

NOAA Ocean Exploration Advisory Working Group

Summary Workshop Report

Technologies for the *Okeanos Explorer*

October 23-24, 2007 Monterey Bay Aquarium Research Institute

1. Background

The NOAA Science Advisory Board (SAB) created the Ocean Exploration Advisory Working Group (OEAWG) to provide NOAA, through the SAB, with timely and expert guidance and oversight pertaining to, (1) general priorities for ocean exploration, including geographic areas of interest as well as subject matter topics, and (2) advice concerning emerging ocean exploration-relevant technologies. The OEAWG met in the Spring of 2006 in Silver Spring, MD to become acquainted with the existing NOAA Ocean Exploration (OE) Program. A subsequent meeting, in Fall 2006, was held in Los Angeles, CA to initiate planning for a workshop to identify targets for the new NOAA Ship *Okeanos Explorer* to investigate during its first two year of operations. This meeting also exposed the OEAWG and OE to the creative concepts of Walt Disney "Imagineering." On May 10-11, 2007, the OEAWG convened the EX planning workshop at the National Geographic Society in Washington D.C. in May 2007. A summary report describing that workshop is available.

On October 23-24, 2007 another OEAWG workshop was convened at the Monterey Bay Aquarium Research Institute. This report describes that workshop, focused on technology needs for the *Okeanos Explorer*.

2. Workshop Goals

In the spring of 2008 NOAA expects to commission a dedicated ship of exploration, the *Okeanos Explorer* (EX). This vessel is intended to carry out a systematic global program of exploration in the oceans linked in real time through satellite and internet telepresence technology to the scientific community, educators, the media and the general public. This workshop was dedicated to discussing the technology suite aboard the EX. As stated by the OEAWG the workshop objective and desired outputs were:

Objective: *The OEAWG aims to collect community input to help shape the technology investments by NOAA's Ocean Exploration program. In what areas might modest investments now in technology development or deployed systems yield high payoff in terms of our ability to explore the ocean with greater efficiency and increase the rate of new discoveries?*

Anticipated Outputs:

- 1) *Refined OE technology priorities, especially in the context of outfitting and operating the Okeanos Explorer.*
- 2) *List of technology gaps for Ocean Exploration.*
- 3) *Strategies for filling those gaps.*

These outputs will provide a foundation for the OEAWG to develop recommendations to NOAA's Science Advisory Board on ocean exploration's technology needs and priorities.

3. Workshop Process

The OEAWG organized and facilitated this workshop through a grant administered by Dr. Ballard's Institute for Exploration. These funds supported the travel costs of the workshop participants. OE assisted the OEAWG in the development of the agenda based on the ongoing developments of technology for the EX, including the vessel refit, telepresence, and the ROV systems. OE offered suggestions for attendance at the workshop as did MBARI technical staff. The final invitations were issued by Marcia McNutt, who served as overall workshop chair. Approximately 35 ocean technologists as well as the OEAWG and select NOAA staff attended the workshop. Appendix I includes the list of attendees. The Monterey Bay Aquarium Research Institute hosted the event.

The OEAWG members served as hosts and facilitators of the workshop. Opening briefings provided attendees with a concept for an ocean exploration vision based on telepresence technology, results from the prior OEAWG workshop, status of the OE program, the EX status and capabilities, the ROV being built for EX and the ongoing technology developments and applications at MBARI. Briefing materials are available and access instructions are included in the References. The full workshop agenda is included in Appendix II.

The plenary briefings were followed by a series of breakout sessions discussing the different modes of exploration described as: 1) Underway Reconnaissance, 2) Water Column Exploration and 3) Site Exploration. Breakout sessions reported back to the main group which reconvened its discussions as a whole. This process was repeated and a final plenary session on the second day focused on the technology of telepresence and its role in science, as experienced at NASA.

4. Opening Discussions

The opening briefings served to provide background information and set the stage for following discussions. The briefings are available online. In addition to this material several ideas emerged during the discussion. These are included here for reference and consideration, not necessarily as recommendations from, or to, the OEAWG.

Maps and images – During discussion after Jamie Austin's presentation on the prior workshop he promoted the idea that EX, and OE, should focus on making visually compelling and scientifically meaningful maps. He suggested: "The Program needs a legacy of great images and great maps." While some felt this was a superficial position it does capture the essence of exploration and serves to make the EX a distinct vessel within the wider oceanographic community. Related to this subject was a discussion of "rigorosity," i.e. how much science would be enough. Different views were shared but all agreed that any science needed to be rigorous but that there was a major difference between exploration supporting an NSF proposal and that supporting a Journal article. Maps and images support both, at different levels.

Managing and delivering expectations – A fair amount of discussion revolved around the issue of managing expectations. Jamie Austin suggested all technology deployed need to be "bulletproof" whereas Marcia McNutt suggested careful advertising could ensure satisfied users. A subsidiary point raised was the fact that transitioning new technology can represent a factor of 10 increase in cost and effort as compared to the initial development. Thus across the group it was recognized that promotion, and application, of the EX and its new technologies requires careful planning and effective communications with many communities.

Community relations – The gap between traditional academic oceanography and applied NOAA mission needs was apparent in various discussion points. Steve Hammond highlighted that the EX, and OE, must be relevant to NOAA. Jamie Austin pointed out that NOAA does not “have to” listen to the academic community and thus the OEAWG and that community should see OE and the EX as an opportunity to strengthen relations. This workshop recognized that data and data “ownership” would continue to be an issue. But, as a technology focused event there was greater concern about how the data would be managed rather than who would “own” it.

State-of-the-art – The various MBARI presentations revealed a gap between the state-of-the-art and the state of technology on EX. This is to be expected as an operational platform. Many of the tools developed and proven at MBARI could benefit OE and the EX. The transition cost question and need to manage expectations tempered the urge to envision EX with all those tools embarked right away. An interesting thematic point was Jim Bellingham’s vision of “pervasive ocean presence.” While ocean observing systems are one component of this vision, underway systems are another. EX, with its telepresence capabilities, is well positioned to be on the cutting edge of this particular technology transition.

5. Breakout Sessions

NOAA staff supported the OEAWG during the workshop by taking notes and offering some of the scheduled briefings. All breakout sessions were attended by at least one note taker and led by a member of the OEAWG. Each breakout session delivered a report to the plenary. This section provides a summary of those reports. The original slides delivered are available (see the References). This section aims to present the themes, recommendations and/or challenges identified by each breakout group. Specific technologies and tools discussed in the breakouts will be collated and discussed in a separate document designed to support ongoing technology investments for the EX as well as broader Ocean Exploration and Research needs.

5.1. Site Exploration

Site exploration can be defined as working within a defined “box” to thoroughly explore a predefined region. and to dive the ROV on specific targets of interest. This includes mowing the lawn using the EM-302, selecting areas of interest for investigating with the camera sled at slow speeds, and conducting full ROV operations on targets of interest to collect high-quality video and stills and representative samples. The majority of the items identified by this group relate to upgrades and modifications to the dedicated ROV and camera platform. These will be reviewed in a separate document. Other thematic concepts introduced included:

Borrow not buy – Rather than begin a major investment in additional tools participants suggested working with the community to borrow items, such as still camera for mosaics, for initial use. Since the exact exploration concept remains undefined such loan programs would allow more cost effective experimentation and concept development. This idea applies to both sub-systems on the ROV and camera platform and major EX systems like AUVs and towed platforms.

Low cost deployable assets – Innovative use of affordable systems like drop cameras and elevators was suggested to augment the ROV and camera platform. Drop cameras were suggested as a low cost way to get very basic imagery of a site without the effort of an ROV dive. Elevators were seen as a potential approach to enable more significant sample collection without numerous ROV recoveries.

Scouting – The need to develop an effective approach and tool suite for scouting was discussed. Options include a camera platform more like the IFE Argus or an autonomous vehicle. In either case it was suggested that the “borrow not buy” approach would be wise in this case.

ROV needs – A long list of ROV tools was created. This list included any items already under consideration by OE and some new suggestions. One example was the need for a fiber-optic gyro, for optimal heading data. This item has been cost prohibitive but will be added as funds are available. The entire list and a procurement plan will be developed separate from this report.

Selling OE – It was recognized that much of the site exploration work would be the primary “selling” material for OE. Sites such as vents and shipwrecks would be of public interest, likely more so than broad area maps. Thus this breakout session suggested technology investments that support this outreach need receive a high priority.

5.2. Underway Reconnaissance

Underway reconnaissance can be defined as using the multibeam sonar and other ship-based sensors while transiting through unknown or poorly known waters for the purpose of detecting an anomaly or something of interest that bears investigation using other tools and techniques. Two of the key systems the EX does not have currently are an ADCP and an EK-60. Both would contribute to the reconnaissance operation, and have the added benefit of providing information that could be analyzed in the context of “regional exploration,” i.e., oceanographic exploration and characterization as opposed to biological or geological exploration.

As with the site exploration breakout a series of specific tools and technologies were discussed by the underway reconnaissance group. These also will be included in the technology discussion document. Ideas and themes of broader interest included:

Aircraft – The potential role of unmanned aerial vehicles (UAVs) balloons, blimps and the like was discussed. Specific roles and requirements for such platforms were not fully developed. However this was a novel suggestion deserving of some additional consideration.

Hull Systems – A variety of vessel mounted systems were discussed. Two systems of great interest were the EK60 and ADCP. Due to budget constraints these systems will not be installed until a future overhaul period. Another system not yet funded but of high importance was the XBT, which is important to effective multibeam mapping. As this system is relatively affordable it will be procured as soon as possible. Two concepts for vessel based reconnaissance were through hull analysis and atmospheric sensors. Both were seen as useful to broad NOAA missions and might also enable new discoveries. A similar idea was to develop approaches to automated bird and marine mammal observations.

Towed Systems – Various ideas were offered on the role of towed systems in underway work. The question was posed, is full speed biological sampling possible? Are there ways to design a net or sampling strategy to allow sampling while underway at full speed? If feasible this was seen as a potential boon to biological oceanography. A similar need would be a towed system equipped with pumps that could feed water samples from various depths to flow-through analysis. A technology required for such activities would be a reliable full-speed towed undulating vehicle

Once per day – The idea of a regular daily activity as part of underway reconnaissance was introduced. The challenge of time management was suggested, as a full depth profile by rosette might take several hours. The use of the camera platform rather than the rosette was introduced

as was a freefall camera with simple CTD and perhaps sampler. This breakout determined that repeatable activity of this nature was appropriate and “worth it” but best defined by the water column breakout group. A later discussion of this topic included the statement by Larry Mayer that some kind of repeatable operation was the best chance for the program to leave a legacy of a broad valuable data set.

5.3. Water Column Exploration

Water column exploration can be defined as investigating the water column using ship-based instruments (such as those that would be used for underway reconnaissance), as well as deployed instruments such as a CTD, the ROV camera sled, and nets. It differs from underway reconnaissance in that the work is done while on station. Water column exploration could be conducted on a daily basis at “Ewing Stations,” which could also include collecting sediment grabs or cores on a daily basis while the ship is in transit. Like underway reconnaissance, the information collected could be used to determine if the ship should stop and conduct a more thorough investigation of an area of interest.

As with the other groups, a series of technologies were identified by the water column team. These will be discussed in detail in the subsequent analytical document. Interesting themes raised by this breakout included:

Technology Transition – As a dedicated vessel the EX can be applied in new ways. Thus it might make time available during each season to explicitly support technology testing. The proof-of-concept work that requires sea time is critical to wider acceptance and use of a technology. It is also difficult for most technology developers to obtain, thus the EX offers a valuable new opportunity. The availability of telepresence is also enabling to technology development. Many new tools for use in the water column require calibration and monitoring by specialists. The hardware can often be maintained by ship techs but the “brains” need support from the inventors. Having a broadband link to shore allows those experts to support new instruments being tested on EX voyages without joining the cruise. This could enable many more innovative technologies to be applied in OE expeditions.

More Platforms – Additional platforms to enable water column exploration were identified. Towed systems that could undulate, reach significant depths and be towed at speed would be useful. AUVs were also identified as of interest, in particular if they could carry new in situ sensors AND collect water samples like the MBARI system described in opening presentations.

Data Bits not Samples – The breakout group recognized that the limited sample storage space onboard EX and the variable nature of its daily activities precluded many traditional biological and chemical approaches. New technologies that collected digital data about the ocean (as opposed to actual pieces of it) were suggested as the best approach to additional water column exploration. The phrase “formaldehyde is obsolete” was used to describe this outlook. While the group agreed this approach made sense it also recognized that significant investments were required to deliver on the promise of such new technologies.

Protocols Required – The need for some standardization of data types and collection protocols was identified as key to methodical water column exploration. A basic effort recommended would include collection of CTD, Chlorophyll, fluorescence, nutrients, backscatter, Fast repetition fluorescence, DO, pH, Oxidation Reduction Potential, CO₂, transmissometer, and broad frequency passive acoustics. While this is an ambitious list it is also all feasible with current technology. Some careful planning would make it possible to equip the camera sled with

instruments to collect all of this data. Proper data management techniques would result, eventually, in a potent database of water column information.

6. Concluding Discussions

The closing plenary included an interesting presentation from Kanna Rajan (a former NASA employee now with MBARI). This briefing discussed how NASA implemented science from afar. The net impact of this presentation and the associated discussion was the understanding that NOAA can learn a great deal from the NASA experience but also that the EX model has its own intricacies that will require additional consideration. This discussion was more contemplative than “decisional” and served primarily to open a new thread of consideration for OE.

Other points were made in the discussion. The following are presented for consideration not necessarily as recommendations of the participants or the OEAWG.

Abandon the water column – Thematically similar to Jamie Austin’s point in the opening session (maps and images) was the comment from Jim Bellingham that the EX is not well suited to significant water column work. From a purely technical perspective it makes sense to apply the vessel and its tools to what they are already optimized toward, mapping and site exploration. Admittedly this would leave out a large segment of science users but it would also make the EX a focused tool more likely to succeed in its mission.

Staffing – The ongoing questions about staffing were raised. The theme during this workshop included the need to align staff with any advanced technology (vice operational) plans. Some time was also spent discussing the role of science techs and the staff ashore. While useful on the whole this discussion highlighted the need for further OE work sessions to develop the detailed plans for EX.

Gaming – The NASA experience, along with some large MBARI field programs, suggested that it would be valuable to engage in gaming sessions. These could take the form of small workshops with a science team and OE/EX staff. Together this group would consider how to execute exploration, thinking through an actual effort in a real-world site.

Equipment loans – several individual attendees indicated that they would be willing to loan equipment to EX to assist in the development of the optimal exploration protocols. These offers will be captured in the technology assessment document under development.

7. Closed Session

After the workshop officially closed the OEAWG members and NOAA staff held a closed session. This proved to be an energetic discussion with many strong views. It highlighted the challenges faced by the program but also the opportunities to deliver a new service to the ocean community. The following themes were represented in the discussion.

Underway (sticks) vs. Site work (boxes) – Strong feelings were shared on the value of sites (e.g. vents, wrecks, reefs) and broad area underway work. The lack of the EK60 and 38kHz ADCP was lamented by those who felt more underway work was critical. The sticks and boxes model provided a vocabulary for the discussion but despite this working model those valuing sticks felt that the boxes had the run of the workshop. The practical limitations of funding closed the discussion. Upon providing the latest budget information on the EK60/ADCP procurement the sticks had to admit that they would have to wait for the inclusion of these tools in the future. The

proponents of boxes were adamant that the tools for that application (i.e. ROV and Camera platform) needed to be enhanced as recommended in the workshop. The potential loan of equipment and low cost solutions was discussed and understood to be a path forward. While there was some dissatisfaction in evidence the discussion led to creative ideas. In particular using the moonpool to install an ADCP as soon as funds became available, as opposed to waiting for a drydock phase, was suggested. It is likely that completion of the 2008 EX schedule/plan will diminish this debate as the realities of fiscal and technical limitations will be fully captured there.

Distinct program, moving slowly – The need for the rollout of the EX to go slowly became very clear. The freedom to do so was also made clear. There was strong agreement amongst the OEAWG members that the “community” had low expectations and could wait while OE began the effort slowly and focused on strong execution. This discussion of community expectations also led to the reminder from OEAWG members that the OE/EX program needs to be distinctive from other efforts. The ongoing back and forth over the ROV was cited as a failure to clearly portray ocean exploration and EX as distinctive from other ocean science efforts and tools.

Communications – The need for more, and improved, communications across many audiences was discussed. The OEAWG members focused on the external communications needs, but recognized OE must also communicate better within NOAA. It was suggested that outreach to AGU (perhaps an EOS article) and similar venues would be advisable. A townhall meeting to present the capabilities of the EX was suggested by NOAA and the OEAWG, recalling the “distinct program” comment suggested such a town hall might focus on the philosophy more so than the ship. That would serve to begin the “selling” of the effort and would also serve to defuse or dilute criticism of the tools. In addition to broad outreach at community events the OEAWG recognized that additional small workshops would be of benefit. Topics of interest included data management, gaming exercises, and perhaps a focus on sticks.

OEAWG issues – The OEAWG also discussed its internal issues including the need to reinvigorate its membership and develop an effective approach to the SAB and NOAA.

8. Next Steps

Several suggestions were made to productively build upon this workshop. The most important step identified was to develop a robust schedule and plan for 2008. Development of scientific plans requires an understanding of what tools will be available, how they will be tested and debugged and what staffing will be available onboard. Developing this schedule is a priority for an already scheduled OE EX team work session.

It was also recommended that OE take more steps to present the plans for the EX to the oceanographic community. Such presentations could reference the OEAWG workshops and the steps OE is taking to benefit from those workshops. While no specific ideas were offered concepts such as town hall meetings at AGU/ASLO/OCEANS were discussed.

References

1) OEAWG (Ocean Exploration Advisory Working Group). 2007. Terms of Reference. National Oceanic and Atmospheric Administration Science Advisory Board. Washington, DC. Accessed 30 May 2007 online at http://www.sab.noaa.gov/Working_Groups/Ocean_Exploration/OE_WG_TOR_final.pdf.

2) B. Evers and J. Manley, "A Vehicle for Science and Exploration: Bringing Offshore Industry Advances and Experience to the Oceanographic Community," *Proceedings of Oceans 2007*, MTS/IEEE, Vancouver, Canada, October 2007.

Appendix I: List of Attendees

Vera Alexander	OEA WG/University of Alaska, Fairbanks
Doug Au	MBARI
Jamie Austin	OEA WG/University of Texas, Austin
Bob Ballard	OEA WG/University of Rhode Island
Jim Bellingham	MBARI
Dave Butterfield	University of Washington
Rich Camilli	Woods Hole Oceanographic Institution
Dave Caress	MBARI
Dwight Coleman	University Rhode Island
Cynthia Decker	NOAA
Brent Evers	Phoenix International
Dan Fornari	Woods Hole Oceanographic Institution
Gwyn Griffiths	National Oceanography Centre, Southampton
Steve Hammond	NOAA
Corey Jaskolski	National Geographic Society
Deb Kelley	UNOLS/University of Washington
Bill Kirkwood	MBARI
Karen Kohanowich	NOAA
Dave Lovalvo	Eastern Oceanics
Justin Manley	NOAA
Larry Mayer	OEA WG/University New Hampshire
John McDonough	NOAA
Marcia McNutt	OEA WG/MBARI
Chris Meinig	NOAA-Pacific Marine Environmental Laboratory
Ken Melville	University of California, San Diego
Luke Nachbar	NOAA
Jim Newman	Woods Hole Marine Systems, Inc.
Joe Pica	NOAA
Webb Pinner	NOAA
Jeremy Potter	NOAA
Mike Prince	UNOLS
Kanna Rajan	MBARI
Tom Rossby	OEA WG/University Rhode Island
Craig Russell	NOAA
Hans Thomas	MBARI

Appendix II: The Workshop Agenda

Tuesday October 23, 2007 – Pacific Forum Conference Room

9:00 – 10:30 Opening Session and Introductions

9:00 – 9:10 Welcome and introduction to the OEAWG - Dr. Marcia McNutt, MBARI

9:10 – 9:35 The Ocean Exploration Paradigm Shift - Dr. Robert Ballard, Institute for Exploration, University of Rhode Island

9:35 – 10:00 Concept of Operations for the *Okeanos Explorer*: Summary of the Results of the First Workshop - Dr. Jamie Austin, Institute for Geophysics, University of Texas, Austin

10:00 – 10:20 NOAA-OE Program Office Plans for Initial Operations of *Okeanos Explorer* – Dr. Steve Hammond, NOAA-OE Program Director

10:20 – 10:35 Break

10:35 – 12:05 MBARI Advanced Technology Concepts

10:35 – 10:55 Advanced Sensors at MBARI, Bill Kirkwood MBARI

10:55 – 11:15 Autonomous Underwater Vehicles at MBARI, Hans Thomas, MBARI

11:15 – 11:40 What is next in ocean technology, Dr. Jim Bellingham, MBARI

11:40 – 12:05 Reality Check: Current Capabilities and Limitations of the *Okeanos Explorer* and its ROV – Craig Russell and Justin Manley, NOAA-OE

12:05 – 1:00 Working Lunch – The podium will be open to any conference attendees who wish to make a pitch for a certain technology or approach, either reinforcing ideas already heard or adding to what was discussed earlier.

1:00 – 2:30: Breakout Sessions –

Group 1 – Underway reconnaissance: Ship's View
OEAWG Facilitator: Dr. Larry Mayer
NOAA Staff: Joe Pica

Group 2 – Water Column Exploration: Ocean View
OEAWG Facilitator: Dr. Marcia McNutt
NOAA Staff: Jeremy Potter

Group 3 – Site Exploration: Pacific Forum
OEAWG Facilitator: Bruce Gilman
NOAA Staff: Craig Russell

2:30 – 3:00 Break

3:00 – 4:00 Breakouts Continue -

4:00 – 5:00 Reconvene and Reporting

4:00 – 4:15: Reconvene

4:15 – 4:30: Underway Reconnaissance

4:30 – 4:45: Water Column Sampling

4:45 – 5:00: Site Exploration

5:00: Adjourn

Dinner: Small groups are encouraged to make their own dinner plans. MBARI staff will provide suggestions.

Wednesday October 24, 2007 - Pacific Forum

8:30 – 8:45: Reconvene and Review

8:45 – 10:00: Final Breakout Session

10:00 – 10:15: Break

10:15 – 11:00: Reconvene and Reporting

10:15 – 10:30: Underway Reconnaissance

10:30 – 10:45: Water Column Sampling

10:45 – 11:00: Site Exploration

11:00 – 12:00: Open Discussion: Have we achieved our aims?

12:00 – 1:00: Lunch

1:00 – 2:30: Final Discussion

1:00 – 1:30: Summary of concepts thus far

1:30 – 2:30: Open Discussion on the role of Telepresence in the technology portfolio, moderated by Kanna Rajan

2:30 Adjourn

3:00 – 5:00 OEAWG Closed Meeting – Harbor Conference Room

Example of the table of technology recommendations table that will be developed

Technology	Status	Anticipated Action	Resources Required	Priority
EX				
EK60	Designed not installed	Install in next major port service period	Get \$ estimate from Craig R.	High
ROV				
Fiber-optic Gyro	Designed not installed	Install when funding permits	~\$100k	High
Camera Platform				
Alternative Frame Shape	Alternative design awaits field experience with current model	Ship's force could possibly construct an alternative frame at sea	Modest personnel and materials resources	Unknown until current design is tested