OCEAN EXPLORATION IN A SEA OF DATA

SATURDAY, OCTOBER 21 + SUNDAY, OCTOBER 22

QUALCOMM INSTITUTE | UNIVERSITY OF CALIFORNIA, SAN DIEGO

DRAFT

EXECUTIVE SUMMARY AND RECOMMENDATIONS

OCEAN EXPLORATION IN A SEA OF DATA

On October 21-22, 2017, nearly 125 experts in fields including ocean exploration and data science came together for the fifth annual National Ocean Exploration Forum at QI, a division of the California Institute for Telecommunications and Information Technology. *Photo by Alex Matthews and Amiel Capinpin for The Qualcomm Institute / UC San Diego.*

EXECUTIVE SUMMARY AND RECOMMENDATIONS

On October 21-22, 2017, nearly 125 experts in fields including ocean exploration and data science convened for the fifth National Ocean Exploration Forum at the University of California (UC) San Diego's Qualcomm Institute (QI).

This Forum took a different approach than past Forums. Focusing on the importance of data and access to data—an important theme from previous forums—*Ocean Exploration in a Sea of Data* brought data scientists and experts in data visualization together with ocean explorers to consider how current and emerging data science and visualization techniques can help us understand the deep ocean in new ways. *Ocean Exploration in a Sea of Data* took advantage of QI's visualization and acoustics laboratories to demonstrate what *can* be done with rich terrestrial data sets, what *might* be done with more limited historical and

contemporary data from the deep ocean, and the potential for conducting ocean science differently using these techniques.

One goal of this Forum was to mobilize a community of young data scientists—not traditionally involved in the emerging national program for ocean exploration—to apply computational methods and data science and visualization techniques to the data produced by diverse oceanographic instruments and sensors. Accordingly, we involved graduate students and early career professionals to create the demonstrations, which included photogrammetric models of deep-ocean environments, point-cloud analysis of complex habitats, deep-ocean soundscapes, three-dimensional under-ice exploration, and a synthesis of multibeam and backscatter data in a data sparse landscape.

Partners from QI, the Lamont-Doherty Earth Observatory (LDEO), the National Oceanic and Atmospheric Administration (NOAA), and others gave presentations, provided demonstrations on priority areas, and held discussion groups. Thinking of "ocean exploration" in broad terms, Forum participants considered how relevant data—whether from satellites, ocean sensors, hydrophones, or deep-ocean cores—could be integrated, analyzed, and visualized to gain additional insight into the deep ocean.

Ocean exploration is multidisciplinary—oceanographers, marine geologists, marine biologists, marine archaeologists, and others collaborate to plan expeditions and participate to ensure as much as possible is learned when exploring an unknown deep-ocean environment. *Ocean Exploration in a Sea of Data* broadened the ocean exploration community's traditional notions of multidisciplinary collaboration to include data scientists, computer scientists, and visualization experts from QI—some of whom are also musicians, artists, and dancers. This synergistic blend of expertise, discipline, perspective, and sensibility allowed participants to experience and understand ocean data in new—and sometimes unexpected—ways.

Forum participants were given a series of demonstrations that presented new ways of experiencing data to make new discoveries and consider opportunities for making data more accessible and understandable. New data science and visualization techniques challenged the ocean exploration community to think beyond the limitations of traditional approaches and can have a real impact on current data acquisition, data analysis, and data management practices. These techniques also have the potential to bring new life to legacy data and present exciting opportunities for more effective communication of results.

The event was organized by Dominique Rissolo of QI, Vicki Ferrini of the LDEO, as well as David McKinnie and Adrienne Copeland of NOAA's Office of Ocean Exploration and Research (OER). The organizers and host institutions are grateful for the generous support of the Schmidt Ocean Institute, James A. Austin, and Dalio Ocean Initiative for *Ocean Exploration in a Sea of Data*.

OCEAN EXPLORATION
IN A SEA OF DATA

BACKGROUND

Since 2013, leading ocean exploration experts have assembled at National Ocean Exploration Forums to discuss the priorities and aims of a national ocean exploration program. These Forums have examined the future of ocean exploration through the lens of a coordinated NOAA-led, multi-agency, federal collaboration with academia, foundations and not-for-profits, and the private sector.

An important part of the Forum is the opportunity to converse with other experts in the field. This dialogue helps the community leverage investments, identify opportunities for collaboration, and lead toward increases in the scope, pace, and efficiency of ocean exploration in areas important to the national interest. *Photo by Alex Matthews and Amiel Capinpin for The Qualcomm Institute / UC San Diego.*

Participants in the inaugural 2013 Forum, called *Ocean Exploration (OE) 2020*, prioritized exploration in the polar, Indo-Pacific, and Central Pacific regions and recommended that traditional ocean exploration be expanded to include ocean chemistry and the water column. OE 2020 recommendations emphasized the importance of using varied exploration platforms, developing new technologies, creating citizen science opportunities, increasing and fostering partnerships, improving low- to no-cost near real-time data accessibility, and enhancing and expanding ways to communicate about ocean exploration. Subsequent Forums have built upon these priorities and recommendations, helping to drive ocean exploration in both the public and private sectors.

With these priority areas defined, further aims established, and additional ocean exploration conducted, the next step with the 2017 Forum was to determine how best to manage the large quantities and diverse types of new and historical data in the ocean exploration community and apply data science analysis and visualization techniques to these data. The 2017 Forum yielded community recommendations for how data scientists, ocean explorers, and members of other disciplines can work together to expand traditional concepts of ocean exploration while driving toward new discoveries, increased access to contemporary and historical data, and improved public engagement.

DAY ONE: THE FUTURE IS ON THE HORIZON

Ocean Exploration in a Sea of Data was designed to first introduce a common understanding of challenges and opportunities in ocean exploration data. After a review of the National Ocean Exploration Forum process provided by Jerry Schubel, host of OE 2020 and a key architect of subsequent events, the Forum featured two distinguished keynote speakers to set the conceptual stage for the rest of the program:

- **MARGARET LEINEN** - Director of the Scripps Institution of Oceanography, UC San Diego Vice Chancellor for Marine Sciences, and Dean of the School of Marine Sciences. She discussed the challenges and opportunities of rich datasets, highlighting the differences between deduction and induction. The abundance of data, combined with growing trends in data science (e.g., data mining and machine learning), are moving us towards "exploring" ocean data in addition to exploring the oceans.

- **LARRY SMARR** - founding Director of the California Institute for Telecommunications and Information Technology (Calit2), a UC San Diego/UC Irvine partnership, and holds the Harry E. Gruber professorship in Computer Science and Engineering at the Jacobs School of Engineering. His discussion focused on our increased ability to move very large volumes of data at high speeds among distributed processing clusters and the opportunities this creates for ocean and other science enterprises.

A special presentation followed that highlighted the importance of considering exploring the time dimension of our dynamic ocean and helped to convey the value of exploring a "cube" of geographic space that extends from below the seafloor to the atmosphere using all available instruments and sensors—not just those deployed from ships. John Delaney, Professor of Oceanography and the Jerome M. Paros Endowed Chair in Sensor Networks at the University of Washington, presented on ocean exploration in the time domain, using the Ocean Observatories Initiative and cabled observatories in general, to illustrate how time-series observations can inform ocean exploration.

DEMONSTRATIONS

Ocean Exploration in a Sea of Data Forum organizers solicited the development of five practical demonstrations that would allow participants to explore and experience data in new ways. The demonstrations at the 2017 Forum relied on technologies developed at QI, the unique capabilities of the visualization and audio laboratories at QI, and the dynamic culture of experimentation and development driven by innovative students and professors— many without prior ocean exploration experience.

Forum participants were assigned small groups to rotate through the five demonstrations, plus a sixth facilitated discussion session that allowed for the sharing of impressions, ideas, and implications of the demonstrations.

OCEAN EXPLORATION
IN A SEA OF DATA

These demonstrations included:

Forum participants learn more about 3D photogrammetry in the WAVElab (Wide Area Virtual Environment). *Photo by Alex Matthews and Amiel Capinpin for The Qualcomm Institute / UC San Diego.*

- **EXPLORING OCEAN DATA THROUGH AUDIO SPATIALIZATION AND SONIFICATION** held in the QI Audio Spatialization Lab (SpatLab) and presented by QI affiliates, Shahrokh Yadegari and Grady Kestler, and NOAA OER Knauss Fellow, Adrienne Copeland. A combination of physical, biological, geological, and anthropogenic sounds make up marine "soundscapes". Exploring marine soundscapes can lead to a better understanding of the deep ocean and is an important aspect of characterizing these environments. The SpatLab allowed participants to explore sound in 3D, observing demonstrations of how ocean phenomena can be modeled acoustically and how sound can be used to explore and understand aspects of the deep ocean in ways otherwise not possible.

- **WAVELAB UNDERWATER PHOTOGRAMMETRY: POINT-BASED VISUAL ANALYTICS AND HABITAT CHARACTERIZATION** held in the Structural Materials and Engineering Building and presented by QI affiliates Falko Kuester (also of the Jacobs School of Engineering) and Dominique Rissolo. Structure-from-Motion (SfM) photogrammetry has become an empowering and widely adopted technique for documenting underwater features or sites in 3D. These techniques render geometrically accurate and photorealistic models that are useful for photo-mapping underwater environments. The resulting 3D data has the potential to serve as a basis for new analytical approaches. The large-scale, immersive visualization system demonstration in the WAVElab (Wide Area Virtual Environment) allowed participants to visualize coral reefs, shipwrecks, and submerged Pleistocene megafauna while exploring the scientific potential of these new analytical tools.

- **CULTURAL HERITAGE ENGINEERING LAB: VISUALIZING ANTARCTIC ICE SHELF AND BATHYMETRY WITH AIRBORNE RADAR DATA** presented by Nicholas Frearson of the LDEO. Acquiring good bathymetry in remote under-ice environments is critical to understanding these deep-ocean regions and how ice sheets are changing. The Cultural Heritage Engineering Lab allows for 3D displays of high-resolution images, video, and photogrammetric point clouds. The ROSETTA project is mapping the least known ocean floor on our planet, using aircraft as platforms for radar, gravimeters, and other instrumentation. This demonstration integrated aerogeophysical data, allowed for visualization of the data to streamline analysis, and included a fly-through of the ice-penetrating radar data to illustrate how the ice shelf is changing.

OCEAN EXPLORATION
IN A SEA OF DATA

- **SUNCAVE: SEABED MAPPING: NEW PERSPECTIVES FROM IMMERSIVE VISUALIZATION** presented by Vicki Ferrini of the LDEO on the QI SunCAVE. Seabed mapping provides critical baseline information for ocean exploration. An immersive experience in near-360 degree presentations of video and data, SunCAVE technologies provided participants with a new way to experience deep-ocean bathymetry, seafloor features, and other attributes of the deep ocean. This type of data visualization can inform science, strengthen public interest in ocean exploration, help educators explain the ocean, and engage more of the public in ocean exploration.

National Ocean Exploration Forum participants explore the SunCAVE, an immersive environment that allows for near-360 degree presentations of video and data. *Photo by Alex Matthews and Amiel Capinpin for The Qualcomm Institute / UC San Diego.*

- **BEING THERE WITHOUT BEING THERE** presented by John Delaney and Aaron Marburg of the University of Washington, Timothy Crone of the LDEO, and Friedrich Knuth of Rutgers University using the QI Vroom (Virtual Room) display wall. The recent completion of the Cabled Array of sensor networks offers unique opportunities to explore the scientific and educational benefits of real-time access to a highly active portion of the Global Mid-Ocean Ridge System—a 70,000 kilometer-long volcanic feature that extends around the world like the strings on a baseball. The Vroom hyperwall and high-definition projections systems demonstrated these capabilities and benefits, highlighting the importance of continuous real-time monitoring to understand change in the deep ocean and the significance of ocean exploration in the time domain.

DISCUSSION

In the discussion session, participants agreed that the Forum demonstrations highlighted the rapid development of visualization technology, allowing researchers to transform their ability to explore, experiment with, and begin to more deeply understand the complex processes that take place throughout global ocean basins. Participants shared impressions of the demonstrations and discussed how these tools could impact their work, areas of interest, and the ocean exploration community. They noted that visualization and audio spatialization techniques like these:

- Could give instant access to data in real time and allow users to control the data.

- Require new best practices, employing stewardship to provide context, and would be transparent, scalable, and developed for multiple interfaces.

OCEAN EXPLORATION
IN A SEA OF DATA

- Could allow scientists to make sense of large quantities of data and lead to new understanding and insights.

- Could "get water out of the way" and help reveal, through multiple senses, a glimpse of the deep-ocean world in terms relevant to most people.

- Would encourage participation in oceanographic research from people of all backgrounds, thus enhancing interdisciplinary and multidisciplinary collaboration.

- Would need to be standardized across platforms and would lay the groundwork for developing new interfaces and user experiences.

Bob Weiss, veteran Hollywood producer and Vice Chairman of the XPRIZE Foundation, shared his thoughts on communicating about ocean science during the Saturday evening reception. *Photo by Alex Matthews and Amiel Capinpin for The Qualcomm Institute / UC San Diego.*

ENGAGING THE PUBLIC: SPACE VS. OCEAN

Reception and dinner speaker Bob Weiss, Vice Chairman of the XPRIZE Foundation, treated the group to his thoughts on making ocean exploration as exciting to the public as space exploration. As a veteran Hollywood producer, Mr. Weiss' observations about the challenges—and opportunities—of engaging the public in ocean exploration were particularly relevant for a national ocean exploration forum focused on visualization, and anticipated the 2018 Forum on public engagement.

DAY TWO: NAVIGATING TO THE FUTURE

The Forum's second day focused on technologies and opportunities close at hand that can help bridge the current state of ocean exploration and its diverse data sources and archives and a future state where the techniques and technologies demonstrated on Day One might be used routinely. Two case studies using advanced visualization approaches were presented to demonstrate what is possible now.

CASE STUDIES

In the first case study, professors and students from the Scripps Institution of Oceanography and QI (Stuart Sandin, Falko Kuester, Vid Petrovic, Nicole Pedersen) demonstrated and explained their coral reef point cloud and automated classification scheme. High-resolution photogrammetric images are converted to point clouds; algorithms automate the classification process so that each point contains location and type information as metadata and detailed analysis is possible.

In the second case study, Alice Winter, a user experience researcher at NASA's Jet Propulsion Laboratory, described how OnSight Immersion Environment and other programs are allowing scientists to explore and conduct science on Mars with avatars in a "mixed reality" environment based on live data feeds. OnSight, or similar technologies, could be the next generation of telepresence-enabled deep-ocean exploration, as autonomous vehicles and sensor networks augment and perhaps replace ship-based exploration in the future.

PANEL DISCUSSION

A panel discussion comprised of the case study presenters and other experts in ocean data examined the implications of the case studies and the previous day's demonstrations. Vicki Ferrini, Forum co-organizer and expert in deep-sea mapping, moderated the panel of Dawn Wright (Esri), Jessica Block (QI), Alice Winter, Vid Petrovic, and Stuart Sandin, which discussed data science solutions to integrating temporally and spatially sparse data. The key points and recommendations from that discussion included:

A panel discussion, moderated by Vicki Ferrini (far right), with (from the left) Stuart Sandin, Vid Petrovic, Alice Winter, Jessica Block, and Dawn Wright examined the implications of the case studies and the previous day's demonstrations. *Photo by Shanni Jin for The Qualcomm Institute / UC San Diego.*

- When integrating data, maintain access and connections to source data, not just derived data products. Aspire to keep the source data in one place and move the algorithms in order to enable a whole range of products.

- Building community and enhancing communication is the key to integrating disciplinary scientists and data scientists.

OCEAN EXPLORATION
IN A SEA OF DATA

- Adding new technology to a field means asking questions different and changing the way science in the field is conducted. Data science provides opportunities for finding signals that traditional processes might not identify. We are evolving as a community and we need to make incremental steps in adopting new technologies.

- Culture change is ongoing with respect to data sharing and code-sharing. The community needs to incentivize data and code-sharing, but also need to recognize that sharing code/data easily falls down the priority list when development/analysis is underway—there is only so much time.

- Public accessibility of curated content is critical—we want humanity to know (and care) more about our planet.

DISCUSSION GROUPS AND RECOMMENDATIONS

The organizers structured the Forum to provide participants, regardless of discipline or experience, with common information and experiences to bring to facilitated breakout sessions. The keynotes, panel discussion, case studies, and especially the demonstrations were intended to share new information, provoke thought, spark creativity, and encourage dialogue across ocean exploration and data science and visualization disciplines.

Breakout session participants were asked to rely on this common information, as well as their own expertise and experience, to address several questions that the organizers intended to help spark discussion about how new techniques in data science and visualization can be applied to ocean exploration to understand the ocean in new ways and to develop recommendations for ocean exploration stakeholders and specific sectors involved in exploring the deep ocean. Each breakout group then presented the results of their discussions in plenary. Their conclusions are summarized below, organized by question.

On Sunday afternoon, Forum participants broke into the smaller groups to discuss several questions designed to get them to think about how they can apply new techniques in data science and visualization to ocean exploration in order to understand the ocean in new ways. *Photo by Shanni Jin for The Qualcomm Institute / UC San Diego.*

1. WHAT DO YOU SEE AS THE MAJOR OPPORTUNITIES DATA SCIENCE AND NEW TECHNIQUES FOR VISUALIZATION OFFER?

Participants identified two major opportunities during discussions. First, through thoughtful and targeted messaging, new technologies and data visualizations can enhance efforts to better engage the public about ocean science and exploration by capturing people's attention and immersing them in the data; helping people visualize, and thus, better understand the complexity, importance, and depth of ocean

exploration and reaching wider, more diverse audiences. Second, visualization can help accelerate and advance new scientific discoveries by encouraging work across disciplines, challenging the traditional hypothesis-driven workflow of science, allowing extraction of relevant data in more intuitive ways, and promoting onshore research of offshore data.

On Sunday afternoon, each breakout group was given an opportunity to present the results of their discussions to the full Forum group. *Photo by Shanni Jin for The Qualcomm Institute / UC San Diego.*

2. HOW SHOULD WE CHANGE OUR CONCEPTS OF OCEAN EXPLORATION? WHAT ARE THE IMPLICATIONS FOR INSTRUMENTATION AND DATA COLLECTION?

One common theme among the breakout groups was the need to make ocean exploration more accessible and inclusive by developing new tools and technologies to lower the cost of ocean exploration; creating more/better opportunities for virtual exploration opportunities; and making data available to the public sooner, to spur innovation and take advantage of open source and citizen science opportunities. Participants also noted that the need to rethink how collected data are managed, both during acquisition and for long-term archiving.

3. WHAT ARE THE IMPLICATIONS FOR "CHARACTERIZATION" OF THE OCEAN? WHAT NEW PARAMETERS SHOULD WE BE THINKING OF?

Baseline characterizations allow us to define what is "normal" for areas of the seafloor, allowing people to better understand environmental impacts. Participants agreed that to create useful baselines, data collection and curation need to be standardized and easily accessible. In addition to the data we already collect, we should also include acoustics, data from towed instruments, and environmental genomics. They suggested optimizing operating costs through closer collaboration between projects, sharing resources, prioritizing how we characterize, mining existing data, and planning for the costs of data storage.

The groups suggested that we expand the scope of our data collection and the capabilities of our sensors—even if we aren't using all of the data we collect—to increase the possibility of using these data in future studies. They thought we should determine what data we lack, turn around raw data interpretation more quickly, and curate data properly—including metadata and a reference library. As getting people to sea will remain a challenge, we should take greater advantage of telepresence technology and increase the utilization of new technologies (e.g., automated underwater vehicles) with less elaborate ships. Tools under development should also
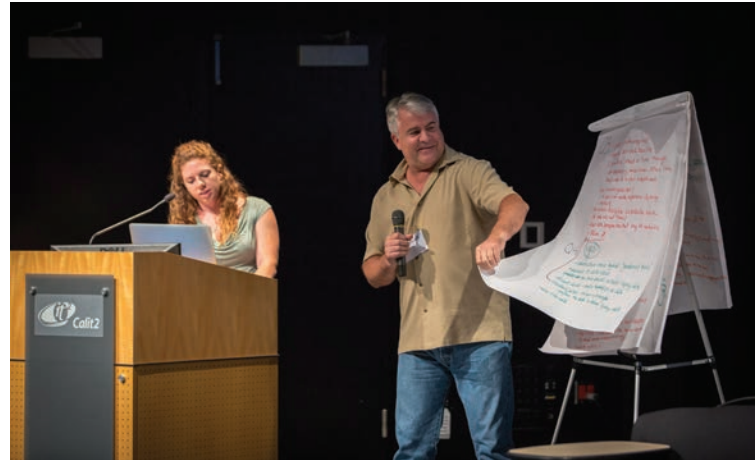
be usable with the data we have collected thus far.

In addition, participants felt that much of the communication about our work focuses on the deterioration of the ocean environment exclusively. To fully engage the public effectively, it is important to also highlight the positive aspects of what we find as we explore the deep ocean, to convey the excitement and wonder of the deep to the interested public.

4. ARE LEGACY DATA RELEVANT? WHAT SHOULD WE DO ABOUT IT?

Participants agreed that legacy data are highly relevant. It needs to be accessible, standardized (metadata and archiving), and preserved in a usable format. We should establish new techniques for data analysis, using automated and standardized methods. The community should encourage people to digitize and update legacy data. It may be worthwhile to pursue crowdsourcing to perform this function, as we might find people who can successfully mine the data and leverage new infrastructures. We should encourage new ways to look at and store legacy data, including visualization techniques.

5. WHAT SHOULD THE FOLLOWING SECTORS DO TO ENCOURAGE CLOSER TIES WITH THE DATA SCIENCE AND VISUALIZATION COMMUNITY AND TO PROMOTE ADOPTION OF NEW APPROACHES THAT COULD YIELD NEW UNDERSTANDING?

- **ACADEMIA:** The academic community should encourage ocean scientists to connect with data scientists. Participants agreed on the importance of making inaccessible or offline data public and felt we should promote the benefits of sharing data (advancing science, professional attribution, recognition). The community should embrace alternative approaches to funding and consider partnering with the private sector for research that may have commercial value. Universities should not lose sight of their role in producing future generations of ocean explorers and scientists.

- **FEDERAL GOVERNMENT:** Federal funding should focus on national priorities and encourage agency or program communications and partnerships. Federal data management policies should encourage proper—and long term—data stewardship and open access.

- **NOT-FOR-PROFITS:** Philanthropy plays a critical role in funding projects that federal grants can't or won't fund. Their flexibility allows for higher risk or "off-the-wall" proposals to proceed—and potentially breakthroughs in discovery and innovation. But revenue streams need to be stabilized over the long term and new revenue streams should be investigated.

- **PRIVATE SECTOR:** The community should create financial incentives for private

sector companies to maintain relationships with researchers after development. Open source, non-proprietary, and expandable standards should be adopted across sectors so everyone from researchers at sea, to students, to government analysts can visualize and share the same types of data. Participants felt industry should steer away from a proprietary model to allow more people access to data. And there was broad agreement that optimizing long-term preservation of data without reducing ready access is important.

The groups concluded that we need to be proactive in bringing these sectors together and find mutually beneficial opportunities. Cross-sector, interdisciplinary collaboration should be encouraged. With more people involved, the work will have a larger global impact, a higher-level message, and is likely to yield the productive merging of data generation, curation, and dissemination.

6. CAN WE LEVERAGE NEW VISUALIZATION APPROACHES AND PRODUCTS FOR PUBLIC ENGAGEMENT? HOW?

There was strong agreement that we can leverage these approaches and products for public engagement. Participants agreed that the community should look for opportunities to bring data and visualization experts, scientists, and storytellers together and merge their expertise with emerging engagement modalities like open source apps and virtual reality (VR), thinking ahead about future types of immersive experiences.

Participants suggested keeping a positive message and encouraging public interaction with the data through these modalities. We should support the use of data visualization and VR in the classroom and beyond (museums, aquaria, etc.). The community should look for engagement opportunities with crowdfunding, crowdsourcing, and citizen science. We should look for ways to coordinate science with private industry and allow for commercial development, including gaming. Field researchers and scientists should help identify ways to create better instrumentation, using human psychology to tailor these instruments and how data are presented. Participants agreed that we should encourage follow-through with university projects by having subsequent students continue work when others graduate.

7. WHAT IS YOUR BEST ADVICE TO NOAA, AS THE COORDINATOR OF A NATIONAL PROGRAM OF OCEAN EXPLORATION?

Participants agreed that NOAA should encourage ways to immerse others into our world, using multiple senses, and invest in immersive experiences. The agency should invest, and encourage others to invest, in technology that maximizes autonomy, automated data capture, and rapid data processing—and should leverage the funding of high-risk innovation. NOAA should encourage standardization. It should encourage

review and investigation of legacy data—exploring ocean data of the past through the archives.

NOAA should leverage the abilities of those who already work in ocean exploration and data science. The agency needs to invest more in the curation, production, and presentation of data. NOAA should continue to refine and clarify priorities, then communicate them to the community, in part through facilitating an active conversation between stakeholder groups. Finally, participants agreed that the agency should implement better NOAA branding and increase public engagement, as this will benefit all ocean exploration stakeholders.

Participants asked questions during the concluding panel, titled *"What Should We Do Next?" Photo by Shanni Jin for The Qualcomm Institute / UC San Diego.*

CLOSE OF *OCEAN EXPLORATION IN A SEA OF DATA*

A final panel discussion with Jerry Schubel, Margaret Leinen, and Larry Smarr reviewed what the community should do next. The Forum closed with remarks from Dominique Rissolo and a reminder that the 2018 National Ocean Exploration Forum will continue to build upon previous recommendations. This upcoming Forum will review ways to better explain ocean exploration to students and the public with the goal of developing recommendations for more effective messaging and engagement strategies.

Keynote speakers Dr. Jerry Schubel, Dr. Margaret Leinen, and Dr. Larry Smarr hosted the concluding panel: *"What Should We Do Next?" Photo by Shanni Jin for The Qualcomm Institute / UC San Diego.*

A NATIONAL OCEAN EXPLORATION FORUM COMMUNITY

This Forum would not have been possible without the active engagement of its participants. The organizers and sponsors of *Ocean Exploration in a Sea of Data* are grateful to those who joined the community in La Jolla—especially new members of the ocean exploration community from the data science and visualization disciplines—as well as our many partners and contributors, for their input, creativity, and support. Thanks are due to all participants for making the time to join this National Ocean Exploration Forum and their willingness to work with their colleagues, and across disciplines, to investigate the exciting world of ocean exploration and data visualization.