

2015 Research Planning Workshop

Transforming Seagoing Science with Robotic Platforms, Innovative Software Engineering, and Data Analytics

Tuesday, August 25th 2015: Day One

8:45 - 9:10 am Welcome & introduction to the workshop

Schmidt Ocean Institute is a seagoing research facility operator focused on advancing marine sciences through *technological innovation* and *open sharing of information*. SOI has no active researchers on staff and relies on the input from independent experts in marine science and technology to advance its research programs. With institutional focus on operational excellence, innovative technologies, and information sharing, this workshop will seek opportunities to refine the SOI program focus, guidelines, and performance metrics in the areas of Perceptive Systems, Intelligent Observing, and Knowledge Interpretation. Opening remarks will also cover the following topics:

- Program and goals of this planning workshop
- SOI strategic interests, R&D focus areas
- Prior workshop recommendations and outcomes
- Recent and planned projects, impact overview
- Innovative technologies at sea: computing, robotics, communications
- Collaborations, partnerships, and student opportunities

9:10 - 9:30 am Briefing: SOI undersea vehicle development program, 4500m ROV

Schmidt Ocean Institute is developing a series of advanced undersea robotic research vehicles for use on RV *Falkor*. The vehicles will support scientific research throughout the full range of ocean depths, including operations at hadal depths, and will provide scientists with access to the deepest parts of the ocean. Our first robotic vehicle will be suitable for operation to a depth of 4500m. Its capabilities will include acquisition of high quality underwater video, scientific data and sample collection, object manipulation, deployment and recovery of instruments, seafloor surveying, and photomosaicing. Scientific data will be collected, post-processed, and shared with the public in formats consistent with the community standards. This ROV will be compatible with emerging telepresence operations and outreach practices, for example, enabling the investigators ashore to virtually participate in research activities involving the vehicle. Its sea acceptance testing is planned for August 2016.

Presenter

David Wotherspoon, HROV Program Manager, **Schmidt Ocean Institute**

9:30 - 10:45 am Plenary session: Perceptive Systems - robotics, sensors, and hardware platforms for ocean science

Session Chair

Dr. Mandar Chitre, head, Acoustic Research Laboratory, **National University of Singapore**

9:30 - 9:55 am Presentation: Sensing with noise

The oceans are filled with various sounds. These sounds are usually a hinderance to acoustic sensing. However, these sounds carry with them valuable information about the ocean environment. In this talk, we explore how ambient noise in the ocean can be used constructively for various sensing applications.

Presenter

Prof. Mandar Chitre, head, Acoustic Research Laboratory, **National University of Singapore**

9:55 - 10:20 am Presentation: The evolution and capabilities of the Sairdrone: a wind powered, autonomous surface vehicle

In just 3 years, the Sairdrone has evolved from a concept into a sophisticated autonomous vehicle carrying an array of atmospheric and oceanographic sensors. A small fleet of vehicles has now undergone arduous testing in some of the harshest conditions on the planet. This presentation explains the evolution, achievements and capabilities of the Sairdrone platform.

Presenter

Mr. Richard Jenkins, founder and CEO, **Sairdrone Inc.**

10:20 - 10:45 am Presentation: ARTEMIS - How to explore Europa

The ARTEMIS autonomous underwater vehicle is being developed by Stone Aerospace under the SIMPLE project funded by NASA's ASTEP program, aiming to develop technologies required for exploration of water bodies on extraterrestrial icy worlds. In October 2015, ARTEMIS will explore under the Ross Ice Shelf in Antarctica. It will be deployed through a borehole in the sea ice next to the shelf, transit under the shelf performing up- and down-look bathymetry, biogeochemical sensing, and water sampling before navigating back to a dock under the deployment hole. In addition ARTEMIS will extend a science arm to contact and scan into the ice ceiling above, looking for biological signatures in this remote environment.

Presenter

Dr. Kristof Richmond, design team & software lead, **Stone Aerospace, ARTEMIS Project**

11:05 - 12:20 pm Breakout discussions: Emerging opportunities, program guidelines, and success metrics for R&D in oceanographic platforms and sensors

Discussion A1: What new horizons are emerging in ocean sensor technologies and how can they advance seagoing marine science?

Discussion A2: How are autonomous marine robotics transforming operational shipboard research?

Discussion A3: How can seagoing research benefit from the rapid progress in communications and information technologies?

1:20 - 1:50 pm Reports on breakout discussions and resulting recommendations

1:50 - 3:05 pm Plenary session: Intelligent Observing - advanced autonomy, artificial intelligence, multi-agent systems

Session Chair

Prof. Stefan Williams, Australian Centre for Field Robotics, **University of Sydney**

1:50 - 2:15 pm Presentation: Making sense of seafloor images collected by autonomous photo-mapping robots

Photo-mapping AUVs are capable of collecting copious amounts of image data, but the surveys typically involve laborious, manual processing to transform seafloor images into quantitative coverage estimates that are useful for science purposes. As a result of this bottleneck, usually only a tiny subset of pixels in less than 1-2% of the collected images end up being selected for detailed analysis. Furthermore, ensuring the data is analysed in a consistent manner across surveys and organisations as well as managing these huge image datasets poses significant additional challenges. We will present results that utilise supervised machine learning algorithms to assist in analysing benthic image data, and we will also discuss the use of online tools for managing, analysing and querying these large datasets.

Presenter

Dr. Ariell Friedman, postdoctoral research engineer, Australian Centre for Field Robotics, **University of Sydney**

2:15 - 2:40 pm Presentation: Multi-vehicle systems for ocean observation: Are we missing something?

The Underwater Systems and Technologies Laboratory (LSTS) vision for the role of networked vehicle systems in future ocean observation systems is outlined and contrasted to the current practice in deployments of unmanned ocean vehicles. In this vision, networked vehicle systems are composed of physical and computational entities with coupled physical and computational dynamics and compositional dynamic structure. Dynamic structure delivers novel system level properties that cannot be found in the constituent physical and computational entities.

The LSTS vision has matured over the years with the design, construction and operation of unmanned underwater, surface and air vehicles for ocean applications. The LSTS has developed the Light AUV, now in its fifth generation. The LSTS control architecture for networked vehicle systems has off-board and on-board components which are implemented with the open source LSTS Neptus-IMC-Dune software tool chain for mixed-initiative control of unmanned ocean and air vehicles operating in communications challenged environments with support for Disruptive Tolerant Networking protocols. Neptus is a distributed command, control, communications, and intelligence framework for operations with networked vehicles, systems, and human operators. IMC is a communications protocol that defines a common control message set understood by all types of LSTS nodes (vehicles, consoles or sensors) in networked environments, thus

providing for standard coupling of heterogeneous components in terms of data interchange. Dune is the vehicle on-board software. Dune has also been integrated with the deliberative onboard planning system TREX. LSTS has been organizing in cooperation with the Portuguese Navy the international Rapid Environmental Picture (REP) annual exercise to test and evaluate new systems and technologies, to develop new concepts of operation, and to promote inter-operability and long term cooperation.

Presenter

Dr. João Sousa, head, Underwater Systems and Technologies Lab, **University of Porto**

2:40 - 3:05 pm Presentation: Advanced AUV capabilities for inspection and intervention

The talk will summarize the leading research activities of the University of Girona in advanced AUV capabilities for inspection and intervention. Real-time sensor processing is used for mapping, target identification and motion planning, allowing a close inspection of the underwater structures. Hovering AUVs equipped with a manipulator are able to recover a target, turn a valve or plug a connector from different configurations and using different techniques. A review of the work done will be given pointing out future steps for making these new AUVs capabilities available for scientific or industrial applications.

Presenter

Dr. Marc Carreras, associate professor, **University of Girona**

3:05 - 4:20 pm Breakout discussions: Emerging opportunities, program guidelines, and success metrics for R&D in vehicle autonomy and computing algorithms

Discussion B1: How can research ships support data collection at sea in more intelligent ways?

Discussion B2: What emerging oceanographic applications can benefit from the advancement in robotic autonomous vehicles?

Discussion B3: What new technology R&D opportunities emerge with the introduction of multi-agent autonomous and remotely controlled robots?

4:40 - 5:10 pm Reporters from each breakout group present summaries of their findings and recommendations

Wednesday, August 26th 2015: Day Two

8:30 - 8:40 am Day one recap

8:40 - 9:00 am Presentation: Overview of RV Falkor cruises in 2013 - 2015 and science systems upgrades

This presentation will provide an overview of technology-driven cruises supported by Schmidt Ocean Institute's Marine Technician team onboard RV Falkor in 2013 - 2015

and the evolution of technology and platform infrastructure on Falkor to streamline support of science at sea.

Presenter

Leighton Rolley, lead marine technician, R/V Falkor, **Schmidt Ocean Institute**

9:00 - 10:30 am Plenary session: Knowledge Interpretation - data platforms, interactive science, and communications

Session Chair

Dr. Vicki Ferrini, research scientist, Lamont Doherty Earth Observatory, **Columbia University**

9:00 - 9:23 am Presentation: Data stewardship for mobile platforms at Ocean Networks Canada

Ocean Networks Canada (ONC) is responsible for the maintenance and operation of the digital and marine infrastructure across the VENUS, NEPTUNE and Cambridge Bay facilities. ONC collaborated with SOI on R/V Falkor in 2013, collecting data via shipboard systems, ROPOS ROV, and profiling platforms. While shipboard and autonomous data have been collected at ONC since VENUS launched in 2006, the emphasis for data acquisition and archiving solutions has focused on networked instruments on the cabled infrastructure. In recent years, increased emphasis has been applied to developing digital infrastructure and data stewardship practices to support the wealth of data acquired from mobile platforms, such as those employed during the *Falkor* expedition. For instance, ONC has expanded its suite of web-based tools and back-end infrastructure for Oceans 2.0 to enable more generalized data acquisition and distribution. A ship-based server solution can support live acquisition for supported instruments, data streams to shore, and seamless archiving into ONC's central repository. Data stewards have developed workflows and best practices for handling data sets from mobile and third party platforms. Despite these advances, additional work remains particularly for video and physical samples. Video management and distribution options are subject to rapidly changing technology and high volume challenges. Physical samples require an alternative solution that considers the entire life cycle of a sample, and incorporates interoperability and community standards for data discovery and exchange. As a member of the ICSU World Data System and contributor to working groups such as the EarthCube iSamples Research Coordination Network for digital curation of physical samples, ONC intends to maintain high standards for data stewardship and repositories.

Presenter

Ms. Reyna Jenkyns, data stewardship, operations support lead, **Ocean Networks Canada**

9:23 - 9:46 am Presentation: Latest developments in oceanographic applications of GIS, including near-real-time interactive map exemplars and scientific empowerment through storytelling

This talk will provide an overview of how intuitive data analytics and visualization tools in geographic information systems (GIS) to inform both shipboard and shorebased science. And further, in the brave new world of science communication we know that scientists can be powerful storytellers as well. We may get the idea from maps, perhaps occasionally from graphs, but we are hardwired to understand stories. Every single scientific success is perfect fodder for a narrative structure. In that vein, I will conclude with an introduction to "story maps" as a fast and simple platform for telling compelling stories with shipboard data, including photos, videos, sounds, and sensor dashboards.

Presenter

Dr. Dawn Wright, chief scientist, **Environmental Systems Research Institute**

9:46 - 10:09 am Presentation: Virtual fieldwork on the seafloor: How to get there, what to take home?

Are we able to extend long standing geological field exploration methods to the sea floor using state of the art technology? The upcoming SOI Virtual Vents cruise will photogrammetrically survey an entire hydrothermal vent complex in order to provide a quantitative visualization of the site. This approach poses challenges in determining a survey strategy, real time data processing, situational awareness through telepresence, inclusion of onshore colleagues through remote interaction, and the onshore exploration of the final data product using immersive visualisation technology, which aims to match the expectations of terrestrial field geologists.

Presenter

Dr. Tom Kwasnitschka, researcher, **GEOMAR Helmholtz Centre for Ocean Research Kiel**

10:09 - 10:30 am Presentation: Collaborative Scientific Visualization Using Commodity Virtual Reality Systems

The difficulty of analyzing large and complex three- or four-dimensional data sets is a roadblock for scientific progress in many disciplines, specifically the Earth and physical sciences, including oceanography.

Virtual reality (VR) is a human-computer interface technology that can present three-dimensional pseudo-holographic virtual objects, and supports natural three-dimensional interaction with those objects. For data analysis, this means 3D data sets can be presented in their natural state, without the distortions incurred from projecting them onto two-dimensional display screens.

This presentation will show how software developed at the UC Davis W.M.

Keck Center for Active Visualization in the Earth Sciences (KeckCAVES,

<http://www.keckcaves.org>) supports interactive data analysis across a wide range of VR display systems, and how a VR tele-collaboration system integrated into that software allows multiple researchers from different locations to jointly analyze their data as if they were in the same physical space.

Presenter

Dr. Oliver Kreylos, Associate Researcher, W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES), Department of Earth and Planetary Sciences, **University of California, Davis**

10:50 - 12:00 pm Breakout discussions: Emerging opportunities, program guidelines, and success metrics for R&D in data platforms, data analysis, and communications

Discussion C1: What analytical, software, and data tools can help make seagoing research with robotic platforms more interactive and effective?

Discussion C2: How can we effectively communicate data-rich knowledge between ship and shore (and other ships) and enhance shipboard science with interactive remote input and participation?

Discussion C3: How can innovative computational algorithms on board research vessels inform seagoing research and facilitate real-time information sharing?

1:00 - 1:30 pm Reporters from each breakout group present summaries of their findings and recommendations

1:30 - 2:00 pm Plenary discussion: Recommendations for Schmidt Ocean Institute program guidelines and metrics of success

2:00 - 2:15 pm Workshop wrap-up, closing remarks, main workshop program concludes

SPEAKERS

Dr. Marc Carreras

Marc Carreras is Associate Professor in the Computer Engineering Department of the University of Girona (Spain) and vice director of the “Girona Underwater Vision and Robotics” lab (<http://cirs.udg.edu>). He holds a B.Sc. degree in Industrial Engineering (1998) and PhD in Computer Engineering (2003) from the University of Girona. His research activity is mainly focused on design of intelligent inspection and intervention AUVs, in research topics such as control architectures, robot learning and motion planning. Since 1999, he has participated in 16 research projects (6 European and 10 National), he is author of more than 90 publications, and he has supervised 3 PhDs thesis (3 more under direction). He led the participation of lab in the Student European AUV competition (SAUC'E) 2006 -1st prize-, 2010 -1st prize-, 2011 -2nd prize-, and in euRathlon underwater competition 2014 -1st prize-. He is leading also the development of hovering AUV platforms for external research institutions (4 developed SPARUS II AUVs). Dr. Carreras is member of the IEEE RAS and OES Societies, and since 2014 he is president of the OES Spanish Chapter.



Dr. Mandar Chitre

Mandar Chitre is currently the Head of the Acoustic Research Laboratory at the Tropical Marine Science Institute of the National University of Singapore, and an Assistant Professor at the Department of Electrical & Computer Engineering. His research interests include underwater acoustic communications & networking, ambient noise imaging, collaborative autonomous underwater vehicles, and acoustic signal processing. He is an Associate Editor of the IEEE Journal of Oceanic Engineering and an IEEE Oceanic Engineering Society technology committee co-chair for Underwater Communication, Navigation, and Positioning.



Dr. Ariell Friedman

Ariell has worked as a software engineer for a renewable energy startup, has run a small web development business and is currently working as a postdoctoral research engineer. He has degrees in Mechatronics Engineering, Commerce (Maj. Finance) and a PhD in the areas of machine learning and computer vision. He has extensive field experience working with stereo camera platforms, underwater



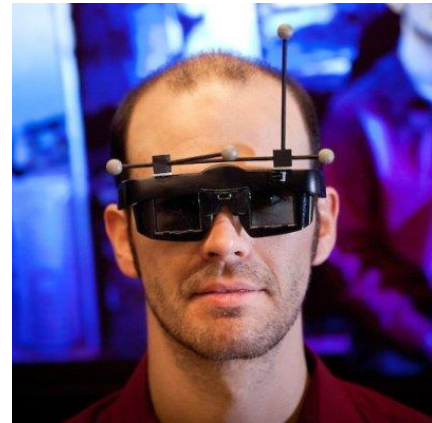
robots and diver propelled systems. Currently Ariell's efforts are focused towards increasing the utility of marine data sets for scientific purposes, which includes developing metrics to quantify the 3D structural complexity of habitats from stereo imagery, and the use of machine learning and computer vision algorithms to improve analysis.

He has also developed online platforms in this domain including a web-based system that streamlines the access, management and annotation of marine imagery, and a multi-vehicle tracking system that is used in field operations and can also be used to facilitate outreach objectives and "citizen science".

Dr. Oliver Kreylos

Dr. Oliver Kreylos is a researcher with the UC Davis W.M. Keck Center for Active Visualization in the Earth Sciences (KeckCAVES). Oliver received an M.Sc. in Computer Science from the Karlsruhe Institute of Technology, Germany, in 1999, and an M.Sc. and a Ph.D. in Computer Science from the University of California, Davis, in 2001 and 2003, respectively.

Oliver has been researching scientific applications of virtual reality (VR) since 1998, and is the primary developer of most KeckCAVES software. His related research interests are low-cost or commodity VR hardware, and development of software infrastructure to create widely portable VR applications.



Mr. Richard Jenkins

Richard Jenkins is a mechanical engineer and specialist in wing sail aerodynamics. He holds the world speed record for wind powered vehicles, with a speed of 126.2 mph, set in 2009 in a craft called the 'Ecotricity Greenbird', which he designed and built. He has spent most of his adult life on or around the water and is a keen sailor and pilot.

Following the land speed record, Richard turned his attention to the oceans, applying the aerodynamic lessons learnt during the land speed record to a unique unmanned sailing vehicle. Richard founded Saildrone Inc. in 2012 and now leads an 8 strong team as CEO.



Ms. Reyna Jenkyns

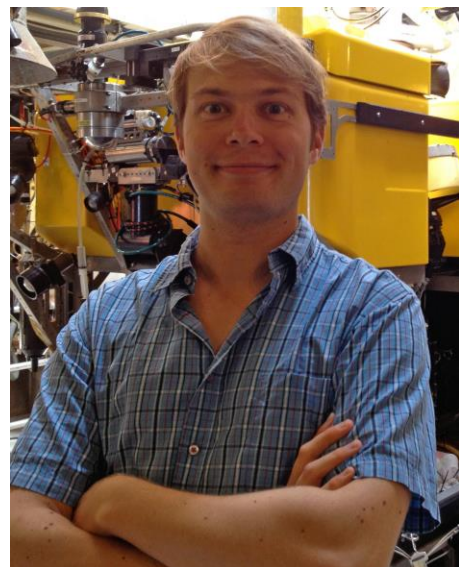
Reyna has served Ocean Networks Canada in its Digital Infrastructure department since January, 2009. Currently, she leads the Data Stewardship & Operations Support team which provides metadata management, geospatial services, data archiving functions, and cruise support. In her previous role as scientific programmer, Reyna generated data products and visuals for the NEPTUNE Canada network. In both roles, she has been a keen contributor in the design of Oceans 2.0 tools and interoperability with other ocean data providers. She enjoys participating in cruise expeditions and collaborating with the oceanographic community.



She received her Bachelor of Mathematics in the Applied Mathematics Co-operative Program from the University of Waterloo, and her Master of Science in Ocean Physics under Dr. Eric Kunze at the University of Victoria. Her research area was the transfer of momentum between internal tides and subinertial flow at a dissipating surface reflection. Prior work experience spans companies specializing in oceanographic monitoring systems, aerospace engineering, and information technology. In her spare time, she enjoys traveling, outdoor adventures and Nordic culture.

Dr. Tom Kwasnitschka

Dr. Tom Kwasnitschka received his PhD in Geology from the Christian-Albrechts-Universität zu Kiel, Germany, and has been a researcher at the GEOMAR Helmholtz Centre for Ocean Research Kiel since 2007. His interests focus on robotic exploration of deep ocean environments, particularly in the field of physical volcanology of seamounts, very deep explosive volcanism, and the temporal evolution of hydrothermal edifices. He has pioneered the use of high-resolution 3D photogrammetric reconstruction of seafloor outcrops and develops camera and lighting systems to collect such data. Tom also conducts research on the use of immersive virtual reality infrastructure to enhance telepresence at sea and visualize multimodal marine and seafloor data. He takes an active role in the popularization of such datasets throughout the international museum community.



Dr. Kristof Richmond

Kristof Richmond is Design Team Lead and Software Lead on the ARTEMIS supervised AUV, built by Stone Aerospace under the SIMPLE project funded by NASA's ASTEP program. Kristof received his Ph.D. in Mechanical Engineering from Stanford University in 2009, where he developed underwater visual mosaicking and navigation systems. He was part of the ENDURANCE development and deployment team which explored ice-covered Lake Bonney in the Antarctic Dry Valleys. His recent work with Stone Aerospace focuses on pushing remote robotic exploration to new frontiers: through ice caps, under ice shelves, and to worlds beyond.



Mr. Leighton Rolley

Leighton is the Lead Marine Technician onboard RV Falkor and has supported 80 scientific expeditions on US, European and SOI operated research vessels from the polar regions to the tropics.



Dr. João Sousa

João Tasso de Figueiredo Borges de Sousa is a lecturer at the Electrical and Computer Engineering Department from Porto University in Portugal and the head of the Underwater Systems and Technologies Laboratory. Since 1997 he has been leading the design, implementation and deployment of advanced unmanned vehicle systems in projects funded by the Portuguese Foundation for Science and Technology, Portuguese Innovation Agency, Luso-American Foundation, NATO, Office of



Naval Research, DARPA and the European Union. He was a Visiting Scholar at the Center for Intelligent Robotics for Space Exploration, Rensselaer's Polytechnic Institute, Troy, New York, USA in 1991. He had several Visiting Scholar appointments at the University of California at Berkeley since 1997. He lectured and delivered seminars on networked robotics at major universities in the US and EU. In 2002 he was awarded the Luso-American Foundation Fellowship by the Portuguese Studies Program from the University of California at Berkeley. In 2003 the Underwater Systems and Technology Laboratory was awarded the Arca second Prize for the best technological realizations Respectful to Environment. In 2006 he received the national BES Innovation National Award for the design of the Light Autonomous Underwater Vehicle. In 2008 he received an outstanding teaching award from Porto University. In 2004 he

contributed to the Report on the Portuguese Strategy for the Oceans. He is a member of the Association of Unmanned Vehicle Systems International maritime advisory committee. He is in the editorial board of several scientific journals. He is a member of several NATO committees. He authored more than 300 publications, including 30 journal papers.

Mr. David Wotherspoon

David has a wealth of program management experience related to full ocean depth submersible operations. Prior to working with SOI, David worked as the project manager and submersible operations director on the DEEPSEA CHALLENGE expedition.



David has a well-established conceptual design, research, planning, analytical and problem-solving skill set that he applies in the development of solutions for a range of complex projects. David has demonstrated success in engineering, development, manufacturing and operations of deep ocean research projects including the ability to liaise at all levels of organization to resolve issues and meet program objectives. Most recently David managed the EPCM of the successful DEEPSEA CHALLENGER, a full ocean depth manned submersible that was piloted by explorer and director James Cameron.

David's career began after enlisting in the Corps of Royal Engineers (UK), where he trained as a mechanical engineer and military diving supervisor. Following this, he spent four years as a development officer in Special Operations Command (Australia).

Dr. Dawn Wright

Dr. Dawn Wright is chief scientist of the Environmental Systems Research Institute (aka Esri), a world-leading geographic information system (GIS) software, research and development company. As chief scientist, Dr. Wright aids in formulating and advancing the intellectual agenda for the environmental, conservation, climate, and ocean sciences aspect of Esri's work, while also representing Esri to the national/international scientific community. She maintains an affiliated faculty appointment as Professor of Geography and Oceanography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University.



Dr. Wright's research interests include geographic information science; ocean informatics and cyberinfrastructure; benthic terrain and habitat characterization; and the processing and interpretation of high-resolution bathymetry, video, and underwater photographic images. She

has authored or co-authored more than 130 articles and five books on marine geographic information systems, hydrothermal activity and tectonics of mid-ocean ridges, and marine data modeling and cyberinfrastructure. Dr. Wright has participated in over 20 oceanographic research expeditions worldwide, including 10 legs of the Ocean Drilling Program, three dives in the deep submergence vehicle *Alvin* and twice in the *Pisces V*. Her fieldwork has taken her to some of the most geologically active regions of the planet, including the East Pacific Rise, the Mid-Atlantic Ridge, the Juan de Fuca Ridge, the Tonga Trench, and volcanoes under the Japan Sea and the Indian Ocean.

Dr. Wright serves on the Science Advisory Boards of NOAA, the EPA, and Conservation International, as well as many journal editorial boards. She is a AAAS Fellow, as well as a fellow of Stanford University's Leopold Leadership Program. In 2007, she was named U.S. Professor of the Year for the State of Oregon by the Carnegie Foundation for the Advancement of Teaching and the Council for the Advancement and Support of Education.

Dr. Wright holds an Individual Interdisciplinary Ph.D. in Physical Geography and Marine Geology from UC-Santa Barbara, an M.S. in Oceanography from Texas A&M, and a B.S. cum laude in Geology from Wheaton College (Illinois).

