once an initial estimate of alignment has been obtained, thus minimizing the amount of image data that must be transferred between agents.

IX. Conclusion

In this paper, we propose a method for aligning robot trajectories that is linear and thus does not require initialization. In addition, the proposed method aligns trajectories without performing data association which decreases the amount of information that must be transferred between agents. We compared the existing method to similar convex methods that fail to enforce that the estimated transformation be rigid. We also applied the proposed algorithm to localization in the context of multi-agent autonomous ship hull inspection.

Future work would include: extending the proposed ideas to three dimensions and relaxing the assumption that the query trajectory be contained within the convex hull of the reference trajectory.

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A Blast from the ... Not So Distant ... Past! OCEANS 2018 Charleston

Bob Wernli—Beacon Co-Editor-in-Chief, photos by Stan Chamberlain

A special thanks to all those who spend their time making OES a success.

Stephen Wood (incoming Secretary) and Marinna Martini (outgoing Secretary).

Chapter Chairs meeting.

Rene Garello (Junior Past President), Philippe Courmountagne (VPW&S), Bill Kirkwood (AdCom).

Shyam Madhusudhana (L) (YP BOOST) and Gerardo Acosta (AdCom and Chapter Coordinator)

Marinna Martini, Mal Heron (VP Technical Activities), John Watson (Incoming VP OCEANS) Diane DiMassa (Outgoing VP OCEANS).

OES Administrative Committee.

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Taking the Measure of Paradise

Dr. John R. Potter (Fellow, IEEE), Capt. David Field (iXblue), Casper J Potter (Jocara) and Andrew Price (iXblue)

Despite great advances in navigational aids (e.g. GPS), in many places in the world there remains great uncertainty as to exactly where dangerous reefs and shoals are in respect to a navigating vessel. Although the vessel might know (via GPS) where it is within a few metres with respect to the World Geodetic System Ellipsoid (WGS84), this is of little help if the chart on which the course is being plotted has a local offset of several hundred metres. And it doesn't make a bit of difference if one is using an old paper chart, or a modern electronic one, because the latter is very likely based on the same old data, either way. Even worse, in remote areas there may very well be shoals and rocks that remain undiscovered, and the chart may suffer not only from a linear offset, but be distorted in some arbitrary way. This is because, even today, the foundation information for many charts of remote areas was laid by seafarers of a bygone age, when ships were driven by sail, positions were determined by sextant and chronometer and depths sounded by a lead line.

It may surprise you to learn that there are parts of the world, often in remote tropical seas, where the charts have not been significantly updated or revised, only a few details amended, since the pioneering work of talented surveyors such as Captain James Cook and other explorers in the 18th Century. How is this possible? The answer lies in the considerable funding and technological capacity that are required to accurately survey an area with modern instruments, balanced against the limited resources available in remote and thinly-populated areas. The remote islands of the Ha'apai group in the Kingdom of Tonga represent one such case.

The Kingdom of Tonga is a Polynesian archipelago, scattered over 700,000 km^2 of the southern Pacific Ocean. Most people have no idea where it is. If it helps, think of Tonga as being about 2/3 of the way from Hawaii to New Zealand. Still struggling to visualize it? Take a look at Fig. 1a, which gives the big picture. Talking of a big picture, did you realize that, viewed from just the right angle from space, the earth appears almost completely covered by the Pacific Ocean?

Tonga has Fiji to its west, Samoa to the northeast, Niue to the east and New Zealand far to the southwest. With only 100,000 inhabitants, spread over 170 islands strewn along a line of over 800 km, that's a lot of ground to survey. Tonga essentially consists of three main parts; the cluster of islands of Vava'u in the north, the Ha'apai group in the middle and the largest island, Tongatapu, in the south, which hosts the kingdom's capital, Nuku'alofa (Fig. 1b).

Tonga was nicknamed "The Friendly Islands" by Captain James Cook because of the congenial reception accorded him on his first visit in 1773. He arrived at the time of a major festival, and he and his crew were invited to the festivities. According to the chronicler William Mariner (who arrived a few years later, on a vessel whose crew were all killed, apart from him) the Tongan chiefs decided to murder Cook and his men so they could loot his ship, and the invitation to eat and drink was a ruse to take them off-guard. The plan stalled when the chiefs argued about how, when and where the ambush should be launched, so Captain Cook and his crew returned safely to their ship none the wiser. In 18th century Tonga, apparently dangerous things lay just beneath the surface, and perhaps, concerning the charts from that era, they still do.

Tonga lies on the Tonga-Kermadec ridge, a geologically active region formed by the collision of tectonic plates in the

Captain Cook and his vessel Endeavour.

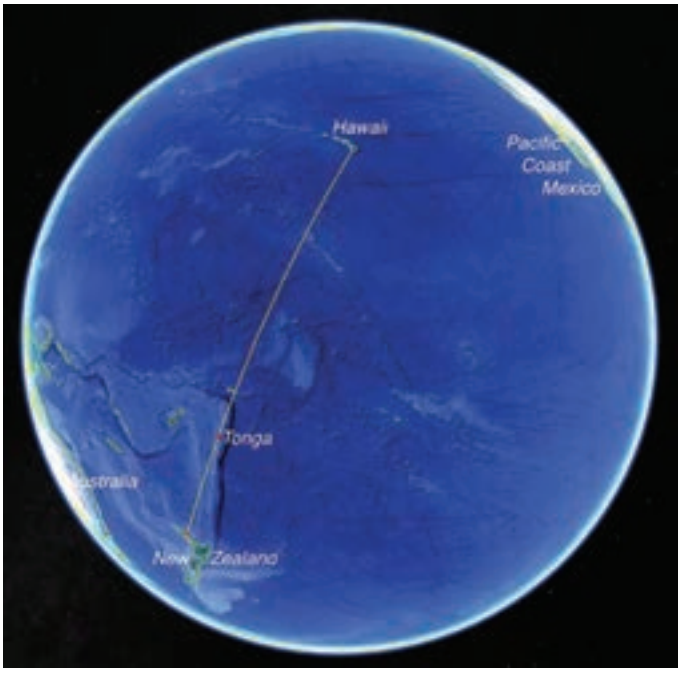


Figure 1a. Where in the world is Tonga?

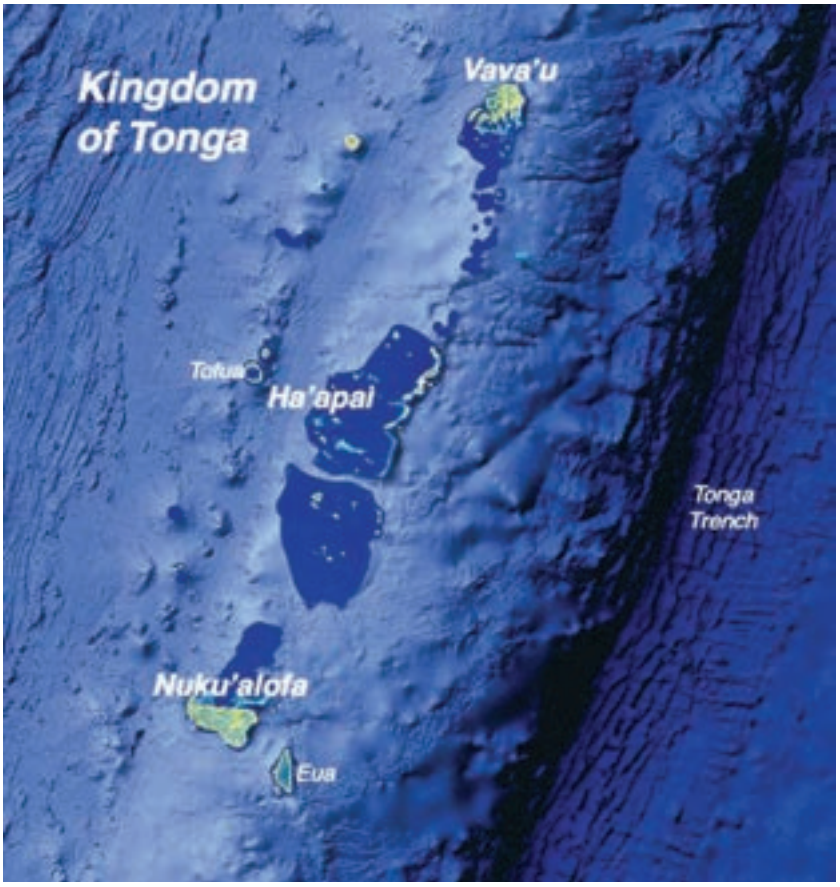


Figure 1b. A close-up of Fig. 1a, showing the Tongan archipelago.

S/Y Jocara, under sail between stations, with iXblue's GPS buoy secured on deck.

Southern Pacific, with a dramatic mix of coral reefs and active volcanoes, including sub-surface. Try charting a sea where brand new islands appear from time to time, such as the one that broke surface in 2015 near Hunga, between Ha'apai and Tongatapu, now some 4 km long and 100 m high. You know that your charts are of doubtful accuracy when you see two islands drawn on the chart, but three clearly visible a few miles off the starboard beam, as happened to Sailing Yacht (S/Y) Jocara this September.

And what, you might ask, was S/Y Jocara doing in Tonga, and more to the point, what has it to do with Ocean Engineering? The answer is that, curiously, in a way we have come full-circle since the days of Captain Cook and his original surveys, conducted from sailing vessels of old. Breakthroughs in charting and surveying technologies, such as airborne LIDAR and multi-beam sonar deployed from Autonomous Surface Vessels, have brought the cost of accurate high-resolution surveying of such large and complex areas into an affordable range. But LIDAR and Sonar depths must be corrected for the tides, to reduce them to a common datum (referred to as Sounding Datum) that closely correlates with the Lowest Astronomical Tide. GPS benchmarks ashore are also needed to fix this datum so that it can be recovered in future surveys, and also to allow referencing of the depths and tide heights to the WGS-84 Ellipsoid and then onto other useful land-based datums. These GPS benchmarks serve the dual purpose of increasing the density of Tonga's national geodetic network and providing sparse high-quality control points in the most remote locations.

Enter S/Y Jocara, which the survey company iXblue chartered to support a team to establish such a GPS reference network and install tide gauges at four locations in the Ha'apai island chain and one to the south, at Eua Island. Choosing S/Y Jocara was an unconventional move. Oceanographic exploration and surveys are normally conducted from much larger, commercial motor vessels. But while a motor-driven ocean-going research vessel needs to be relatively large (to accommodate fuel and engines), typically costing tens of thousands of US Dollars per day, a blue-water sailing vessel such as S/Y Jocara can be chartered for a fraction of the cost, and yet be a perfectly good platform for lightweight exploration and ocean engineering work in remote places, e.g. installing tide gauges and landing ashore to survey GPS reference points. While relatively small (18 m in length with a 4m beam), S/Y Jocara is full-ocean capable with an autonomous endurance between refueling/resupplying spanning many weeks, if not months. S/Y Jocara is also equipped with an instrument-grade pure sine wave inverter to provide mains AC power and copious USB recharging sockets so everyone can keep their personal devices, laptops and scientific recording equipment up and running. In summary, S/Y Jocara offers a cost-competitive solution to

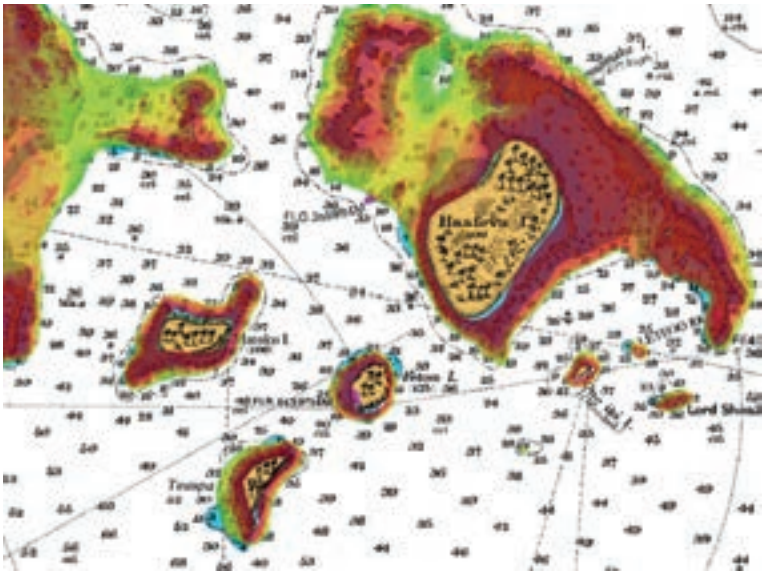
small expeditionary survey teams who need access to remote islands, even for extended periods. Finally, it just so happens that S/Y Jocara is owned and operated by Dr. John Potter, an IEEE Fellow and a member of the OES AdCom, who has spent the better part of 2018 working alongside his son, Casper, in New Zealand refitting S/Y Jocara in preparation for supporting just this kind of remote surveying and research effort.

On this occasion, a 4-man surveying team was formed by iXblue under a contract from Land Information New Zealand (LINZ) funded by the Ministry of Foreign Affairs and Trade (MFAT) under the Pacific Regional Navigation Initiative (PRNI). The PRNI has NZ$7.2m to invest over a 6-year programme to improve maritime safety, including hydrographic charts, in the Pacific. Their focus is on the countries for which New Zealand is the Primary Charting Authority (Tonga, Tokelau, Niue, Samoa and the Cook Islands). Obviously, it is not possible to survey every part of such a vast area, nor is it possible to detect and accurately describe every hazard, and inevitably some will remain uncharted. Nevertheless, the PRNI works in close partnership with LINZ and the Pacific Community (SPC), with the aim to enable countries to establish points of contact who can coordinate Maritime Safety Information, forming a key link in getting Notices to Mariners (warning of hazards) communicated effectively. As part of this effort, nautical charts are being updated and converted to Electronic Navigation Charts following high-resolution hydrographic surveys. These new charts will empower compliance with international maritime regulations and provide for safer maritime transport, in addition to facilitating increased tourism by a variety of smaller sail and motor vessels. PRNI is also delivering capacity building and training to Pacific island officials, one of whom was on board S/Y Jocara as part of the survey team.

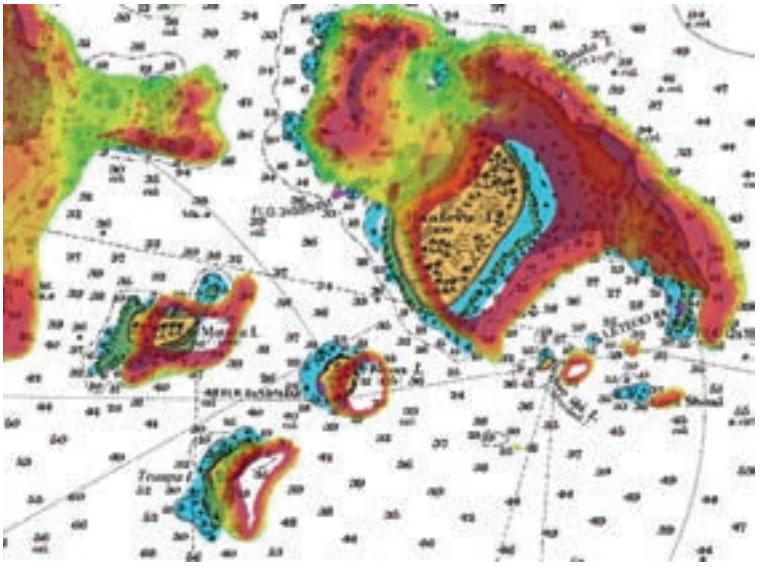
Jocara began her charter in North Island, New Zealand, by taking on board 400 kg of equipment for the expedition, which she then ferried up to Nuku'alofa, the capital of Tonga, in a 7-day ocean transit of 1,100 n.m. The survey team then flew in and joined Jocara in Nuku'alofa, from where she headed out to the island of Eua to establish the first station. Each station required Jocara to stand by for 2-3 days while three GPS receivers, accurately positioned directly over the installed GPS benchmarks, collected sufficient data to establish, via post-processing, a GPS reference point and for the tide gauges to get a preliminary estimate of tidal components and phases. Then the team would recover the GPS receivers, re-deploy the tide gauges to collect a longer-term record, and we'd move on to the next site. Each site might typically be separated by 30-60 n.m. from its nearest neighbours, with the five sites distributed through the Tongan archipelago so as to provide the best network coverage.

Fig. 2a shows a preliminary result (not to be used for navigation), overlaying LIDAR bathymetric data (shown as a colour scale) onto an existing chart. The

The survey team hard at work, setting up a GPS receiver.



(a)



(b)

Figure 2. Preliminary LIDAR bathymetry (not to be used for navigation) (a) superimposed on an existing chart that has had a 350 m corrective offset applied, (b) superimposed on an existing chart, with no offset correction.

colour is intuitively graded from purple (very shallow) through red, orange, yellow and green (deeper). LIDAR is most useful in providing bathymetric coverage over inshore areas, which may not be deep enough for a vessel to safely navigate. At depths greater than 20-40 m (depending on water clarity) the shallow-water LIDAR system employed (a Leica Chiroptera 4X) becomes increasingly less able to detect the reflected laser beam from the seabed, and eventually cannot determine the depth. This is where iXblue's Autonomous Surface Vessel, with its multi-beam sonar, takes over. So the colour depths overlaid in Fig. 2a only extend to intermediate depth water, the deepest areas remaining white as the LIDAR data overlay becomes transparent. The example in Fig. 2a shows the island of Ha'afeva, in the central region of the Ha'apai, with numerous smaller islets scattered to the south and west, and an extensive reef to the west.

At first glance, the LIDAR bathymetry seems to agree remarkably well with the older chart, whose depths are marked in fathoms. The shape of the islands, and of the shallow-water bathymetric contours, are in close agreement. It seems that Capt. Cook did a pretty good job, with his limited technology. And so he did, at least in describing the general shape and arrangement of the islands and reefs.

The most startling, and alarming, feature of this overlay is that, in order to align the LIDAR bathymetry up with the chart, a 350 m offset had to be applied to the chart. That is, the current chart has a local positional error of some 350 m. The equivalent overlay, but without the 350 m chart offset, is shown in Fig. 2b.

If a vessel is negotiating a narrow pass into an anchorage, Fig. 2b shows that this can make the difference between being squarely in the middle of the channel, and being wrecked on a reef. It is this chart offset, reflecting the difficulty of precise positioning in Latitude and Longitude in the days of Captain Cook, that makes an apparently detailed and mostly accurate chart an invitation to disaster, if the local chart offset is unknown. This is enough to deter unfamiliar mariners and pose a real threat to vessels venturing into the area without local knowledge. It is thus vital, but often poorly-understood, that the local offset, if any, is carefully estimated before entrusting the navigation of a vessel to GPS.

Even so, this 'offset' is only a local linear approximation to a more complex distortion of the chart's features, so needs to be determined separately for different areas covered by the chart. Jocara routinely estimates the local chart offset by aligning radar returns from islands, and breakers over reefs, with the electronic chart. We are fortunate to be able to directly overlay radar returns onto the electronic chart on the 12" colour screen of our electronic navigation system. By applying East-West and North-South shifts, and perhaps also a rotation, radar features and expected returns from elements shown on the chart can often be reconciled and the differences minimized to provide a good estimate of the local chart offset. Jocara can then proceed with caution, and always with a sharp lookout for the changing colours of shallow water. Even so, it has happened more than once that a lookout on the bowsprit has seen a coral head appear out of nowhere, directly ahead, the coral polyps clearly visible, only to slip harmlessly beneath the keel a few seconds later, while the helmsman in the cockpit believes himself to be in deep water with no dangers indicated for miles.

S/Y Jocara at anchor at one of the stations in Ha'apai.

The westernmost site we were called on to survey was on the extinct volcanic island of Tofua, with its towering steep-sided cliffs guarding its entire shoreline. Captain Bligh certainly found Tofua inhospitable, having been cast adrift by Fletcher Christian with nothing more than a few rations, plus a quadrant and compass to navigate by (no charts or chronometer). Bligh (who had served under Captain Cook) stopped at Tofua, but one of his men was killed by the locals, so he ended up sailing another 3,500 n.m. west to reach Timor in Indonesia, regarded to this day as one of the most accomplished feats of open water navigation.

At each station, our local surveyor, from the Ministry of Lands and Natural Resources, was of invaluable help in providing liaison, often being called upon to explain why these odd characters with their yellow tripods and brightly-coloured safety gear, carrying strange equipment, should be left alone to drill into rocks and concrete jetties, cementing in their GPS reference marks. Sometimes its hard to explain to a hard-working man, laboring under the weight of a pig or two, that it is so important not only to not bump into, but not even to touch, a sensitive tripod with its GPS receiver, surveyed to an accuracy of millimeters rather than metres.

A fine young yellowfin tuna—sashimi and sushi on the menu tonight!

As our work drew to a close, Jocara sailed back south to Nuku'alofa, revisiting some of the sites along the way to check on the tide gauges, and eventually discharged her survey team back on to dry land for their flights home. The

team, having previously been accustomed to working on grimy workboats smelling of diesel, left with a new experience of surveying from a compact, wind-powered alternative surveying support vessel, finding it a novel but very pleasant alternative. The food wasn't too bad either, often supplemented by the fresh catch of the day, including sashimi and sushi (Jocara is furnished with Japanese rice wine, sushi nori dried seaweed sheets, the best wasabi and soy sauce and bamboo mats to roll the sushi in).

iXblue are now engaged in conducting the multi-beam sonar part of the work, using their in-house designed 8 m Autonomous Surface Vessel, supported by a larger (but much more expensive) motor vessel. Once all the data is in, and the data analysis complete, we can all look forward to seeing the first genuinely new charts of the Ha'apai island chain, with unprecedented accuracy and resolution, courtesy of iXblue, LINZ, MFAT and PRNI. But lest we be tempted to rest on our laurels, there's a lot more to do, as Fig. 1a illustrates!

Plans are to continue to use S/Y Jocara for expeditions, research, adventure and eco-tourism anywhere in the world, given the time and water under her keel to get there.

https://www.facebook.com/JocaraOceanExpeditions http://www.jocara.net.

Milestone Ceremony—French Cable Station Museum Thursday, September 6, 2018

René Garello, IEEE OES Junior Past President

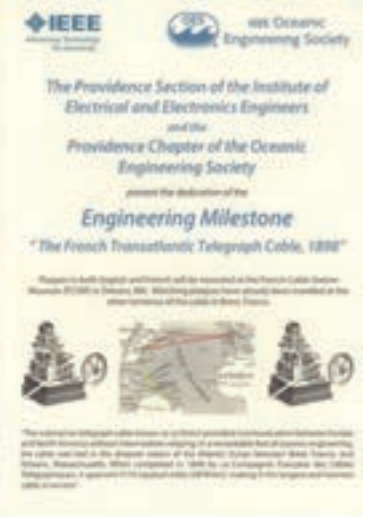
On a very sunny day, the IEEE milestone ceremony for celebrating "The French Transatlantic Telegraph Cable, 1898" took place in Orleans, MA. The picture below presents the dedication of the milestone.

The following page provides the keynote address from René Garello, past President of the IEEE Oceanic Engineering Society, along with some pictures of the ceremony.

René Garello Keynote Address

Mr. President, dear colleagues, ladies and gentlemen,

At first, thank you for inviting me to attend this ceremony. I'm honored and very pleased to be here in this beautiful surrounding. My name is René Garello and I'm bearing several hats here. One being as a representative of the French and Brittany community, still faithful to the history of the cable "Le Direct". Indeed, the site of Deolen, where the cable started, in Locmaria-Plouzané, near Brest in France, is about 1 mile away from my house. I'd like to thank the supportive groups ("associations" in French) of "Locmaria Patrimoine" and "Les Amis de Deolen" helping me to smooth administrative hurdles, the county authorities giving all authorizations, the IEEE France section accompanying the process and mainly the IEEE Oceanic Engineering Society when, as President, I promoted the installation of the very same plaque on the coastal trail, at the cable station last year in Deolen.



And the next one, the program of the afternoon.

This Plaque is an IEEE Milestone. What Does it Mean?

It's meant to be a remembering of a great achievement in IEEE history. IEEE, and Jim (1) could tell you more, resulted in 1963 of the merging/convergence of, on the one hand the AIEE (American Institute of Electrical Engineers), the "Electrical" side of the IEEE, founded in 1884 with such big names as Thomas Edison or Graham Bell (Electricity, telegraph, telephone) and on the other hand, the "Communication" side with the IRE (Institute of Radio Engineers) founded in 1912 and arising from Marconi's works in 1895/96 with an evolution to electronics (vacuum tube, transistors, …).

But already in the beginning to the mid-19th century, we had the early stages of what is the core of IEEE: "Information" and therefore its communication. Humankind has always been very clever in trying to communicate, to send messages by any available means: by foot, by horses, by ships, fire signals, sound signals (bells, canons, …), etc. It shaped large portions of the economy and, of course, via the technical developments, long-range planning that could seem futile today. For instance, raising great quantities of trees for the fire signals in the light houses (semaphores) or for having very straight and long tree trunks for the ship masts.

Communication! Leo Tolstoy asked the question "What is art?", replied "Art is communication." But what was a more essential problem then?

Time! Time is the Answer

Time for sending, for transmitting. Time because the messages were too long to bear some significance or useful content using those primitives means over long distances. At the end of the 18th century, Claude Chappe (and his brother) invented the earlier version of the telegraph (they called it so). That was optical (semaphore) and worked only during the day and in clear air. But it was the beginning of yet another IEEE core: coding or in this case, transcoding the alphabet and the 10 digits. The system was delivering short messages, on land or near the coast, as fast as 500 km/h (about 140 m/s, much faster than any horse). And in the first half of the 19th century two main "discoveries" took place: electricity sent through a copper wire in 1837 and the Morse code in 1838 (replacing the more complicated Chappe code). That achievement was nevertheless only used for terrestrial transmissions.

The media industry was delighted: fresh news (and not fake news …). And also, the militaries, of course (war being another matter in which Humankind is very good at). The system was able to deliver 100 words in 5'!

But a much bigger challenge was to bring news to another continent. The Atlantic was the next frontier. The only means then was by ship, meaning two to three weeks to send anything. Within a very short span of time, fantastic developments were achieved. I'm still amazed and marveled by the ability of humankind to adapt solutions. The "obvious" one was to lay a cable between the two continents. The first tests were in the Mediterranean, but the Atlantic Ocean is an order of magnitude larger. The driver was, as often, commercial (money). Investing in submarine cables was much more profitable than in railways for instance. And now, the challenge was there: over 3,500 miles of cable, weighting about 20 tons/mile! Transporting these cables wasn't trivial. Huge boats (100 to 200 meters long) were conceived. I won't detail what is described in the museum behind me. Great Britain was the main leader in the 1860s, with cables from England to Newfoundland and then Cape Cod (Duxbury). The USA weren't yet interested, being in the midst of the secession war. The first cables from the French side weren't a commercial success. A company, by the way mainly funded by British capital, installed a cable from Brest to St Pierre et Miquelon, near Newfoundland and Cape Cod again.

In any case we were entering a new era. The first cables showed this by being able to send around 20 words per minute. The world started to shrink! Of course, big countries

The French cable Station Museum.

Keynote address from René Garello.

Cathy Ann Clark, Providence Section Chair.

Jim Jefferies, IEEE President.

René Garello, IEEE OES Junior Past President.

Group picture, René Garello, Michael Geselowitz, Jim Jefferies, Cathy Ann Clark, Joseph Mana, Rob Munier and Ron Brown (L to R).

Jim Jefferies, unveiling the plaque.

Ceremony Celebrates Communication Link Between France And Cape Cod

couldn't be satisfied by a British monopoly. Hence the other driver for the "submarine cables" was political. That is the main reason behind the support of what we are here today to celebrate; the "Le Direct" Transatlantic cable. Indeed, the indirect paths via Newfoundland weren't secure enough, were difficult to maintain and mainly operated through Great Britain. "Le Direct" proved its efficiency by being operated for many decades before being obsolete in the mid '50s with the new co-axial cable technologies allowing more simultaneous messages (telex, telephone) to be sent. "Le Direct" was a success and for what concerns France a model, duplicated to other important places at this time, that is the African continent and the French colonies.

French Cable Station wins achievement award

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In closing, what is the status today? The former copper in the cables was replaced mainly by fiber optics. Most of our digital communications are nowadays still using cables. Over 99% of the traffic is underwater with above 300 cables totaling one million kilometers of cable and dozens of cable ships. So, yes, recognizing the "Le Direct" cable as a pioneer for bringing the world to a new stage is evident. And recognizing it as an IEEE milestone is more than natural: "Advancing technology for Humanity" is exactly what "Le Direct" did.

Thank you for your attention.

1) Jim Jefferies, IEEE President & CEO

From Cape Cod Chronicle, September 13, 2018

The European Robotics League (ERL) Emergency 2018

Gabriele Ferri[1], Fausto Ferreira[2]
[1]ERL Emergency 2018 Director [2]ERL Emergency 2018 Deputy Director

The European Robotics League (ERL) Emergency Robots is an outdoor robotics competition funded by the European Union in the framework of the SciRoc H2020 Project. After the success of RockEU2 project (2016-2018) and the launch of ERL in three vibrant fields of robotics: industrial, service and emergency robots, SciRoc project extends the ERL concept to Smart Cities environment.

NATO-STO Centre for Maritime Research and Experimentation (CMRE) has been organizing Student AUV Challenge—Europe (SAUC-E), the premier European student competition for underwater vehicles, since 2011. SAUC-E allowed CMRE to be part of the euRathlon EU project in which CMRE organized the first world's multi-domain (air, sea, land) robotics competition in 2015, the euRathlon 2015 Grand Challenge, which was inspired by the Fukushima 2011 accident. Following the success of last year's ERL Emergency 2017 competition, which was organized by CMRE in Piombino (Italy), the Centre was once again privileged to host this year's land + marine competition in La Spezia at CMRE's premises.

The Competition

CMRE hosted the annual European Robotics League (ERL)-Emergency 2018 robotics competition from 14 to 20 July. It was a double domain competition where land robots and AUVs could participate. This year competition was based on a Yacht accident in a harbour connecting it to the general theme of the SciRoc project: Smart Cities. This materialized in tasks similar to those presented in ERL Emergency 2017 such as underwater structure inspection, passing though validation gates and searching for a missing person underwater, represented by a realistic mannequin. This year we added obstacle detection and avoidance and detection of a wall damage (represented by a marker) for what regards the marine domain. The land domain had also some novelties and the scenario was as challenging as in Piombino according to teams' feedback.

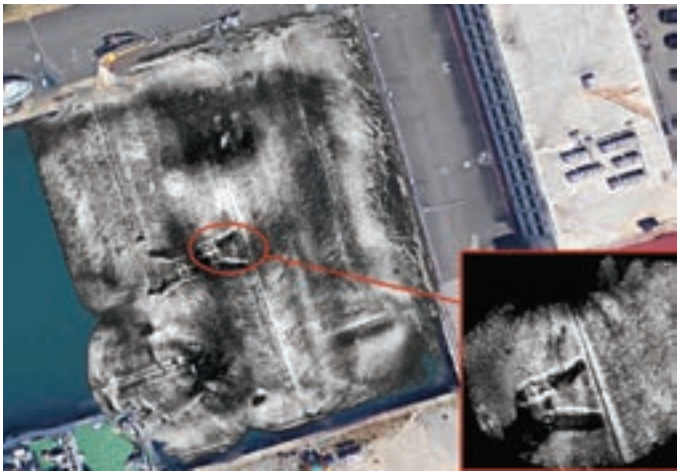


Figure 1. Sonar mosaic of ERL Emergency 2018 Arena. Underwater structure highlighted. Courtesy of UNIFI Team [1].

As in the previous SAUC-E editions, the challenges were held at the CMRE waterfront sea basin, which is a sheltered harbor that offers participants the opportunity to handle real-life sea conditions, including limited visibility and salty water, but within a safe, controlled environment. The limited visibility added severe difficulties to object recognition by AUVs, even if the targets were bright orange or red in colour.

Nonetheless, several teams were able to tackle the tasks, mostly achieving their goals. Unfortunately, one of the teams had a major hardware fault (DVL) that could not be debugged even by the manufacturer in remote support. Out of the 4 marine teams registered, all tested their vehicles in the water. One of the teams, due to their limited experience could not accomplish much but they did learn a lot and improved their vehicle considerably. This is part of the mission of this competition: serving as a hands-on learning experience for less experienced teams. These teams might have rare access to the water and attending a challenging competition in real world conditions is an excellent opportunity to learn and validate their vehicles.

One of the interesting things we have noticed is the evolution of the teams over the past years. We have seen significant and steady progress from year to year in several teams. For instance, AUV Team TomKyle managed to run their AUV even after the major hardware fault. The robustness that they have shown comes from 5 years of experience in robotics competitions. The winning UNIFI Team has shown resilience since in ERL Emergency 2017 their vehicle had a major leak and sank leading to a revamped vehicle in 2018. Not only, they have improved their sonar processing, machine learning techniques and acoustic communication capabilities. An example of their sonar mosaic of the competition arena obtained with the FeelHippo AUV is shown in Figure 1. The below figure is obtained from [1], a paper published at IEEE OES AUV'2018 Symposium based on the results of the ERL Emergency 2018 competition. This is the kind of impact we wish to have in the community where the advancement of state of the art through competitions is then shared through scientific papers.

The Participant Teams

This year we had to limit the number of teams to 8 teams (4 land and 4 sea) due to the logistics involved for a double domain

Figure 2. The winners of ERL Emergency 2018 with CMRE's Director, Gabriele Ferri and Fausto Ferreira.

competition in the La Spezia site. Due to last minute drop-outs, we had 6 teams (4 sea and 2 land) of which one had two domains. Of these, 5 had previously participated in our competitions, showing how ERL/SAUC-E is today a fixed appointment for several European research groups. Moreover, one of the teams had been away from the competition for 2 years and came back this year, which highlights that the competition can be a strong stimulus for research groups to continue working on underwater vehicle technology.

Figure 3. The Organizing Committee receives the plaque from Dr. Bill Kirkwood.

Figure 4. The Judging Team with CMRE's Director and CMRE Staff.

As we did for the past four years, CMRE was able to loan, without charge, one AUV robotic kit to be given to a team. As in ERL Emergency 2017, the robotic kit was the basic version of a SPARUS II AUV with a DVL. This initiative aims to expand the number of teams by providing a selected team a sort of "jump start", since building an underwater robot is not a trivial task, and to promote rapid development and innovation. This year the chosen team was Fuerteventura BD Robotics. This team had some past experience with this robot. This year the team had very little time to practice with the robot and integrate the payload, which reflected in the performance. The SPARUS II is a success story of the past years of competitions. The platform was designed and produced based on the experience matured in previous editions and is currently commercialized by a spin-off of the University of Girona. This is the kind of technology transfer that we would like to encourage as an output of robotics competitions.

The Participant Teams Were:

1) AUV Team Tom Kyle (Germany); from the University of Applied Sciences of Kiel. This team has participated since 2014 yearly in our competitions. Typically a marine team, this year, due to last minute issues with their land partner, they brought their own small land vehicle.
2) Fuerteventura BD Robotics (Spain); from the company Black Display Robotics in Fuerteventura, Canary Islands, Spain. This was their first participation, although part of the team members participated previously as participants in other teams.
3) MSAS (Mobile Spatial Assistance System); the land MSAS land team comes from NASK company in Poland. First participation as MSAS but the same vehicle and part of the team participated previously in 2015 and 2017.
4) Team Bath Marine Drones; from the University of Bath, UK. This team participated for the first time showing that the competition continues to attract new teams.

5) UNIFI Team; from the University of Florence (Italy). A veteran of our competitions (first participation in 2012).

The Winners

The winners of the ERL Emergency 2018 sea + land Tournament were:

- 1st Place - UNIFI Robotics Team + MSAS
- 2nd Place - AUV Team TomKyle

Other prizes awarded were:

- "Creativity Award – land team" – AUV Team TomKyle,
- "Best Rookie Award" – Team Bath Drones Marine,
- "Best Marine Team Award" – UNIFI Robotics Team,
- "Best Fair Play Award" – AUV Team TomKyle,
- "Persistency Award" – Fuerteventura BD Robotics,
- "Resilience Award" – AUV Team TomKyle.

The Judges

This year we had a large pool of judges coming from all over Europe and the U.S. We are pleased to thank AUVSI, IEEE OES, CNR-INM, Jacobs University, Polytechnic University of Le Marche, University of Padova, University of the West of England and the University of Zagreb, who provided exceptionally qualified judges, increasing the quality of the competition. Dr. Bill Kirkwood also presented a plaque in appreciation for the organisation of the competition to the local organizing committee.

Sponsors

IEEE OES played a fundamental role as the Main Sponsor. One of the ERL goals is to educate future multi-disciplinary engineers. Therefore, the sponsorship of 'Breaking the Surface' 2018, the 10th Interdisciplinary Field Workshop of Marine Robotics and Applications, is well aligned with our mission. The organizers of 'Breaking the Surface' provided 2 complimentary registrations to the best rookie team and 2 to the land team that won the creativity award, allowing 4 students to participate in the 10 years edition of this multi-disciplinary and educational workshop.

We also engaged with the marine robotics commercial sector, with Blue Robotics that offered three vouchers for their online shop to the teams that won the Resilience award, the Persistency award and the Best Marine Team award. This will help these teams to improve their vehicles for the next editions.

Our aim is to continue to develop ERL Emergency as a unique event that challenges teams with realistic conditions, with an emphasis on multi-vehicle cooperation (through double and three-main competitions). These achievements were made possible thanks to the fundamental support of IEEE OES and all our other sponsors. We thank all the teams, judges, exhibitors, visitors and everyone involved, who made ERL Emergency 2018 such as a successful event.

Next year, we will have two ERL Emergency events: one dedicated to land and aerial robots and one for marine and land robots as in 2018.

Reference

[1] Matteo Franchi, Alessandro Ridolfi, Leonardo Zacchini, "A Forward-Looking Sonar-Based System for Underwater Mosaicing and Acoustic Odometry", 2018 IEEE OES Autonomous Underwater Vehicle Symposium (AUV 2018), Porto, Portugal.

Who's who in the OES

M. A. Atmanand (Atma), OES AdCom member

Hello. My name, Atmanand, sounds unique for any one not from India. The meaning is: "Atma" means "soul" and "Anand" means "happiness." You may call me Atma for short. I am not sure if I am always happy, true to my name!

I was born in the town of Palakkad in the south west part of peninsular India. I did my schooling and college education in the region, the state called Kerala, which is nowadays mentioned as "God's own country" by the tourism industry. I moved to the south east of India to pursue my Masters and PhD degrees. My initial career was at Fluid Control Research Institute, where I had interactions with many United Nations experts from abroad in setting up the Laboratories for flow measurement and control. This was the place from where I really got practical experience after completing my University education. I then moved on to the National Institute of Ocean Technology (NIOT), in 1997, which was established in 1993. I was one of the few engineers who joined the Institute in the initial formative years. Here my initial period was

Wave energy plant at Vizhinjam in south west of India

on commissioning of wave energy turbine at a platform created for this purpose at Vizhinjam in Kerala, which is in the south west coast of India. I could really participate in the commissioning of the impulse turbine with flipping vanes. This was commissioned in 1997 under my supervision on the caisson which had the motion of waves converted to air movement. It was a marvelous sight to see the flipping of vanes according to the wave motion. The conversion of waves to power was established and a lot of data was collected from this plant.

Soon I moved to the area of deep-sea technologies, which was being formed at the Institute. My work started with designing the electrical, instrumentation and control system for an underwater mining machine, along with our German collaborators from University of Siegen. After completing the work, sea trials were done from on board the Ocean Research Vessel (ORV) Sagar Kanya. The task was stupendous in that almost none of us in the team were experienced in handling such operations those days, including our German colleagues. While launching the crawler, weighing nearly 10 tonnes in air, was attempted without a proper handling system and Dynamically positioning (DP) system on the ship, it made the crawler move in an uncontrolled manner, which eventually lead to parting of the cable and we lost the crawler. Luckily, it was shallow at that location and we managed to salvage the same within about 10 to 15 days. We had to spend many months in rectifying the problems and got back to the sea again with a crude type of dynamic positioning using tugs and boats to keep the vessel in place. This too was risky and we managed later to have a proper launching system and DP system on board the ship Sagar Kanya. With this in place we could do the launching and retrieval of the crawler properly and do sand mining at a depth of 500m. After we completed the sand mining trials, we modified the crawler with collector and crusher to collect and crush nodules. As there were no nodules at depths of 500 m, artificial nodules, having same property of original nodules, were prepared, laid on the sea bed and mined to the surface.

One of the other important projects, which was successfully executed, was the design and development of an in-situ soil property measurement system. It is necessary to measure the property of the seabed in-situ, as you know, sea bed property changes when it is taken out from its nascent state and then tested. So, it is necessary to measure the main properties, namely bearing strength and shear strength, in-situ. Bearing strength is measured by means of a cone penetrometer, which is conventionally used by civil engineers, and the shear strength is also measured using a cone penetrometer. The most important aspect is that the bearing strength values are small and it has to be measured when the ambient pressure is about 600 bar at 6000 m water depth. We had the assistance from a company Sevmorjeo from Russia with whom we developed the system. It was calibrated inland and the integrated system was taken to Central Indian Ocean Basin (CIOB) on board ORV Sagar Kanya. The system was launched using a cable, which carried the entire weight of the system. Power was provided using the same cable at high

Pretrial preparations of underwater crawler on board Sagar Kanya

Sea trial of In-situ soil tester in the Central Indian Ocean Basin

Tense moments on board Sagar Kanya when the soil tester is underwater

After successful completion of sea trails of In-situ soil tester at the Central Indian Ocean Basin

On my left is my wife Anitha and on my right is our son Achyuth at the Mughal gardens in Srinagar, India

voltage and a fiber optic line deep inside was used for data transmission for instrumentation and control. The system was successfully tested at a depth of more than 5000 meters. This was done for the first time in India and I was happy that I could lead the team and get the project done successfully.

During this cruise, we had to cross the equator and go to the southern hemisphere. During those days, passing the equator used to be a great event, and there used to be a sort of fun program for first timers after which the captain issues a certificate indicating that the Lord of the seas is pleased to allow us to cross over the equator. I was trying hard to locate the certificate, which is of a jocular nature, so that all of you could enjoy it. Unfortunately I was not in a position to track it from my old records. Some of the pictures taken during the cruises are provided here.

I had the good fortune of sailing on the Sagar Kanya, Sagar Manjusha, Siderenko, Boris Petrov, etc., for various projects. On Sagar Kanya I had sailed as team member and as Chief Scientist. Apart from the technical work on board the ship, I had the good fortune to enjoy the beautiful skies with its moonlight during the Full Moon Nights and the beautiful sunrise and moonrise with unpolluted air.

The work continued and multiple systems were designed and developed and tested successfully for the past many years. The success of all these gave me more responsibilities and I took over as the Director of Institute in October 2009 and continued to be in that position for more than five and a half years. After this, activities like preparing a vision document for the institute and also activities related to the Intergovernmental Oceanographic Commission (IOC) of UNESCO were taken up. In the month of February, 2018, I once again took over as the Director of the Institute for a second term and am currently pushing hard for the large projects of manned submersible, deep sea mining, ocean energy, etc.

On the personal front, I was immensely supported by my wife Anitha and son Achyuth. My family really did not grumble when I used to go for long cruises leaving everything to be taken care of at home. My son was seeing me going on cruises and doing lots of technical work, which perhaps turned his attention to engineering. He completed his bachelor's degree from India and master's degree from France and is currently working in Paris. Our family photo, taken during one of our family vacations, is shown below.

Member Highlights

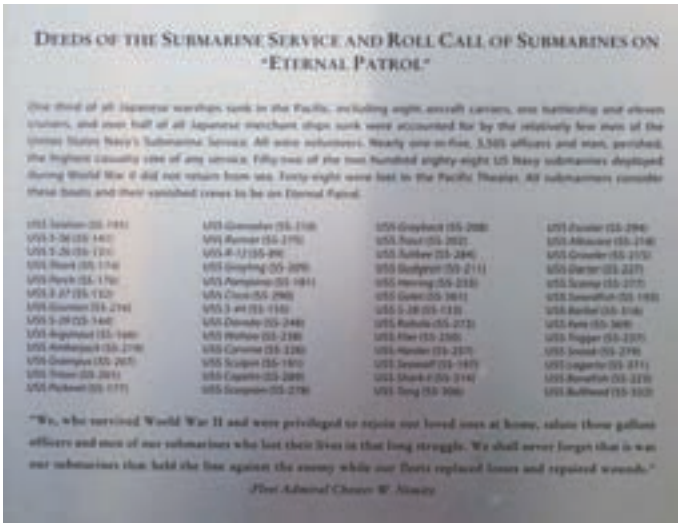
Tamaki Ura, IEEE Fellow

On the way back from OCEANS 2018 Charleston, I visited the National museum of the Pacific War in Fredericksburg, Texas, mainly for looking at the birthplace of Freet Admiral Nimitz and studying the American view of the Pacific War. I stayed at the museum all day through.

I and my team found the wreck of 14,000-ton passenger ship "Taiyo Maru" which was sunk in 1942 in the East China Sea by the torpedoes from USS Grenadier (SS-210) resulting in 817 lives loss, at 140 meters in depth in August two months ago. Grenadier surrendered and sank at the Malacca Strait in 1943. The name of Grenadier was in the middle of "Deeds and Roll Call" written by Nimitz.

The Japanese garden which was designed as a replica of the private garden of Gensui The Marquis Togo, the main Imperial Japanese Navy commander, is attached to the museum. Its title is "The Garden of Peace". In the dry land of Texas, the garden produces a singular point, but I felt Nimitz' deep understanding of Japan.

The Garden of Peace.



Deeds and Roll Call.

Japanese Garden.

OES Thanks Outgoing AdCom and ExCom Members

Each year at the North American OCEANS conference, this year it was OCEANS 2018 Charleston, the OES thanks the outgoing members of the Administrative and Executive Committees for their time and support as volunteers. This year we thanked the following for their service to the society:

Administrative Committee:
- John Potter
- Ken Takagi
- John Watson
- Thomas Wiener

Executive Committee:
- Marinna Martini—Secretary, 2015-2018
- Diane DiMassa—VP for OCEANS, 2015-2018

Incoming Executive Committee Members

Also at OCEANS 2018 Charleston was the election of officers to fill the upcoming openings on the Executive Committee. Those elected to continue in their present positions include:

President—Christian de Moustier
VP for Technical Activities—Malcolm Heron

Newly elected officers include:

VP of OCEANS—John Watson
Secretary—Stephen Wood

Congratulations and thanks to all of our outgoing, continuing and newly elected officers.

René Garello, Junior Past President presents plaque to John Potter.

Chris de Moustier presents plaques to Ken Takagi, John Watson, Diane DiMassa, Marinna Martini.

Welcome New and Reinstated Members

Argentina
Eduardo Matias Robador

Australia
Geoff Page
Kevin Munguia

Canada
Ian Church
Dylan James Bastin-Decoste
Nathan Werner Louis Ehrenholz
Nathan Hood
Surinder Singh

China
Hou Chaohuan
Daiwei Li
Wei Li
Yi Sun
Rui Yang
Shaolong Yang
Caoyang Yu
Siyu Yu
Qin Zhang
Yuxin Zhao
Haiyong Zheng

Croatia
Anja Babic
Nadir Kapetanovic
Igor Kvasic
Ivan Loncar

Ecuador
Keysi Dayana Aguilera Mero
Barbara Arbanas
Cesar Andres Enderica
Kleber David Arcentales Huayamabe
Jeniffer Arian Mero Romero
Ivette Marisol Chiquito Noboa
Dayanna Andre Zambrano Sanmartin

France
Jack Sauvage

Germany
Celeste Mason

India
Subramanian An
Mahadev Shiva Bhat
Atul Chaudhary
Jawahar K
Preethi K
Arun M
Rishabh Alpeshkumar Mewada
Jay Parag Parikh
Abirami R P
Anishka S
Malathi S
Janani S V
Sundar Vallam
Anup Vittal

Japan
Hiroyasu Kifune
Masashi Mochizuki
Shuhei Nishida

Korea (South)
Byeongjin Kim
Jason Kim

Norway
Robin T Bye

Peru
Juan C Cutipa Luque

Romania
Victorita C. Radulescu

Saudi Arabia
Andrew Mahon

Singapore
Rui Gao
Phillip Thomas
Liang Jie Wong

Sweden
Sriharsha Bhat
Clemens Deutsch
Christin Rhen
Ivan Nils Stenius

United Kingdom
Yigit Kemal Demirel
Christos Gkerekos
Olena Karpenko
Anthony Lindley
Alan J Hunter
Michael Hosseini
Sofia Koukoura
Alessandro Marino
Vasiliki Pasia
Gregory Payne
Yi Sheng Tan
Dogancan Uzun

USA
Randell K Ashford
Neil M Blecherman
Benjamin Sinclair Bloss
Courtney Bouchard
Mustafa Kemal Cambazoglu
Charlotte Debossu
Steve Dewitt
Samuel Glasscock
Arundhoti Ghatak-Roy
Jeny Victoria Hehir
Joseph D Hersey
Laura Elizabeth Hode
Byron R Hohrein
Stephan Howden
Eduardo Alexander Iscar Ruland
Amirkhosro Kazemi
James Kinsey
Yanjun Li
Joshua Anglin Mashewske
Robert J Mccummins
Chris Menchaca
Todd K Miller
Douglas Moreman
Uchenna Nwankwo
Jamie O'brien
Timothy David Pennington
Mark Quenneville
Martin C Renken
Robert Rutherford
Joanna Slawinska
Rick Spinrad
Kevin Sprenger
Jason Rudzinsky
Grant Webb
Aaron Wheeler

A Warm Greeting to the IEEE/OES Team from those that are Part of the IEEE/OES Student Chapter of the Escuela Superior Politécnica del Litoral "ESPOL"

Karen Aguirre, Current Chair/President of the first IEEE/OES Chapter in Ecuador and an Oceanographic Engineering student

Let Me Tell You a Little Bit About Our Chapter and How it Began

About a year ago I had the opportunity to obtain a scholarship for traveling to Rio Acoustics Symposium and present a project that I developed with our actual advisor and teacher, whose proposal was to implement a low-cost bathymetry system for easy access to teachers and researchers. During the symposium I experienced great things and met incredible people like Jean Pierre Hermand, who would immediately become our IEEE/OES-ESPOL mentor. During the symposium development I could see the world from a different perspective, with a point of view of a researcher. I truly believe that my partners are potential researchers, they are brilliant, however, Ecuador is a country where the research area in marine sciences is underdeveloped, nonetheless, far from being an obstacle, this was a huge motivation to create the initiative to guide the Ecuadorian youth in different areas of marine research. This was the beginning of my idea to create an OES student chapter in my university. I had the aim that my partners would have the same opportunity of sharing their ideas to the world and of being part of the greatest and important worldwide organization of engineers.

First Official Photo of IEEE/OES-ESPOL student chapter with the local authorities form ESPOL. The chapter was officially created on November 2nd, 2017 with 8 members.

Jean Pierre was Always Very Aware of our Growth and Projects. Following is an Article Published in the OES Beacon Newsletter

"Following Ecuadorian student Karen Aguirre's participation, an OES Student Branch Chapter was recently formed at the Escuela Superior Politécnica del Litoral—ESPOL, Guayaquil. Karen wrote "One of the main objectives when entering the university is to be part of something big and if possible, to found that big thing. Thanks to my teacher and tutor, I had the opportunity to know about IEEE. Later, while we were working on an acoustic project, the call to participate in the RIO Acoustics symposium came to our hands. Thanks to our effort and the support of the organizers of the event, we obtained one of the nine twelve scholarships for Latin American students. When I arrived in Brazil and observed the magnitude of the event organized by IEEE/OES, I knew that my goal was to be part of IEEE/OES, but I also felt that I should share this experience with my colleagues and professors in Ecuador. That is why the idea of creating our chapter was born, where everyone can access the sea of opportunities and benefits offered by IEEE and OES, enter the world of ocean engineering society and contribute with new ideas and projects from the researcher profile. Our current goal is to continue integrating members into the IEEE/OES family and open the doors to a host of new experiences and opportunities that will enrich our professional life."" (Hermand, 2017)

Published photo in OES Beacon, DECEMBER 2017, Volume 6, Number 4.

A spinoff of RIO Acoustics 2017: The OES-ESPOL Student Branch Chapter in Ecuador.

Our First Event as a Chapter was a Basic AutoCad Course for the Design of Ocean Structures

During the month of May, we organized a meeting with WIE, IEEE and the Georgia Institute of Technology representatives in

AutoCad course.

AutoCad course Closing.

Meeting with WIE and IEEE in Atlanta, Georgia.

Weekly meeting of OES student chapter.

Meeting with Jean Pierre Hermand, Arthur Ayres Neto and ESPOL authorities.

Flyer First Congress "Ocean Technology."

Atlanta, where, with our IEEE/OES-ESPOL past president, we had the chance to interchange ideas, experiences and to plan future projects together.

This year we are honored to have 20 members and volunteers, which represents double the number when we began.

As a student chapter, it is of vital importance to participate and attend scientific congresses, being part of them, and exchange ideas and experiences with long-term researchers. Due to that, and thanks to our continuous communication with Jean Pierre, professor Arthur Ayres Neto and him decided to come and visit us for the planification of future projects, as the Rio Acoustics Symposium in Ecuador and student exchanges for being part of their international projects. Also, we were honored to organize the FIRST CONGRESS OCEAN TECHNOLOGY, taking place on September 1st, 2018; where Jean Pierre Hermand and Arthur Ayres Neto were our main lecturers.

Due to our recent creation, and that this event was the first one of this magnitude, we attend a considerable number of assistants, but the acceptance was so great, that we had to manage a bigger auditorium that could afford the increased attendance. Finally, we had 120 assistants divided in: 80 students, 30 professionals, 10 representatives of the main marine science organizations and ESPOL authorities. During the event, 10 distinguished national and international lecturers joined us (Belgium, Brazil, Japan, Ecuador and Venezuela) who developed several topics related to marine science and technology, such as underwater robotic, aquiculture, marine ecosystem remediation, bathymetry using satellites, and other interesting topics. With that, we gave our students a vast panorama to help their initiative in any of the oceanic engineering fields and where they had the most interest. The congress began September 1st, 2018 at 0900 and finished at 1700 the same day. Each lecturer had a period of 45 minutes for the exposition, meanwhile, we gave a space for doing networking between the assistants and the lecturers; in this way they could exchange their ideas and propose projects to work with. Finally, an assistance certificate was given to lecturers and assistants.

Our big family OES/IEEE.

Is important to remark that the event was organized in only three weeks of anticipation, because it was difficult to get some details of Jean Pierre and Arthur's visit. Also, it was the last event of the semester. That was the reason it was planned for one day after the students went on vacation; with this inconvenience we decided to transmit the event in the social networks. That allowed those who couldn't participate to at least see the event and ask some questions to the lecturers. This was a total success because we reached more than one thousand visits during the transmission.

Our Project proposal, for the contest in social network, is to reach the attention of new members and volunteers that are related with the academy, science and oceanic engineering. For that we will keep doing contests, workshops, technical visits and congresses; with these they will become more and more interested in participating and being part of our student chapter.

Underwater Robot Convention in JAMSTEC 2018 — from an Educational Perspective

Hirokazu Yamagata and Toshihiro Maki (The University of Tokyo)

1. Introduction

Underwater Robot Convention in JAMSTEC 2018 was held at JAMSTEC (Japan Agency for Marine-Earth Science and Technology) on 25-26th August 2018. The event has been held annually since 2007, and there are three classes: AUV, Free, and Junior. AUV Class was not held in this year because it was held at the underwater robot competition in OCEANS'18 / Techno-Ocean 2018 Kobe (OTO'18).

This report provides an overview of the event including the regulations, trends of robots, and results from the viewpoint of education.

2. Free Class

In the free class, teams compete for the originality of their robot. The free class has two roles. One is acceptance of ideas that cannot be evaluated by the AUV class, and the other is a 'next goal' for teams participated in the junior class described later. So, there are not strict limitations on the robots and many unique robots have been created by various teams up to now.

Evaluation of the teams is based on the total of weight points, presentation points, and competition points:

(1) Weight Points 20 pt.
(2) Presentation Points 40 pt.
(3) Competition Points 40 pt.

For a combined total score of 100 points.

(1) Weight Points

The score is determined by a dry weight of the robot as shown in Table 1.

Table 1. List of the weight point.

Weight [kg]	Point
Under 20 kg	20
20 kg or more and less than 30 kg	15
30 kg or more and less than 40 kg	10
40 kg or more and less than 50 kg	5
50 kg or more	0

(2) Presentation Points

The teams are requested to explain about their robot by a handout (A4 1 page) and 5 minutes presentation and discussions. Presentation points are given based on the quality of the presentation, handout, technical details, and originalities.

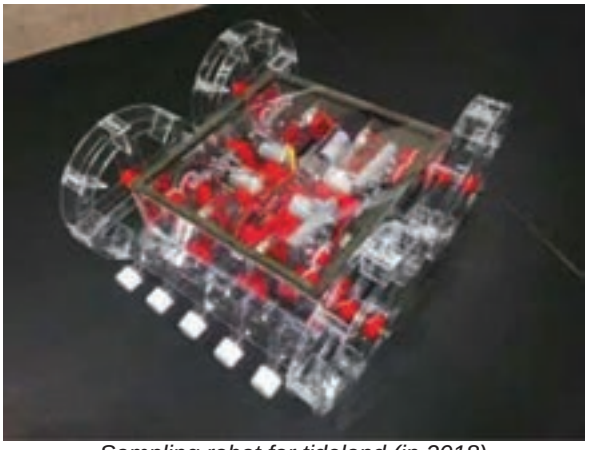
(3) Competition Points

The competition points are scored by a 5 minute demonstration at the pool. There are two chances of demonstration for each team. Evaluation focuses on the quality of performance, technological level, and ideas.

In 2018, the sampling robot for tideland (by "Tidal Robot Production Team" from Tokyo Institute of Technology 12th Phase Machinery Department) won first prize. It is designed to run about 4 hours and get a mud sample, measure location and temperature of the tideland. High school students have made this robot and operated it. (Fig.1)

There have been a lot of unique robots in previous years, including a penguin robot, an anomalocaris robot, an archerfish robot, and a robot that supplies drinking water to divers (see Fig. 1). In 2016, Octopus shaped ROV called Sakasatako" (by Oyama College of Technology "Sakasatako" Development Team) won first prize. The name of the robot comes from a homophony of "Sakasa" as an upside down and "Kasa" as an umbrella in Japanese. "Tako" means an octopus in Japanese. Actually, the robot has an umbrella. This robot moves by closing the umbrella.

In past years, there used to be many robots that could not move at all in the water. However, owing to recent development of ready-made products such as a brushless motor, waterproof RC servo, waterproof box, motor part of a fuel pump, increasing number of teams can build more reliable robots and various ideas come true, reaching Cambrian.



Sampling robot for tideland (in 2018)

Octopus Robot "Sakasatako" (in 2016)

Penguin Robot "Morupen" (in 2014)

Figure 1. Robots that entered the free class.

3. Junior Class

3.1 Educational Target and Schedule

The junior class is for junior high, high school and technical college students. In other words, this class is for young people who are aged 13 to 20 years old. This class aims to make the above people interested in the ocean/ocean engineering and to provide STEM (Science, Technology, Engineering, and Mathematics) learning. Considering the learning contents of junior high schools and senior high schools, the static balance of forces was selected as the main learning target. There are three forces on an underwater robot: buoyancy, gravity, and thrust.

The schedule is shown in Fig.2. Each team receives the specially designed ROV kit for free beforehand. They assemble

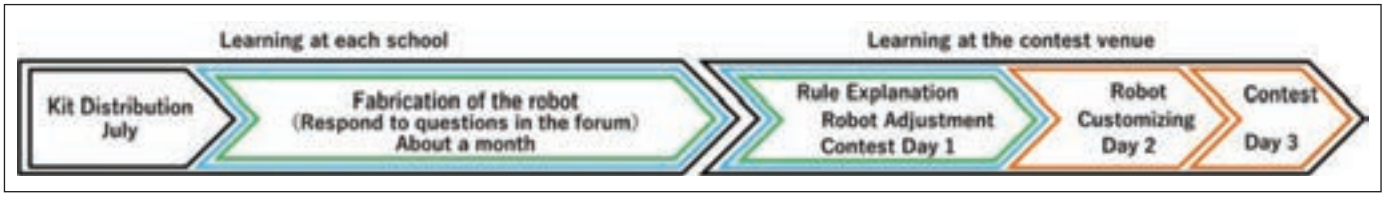


Figure 2. Schedule of the junior class.

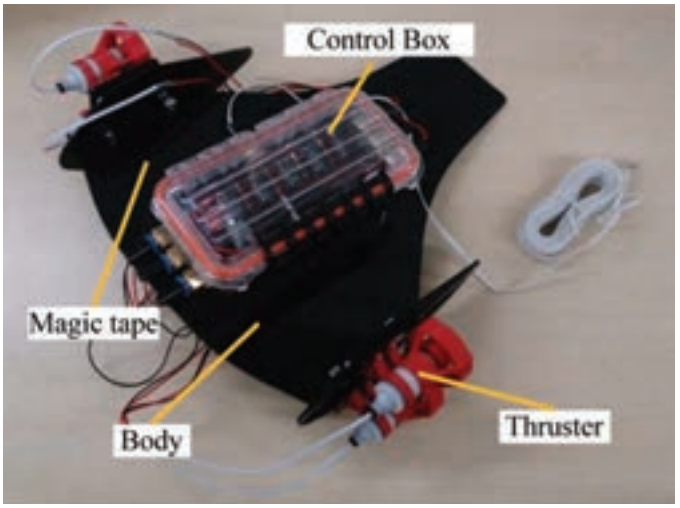


Figure 3. Educational ROV "Mark3".

Table 2. Specification of Educational ROV.

Length	0.40 m
Width	0.40 m
Height	0.17 m
Weight	1.6 kg
Depth rating	5 m
Cost	400 USD (approx.)

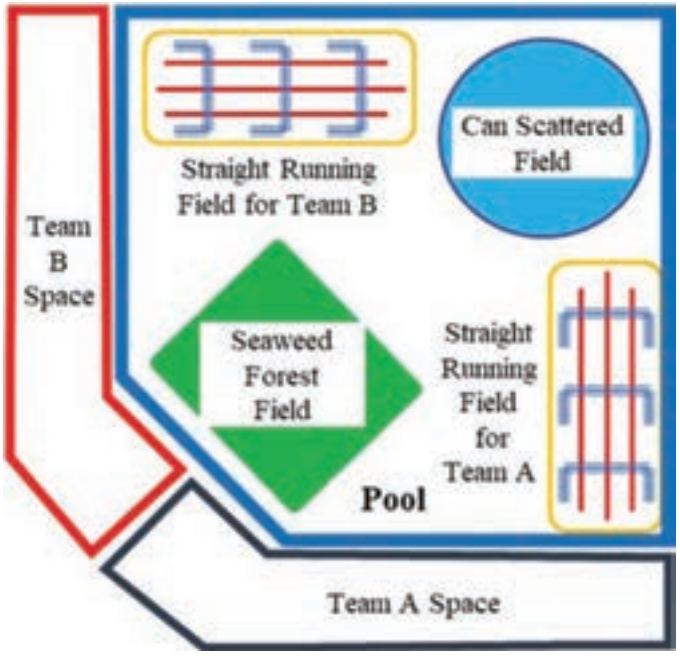


Figure 4. Competition field of the junior class.

and customize the ROV for a month before the competition. While building the kit, they can ask us questions via the website (http://edurov-mark3.com/). All the parts and design data used for the ROV are also available on the website.

3.2 Educational ROV

Educational ROV, an ROV specially designed for education by us, is shown in Fig 3. The flat plate part is the body. Buoyancy materials, thrusters, a control box, cameras, etc. can be fixed in arbitrary position of the body using a magic tape. Weight and size of the ROV is designed to make it easy for students to handle it. Table 2 shows the specifications of the ROV. Because the body and the control box is flat, building is easier than cylindrical parts. In addition, by using the magic tape for fixing parts, it is possible to arrange parts at an arbitrary position and orientation like a block toy, and it has a structure that can be easily adjusted/customized. It is possible for the users to understand the sense of balancing forces through trial and error based on statically thinking.

3.3 Competition Rules

In order to increase educational effect, it is desirable that teams achieve learning goal in a competitive way. We have tested the speedrun type competition at a maze in the past. In this year, although the speedrun type competition seems to be effective, we designed a more competitive game to increase educational effects.

Fig. 4 shows the competition field. The field consists of the three elements of the straight running field, the can scattered field, and the seaweed forest field. The wide variety of the tasks prevent the teams from optimizing their robots in a uniform way. Although optimization to a single goal makes it easier to evaluate the result, it makes it difficult for the teams to learn by self-effort. Furthermore, the skill of the operator will have more weight than the quality of customization, in such situations.

The teams operate the ROV and compete the number of cans they have collected in 5minutes. The cans are placed at the two fields: can scattered field and seaweed forest field. The seaweed forest field is more challenging, and it has higher points for collecting the cans.

• Straight Running Field

Three gates, consisting of two poles, are arranged in a line. Teams can get points by going through each gate. The aim of this field is to evaluate the straight running stability of the robot, which is one of the most fundamental and important characteristics of underwater robots.

• Can Scattered Field

The cans are widely placed at the field. The number of the cans is the same as the seaweed forest field, but their density is half. As the field is far from the start position, and cans are widely distributed, speed of the ROV is more important than controllability, to collect cans at this field.

• Seaweed Forest Field

The field has seaweed like structures made by PP tape and a metal net. PP tape has positive buoyancy and stands upright as shown in Fig.5. It resists when the robot intrudes. By adjusting the density of seaweed, the robot can only approach from the horizontal direction. Compared with the can scattered field, more control accuracy is required. The score for the cans collected at this field is twice as high as it at the can scattered field.

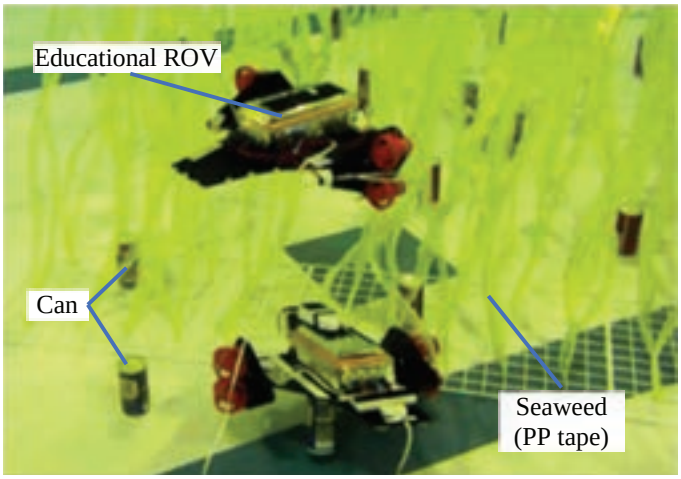


Figure 5. Overview of seaweed forest field.

3.4 Results

The competition took place in three days. In 2018, there were 14 teams from all around Japan, consisting of 4 junior high schools, 8 senior high schools, and 2 technical college. The number of participation teams increased about twice as compared with last year.

The first day was spent for customizing their robots. We helped the teams but avoided showing a direct solution. Instead, we told the teams about FBD (Free Body Diagram) so that they can voluntarily understand the importance of the force balance.

In the second day, we provided a review on the rules and schedule explained in the forum beforehand and made safety education. After that, the teams customized their robots like the first day. Some teams developed tools not to be mounted on their robots, but to support operations such as underwater glasses to check the position of the ROV.

The tournament was held in the third day. As a result, all the teams succeeded in going through all the gates. Many teams challenged the seaweed forest field, and only one team succeeded in collecting cans there. Keio A team (by Keio Shonan Fujisawa Junior & Senior High School) won first prize this year (in 2018 at left, Fig. 6).

As an exhibition match after all games, we held a game with all the teams without the restrict rules (Fig. 7). By announcing about the exhibition in advance, teams lost in an early stage further customized their robots. All the teams succeeded in scoring at the exhibition match.

We conducted a questionnaire to the teams after the event and confirmed that they are satisfied with the competition and the difficulty level of the kit. For example, the difficulty of the kit was evaluated as hard as 2.4/5 on average. The number of people who answered "difficult" has increased from last year. On the other hand, the enjoyment of the tournament is 4.3/5 on average. It can be said that participants enjoyed the competition. From the answers of these questions, it seems that the participants enjoyed the difficult tasks.

3.5 Trends of the Teams

In this section, we discuss about participating teams' understanding of statics and technical aspects from the trend about how the teams customized their ROVs in recent three years. There are three teams participated every year. They improved technical level through continuous participation. For example, cameras were adopted by 35% of the teams in 2018, which only 1 team adopted in 2017. Therefore, the teams who participated in 2018 seem to have studied the ROVs developed in 2017 and 2016.

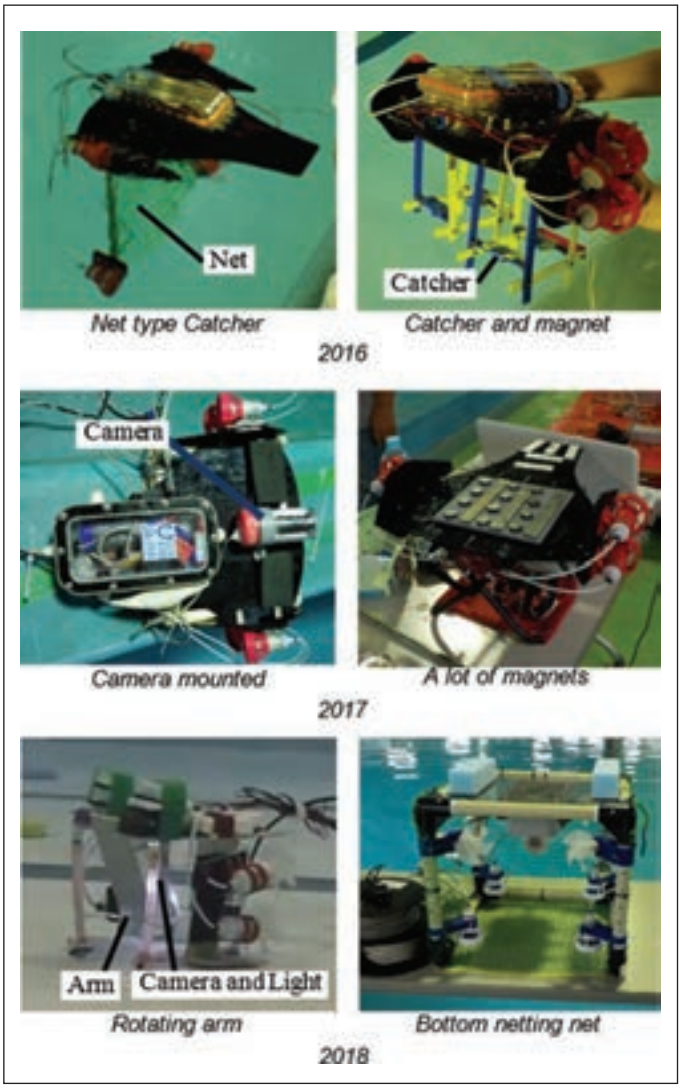


Figure 6. Examples of the robots in junior class.

In 2018, a team attached a rotating arm to their robot as shown in 2016 at left, Fig.6. This ROV ran at the bottom of the pool and collected cans by the arm. In order to realize this behavior, the team adjusted the buoyancy of the ROV. The team seems to have understood that the relationship between buoyancy and center of gravity is important. It seems that this customization was made based on the experience in last years shared among the teams.

In early years, there were some customization that lacked consideration of statics, such as attaching a large net as shown in Fig. 6 (in 2016 at left). However, we observed the teams explaining the reasons for the failure, presenting a new customization plan, and observing its results. For example, the robot in Fig 6 (in 2016 at left) can catch a can at near the center of

gravity of the robot using the catcher with a magnet. Furthermore, this customization does not degrade mobility of the robot so much.

As only steel cans were used in 2016, catchers using magnets were mainly used. Since 2017, aluminum cans have also been placed. This made some teams to develop robots with a net and robots with combination of net and magnets. Also, bonus points by shooting crab models placed on the floor of the pool contributed to the appearance of a robot with cameras as shown in Fig. 6 (2017 at left and 2018).

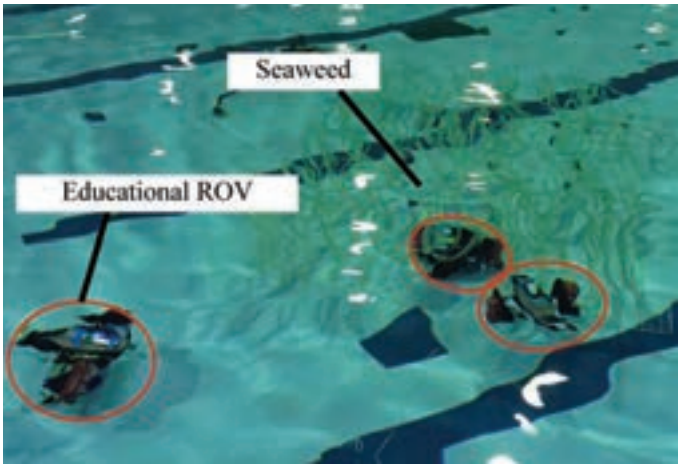


Figure 7. Overview of the exhibition match.

4. Conclusions

Underwater Robot Convention in JAMSTEC 2018 ended successfully. Teams increased in these three years. Through the recent three years, diversity of the robots in the free class has been increased, owing to the improvements of ready-made products. Also, in the junior class, the quality of the robots has been gradually improved, and there is a team that graduated from junior and participated in the free class. We are very glad about that.

We will continue to help people leaning through the experience on underwater robotics.

Acknowledgments

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Group photo of junior class in 2018.

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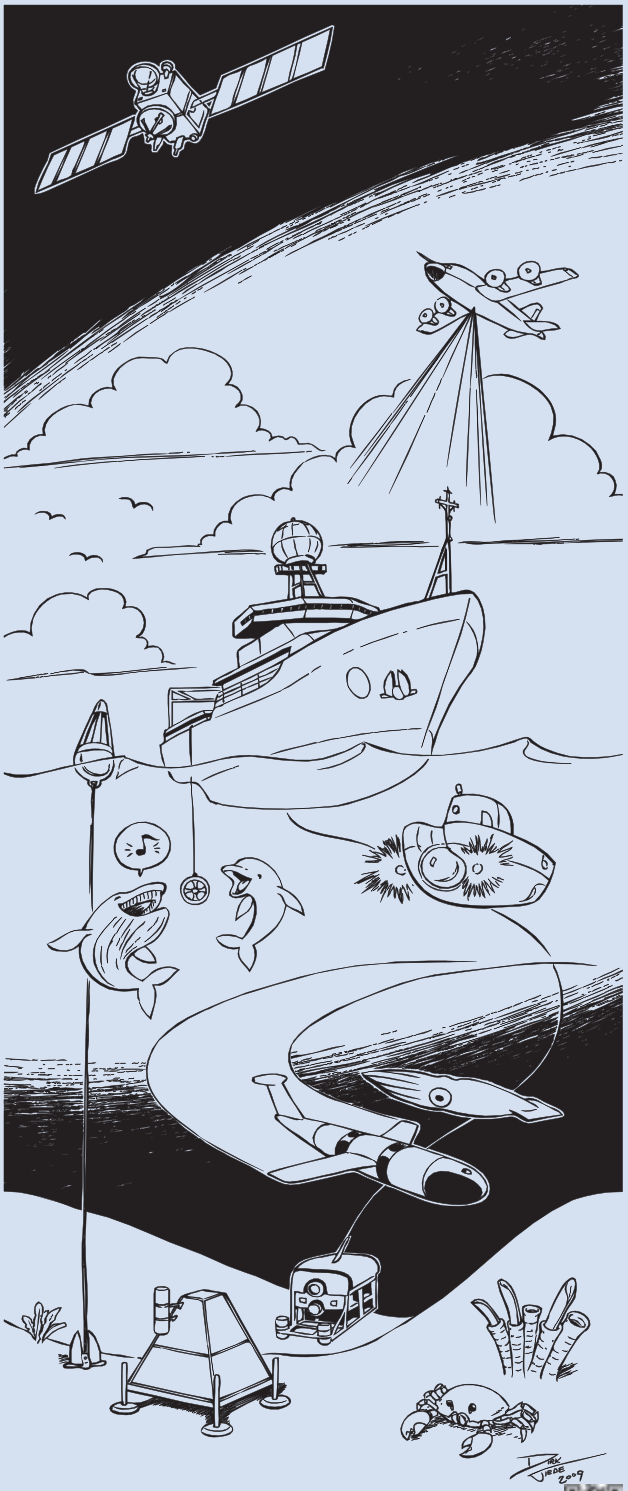

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