

Workshop Proceedings



Mobile Sensor Platforms: Management Applications for AUVs and Gliders in the Nearshore Environment

*Cape Elizabeth, Maine
April 28-30, 2004*



*Funded by NOAA's Coastal Services Center through
the Alliance for Coastal Technologies (ACT)*

An ACT 2004 Workshop Report

**A Workshop of Developers, Deliverers, and Users of
Technologies for Monitoring Coastal Environments:**

**Mobile Sensor Platforms: Management Applications
for AUVs and Gliders in the Nearshore Environment**

Cape Elizabeth, Maine
April 28-30, 2004



Sponsored by the Alliance for Coastal Technologies (ACT) and NOAA's Center for Coastal Ocean Research in the National Ocean Service.

Hosted by ACT Partner organization the Gulf of Maine Ocean Observing System (GoMOOS).

ACT is committed to develop an active partnership of technology developers, deliverers, and users within regional, state, and federal environmental management communities to establish a testbed for demonstrating, evaluating, and verifying innovative technologies in monitoring sensors, platforms, and software for use in coastal habitats.

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ACT WORKSHOP: MOBILE SENSOR PLATFORMS: MANAGEMENT APPLICATIONS FOR AUVs AND GLIDERS IN THE NEARSHORE ENVIRONMENT

EXECUTIVE SUMMARY

The Alliance for Coastal Technologies (ACT) Workshop "Mobile Sensor Platforms: Management Applications for Autonomous Underwater Vehicles (AUVs) and Gliders in the Nearshore Environment" was held in Cape Elizabeth, Maine, April 28-30, 2004, with sponsorship by the Gulf of Maine Ocean Observing System (GoMOOS), an ACT partner organization. The purpose of the workshop was to explore the use of existing AUV and glider technologies in nearshore environments. Participants included representatives from state, and federal environmental management agencies as well as academic research institutions currently using this technology or interested in their applications. Manufacturers and developers of AUV and glider systems, along with those involved with compatible sensor technologies were also represented at the meeting.

The Workshop attendees discussed the potential benefits for using AUV and glider technologies in nearshore management and research applications, the barriers and limitations of the existing technology that impedes more widespread use of the technology, and recommendations for expansion of the technologies into this arena.

The Workshop concluded that both AUVs and gliders hold great promise for the coastal management community because of their flexibility, portability and ability to respond to emergency situations. These new technologies will augment, not replace, existing sampling techniques by increasing the ability to collect data throughout the water column and over large areas. While AUVs and gliders are not yet in wide spread use in the management community, workshop attendees felt that the technologies are well suited to such applications. The following recommendations are offered to assist with this transition:

1. **Increase use of AUVs and gliders in nearshore environments.** Many of the barriers to expanded use of the technology stem from the lack of familiarity with the technology on the part of managers and with the lack of understanding on the part of industry on the unique needs of managers. Increased use of the technology can be fostered by:
 - a. Encouraging Federal funding of peer-reviewed demonstration projects (i.e., through the NOPP Program). These projects should focus on demonstrating the potential management applications using autonomous platforms and require partnerships among resource managers, industry and scientists.
 - b. Establishing "Centers for Excellence" for AUV and glider technology in connection with developing Regional Associations under the Integrated Ocean Observing System (IOOS). The centers would build on existing expertise to provide technical assistance

on the use and maintenance of the systems, troubleshooting problems, calibration and other issues.

- c. Encouraging use of AUVs and gliders by the Environmental Protection Agency and other federal agencies to demonstrate their capabilities for management applications.
- d. Encouraging the training of operators to broaden the technical knowledge of operating AUVs and gliders.

2. Increase education and awareness of how AUV and glider technologies can be applied in coastal environments:

- a. Use the ACT website as a vehicle to provide information how these technologies are being used in nearshore environmental studies, the inherent costs for purchasing, operating, and maintaining these systems, and providing case studies on the use and maintenance of AUVs and gliders.
- b. Encourage researchers and others using AUVs and gliders to publish their research in peer-reviewed literature.
- c. Request ACT to conduct a customer needs and use assessment for potential users of AUV/glider technologies, including the need for specific sensor capabilities.
- d. Utilize the ACT website to provide a data base of existing technologies, including capacities in size, power, payload, endurance, depth, velocity range, spatial range, communication methods, navigation, number of people needed to operate, available sensor options, operating software, data processing and analysis tools, and range of cost/expenses.

3. Encourage users and developers of the technology to be proactively involved in the regulatory and liability governance issues.

ALLIANCE FOR COASTAL TECHNOLOGIES

There is widespread agreement that an Integrated Ocean Observing System (IOOS) is required to meet a wide range of the Nation's marine product and information service needs. There also is consensus that the successful implementation of the IOOS will require parallel efforts in instrument development and validation and improvements to technology so that promising new technology will be available to make the transition from research/development to operational status when needed. Thus, the Alliance for Coastal Technologies (ACT) was established as a NOAA-funded partnership of research institutions, state and regional resource managers, and

private sector companies interested in developing and applying sensor and sensor platform technologies for monitoring and studying coastal systems. ACT has been designed to serve as:

- An unbiased, third-party testbed for evaluating new and developing coastal sensor and sensor platform technologies,
- A comprehensive data and information clearinghouse on coastal technologies, and
- A forum for capacity building through a series of annual workshops and seminars on specific technologies or topics.

The ACT workshops are designed to aid resource managers, coastal scientists, and private sector companies by identifying and discussing the current status, standardization, potential advancements, and obstacles in the development and use of new sensors and sensor platforms for monitoring, studying, and predicting the state of coastal waters. The workshop goals are to both help build consensus on the steps needed to develop and adopt useful tools while also facilitating the critical communications between the various groups of technology developers, manufacturers, and users.

ACT Workshop Reports are summaries of the discussions that take place between participants during the workshops. The reports also emphasize advantages and limitations of current technologies while making recommendations for both ACT and the broader community on the steps needed for technology advancement in the particular topic area. Workshop organizers draft the individual reports with input from workshop participants.

ACT is committed to exploring the application of new technologies for monitoring coastal ecosystem and studying environmental stressors that are increasingly prevalent worldwide. For more information, please visit www.act-us.info.

ACT Headquarters is located at the UMCES Chesapeake Biological Laboratory and is staffed by a Director, Chief Scientist, and several support personnel. There are currently seven ACT Partner Institutions around the country with sensor technology expertise, and that represent a broad range of environmental conditions for testing. The ACT Stakeholder Council is comprised of resource managers and industry representatives who ensure that ACT focuses on service-oriented activities. Finally, a larger body of Alliance Members has been created to provide advice to ACT and will be kept abreast of ACT activities.

GOALS FOR THE AUV WORKSHOP

The ACT Workshop on The Management Applications for Autonomous Underwater Vehicles (AUV)s and Gliders in the Nearshore Environment was convened on April 28, 2004 in Cape Elizabeth, Maine. Key objectives of the workshop were:

- (1) To summarize the state of existing AUV and glider technology,
- (2) To encourage an open dialogue that would motivate the use of AUVs and gliders in coastal and nearshore monitoring and research projects, and
- (3) To make strategic recommendations for the future development and application of these platforms and sensor technologies for coastal environmental research and monitoring.

ORGANIZATION OF THE AUV WORKSHOP

The two and a half day workshop included both formal presentation and group working sessions. Invited speakers discussed the state of AUV and glider technologies, including recent developments, the integration of sensors into AUV and glider systems, and the potential for resource management applications (Table 1). Presentations are available at the GoMOOS website address <http://www.gomoos.org/act/auv.html>.

Table 1. *Workshop Presentations*

Name and Affiliation	Title of Presentation
Dr. Mary Jane Perry University of Maine	AUVs and Gliders for the Coastal Ocean
Dr. James Bellingham, Monterey Bay Aquarium Research Institute	AUVs in Transition
Dr. Oscar Schofield Rutgers University	Dawn in the Age of Ocean Robotics
Dr. Ron Zaneveld Wetlabs Inc.	Sensors for Autonomous Underwater Vehicles
Dr. Jan Newton Washington State Department of Ecology	Resource Management Applications: AUVs and Gliders in the Nearshore Environment
Lt. J.G. Ben Evans, NOAA Office of Coast Survey	NOAA Internal AUV Workshop and Current Initiatives

The workshop format of plenary and breakout sessions insured that expertise, views and concerns from all the sectors were identified and discussed. In the morning breakout sessions, the managers, researchers and industry representatives formed three separate work groups to discuss the status of AUV/glider technology and applications, the potential for utilization of the technology in nearshore and coastal regimes and the limitations or barriers to such applications. In the afternoon, the representatives of the various sectors were integrated into three working groups to make recommendations for improving the technology for use in monitoring, coastal research and management applications. These sessions produced a series of recommendations to not only guide future development of AUVs/glidors and sensors, but to also define possible approaches for getting the AUV/glider platforms more widely used in the field.

**STATEMENT OF PROBLEM: THE COMPLEXITY
OF OBSERVING THE COASTAL ENVIRONMENT**

Ocean environments result from many interacting physical, chemical, and biological processes that occur over a variety of space and time scales. In the highly productive coastal region, terrestrial and riverine inputs, complex bottom topography, and high-energy wave environments and shoreland development amplify these interactions. Fisheries managers, coastal managers, and environmental managers tasked with protecting and managing these coastal waters seek reliable technologies that can be used to monitor coastal environments and provide high quality information on environmental conditions in order to guide management actions and decisions. As the policies and regulations become more sophisticated so does the need for more accurate data about the coastal environment. The need for data ranges from monitoring the change of a particular resource to large scale, system-wide concerns and for assessments that examine multiple parameters.

Often, critical events are missed because of sparse data points or the difficulty in continuously measuring the three-dimensionality of the water column. Under emergency situations, hazardous conditions and the lack of capacity to respond quickly in order to capture a cause/effect relationship (e.g., investigating a fish kill or responding to an oil spill) can restrict successful data collection.

Resources available to the resource manager are constantly under pressure by budgetary constraints. Before a state or federal manager can invest in new technology, he/she must be able to justify the investment in equipment and human resources. Public agencies often have limited staff resources with restricted experience and skills in cutting edge technology. Changing political agendas and fiscal policies can make sustaining long-term consistent monitoring and assessment program a challenge. As a result, there tends to be profound under-sampling of the environment and great difficulty in securing the funds and technical capacity required for modernizing existing monitoring and assessment programs.

EXISTING METHODOLOGIES AND PLATFORMS USED IN COASTAL RESEARCH AND MONITORING

Sampling methods vary, and often times, multiple platforms and approaches are used to achieve a given set of objectives. These are briefly described to provide perspective on how AUV and glider technologies can extend existing capabilities.

Shipboard surveys are the traditional means of collecting observations in the ocean and coastal waters, and are typically designed to encompass specified areas over a limited amount of time. Moored observing systems provide high frequency time series data, which are critical for the parameterization of in situ processes, observing episodic events, and collecting data during inclement conditions. While moorings remain a central technology for ocean observation, they do not always provide the necessary spatial information required to understand mesoscale processes. Therefore, spatial observations provided by satellites and high frequency radar become increasingly important in the suite of existing measurement capabilities. Improvements in satellite and remote sensing technology now can allow measurements down to 250 m.

AUV, GLIDER AND ADAPTABLE SENSOR TECHNOLOGIES: OVERVIEW OF EXISTING TECHNOLOGY

Emerging Technology:

Autonomous Lagrangian Platforms (ALPS)

Autonomous Lagrangian Platforms (ALPS) perform near-simultaneous spatial and temporal data collection, and offer many advantages to coastal observational programs, including the ability to operate autonomously for long periods of time in remote, hard to reach places that would be expensive or impossible to reach by ship. AUVs and gliders belong to this latter group of observational platforms.

The Autonomous Lagrangian Platform and Sensors (ALPS) Workshop Report (Rudnick, D.L., and M.J. Perry, eds. 2003) provides an excellent background on autonomous platforms and presents a set of recommendations for enabling broader community use of ALPS. The ALPS Workshop information and report can be viewed and downloaded from the following website: - www.geo-prose.com/ALPS. The ACT workshop on mobile sensor platforms built on the principals of the ALPS workshop, but focused on the application of two specific technologies - AUVs and gliders - for coastal management applications.

Existing Technologies:

AUVs and gliders offer an exciting opportunity for improving the type and amount of data collected on coastal environments. They augment the existing technologies by offering a flexible platform that can be deployed in a variety of situations, including in conditions when it would be cost ineffective, impossible or unsafe to send a ship and crew out. The future for this technology is promising. In the last 10 years, AUV and glider technologies have migrated from requiring teams of engineers to operate to being deployed by individual scientists using them in their research. The next step is to make the technology usable to the needs of managers. The different capabilities of AUVs and gliders are outlined below.

Gliders

Underwater gliders are profiling floats with wings for horizontal propulsion and rudders for steering. They move vertically by controlling buoyancy, therefore they move more slowly (~20 km/day) and are not as maneuverable as a propelled vehicle. Their payload is restricted to sensor technologies that won't interfere with their hydrodynamic profile or require large external power supplies. However, due to the fact gliders are not powered and restricted to battery capacity issues, gliders can cross large horizontal areas while vertically undulating for long periods of time (~ weeks to ~ 5 months). Not only can they cover large horizontal spatial areas, but gliders can also act as a virtual mooring, undulating continuously throughout the water column at a near-fixed position, allowing for the observation of parameters over the vertical spatial scales of interest to the user. Gliders follow a set of programmable mission parameters that can be changed to address the needs of any given mission. They report data when on the surface via two-way telemetry, where communications are facilitated through radio modems, cell phones, and global satellite phone networks (e.g., Iridium).

AUVs

AUVs are self-propelled autonomous vehicles that can carry a larger payload because they are externally powered. They are more maneuverable than gliders and they travel faster (~1-1.5 m/s). However, increased power usage and limitations restrict AUVs to short duration missions, on the order of 1-2 days. A variety of AUVs are currently being used by the military, research and industrial sectors that range in size from a few inches to several meters, depending on the activity. A single person can deploy some AUVs, whereas others need a shipboard crane or lifting device to be put into the water.

Sensors

Most sensors available for use underwater can be deployed on AUVs and gliders. Table 2 lists a variety of sensors currently being used on gliders, some of which are commercially available. AUVs and gliders have restricted space and limited battery capacity available for accommodating sensors, requiring adaptable sensor and sensor packages to be relatively small and power stingy.

The continued improvement in sensor technologies used in underwater applications will enhance the list of sensors that can be interfaced with AUVs and gliders in the future.

Currently, AUV and glider technologies are being used by military institutions for research and defense purposes, as well as by academic research institutions and commercial operations, such as survey companies and the oil industry. Though not an exhaustive list, some examples of nearshore environments where AUV/gliders are being used to collect environmental data include Buzzards Bay (MA), the Mid-Atlantic Bight (NJ), San Diego and Monterey Bays (CA), the Pacific Northwest Coast (WA), Rotterdam Harbor (Netherlands), Narragansett Bay (RI), the Gulf of Mexico, and in the Mediterranean. AUVs are even being operated in water depths as shallow as 3 feet. Clearly, AUV/glider technologies have arrived in the coastal environment, and should be considered an available tool for coastal management applications.

Table 2. *Sensors used on AUVs and Gliders.*

Underwater Sensor	Commercially available and being used on AUV/Gliders	Not necessarily commercially available for use on AUV/gliders, but being used in research AUV/gliders
conductivity/temperature/pressure (CTDs)	x	
Oxygen	x	
PH	x	
nutrients and dissolved metals		x
Acoustic Doppler current profilers (ADCPs)	x	
side-scan sonar	x	
bio-acoustics		x
turbulence probes		x
fluorescence and backscattering, beam attenuation	x	
Spectral radiance and irradiance	x	
UV spectral absorption		x
mass spectrometry for gases		x
bioluminescence		x
flow cytometry		x
backscattering ratio		x
spectral beam attenuation		x

ADVANTAGES OF USING AUV/GLIDERS FOR COASTAL MANAGEMENT

AUVs and gliders offer managers a unique opportunity to complement their existing monitoring and sampling programs with increased temporal and spatial coverage. The technology is portable, allowing it to be deployed in specific areas of concern or in distant, remote locations. They can be used to monitor large geographic areas or programmed to sample intensely in one location.

Features of AUVs and gliders that make them advantageous for coastal management applications include:

- They are autonomous mobile platforms without tether to ship or land (no need to moor or manage with shore to sea wires; reduce shiptime needed to monitor a given area; deployable in adverse weather and environmental conditions),
- They can travel under motorized power or by means of buoyancy giving the capability to sample continuously both vertically and horizontally,
- They can accommodate a variety of chemical, physical, and biological sensors, and
- They provide near real-time data transmittal and instrument tracking using wireless communications.

COASTAL APPLICATIONS FOR AUV/GLIDER PLATFORMS

The potential applications for AUVs and gliders for coastal research and resource management are many and varied. Some of them include:

- Water quality monitoring;
- Fisheries habitat mapping;
- Stock assessment and larval transport studies;
- Aquaculture sighting and monitoring;
- Environmental monitoring of discharge from municipal treatment plants, oil industrial complexes, etc.;
- Dredge spoils monitoring;
- Hazardous spill response activities;

- Emergency response;
- Monitoring for national security purposes.

The ability of AUVs and gliders to provide versatile modes of sampling, from a static mode to a survey mode, makes them particularly suitable for environmental monitoring. The modal approach can be economical for monitoring activities because it:

- Can provide consistent data due to emerging high precision and accurate sensor capabilities;
- Remains flexible in its application as it allows large spatial scale sampling required in monitoring programs, but can also be used to examine smaller scale processes;
- Provides a platform that is adaptable to a variety of sensor capabilities across environmental disciplines, making it possible to address complex issues.

Potential advantages of using AUV/gliders technology in coastal research and monitoring include:

- Increased and simultaneous spatial and temporal coverage capabilities;
- Ability to sample on the specific time and space scale of process/parameter being sampled;
- Ability to operate in hazardous conditions (e.g., extreme weather conditions, toxic spills);
- Ability to operate in otherwise inaccessible places (e.g., under ice);
- Allowance for strategic and targeted sampling, as well as routine sampling objectives;
- Ability for rapid response when there maybe staff and ship scheduling conflicts;
- Potential for improving cost efficiency (e.g., ship time is expensive).

CURRENT BARRIERS TO UTILIZATION OF AUVs/GLIDERS

Advancements in AUV and glider technology are encouraging and may solve some, if not many, of the sampling issues faced by researchers and resource managers. However, there are still concerns that must be dealt with in order to make mainstream use of this relatively new sensor platform desirable and achievable. Some of the barriers, concerns and limitations to their widespread use identified at the workshop include:

- Cost, which includes initial purchase of unit(s) and sensors, as well as expense in terms of labor needed to maintain and operate;
- Ability to use the technology without extensive engineering or support assistance;
- Cost (monetary and data) associated with damage or loss of equipment;
- Regulatory concerns of liability for conflicts with other water craft, moored buoys, swimmers, and marine mammals, fishing gear, reefs, and uncharted wrecks, and other obstacles in the water;
- Fouling of AUV and glider propulsions on long endurance missions;
- Data quality and reliability;
- Navigational control and docking issues;
- Navigational specificity when working around hazards such as near rugged bottom topography and fishing gear;
- Operational requirements and maintenance issues;
- Power limitations that determine mission endurance;
- Size, weight and ease of deployment;
- Communications;
- Overcoming the resistance to and difficulties in adapting new technologies for monitoring purposes;
- Lack of funding opportunities to support development of AUV/glider technologies for coastal management applications.

Since AUVs and gliders are simply platforms for oceanographic sensors, workshop participants also identified concerns about the sensors, including:

- Adaptability of existing sensors to commercially available AUVs and gliders;
- Availability of sensors needed by resource managers (e.g., nutrients, bacteria);
- Ability of systems to carry more sensors, which requires the sensors to be flush mounted or positioned such as not to alter the hydrodynamic features of the unit;
- Funding to support research and development of new and improved sensors.

Data management and handling, due to the fact that AUVs/gliders can acquire very large quantities of data, which are not purely Lagrangian is a potential problem for management agencies that may lack the personnel capable of handling and analyzing the AUV/glider data, and programming data translation software to output products needed by managers.

The question of reliability and interpretation of the data collected by these systems remains a concern for many managers. This is largely driven by the need for defensible data to support required monitoring and assessment decisions that maybe challenged in court.

Finally, in order to make AUVs and gliders a mature component of ocean observing and coastal monitoring programs, they need to be cost effective.

WORKSHOP RECOMMENDATIONS

Workshop participants identified both near-term goals for industry developing AUV/glider technologies, and approaches for overcoming the barriers to AUV/glider utilization in coastal research and resource monitoring. The consensus of the group was that expanding the use of these technologies would be the best way for solving many of the issues identified.

The main conclusions and recommendations derived during the workshop are:

1. *Increase usage of existing AUV and glider systems in nearshore coastal environments:*
 - a. Encourage federal funding through peer-reviewed demonstration projects (i.e., the National Ocean Partnership Program (NOPP)). These projects should encourage partnerships between resource managers, industry and scientists and should be focused on demonstrating the potential management applications using autonomous platforms and identifying the specific parameters required for management missions.
 - b. Establish Centers for Excellence for AUV and glider technology in connection with developing the Regional Associations under the Integrated Ocean Observing System (IOOS). The centers would provide technical expertise on the use and maintenance of the systems, assist with applications, troubleshooting problems, calibration and other issues. These centers should leverage off existing expertise and should be a distributed network so as to utilize the diverse talents throughout the country.
 - c. Encourage use of the technologies by lead federal agencies, such as the Environmental Protection Agency, to demonstrate potential for AUV/glider use in management applications.
 - d. Encourage the training of operators to establish a resource of technical knowledge in operating AUV/gliders.

2. *Increase education and awareness of how AUV and glider technologies can be applied in coastal environments:*
 - a. Use the ACT website as a vehicle to provide information related to AUV/glider technologies, how these technologies are being used in nearshore environmental studies, the inherent costs for purchasing, operating, and maintaining these systems, and real-world examples of resource management applications.
 - b. Encourage ACT to collect and publish case studies that focus on the management applications, on the costs and merits to using AUVs and gliders.
 - c. Encourage people using AUVs and gliders to publish their research in peer-reviewed literature.
 - d. Request ACT to conduct a customer needs and use assessment for potential users of AUV/glider technologies, including the need for specific sensor capabilities.
 - e. Utilize ACT website to provide a survey of existing technologies, their capacities including size, power, payload, endurance, depth, velocity range, spatial range, communications methods, navigation, number of people needed to operate, available sensor options, operating software, data processing and analysis tools, and range of cost/expenses.
3. *Encourage users and developers of the technology to be proactively involved in the regulatory and liability governance issues.*

Near-term considerations for industry in developing technologies for near shore applications include:

4. *Enhancement of medium-sized vehicles by increasing the length of missions, improve the reliability for deployment and successful recovery and improved communication systems;*
5. *Continued development of smaller vehicles that have:*
 - a. Increased mission duration;
 - b. More flexibility in mission planning and adaptive mission planning;
 - c. Options for navigation depending on mission requirements;
 - d. Obstacle avoidance capabilities.
6. *Continue development of adaptable sensors and new sensor technologies:*
 - a. To be smaller in size for deployment on smaller platforms;

- b. To have increased power efficiency in increase mission duration;
- c. To be modular sensor packages that are readily adaptable to multiple platforms; and
- d. To include development of sensors to meet the needs for monitoring programs - e.g., bacteria, nutrients, metals, etc.

To assist the industry sector in the continued development of AUV/gliders technologies, current and potential users need to provide the following:

- 7. *Well-defined needs and mission requirements, including concerns and problems with existing systems and methods of sampling (requesting cost-effective and 'easy-to-use' equipment does not provide industry with an understanding of how to improve the state of sensor and platform technology), and*
- 8. *Assistance in identifying sources of research and development monies to invest in the technology in order to make it marketable to a larger audience.*

ACKNOWLEDGEMENTS

GoMOOS would like to thank the participants for engaging in a constructive discussion on the use of gliders and AUVs. Dr. Mary Jane Perry of the University of Maine and James Bellingham of MBARI are thanked for their illuminating talks on AUVs and gliders and Lt. J.G. Ben Evans from NOAA for his overview of NOAA's AUV and glider initiatives. Special thanks goes to Dr. Oscar Schofield (Rutgers University), Dr. Jan Newton (Washington State Department of Ecology/University of Washington), and Dr. Ron Zaneveld (Wetlabs, Inc.) for serving on the steering committee for the workshop and providing excellent guidance. The workshop would not have been possible without the logistical efforts and good cheer of Jodi Clark, the GoMOOS Office Administrator. Particular gratitude is extended to Dr. Carol Janzen of the University of Maine, who coordinated all aspects of the workshop and prepared the final report. The comments and suggestions of Mario Tamburri of ACT Headquarters were particularly helpful in shaping the workshop.

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