

*Workshop Proceedings*



**TRANSFER OF MEDICAL  
SENSOR TECHNOLOGIES TO  
ENVIRONMENTAL MONITORING**

*Solomons, Maryland*

*April 6-8, 2005*

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

**An ACT 2005 Workshop Report**

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

***Transfer of Medical  
Sensor Technologies to  
Environmental Monitoring***

Solomons, Maryland

April 6-8, 2005



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 Chesapeake Biological Laboratory of the University of Maryland Center for Environmental Science in Solomons, Maryland.

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: *TRANSFER OF MEDICAL TECHNOLOGIES  
TO ENVIRONMENTAL MONITORING***

**EXECUTIVE SUMMARY**

The Alliance for Coastal Technologies (ACT) Workshop "Transfer of Medical Sensor Technologies to Environmental Monitoring" convened in Solomons, Maryland, April 6 to 8, 2005. The workshop was sponsored by the University of Maryland Center for Environmental Science (UMCES) Chesapeake Bay Laboratory (CBL), an ACT partner institution. Participants from various sectors including research/academia, resource managers, and industry, collaborated to foster the exchange of information and ideas on the transferring of medical technologies to environmental sensor technologies for use in coastal monitoring.

Technologies developed and manufactured for medical and bio-defense applications may represent opportunities for significant improvements in the environmental monitoring field. Environmental scientists and resource managers depend upon sensors that meet constraints specific to their respective applications. These scientists and managers should look to nanotechnology and other medical biotech and bio-defense technologies as potential sources of a new generation of environmental sensors. This workshop was formatted with plenary and breakout sessions to ensure the expertise, views and concerns of the research scientist / environmental manager / commercial technology developers were identified and cross fertilized.

Through these series of breakout and plenary sessions, the workshop attendees identified problems and solutions associated with the transfer of medical sensor technologies to environmental monitoring sensors. The workshop participants also explored short-term and long-term initiatives that could facilitate the assimilation of these two fields.

**CONCLUSIONS**

Workshop participants established that several limitations and barriers exist that make the transition from medical sensor technology to environmental monitoring difficult. Among these concerns were:

- Regulatory issues such as Federal approval and acceptance of new sensor technologies.
- Legal concerns such as contractual requirements which could limit cost-effective access to improved technologies.
- Commercial issues regarding manufacturing expenses, market size and demand.

- Technical issues regarding durability and reliability of these new sensor technologies when exposed to harsh conditions.
- Serviceability and compatibility concerns.
- Research and development issues such as funding and lack of coordination between the biotech/medical and environmental communities.
- Communication and information exchange obstacles like market driving factors and inhibiting influences such as intellectual property practices.

Based on their discussions, the attendees developed several conclusions to overcome the aforementioned limitations and barriers. Among these findings were:

- Regulatory standardization and validation of methods for environmental monitoring as well as increased exposure of environmental and health issues within a public forum.
- Legal facilitation of shared intellectual property through improved communication and joint funding of shared technologies.
- Commercial targeting of new technologies such as specific marketing to niche environmental markets.
- Technical improvements that aim at utilizing medical technologies in environmental auto-sampling applications.
- Identification of environmental applications which could utilize specific medical/biotech cross-over technologies along with support from the National Institute of Health (NIH).
- Communication, information exchange and education such as intra-university seminars and classes which integrate the interdisciplinary groups.

## **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, Headquartered at the UMCES Chesapeake Biological Laboratory, has eight Partner Institutions around the country that provide a variety of habitats and a range of technical expertise for testing sensor sensor/platforms for use in coastal observing systems.

The Stakeholder Council provides input into ACT priorities from private sector companies and resource managers involved in sensor technology development and use.

The regional Alliance Member Chapters organized by each ACT partner assures input from the broader coastal observing community stakeholders.

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 <http://www.act-us.info/>.

## **TRANSFER OF TECHNOLOGIES: BACKGROUND INFORMATION**

The ability to identify opportunities in transferring biotech, medical and bio-defense technologies, including nanotechnologies, to environmental applications would provide useful direction in the development of new environmental sensors. Technologies developed and manufactured for medical applications are believed to present immense opportunities for significant improvements in the development of new environmental sensor technologies. Environmental scientists and resource managers depend upon sensors that meet constraints specific to their respective applications. There is an ongoing attempt to identify medical, biotech and bio-defense technologies, including nanotechnologies, representing significant opportunities in the development, incorporation, and adaptation in environmental applications. Areas of specific interest include: availability, cost, sensitivity, size, ease of use, remote operations, and resistance

to environmental wear and tear. In preparations for this workshop, a brief review of the recent scientific literature by the organizers produced several examples of recent developments that encourage scientists and managers to explore the transfer and adaptation of these new technologies to environmental applications. These include:

- Rapid detection of bacteria with miniaturized pyrolysis-gas chromatography,
- Nanotechnology that catalyze environmental remediation,
- Wireless sensing platform employing digital compensation, self-test, and distributed power management,
- Rapid detection of pathogenic bacteria by volatile organic analysis,
- Amplified fluorescent detection of bioanalytes,
- Near real-time procedures for detecting *Staphylococcus aureus* enterotoxin A in military rations,
- Nanomaterials and nanoelectronics in automotive applications,
- Wireless passive resonant-circuit sensors for monitoring food quality,
- Insect-gene activity detection systems for chemical and biological warfare agents,
- Micro Electro Mechanical Systems (MEMS) used to produce micro-sized instruments for optical detection of trace amounts of chemical species in aqueous solution, and
- Portable sequential analyzers for on-site screening of chemical weapons degradation.

The challenge will be to adapt these technologies to in-situ field applications.

### WORKSHOP GOALS

Public health and environmental professionals rely heavily on data generated by environmental monitoring devices to manage and improve the quality of coastal waterways. The extent, frequency and quality of environmental monitoring programs, as well as the development of technologies used in these programs has typically been budget-constrained. Consequently, environmental monitoring devices are typically developed with significant budget restrictions in mind.

On the other hand, the development of medical sensors enjoys an R&D environment that recognizes significantly larger markets for devices that may improve human health care. An investment of several million dollars in a potentially new sensor device is not uncommon for medical markets that can approach or exceed \$100 million in annual sales. This dramatic contrast in the R&D environments for environmental sensors versus medical sensors provokes questions about potential synergies in adapting medical sensors to environmental applications. Specifically, do medical, biotech

The challenge will be to adapt high-cost technologies developed in the medical technologies field into realistically affordable sensors for environmental managers.

and bio-defense technologies offer significant, near-term opportunities for improvements in environmental monitoring?

The workshop was designed to address four goals:

- 1) Prioritize environmental needs for technologies having new applications and / or increased sensitivity, as well as reliability and/or versatility.
- 2) Identify existing medical, biotech and bio-defense technologies that may satisfy the highest priority environmental needs.
- 3) Identify limitations and barriers to cost-effective adaptation of existing medical, biotech and bio-defense technologies for environmental applications.
- 4) Propose recommendations for overcoming significant limitations identified in Goal #3.

## **WORKSHOP STRUCTURE**

The Workshop was hosted by the Chesapeake Biological Laboratory (UMCES) on April 6-8, 2005 in Solomon, Maryland. The first two days of the workshop were held at the Holiday Inn in Solomons. The third day was held at Chesapeake Bay Laboratories (CBL), University of Maryland in Solomon, Maryland. The meetings were devoted to small working groups of invited participants to develop consensus about impediments to and opportunities for the future adaptation of medical technologies for environmental applications.

There were 20 invited participants (Appendix A), who were selected to represent three segments of the community: researchers (technology developers and users), commercial vendors (technology suppliers) and resource managers (technology users). Participants were separated into three groups that included each of these communities during each breakout session, and all groups were asked to address the same set of questions/issues. After each session, all participants reconvened to compare recommendations among groups. The following sections of this report summarize the recommendations that evolved from those sessions.

## **WORKSHOP FINDINGS**

### **First Breakout Session**

The first breakout session was designed to encourage initial discussion of Goals 1 and 2 by participants within the three environmental community segments (industry, managers, researchers). Each group worked separately to prepare notes and summary recommendations for



later review and discussion with all workshop participants. The notes and summary recommendations generated during the first breakout session reflect the similarities and differences in perspective among the three groups.

### Researchers

In addressing Goal 1 ("prioritize environmental needs"), the research group expressed a need for sensors capable of the following:

- Identification of and profile development for biological species (micro-and macro-organisms)
- Chemical measurements for nutrients, bio-limiting trace metals, gases present at the air-water interface
- Resistance to bio-fouling
- Benthic measurements (e.g., ultrasound imaging, *in situ* microscopy, micro-flow)
- Assessment of biological community dynamics (individual behavior, tracking devices)
- Automated data-handling and data forecasting
- Remote sensing selectivity

In addition to these specific capabilities, researchers made special note of a more generic need for "integrated systems with real-time, high-frequency, two-way communication capabilities." They also identified a need for additional industry focus on mass manufacturing (cost reduction) and market development.

The technologies identified by the researchers to "satisfy the highest environmental needs" (Goal 2) spanned a wide range of sensors, processes, techniques and concepts that are now considered almost commonplace in medical and biotech applications:

- Drug delivery polymers as anti-fouling coatings and to provide target specific chemistry
- High frequency imaging (e.g., acoustic technologies)
- Biochips and Microsystems including:
  - o Array biochips: solid surfaces on which multiple biological molecules are immobilized or built in an array pattern
  - o Multi-analytes: measured multiple chemical species
  - o Micro-fluidic technologies: systems that can deliver nanolitre amounts of liquid to a desired location or target
- Bio-informatics: use and organization of information of biological interest
- Data mining: deriving useful information from large data banks
- Machine learning: use of iterative computer feedback to tailor a mechanical action
- Dip-stick assays
- Optical coherence tomography
- Magnetic Resonance Imaging (MRI)
- Fiber optic sensors
- High through-put screening

- Magnetic bead separation
- Integrated CAD tools:
  - o Muscle-like actuators
  - o Medical robotics
  - o Tele-medicine
  - o Bio-materials

### Managers

The managers determined at the outset that due to their general lack of familiarity with available medical and biotech technologies, their first session efforts would focus on addressing Goal 1 ("prioritize environmental needs"). Specific needs identified by the managers were:

- Biological measurements (including HAB's, pathogens and invasive species) with characteristics for:
  - o Developing 'field friendly' molecular identification methods
  - o Meeting reliability thresholds
  - o Providing ecosystem status (including populations assessments)
- Implantable sensors that meet rigorous size and power requirements.
- Diagnostic indicators capable of:
  - o Resisting environmental exposure
  - o Providing reproducible results
  - o Identifying organisms on a species level
  - o Detecting and quantifying exotic or invasive species
  - o Differentiating "known" versus "unknown" species
  - o Identifying and quantifying chemical species as it relates to nutrients, metals and oils with the capability for source identification, e.g. by chemical clues

After listing specific environmental sensor needs, the managers determined that a list of "general" needs for improving current environmental sensors was justified. The group listed the following characteristics for improving environmental sensors:

- Make them smaller, cheaper, faster
- Minimize/reduce biofouling
- Improve reliability
- Evolve from individual, independent sensors to multiple, integrative sensors
- Improve methods for sample acquisition, sample preparation and sample storage

## Industry

The industry group divided needs for environmental sensors (Goal 1) into two categories:

### *Technical Needs:*

- Physical, chemical and biological parameters
- Quantification capabilities with:
  - o Baseline establishment
  - o Improved precision and sensitivity
  - o Real-time measurement
- Standardized and validated techniques/methodologies
- Sample preparation for lower concentrations of analytes/species
- Greater measurement density (higher frequency and reach" of sampling) for both:
  - o Fixed platform
  - o Mobile devices

### *Economic and Legal Needs:*

- Market assessment and identification (complete profile).
- Market quantification.
- Low acquisition costs.
- Low maintenance and supply (especially "consumables") costs.

In addressing Goal 2 ("satisfy the highest environmental needs"), the "Industry" group listed both specific technologies and general concepts, including:

- Cantilever, label-free micro-mechanism devices.
- Surface plasmon resonance techniques.
- Molecular recognition techniques (including immunoassays).
- Wireless sensor networks.
- Interoperable devices.
- Fluorometry (enhanced).

In addition, the group raised an interesting question about whether or not the pharmaceutical industry can offer other technologies and approaches that are not evident to individuals in other industries (e.g., the environmental industry).

A suggestion was made and supported by the industry group that a workshop bringing together representatives of the environmental and pharmaceutical communities may be warranted.

## Second Breakout Session

Groups were organized along "multi-disciplinary" lines for the second breakout session. The three discussion groups were organized so as to include members of the original researcher, manager and industry groups in each of the three new groups. An additional list of questions, generated by the workshop facilitators, was provided to the groups for consideration and guidance in addressing Workshop Goals 3 ("identify limitations and barriers to cost-effective transfer") and 4 ("propose recommendations for overcoming limitation and barriers"). The 3 guidance questions were designed to emphasize three key areas:

- 1) What are the implications of transferring medical diagnostic technologies that offer improved sensitivity and reliability?
- 2) As medical technologies are adapted for environmental uses, what limitations do you foresee in sample collection and preparation?
- 3) As a limitation to the transfer of medical/biotech technologies, comment on mechanisms to overcome the barrier of information exchange between the medical/biotech community and the environmental community.

### LIMITATIONS AND BARRIERS

Results of the second breakout session were presented to all attendees at the end of the second day. During these sessions, participants presented and discussed their groups' findings with regard to the limitations and barriers to cost-effective transfer of medical, biotech and bio-defense technologies for environmental applications (Goal 3). These findings fell into six major categories of limitations and barriers:

- 1) Regulatory:
  - o Regulatory compliance has specific standards; major changes in technology require a "recalibration" for compliance
  - o A general resistance to change
  - o **Regulatory conflict and confusion while companies wait for EPA to clarify regulations**
  - o Costs to carry out legislated regulations
  - o **Public and political justifications are required to offset potential for increased expenditures**
- 2) Legal:
  - o Restrictive, burdensome medical procedures may make diversification difficult.
  - o **Contractual (business) requirements limit cost-effective access to improved technologies.**
  - o Potential liability associated with influx of more detailed information (e.g. improved sensitivity) may increase.

- o Legal issues (e.g. potential liability) drive the need for improved sensitivity but at the same time, improved sensitivity may, in the minds of environmental managers, lead to more stringent regulatory scrutiny.
- 3) Commercial:
- o Compliance with two sets of regulations (biotech/medical versus environmental) may require partitioning of companies for production, accounting, etc.; represents a resource burden resulting from diversification.
  - o **Environmental market size may not be large enough to support technology transfer or development and production costs for expensive sensors.**
  - o Cost of adaptation (from medical to environmental applications) may be cost prohibitive; different methodologies used in different markets and the environmental needs (in terms of sensors) are extremely diverse.
  - o Contractual obstacles and negotiated legal language in agreements limit technology transfer.
  - o Appropriate business model(s) may not be readily available.
- 4) Technical:
- o Targets (i.e. species of interest) are not well defined in all cases.
  - o Environmental packaging requires reliable operation in harsh, variable environments.
  - o Environmental characterization is a complicated goal requiring multiple measurements for species (chemical, biological) of interest, over time and in fluctuating environments.
  - o Repairability and serviceability.
  - o **Uncertainty as to whether or not medical and biotech sensor technologies actually offer improved sensitivity and reliability for environmental applications.**
  - o Need for improved sensitivity may vary regionally or on a case-by-case basis; improved sensitivity may lead to increased regulatory scrutiny.
  - o Sample preparation, especially overcoming concentration (of species), salt removal and temperature fluctuation issues.
  - o Sample collection, especially addressing improved sensitivity and reliability while providing automated sampling and acceptable levels of sterility and stability.
  - o Sample collection, stabilization, concentration, archival and storage, and wet chemistry requirements specifically related to the development of a "gold" standard accepted by regulators.
  - o Tolerance of sensors for one another on multi-sensor platforms (i.e. overcoming interference and incompatibility issues).
- 5) Research & Development:
- o Increased availability of resources from bio-defense and medical communities needed: funding, technology development, prototypes, and market analyses.
  - o Association with bio-defense and medical organizations analogous to ACT.
  - o Lack of broad interaction between biotech/medical and environmental communities.
  - o Translation of new requirements for increased sensitivity and reliability into basic research opportunities.

- 6) Communication, Information Exchange and Education:
  - o Impetus for IOOS sensor platform is required to overcome other industry barriers to change.
  - o **Positive public perception is critical to drive market.**
  - o Current lack of awareness between disciplines in environment and medicine.
  - o Technology transfer and intellectual property practices that are counterproductive in achieving transfer between the two disciplines of environment and medicine.

Those limitations and barriers determined to be most important to the workshop participants are presented in bold type in the above lists.

### **Recommendations to Overcome Limitations and Barriers**

1. Regulatory:
  - o Mandate standardization and validation of methods for environmental monitoring.
  - o Establish and/or strengthen link in public's mind between environment and public health.
2. Legal: (none)
3. Commercial:
  - o Cater the adoption of medical technologies to niche environmental markets.
  - o Determine how to adopt strategies for tapping into biomedical capitalization for the environmental fields.
  - o Build a large environmental market.
  - o Tap into the existing medical/biotech market with existing technologies developed for environmental applications.
  - o Broaden the perceived market base for environmental sensors.
  - o Fund a market study that identifies and quantifies market segments for the overall environmental market.
  - o Foster relationships with filtration manufacturers and service providers.
4. Technical:
  - o Explore medical systems and devices for auto-sampling in environmental applications.
  - o Assume that with nearly unlimited funds, improvements in environmental technologies are certain.
5. Research & Development:
  - o Identify specific goals for adopting medical/biotech technologies for environmental applications with NIH involvement and support.
6. Communication, Information Exchange and Education:
  - o Adopt short-term, lower payoff strategy for technology transfer at Universities.

- o Develop new workshops and conferences specifically designed to bring separate disciplines together; ensure that instrument and sensor manufacturers are involved.
- o Develop and support individual disclosure web sites with enough information to visualize other applications (e.g., University of Cincinnati web site).
- o Survey medical technology and other web sites for potential environmental applications.
- o Encourage NIH technical briefs for increased visibility of the potential for use of medical sensors in environmental applications.
- o Incorporate and emphasize additional multi-disciplinary work in engineering educations at the undergraduate level.
- o Update and modernize course work in electronics, instrumentation and engineering for life science students.
- o Provide more support for integrating continued education in coastal management and technologies related to coastal management in K-12 education.
- o Develop intra-university seminars to cover multidisciplinary issues.
- o Develop and adopt any ideas that improve communication and coordination among interdisciplinary groups.
- o Environmental community must evaluate and understand where to look and who to contact regarding medical/biotech technologies.
- o Encourage and support joint workshops versus conferences (e.g., Pittcon, ACS); organize special sessions as part of larger conferences.
- o Sponsoring institutions should offer joint science meetings that "piggyback" on large conferences and other meetings.
- o Encourage and sponsor videoconferences between industry and researchers.
- o Identify lead institutions that promote technology transfer into environmental applications.

## **WORKSHOP MAJOR CONCLUSIONS**

Based on their discussions, the attendees developed several conclusions in response to overcoming the limitations and barriers associated with the transfer of medical technologies to environmental sensors.

Among these findings were:

- The need for regulatory standardization and validation of methods for environmental monitoring as well as integration of environmental and health issues into the public forum.
- Legal facilitation of shared intellectual property through improved communication and joint funding of shared technologies.
- Commercial targeting of new technologies such as specifically marketing to niche environmental markets.

- Broadening of the perceived market base for environmental sensors and funding of a market study that identifies and quantifies market segments for the overall environmental industry as well as fostering relationships with filtration manufacturers and service providers.
- Technical improvements that aim at utilizing medical technologies in environmental auto-sampling applications.
- Identification of environmental applications that could utilize specific medical/biotech cross-over technologies along with support from the National Institute of Health (NIH).
- Increased communication, information exchange, and education such as intra-university seminars and classes that integrate the interdisciplinary groups.
- Development and support of individual disclosure websites with ample information on sensor applications.
- Encouragement of NIH technical briefs for increased visibility surrounding the potential use of medical sensors in environmental monitoring applications.
- Incorporation and emphasis on additional multi-disciplinary work in engineering educations at the graduate level featuring modernized course work in electronics, instrumentation and engineering for life science students as well.
- The Adoption of short-term, lower payoff strategies for technology transfer at Universities and the development of new workshops and conferences specifically designed to bring the separate disciplines together.

## WORKSHOP RECOMMENDATIONS AND ACTION ITEMS

The environmental community should consider the following recommendations to facilitate the technology transfer of medical sensors to environmental monitoring applications:

*Action Item #1: ACT should partner with groups from both the environmental and medical communities to organize more cross-discipline workshops.*

- Reevaluate ACT's role and coordinate with other entities.
- Narrow the topics so that they are more product specific.
- Encourage representatives in the technologies community to attend large conferences for the purpose of recruiting and targeting participants; post-docs and others should engage medical scientists and technology developers in technical discussions.
- Participate in tailored workshops with other organizations based on positive responses from "recruitment" efforts (see above).
- Advertise industrial meetings and conferences such as Pittcon.



*Action Item #2: The environmental community needs to address the issue of a perceived "small" environmental market.*

- Encourage that market studies be undertaken via universities, business schools, outside consultants, etc., that analyze the potential integration of medical sensor technologies into the environmental sensor field.
- Determine whether the need for multi-sensor technology in environmental applications is economically attractive for developers of medical/biotech sensors and equipment; higher cost sensors may be justified for this broad subset of environmental applications.
- Improve public awareness to emphasize value-added applications in saltwater environments versus freshwater environments.

Specify suggested (narrow) topics:

- Amplification technologies.
- Detection and quantification technologies.
- Sample preparation and collection for *in situ* methodologies

*Action Item #3: Legal barriers to technology transfer must be examined and rectified.*

- Emphasize the fact that adapting existing products for new applications offer short cuts and, therefore, cost savings as a result of shorter research and development time.
- In fostering technology transfer, ACT should help build relationships at the research and development level between industry and university researchers; improvements in recruitment, technology transfer, and partnerships are all potentially positive outcomes.

*Action Item #4: Address the basic question of whether or not medical detection technologies are more sensitive than current environmental detection technologies. Is the cost of transferring technologies worth the investment?*

- Emphasize a broader review of medical technologies that represent opportunities for environmental applications (i.e. "cast a broad net").
- Encourage two-way dialogue between the two communities about versatility and reliability of sensors.
- Take advantage of technology "hi-jacking" by encouraging first use of medical or biotech sensors in specific environmental applications.
- Encourage environmental companies to review and assess medical technologies that offer new or improved capabilities.
- Take advantage of "Species 10" program (population nutrients, diversity, multi-probe approach).

- Encourage the environmental and medical sensor communities to initiate awareness within universities that have both medical/biotech and environmental programs (and other programs that offer assistance with business and engineering issues); this could reduce the time and cost associated with promoting awareness and, ultimately, inter-disciplinary collaborations.

*Action Item #5: Identify research goals for scientists that promote the transfer of medical/biotech sensors to environmental applications.*

- Improve access to existing NIH programs to foster multi-disciplinary collaborations for the environmental community.
- Encourage the biotech and environmental communities to create incentives for research collaborations that emphasize medical/environmental interdisciplinary projects.

NIH should be encouraged to issue an SBIR specifically designed to promote adaptation of medical sensors for environmental use.

*Action Item #6: Improve sample preparation for environmental applications.*

- Assist in the developing and promotion of relationships between instrument manufacturers and filtration companies to explore utility of improved filtration technologies (e.g., blood filtration) for environmental uses; may identify opportunities stemming from access to new materials.
- Recognize that environmental applications face unique challenges that may not be addressed by current medical and biotech technologies; however, *in situ* technologies represent a real need/gap in environmental technologies.
- Recognize that the improvements needed for environmental uses should focus on the technologies and not standard, industry- and governmental-approved methodologies.
- Equipment size (i.e. preference for smaller equipment) must be addressed, especially as it relates to power requirements and sources; self-contained power sources may not necessarily represent an improvement.
- Promote along with other members of the environmental and medical sensor field, the idea that the term "sampling" should be broadened to include macro-level procedures such as "fish tagging".
- Emphasize rapid, larger scale (mass) collection technologies.
- Address archiving capability for samples, especially as it relates to remote, autonomous sampling and stability of the species of interest (e.g., molecular targets).

*Action Item #7: Promote multi-disciplinary education within formal education programs (e.g., engineering).*

- Help promote education of researchers and scientists within degree programs that emphasize cross training with engineering coursework.
- Encourage that an analysis to determine and define technical education requirements for enhancing the medical/biotech/environmental overlap.
- Advise engineering departments at universities to encourage their students to get involved in marine-related research projects.
- Encourage the incorporation of regulatory education into scientific and engineering curriculums to promote better understanding of the important market drivers (regulations and legislation).

Assist in the identification of specific needs for cross training and educating chemists and environmental scientist in aspects of engineering that will enhance their overall capabilities.

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**APPENDIX A: WORKSHOP PARTICIPANTS (CONTINUED)**



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