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Workshop Proceedings

HYDROCARBON SENSORS FOR OIL SPILL PREVENTION AND RESPONSE

Seward, Alaska
April 8-10, 2008

Funded by NOAA through the Alliance for Coastal Technologies (ACT) with support from the Oil Spill Recovery Institute (OSRI)

An ACT Workshop Report

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

Hydrocarbon Sensors for Oil Spill Prevention and Response

Seward, Alaska
April 8-10, 2008

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

Hosted by ACT Partner Organizations, University of Alaska Fairbanks and the Alaska SeaLife Center.

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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Executive Summary

During April 8th-10th, 2008, the Alliance for Coastal Technologies (ACT) partner institutions, University of Alaska Fairbanks (UAF), Alaska SeaLife Center (ASLC), and the Oil Spill Recovery Institute (OSRI) hosted a workshop entitled: "Hydrocarbon Sensors for Oil Spill Prevention and Response" in Seward, Alaska. The main focus was to bring together 29 workshop participants – representing resource managers, scientists, and technology developers – together to discuss current and future hydrocarbon in-situ, laboratory, and remote sensors as they apply to oil spill prevention and response.

Hydrocarbons and their derivatives still remain one of the most important energy sources in the world. To effectively manage these energy sources, proper protocol must be implemented to ensure the prevention and response to oil spills, as there are significant economic and environmental costs when oil spills occur. Hydrocarbon sensors provide the means to detect and monitor oil spills before, during, and after they occur. Capitalizing on the properties of oils, developers have designed in-situ, laboratory, and remote sensors that absorb or reflect the electromagnetic energy at different spectral bands.

Workshop participants identified current hydrocarbon sensors (in-situ, laboratory, and remote sensors) and their overall performance. To achieve the most comprehensive understanding of oil spills, multiple sensors will be needed to gather oil spill extent, location, movement, thickness, condition, and classification. No single hydrocarbon sensor has the capability to collect all this information. Participants, therefore, suggested the development of means to combine sensor equipment to effectively and rapidly establish spill response.

As the exploration of oil continues in polar latitudes, sensor equipment must be developed to withstand harsh, arctic climates, be able to detect oil under ice, and reduce the need for ground teams because ice extent is far too large of an area to cover. Participants also recognized the need for the United States (U.S.) to adopt a multi-agency cooperation for oil spill response, as the majority of issues surrounding oil spill response focuses not on the hydrocarbon sensors but on an effective contingency plan adopted by all agencies. It was recommended that the U.S. could model contingency planning based on other nations, such as Germany and Norway.

Workshop participants were asked to make recommendations at the conclusion of the workshop and are summarized below without prioritization:

- Outreach materials must be delivered to funding sources and Congressional delegates regarding the importance of oil spill prevention and response and the development of proper sensors to achieve effective response.
- Develop protocols for training resource managers as new sensors become available.
- Develop or adopt standard instrument specifications and testing protocols to assist manufacturers in further developing new sensor technologies.

- As oil exploration continues in polar latitudes, more research and development should be allocated to develop a suite of instruments that are applicable to oil detection in or under ice.
- Develop a standard GIS data management protocol to be implemented so that data can feed directly into the Maritime Domain Awareness or Dynamic Decision Support System (DDSS).
- Resource managers proposed that hydrocarbon sensors undergo performance standards to ensure global compliancy. It was recommended that ACT, working with various developers/manufacturers, test the ability to measure hydrocarbons on water and under ice using both in-situ and remote sensing technologies.
- Resource managers and technology developers should revisit funding sources and explore novel approaches towards obtaining necessary support.

Alliance for Coastal Technologies

The Alliance for Coastal Technologies is a NOAA-funded partnership of research institutions, resource managers, and private sector companies dedicated to fostering the development and adoption of effective and reliable sensors and platforms. ACT is committed to providing the information required to select the most appropriate tools for studying and monitoring coastal environments. Program priorities include transitioning emerging technologies to operational use rapidly and effectively; maintaining a dialogue among technology users, developers, and providers; identifying technology needs and novel technologies; documenting technology performance and potential; and providing the Integrated Ocean Observing System (IOOS) with information required for the deployment of reliable and cost-effective networks.

To accomplish these goals, ACT provides these services to the community:

- Third-party testbed for quantitatively evaluating the performance of new and existing coastal technologies in the laboratory and under diverse environmental conditions.
- Capacity building through technology-specific workshops that review the current state of instrumentation, build consensus on future directions, and enhance communications between users and developers.
- Information clearinghouse through a searchable online database of environmental technologies and community discussion boards.

ACT is organized to ensure geographic and sector involvement:

- Headquarters is located at the UMCES Chesapeake Biological Laboratory, Solomons, MD.

- Board of Directors includes Partner Institutions, a Stakeholders Council, and NOAA/CSC representatives to establish ACT foci and program vision.

- There are currently eight ACT Partner Institutions around the country with coastal technology expertise 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.

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's goal is to help build consensus on the steps needed to develop and adopt useful tools, while facilitating critical communication among 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.

Hydrocarbon Sensors for Oil Spill Prevention and Response Workshop Goals

Planning for the ACT Workshop on hydrocarbon sensors was undertaken with the following objectives in mind:

- to identify and summarize current hydrocarbon sensors in the in-situ, laboratory, and remote sensing fields pertaining specifically to oil spill prevention and response;
- to elucidate the strengths and limitations of each type of hydrocarbon sensor;
- to discuss the expected resource manager needs from hydrocarbon sensor technology and scientists to ensure proper management, funding, and action;
- to determine future hydrocarbon sensor technology that would enhance oil spill detection and response;
- to make recommendations and priorities for ACT and the broader community to pursue.

Organization of the Workshop

The two-day workshop was co-sponsored by ACT and OSRI and hosted by ASLC and UAF as ACT partner institutes. The workshop was organized by Dr. Shannon Atkinson (UAF) and Dr. Scott Pegau (OSRI). A stakeholder committee was assigned, which included Dr. Buzz Martin, Ms. Chelsea Donovan, and Dr. Guy Meadows. Dr. Robert Shuchman was later assigned to the committee to replace Dr. Meadows.

On the first evening, workshop participants convened for a reception and dinner in the Alaska SeaLife Center's Underwater Viewing area. Dr. Shannon Atkinson delivered the workshop's opening remarks, along with a brief introduction about ACT and its mission. Discussing the importance of under ice hydrocarbon detection using Ground Penetrating Radar (GPR) techniques was the topic of the workshop's keynote address presented by Mr. Lee Majors of Alaska Clean Seas.

The workshop commenced the following day with an introduction by Dr. Scott Pegau (OSRI) and a series of presentations delivered by the stakeholder committee members. These presentations included: 1) A summary by Ms. Chelsea Donovan of the most recent and available hydrocarbon technologies; 2) Special Monitoring of Applied Response Technologies (SMART) as discussed by Dr. Buzz Martin; and 3) The future of hydrocarbon technologies by Dr. Robert Shuchman. Workshop participants were then classified according to user group (technology developer, scientist, or resource manager) for the morning and afternoon breakout sessions.

Prior to the workshop, participants were given breakout session questions that served as the framework for discussion. Breakout sessions were pre-assigned based upon two categories of hydrocarbon technologies. The first morning session focused on in-situ and laboratory technologies, and the afternoon session concentrated on remote sensing technology. To maintain discussion consistency, the same breakout session questions were administered for both morning and afternoon sessions. Workshop participants were randomly assigned to three designated conference rooms at ASLC. To foster open and unique dialogue among workshop participants, user groups were integrated within each conference room. A stakeholder committee member served as moderator in each of the designated conference rooms. Following both breakout sessions, each group reported their findings in a plenary session.

Breakout Session Questions (Morning and Afternoon Sessions)

In-Situ, Laboratory, and Remote Sensing Technologies

- What hydrocarbon sensors are currently available?
- What do the sensors measure, and what does this information mean?
- What are their limitations and strengths?
- What do resource managers need from hydrocarbon sensors?
- What are the expected future needs?
- What needs to be done to ensure new sensors are accepted by the resource management community?
- What are the challenges from a development standpoint to design hydrocarbon technologies?
- Are there other approaches and/or technologies that are worth pursuing?

On the final day, workshop participants met for a third breakout session discussing the future of hydrocarbon technologies as they relate to oil spill prevention and response. Breakout session questions for this particular session were distributed prior to the workshop and served as the framework for discussion. Stakeholder committee members led a panel discussion with all workshop participants present. During this session, participants were also asked to discuss recommendations and priorities for ACT to pursue.

Breakout Session Questions (Final Session)

Vision and Future Developments

- What areas of research and development are most needed?
- What actions are needed within the next year?
- What actions are needed within the next 3 years?
- How might we achieve the needed actions?

Hydrocarbon Sensor Background

Hydrocarbon derivatives have remained one of the world's most important energy sources since the 19th century. They have helped establish global economies, drive industrialization, and fuel transportation and heating needs to even the most remote regions on the planet. The global dependence for hydrocarbons, a non-renewable resource, has triggered a growing demand that has entrenched itself within political, socio-economic, and environmental arenas. As a result, technological advancements in areas of exploration, extraction, monitoring, detection, and refinement must meet this global demand while also reducing potential environmental consequences.

Whether extracting crude oil, refining the product, or transporting hydrocarbon derivatives, there is an inherent risk that oil spills will happen and continue to occur. Oil spills may occur in many environments, as oil exploration and development can be found both terrestrially and aquatically. These environments include the nearshore, offshore, under snow and sea-ice, on land, estuarine, and riparian habitats. Additionally, hydrocarbon derivatives are often transported overseas making long trans-Atlantic and trans-Pacific journeys over ecologically sensitive areas. Oil spill incidents surrounding oil tankers, however, occur at relatively low frequencies when compared to annual global oil spills. Worldwide, fuels account for 48% of the total oil spilled into the sea worldwide, while crude oil spills account for 29% of the total (Brekke and Solberg, 2005). Most oil spills are diesel and hydraulics, which are aromatic hydrocarbon compounds that generally do not sink in the water column.

Discharged oil on water is classified as an oil spill, slick, or sheen in descending order of magnitude. As time passes and with increased wave and wind action, oil spills will disperse and gradually degrade. Heavier oils such as crude oil, for example, persist in the environment much longer than lighter oils that typically evaporate. Though not as toxic as lighter oils, crude oil has far greater environmental consequences associated with it, as it can directly and indirectly impact multiple trophic levels such as phytoplankton, benthic invertebrates, fish, marine mammals, and sea birds.

Federal, State, and industry standards of prevention and response have shown significant improvements over the past 20 years stemming largely from incidents surrounding the 1989 Exxon Valdez Oil Spill. In 1990, Congress passed legislation in the form of the Oil Pollution Act of 1990 (OPA 90) to improve oil spill prevention and response. The OPA expanded federal funding and resources to facilitate oil spill response, established new requirements for national and industry contingency plans, imposed stricter penalties for improper oil discharge, and maintained State authority to establish law governing oil spill and response (EPA 1990).

An equally important aspect to spill response, aside from prevention, is the mechanism(s) by which hydrocarbons are detected at the onset of a spill. There are a suite of hydrocarbon sensors designed to accommodate in-situ, in-vitro, and remote sensing methods of oil spill detection. However, no single, current hydrocarbon sensor has the capability of providing all the information required for oil spill contingency planning (Jha et al., 2008). As a result, resource managers and scientists must depend upon multiple technologies to arrive at sound, effective management.

Hydrocarbon detection in water has remained largely unchanged since the 1970s despite the advancements of different sensor technologies. Sensors are continuing to detect electromagnetic energy absorbed, reflected, and fluoresced across different wavelength spectrums or utilizing mass spectrometry to fingerprint oil. Depending upon the sensor used, one can detect the absorption, reflectance, and fluorescence by hydrocarbons at different wavelengths within the electromagnetic spectrum. Remote sensing has shown vast improvements since thermal, visible, and aerial scanning and photography systems were used at the start of the 1970s (Jha et al. 2008). Yet these remote scanning systems still utilize some of the same principles of detecting oil in water. Electromagnetic absorption and emission remain as one of the most effective ways to determine the presence of oil either remotely or in-situ.

For the purpose of this workshop, participants were asked to focus their efforts upon hydrocarbon sensors that provide immediate, rapid response for sea-ice, snow, and water-related oil spills; estuarine, nearshore, offshore, and riparian environments were considered water-related. Land-based oil spills were not addressed in this particular workshop, as response and contingency planning differs from that of under ice and water-related oil spills. Additionally, because the term “hydrocarbon” encompasses multiple compounds and derivatives making its definition complex, participants defined “hydrocarbon” for this particular workshop as both crude and refined oil products. Hydrocarbon sensor discussions, therefore, were not compound-specific, but rather addressed hydrocarbons in the broad contextual sense.

It should be noted that there was general consensus among all workshop participants that in order to determine the most effective hydrocarbon technologies for oil spill prevention and response, there was no endorsement of any specific instrument or developer.

Current Hydrocarbon Sensor Technologies: In-Situ, Laboratory, Remote Sensing

In-Situ and Laboratory Sensors

In-situ sensors were defined as any sensor that makes direct contact with the oil or the media that the oil is in. Laboratory sensors and only in-situ sensors that were classified as rapidly deployable were listed in Table 1. Much of the hydrocarbon sensor technology revolves around oil’s electromagnetic absorption and emission of energy through different wavelengths within the electromagnetic spectrum. These include the visible, infrared, ultraviolet, radio wave, and microwave wavelengths. Listed are general types of hydrocarbon sensors and, therefore, have no specific endorsements, evaluation, or quantitative comparison. Cost was an exclusionary factor for either strength or weakness considerations, as cost can be subjective and relative.

Remote Sensing Technology

Remote hydrocarbon sensors were defined as sensors that are not in direct contact with oil or media that the oil is in. These technologies included airborne and satellite-based remote sensors. Another classification that participants used was "near" and "far" range forms of indirect measurement. Remote sensing technology enables first response units to continuously track and stay on the oil for proper containment. Additionally, with the exception of Synthetic Aperture Radar (SAR), remote sensing can be recorded in real-time—SAR has this capability but is costly. Listed in Table 2 are general types of hydrocarbon remote sensors and, therefore, have no specific endorsements, evaluation, or quantitative comparison. Cost was an exclusionary factor for either strength or weakness considerations, as cost can be subjective and relative. Jha et al. (2008) also provides a good review on current remote sensing technologies for oil spill disaster management

Resource Manager Needs

To properly assess the extent and magnitude of oil spills, there is a suite of criteria needed for resource managers to obtain and monitor before, during, and after the spill has occurred. Synthesizing these data, however, proves challenging, as information is being compiled from both in-situ and remote sensing hydrocarbon sensors. To date, there is no composite hydrocarbon sensor that accommodates multiple, continuous, real-time data for resource managers to use. Rather, they must draw from multiple hydrocarbon sensor technologies to arrive at proper contingency planning. Workshop participants discussed the most important resource manager needs for proper oil spill response (i.e., burning, dispersants, etc.). Their criteria are listed below and include sensor data requirements and specifications:

Detection

Sensors must be able to detect the presence and/or absence of oil in areas where there are potential oil discharges. In addition, resource managers want to detect the amount of oil that is not only at the surface but is mixed in the water column. Many in-situ and remote hydrocarbon sensors detect wavelengths of electromagnetic energy either absorbed or reflected by oil in the infrared, visible, microwave, and ultra-violet spectrums. Limitations arise, however, when penetrating fog or conducting night observations—concerns that are especially important to resource managers located in northern latitudes.

Location

Sensor technologies must be able to determine the location of the oil spill. This is perhaps the single most important data point for resource managers to acquire. Response techniques may differ depending upon the location of the spill (i.e., nearshore, offshore, riparian, under ice, etc.).

Spatial Extent and Thickness

Knowing the discharge area alone can vastly underestimate the extent of the oil spill as 90% of the oil is generally found within 10% of the spill area. Combining both area and thickness will determine the best available technologies for response in different locations. Understanding these volumetric constraints also yields a better approximation of the quantity of oil discharged—another data point essential for resource managers. It was recommended that repeated thickness measurements be obtained due to the dynamic and fluid nature of oil on water.

Viscosity

Viscosity describes the overall fluidity of a particular substance. Heavier oils are more viscous (i.e., less fluid) than lighter hydrocarbons, such as methanol, acetone, and benzene; and thus require more time and surface wave action to breakdown and disperse. Knowing the viscosity of the discharged oil will determine the appropriate response mechanisms to be deployed.

Movement and Tracking Over Time

Discharged oil on water is a fluid, dynamic substance that responds to environmental and oceanographic change. Resource managers must be able to track the movements of oil on water and under ice—especially in either populated or ecologically sensitive nearshore habitats—in real-time capabilities.

State of the Oil

Oil is made up of many complex hydrocarbon chemicals. Each chemical compound responds differently to the environment and degrades at various rates. Sunlight, microbes, and wave action, for example, can all profoundly impact oil composition over time. Oil degradation or "weathering" is the process from which oil loses its resemblance to a state of unspilled oil. It is important for resource managers to continuously know the state of spilled oil as it weathers or if there is chance for recovery.

ID Classification (Oil Fingerprinting)

Using forensic techniques, resource managers and scientists have the ability to determine the source of oil spills in the natural environment. Hydrocarbons have specific chemical signatures or fingerprints that reveal its specific chemical origins and geological processes it has undergone. Crude and refined oils, therefore, have their own unique fingerprint. Not only does this provide a framework for issuing proper contingency plans because it identifies what type of oil is present, but it also aids in legal ramifications when determining perpetrators of oil spills.

Sensor requirements

The aforementioned criteria discuss the variables in-situ and remote sensors must be equipped with in order to properly respond to oil spills. How sensors are packaged, however, is yet another set of criteria that workshop participants discussed. The SMART protocol provided much of the context on how sensors should be packaged (Appendix B).

Remote sensing and in-situ hydrocarbon technologies must collect data in real-time format and be accessible to first responders and resource managers. The overall consensus was to have inexpensive, portable, and rugged units that can be deployed by first responders. These units must be rapidly deployable and extremely reliable such that they can be switched on after inactivity for many years. Hydrocarbon sensor technologists should also begin exploring the combination of multiple sensors on one platform. Because multiple users will operate these sensors, they need to be simple, have sufficient operating instructions, and be operational for up to 6 hours.

With respect to remote sensing systems, they must provide good coverage, discern extent and thickness of oil, and be able to collect data at night and through fog conditions. It was also suggested that these instruments be linked via GIS and have a web-based interface to remotely access data. Remote sensors require more robustness, being field deployable, display a 3D image, and possess stronger resolution capabilities. Reducing the amount of false positives in oil spill detection was another key component to making remote sensing more applicable.

User Friendly Instrumentation and Interpretation

Different users, such as first responders, resource managers, and scientists, utilize hydrocarbon sensors to effectively prevent, detect, and manage oil spills. Vitally important is the ability for these users to understand how to use the equipment and, secondly, interpret the data the sensors are collecting. With the advent of more sophisticated remote sensing equipment, resource managers have urged the implementation of training tools to instruct the use of them, the capabilities of this equipment, and the interpretation of results.

Data Integration

Resource managers utilize multiple hydrocarbon sensors to determine the most effective and necessary response and contingency plans. Participants discussed the need for in-situ technologies and remote sensing capabilities to be integrated, such that managers have a single interface from which to view data. Suggestions for such integration included georeferencing and entering this information into a real-time Geographic Information System (GIS) interface that could later feed into the national plan to achieve Maritime Domain Awareness. Maritime Domain Awareness (MDA) has been defined as, "the effective understanding of anything associated with the global maritime domain that could impact the security, safety, economy, or environment of the United States," (DHS, 2005). Another integration tool beginning to emerge is the use of Dynamic Decision Support Systems (DDSS) to identify, classify, and remediate oil spills. Dynamic Decision Support Systems utilize a new generation of smart autonomous in-situ sensing buoys, remote sensors, and background GIS layers describing biological and oceanographic parameters (Shuchman and Meadows, 2008).

Developmental Challenges Toward Oil Spill Prevention and Response

Workshop participants identified two types of challenges that have prohibited quick, effective oil spill response: sensor technology issues and execution challenges. Both are addressed within the broad context of developmental challenges to oil spill response.

Workshop participants emphasized that the difficulties with oil spill response was not the technological means of gathering information. Remote and in-situ sensors have been performing to their abilities, but scientists and resource managers would like to begin seeing the development of integrated sensors that can perform multiple variable testing. To accomplish this task, however, developers noted that to integrate sensors would require immense startup costs and would not become a portable, rugged, repeatable, and easy-to-use option for many years. The Slick Sleuth sensor, for example, has multiple sensors and linked with a GIS interface, but the equipment is still in the research stages and not ready for quick oil spill response. The instrument is still far too large for first response units. Real-time GIS integration was another sensor challenge in the U.S. that has impeded the full potential of quick response. The general complaint was that, without a GIS interface, by the time the data processing is done, the data are no longer relevant.

Current sensor technology provides an overload of data that proves difficult for first responders and resource managers to synthesize into means of quick response. To develop sensors that are more "user-friendly" would require a longer research and development stage. Climate and location also play an important role in the developmental stages of sensors and can pose serious limitations in extreme environments. Power, calibration, sensitivity, and biofouling are other problematic concerns, especially with portable in-situ hydrocarbon sensors.

Oil spill response challenges at the broad management level in the U.S. include insufficient funding, multi-agency responsibility, environmental legislation, and federal aviation protocols. To combine sensor technologies with integrated GIS interfaces would be incredibly expensive to develop for such a small market of users. Funding for oil spill response continues to be one of the largest challenge for proper oil spill response in the U.S. Funding for oil spill prevention and response has remained largely in the form of prevention. The oil spill response industry is not a driver of technology development. Federal agencies must realize the "real cost" of responding to an oil spill before sound funding is allocated to effective technology and subsequent response. To date, the U.S. has not maintained a consistent approach towards oil spill response. This is due in large part because of multi-agency responsibility and accountability at the State and Federal levels for oil spill response. Too many agencies are involved within the U.S. to make quick, effective decisions. There is no common approach to response adopted in the U.S. Cohesion among agencies could be modeled after foreign countries, such as Germany and Norway, where standardized protocols have been adopted in the form of the Bonn Agreement. Foreign strike teams employ aircrafts that are not used only for spills but for surveillance as well and are equipped with hydrocarbon sensors, such as Side –Looking Airborne Radar (SLAR) and Infared/Ultraviolet (IR/UV) remote sensors, all integrated with GIS interfaces. Perhaps due to multi-agency complications or the size of the U.S. coastline, the regional availability of sensors is limited, and no effective means of capitalizing on existing air patrols for oil spill detection and monitoring has occurred. Additional setbacks arise when new technology is to be equipped on fixed wing or non-fixed wing aircraft. Supplemental Type Certificates (STC) must be filed and approved, which may take 3-4 weeks. This delay may impede proper contingency planning should a spill occur within that time period. The fractured approach to spill response means that no group is able to afford the more expensive technologies. It also slows the incorporation of new technologies that require trained users.

Environmental legislation has also impeded the ability for the U.S. to conduct sufficient and adequate tests of new technologies in the field. Foreign countries have less stringent legislation surrounding the testing of sensor equipment in oiled waters. Due to the Clean Water Act (CWA) and OPA 90, scientists cannot intentionally spill oil in U.S. waters to test the efficacy of new oil detection technology. In other countries, however, abilities to do such testing have been more successful.

Vision and Future Developments

In a round table discussion, workshop participants discussed the future of hydrocarbon sensors as they relate to oil spill response. Participants also sought the opportunity to discuss programmatic objectives that may also contribute to the improvement of oil spill detection and response. The original premise was to discuss foreseeable action within one year and three years, respectively. As discussion unfolded, it was apparent that most development ideas would require significant research and development that would exceed the one-year criteria.

As oil exploration continues in the polar latitudes, the need for hydrocarbon sensors to detect oil under ice will become increasingly important. Hydrocarbon sensors in this harsh environment must be rugged, portable, and have low false alarm rates. Remote monitoring devices should cover greater area and volume and, in the future, replace field-based crews after proper ground-truthing has been conducted. Ground Penetrating Radar (GPR) has begun to show promise in the Arctic, but further research and development is needed to make this into a functional remote monitoring sensor.

One of the key areas participants concentrated their discussion was the development of various platforms for hydrocarbon sensors. These included both stationary and mobile platforms for in-situ monitoring and detection. Existing U.S. Coast Guard buoys and channel markers were deemed a viable stationary platform that could have in-situ fluorometry devices attached to them, but these units would have to be mass produced at a relatively low cost. It was suggested that these sensor platforms could be concentrated around large harbors that are equipped with unmanned aerial vehicles (UAVs) deployable via satellite or aircraft uplink, albeit at substantial cost. In-situ mass spectrometers detecting oil thickness need to improve their range of detection to include centimeters to nanometers.

Mobile platform discussion included the attachment of hydrocarbon sensors on large ocean-going vessels, the development of autonomous underwater vehicles equipped with hydrocarbon sensors, and nanotechnology that would allow sensors to be deployed within the oil slick to track movements. University of Michigan has been developing several autonomous vehicles, such as the BathyBoat, Flying Fish, and the Automated Lagrangian Water Quality Assessment System that could have hydrocarbon sensors attached with GPS interfaces built in. Helikites have also been developed that are either helium driven or pulled behind a vessel. Difficulties in autonomous vehicles arise in polar latitudes, however, as their reliability is reduced because of the extreme operating conditions. The application of remotely operated underwater vehicles (ROVs) should be explored further in polar latitudes, as they provide an opportunity to explore under the sea ice. ROVs could be manned with various hydrocarbon sensors that measure extent and thickness.

Tracking the movements of oil could be accomplished using sensors that either float on the oil's surface or be imbedded within the oil. Multiple sensors of this nature could be deployed quickly and effectively and reduce the need for continuous monitoring of oil spill movements. The Argosphere drifter developed by Norwegians has the capability to float and stay with oil slicks tracking movements and thickness. The other option would be to develop nano-sensors that could be imbedded within the oil. These could potentially have a Radio-frequency (RF) tag, such as a RF cavity resonator with an oleophilic sensor. The ability to track and monitor oil mineral aggregates (OMA) was also discussed. To accomplish this, participants recognized the need to have field based epifluorescence monitors that detect small droplets of oil possibly in the surf zone and determine if the aggregate is efficiently absorbing the oil.

Future sensor development focused primarily on remote sensing capabilities, but there were some novel approaches to in-situ technology. In-situ bioavailability and underwater in-situ techniques utilizing different marine species, such as filter-feeding mussels or phytoplankton, may serve as means for oil spill detection. Improvements in beach probing were also suggested as this is one of the primary methods of detecting oil along shorelines. Flow cytometry that determines oil spill size and flow has now become an in-situ method of detection, but further research is needed in this application. Time delay fluorescence is another method of detection that may help tease apart different components within the oil compounds. There was also a recommendation to manufacture a "sensor suitcase" that would have the necessary sensors to implement proper oil spill contingency planning. This suitcase model would be rapidly deployable, rugged, and have the robustness to withstand years of non-use. Resource managers and scientists also recommended that in-situ sensors be equipped with an adapter that GPS devices could be plugged into. Remote sensor development included the testing of GPR, Lidar scattering sensors, laser fluorescence technology, Nuclear Magnetic Resonance (NMR), SAR, Radar SAR II, and interferometric and polarimetric technologies.

Warranting further discussion during the Vision and Development Breakout Session was having an integrated approach towards oil spill detection and response. This was discussed at the programmatic level of multi-agency cooperation within the U.S. and the development of hydrocarbon sensor combinations. Federal and State agencies should begin piggybacking on existing surveillance and patrol missions to monitor oil spills as foreign countries such as Germany have implemented. Accessibility to data sets should also be integrated within Federal and State agencies forming multi-user oil reference libraries. First response strike teams assessing proper oil spill response should also be formally trained in the operation and use of existing and future hydrocarbon technologies.

Workshop Recommendations

Resonating throughout the workshop was the immediate and long-term need to integrate in-situ, laboratory, and remote hydrocarbon sensors in the U.S. There are many different sensors and manufacturers that ultimately measure similar variables pertaining to hydrocarbon discharge, but lacking is an effective method to bring all this information together. This issue is further compounded due to the fact that there are multiple agencies involved with detecting oil spill discharge within U.S. waterways. During the final breakout session, workshop participants devised other key recommendations for ACT and the broader community to implement that addressed both short-term and long-term objectives. These recommendations are bulleted below:

Outreach Initiatives:

- It is recommended that ACT and workshop organizers distribute either the Executive Summary or Workshop Proceedings to national and international oil spill conferences, such as the International Oil Spill Conference. Additionally reports should be provided to Congressional delegates, The US. Arctic Commission, the Regional Citizen's Advisory Councils (Prince William Sound and Cook Inlet and the Arctic Council for Emergency Preparation, Prevention, and Response (EPPR).
- Further dialogue between resource managers, scientists, and developers need to take place to find the most effective means to develop composite sensors integrated with georeferencing or GIS interfaces.
- As new in-situ and remote sensing technologies come available, a consistent approach to use of spill sensors for training resource managers and first responders on the use and interpretation of the data collected must be administered.
- Submit proceedings to appropriate funding sources, such as Exxon Valdez Oil Spill Trustee Council (EVOSTC) and OSRI.

• As oil exploration continues in polar latitudes, more research and development should be conducted to develop a suite of instruments that are applicable to oil detection in or under ice. Stemming from developments, such as GPR, it would be ideal to develop a remote system that could be performed without significant ground-truthing. Putting personnel on sea ice can be dangerous and is often not the quickest way to respond. Technologies that would measure dynamic ice conditions, be helicopter-based, and cover large areas are at least three years from deployment and would most likely include either GPR or NMR.

• It is recommended that a standard GIS data management protocol be implemented that can feed directly into the Maritime Domain Awareness or DDSS. Further development should also be explored into making these data management portals internet accessible, (web-based) such that first responders and resource managers can enter and manipulate data in real-time. This would also reduce the amount of personnel required to be onsite.

• Currently, there is no common approach to oil spill response in the U.S. Perhaps the U.S. can draw from protocols issued by the Bonn Protocol.

• Resource managers proposed that hydrocarbon sensors undergo performance standards to ensure global compliancy. This would also allow for hydrocarbon sensor technologies to be evaluated and compared for different response scenarios and deployment locations. To obtain a level of standardization, the American Society of Testing Materials (ASTM) or ACT could test hydrocarbon technologies. Although methods of data collection may vary depending upon which in-situ or remote sensing equipment is used, ACT may be able to undergo broad in-situ and remote sensing evaluations. Expanding upon this recommendation may include the certification of new sensor technologies by a lab, possibly ACT or Ohmsett, the National Oil Spill Response Test Facility, in an underwriting capacity. NOTE Ohmsett will test and evaluate equipment and sensors but will not certify equipment or sensors. They only certify the test data and results provided to their customers.

• One of the first efforts towards standardization would be to adopt protocols that have already been administered, such as by the Europeans or by SMART in 2006.

- It was recommended that ACT, working with different developers/manufacturers, evaluate the ability to measure hydrocarbons on water and under ice using both in-situ and remote sensing technologies. It is important to examin how these sensors perform under these conditions.
- Develop in-situ tracking devices such as drifters, buoys, and helicopter-deployed grabbers that sample oil to help identify and track oil discharge movements. Discussion also surrounded the improvements of fluorescent dyes that are passive and can bind directly to the oil. All of these help identify where sensors should be targeted, although they are technically not sensors themselves.
- Resource managers and developers should revisit funding sources and explore novel approaches towards obtaining necessary monies. Suggestions included writing grants to the Office of Technology's Small Business Innovative Research (SBIR) Program and Small Business Technology Transfer (STTR) Program. Another novel approach would be to make the polluters pay for either new technologies or the integration of existing technologies.

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References

Brekke, C. and A. Solberg. 2005. Oil spill detection by satellite remote sensing. Remote Sensing of the Environment 95: 1-13.

Chase, C. R. and S. V. Bibber. 2006. Utilization of automated oil spill detection technology for clean water compliance and spill discharge prevention. Freshwater Spills Symposium (FSS). Portland, Oregon. 15 pgs.

Department of Homeland Security. 2005. National plan to achieve maritime domain awareness for the national strategy for maritime security. 28 pgs.

Environmental Protection Agency. 1990. Oil Pollution Act. 66 pgs.

Jha, M. N., Levy, J., and Y. Gao. 2008. Advances in remote sensing for oil spill disaster management: State-of-the-art sensors technology for oil spill surveillance. Sensor 8: 236-255.

Shuchman, R. A., and G. A. Meadows. 2008. Future Hydrocarbon Technologies. Hydrocarbon Sensors for Oil Spill Response Workshop. Presentation.

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Appendix B: Hydrocarbon Sensors for Oil Spill Prevention and Response Workshop Participants

Appendix C: Current In-Situ and Laboratory Hydrocarbon Sensors Currently Used

Table 1: Current *In-Situ* and laboratory hydrocarbon sensors currently used by resource managers and scientists. Qualitative assessments of their performance is provided.

Hydrocarbon Sensor Type	Measurement	Information Provided	Strengths	Weaknesses
Fluorometer	Detect the presence of oil by excitation and the measurement of light absorbed vs. emitted. For this instrument, oils typically absorb light in the ultraviolet spectrum (300 and 400nm), and emit light in the visible spectrum (450 to 650nm range; (Chase and Bibber, 2006).	Detects presence/absence of oil, oil classification or oil fingerprinting, and concentration; analysis range is low ppm.	Rugged, easy to use, no sample prep time required, portable and in-line analyzers most commonly used and available thereby increasing consistent evaluations; single and multiband detectors.	Calibration issues because there are multiple compounds in the water column emitting energy; back scattering and potential false positves; you have to know what is in the water column before sampling for oil; cannot identify specific hydrocarbons such as aliphatic vs. aromatic hydrocarbons.
Fourier Transform Infrared (FTIR) Spectrometer	Laboratory technique that utilizes the absorption and emittance of electromagnetic wavelengths (similar to fluorometer) in the infrared spectrum.	Evaluates the condition of the oil such as the degree of oxidation, nitration, and soot content, presence/absence, oil fingerprinting, concentration.	Precise measurement method with no external calibration, rapid screening, increased sensitivity.	Non-portable and mainly a laboratory tool.
Turbidity Meters	Measures how much light is diffracted from particulates in the water column.	May show the prescence or absence of oil.	May be a primary tool to detect oil but their applications are severely limited.	Provides a very esoteric number because turbidity can be subjective; cannot differentiate between oil and other particulate matter.
Mass Spectrometers	Measures the mass to charge ratio of charged particles which generates a mass spectrum representing the masses of sample components.	Determines relative concentrations of oil compounds; presence/absence; oil classification.	Easy to use; classify oil; field portable; rugged; underwater sampling capabilities; underwater and in air; waterproof.	Difficulty to interpret; extensive training is required; analysis range is ppb; high resolution only.
Total Organic Vapor Monitors	Detects dissolved carbon in air and has the potential to detect volatiles.	May detect presence of oil compounds and some oil identification with calibration charts.	Saftey, field rugged, well accepted, easy to use, portable.	Performance degrades in cold weather; have to be aromatically detected; battery life in cold climates; analysis range is ppm.
Particle Size Analyzer	Determines the distribution of sizes in a sample of particulate material using modern, static light scattering instruments.	Oil droplet size; relative abundance of particles as surface size; concentration and the ability to differentiate between sediment.	Strong lab acceptance.	Not rugged or field-tested. Available Commerically.
Toxic UV & IR Absorption	Different sensors that detect the aborption of oil through different wavelengths within the electromagnetic spectrum, specifically UV and IR frequencies.	Detects presence/absence of oil; can follow thickness of oil.	Contact sensors good for leak detection; groundwater capabilities.	Not as rugged; calibration is user specific; misses some compounds (i.e. alcohols); low resolution.
Radiofrequency Absorption and Detection	Electromagnetic absorption within the radiowave wavelength part of the spectrum.	Detects presence/absence and abundance of oil; thickness up to 25mm.	Easy to use: easy detection system with will detect presence up to 25mm thick; good in ports; have solar panels attached providing good battery life.	Cannot detect with a high oil flow; 6ft seas or more and unit loses quality; depth limitations (cannot see underneath oil greater than 8 inches)
Imaging Sensors (Optical, Thermal) equipped on ROVs or AUVs)	More of a sensor platform but Remotely Operated Vehicles (ROVs) or Autonomous Underwater Vehicles (AUVs) may be equipped with different electromagnetic sensors.	Detects presence/absence; aerial extent; thickness via color scale method of detection; quantity; recoverability.	Relatively abundant; can be used under sea ice; easy to use.	Some ROVs and AUVs are only equipped with optical tools and thereby do not have quantitative evaluations; need expertise in interpreting information in sea ice condictions as few indiviuals have visually observed under sea ice.

Appendix D: Remote Sensing Sensors and Their Qualitative Assessments

Table 2: Current remote sensing hydrocarbon sensors currently used by resource managers and scientists. Qualitative assessments of their performance is provided.

Hydrocarbon Sensor Type	Measurement	Information Provided	Strengths	Weaknesses	Remarks
Side Looking Aerial Radar (SLAR)	Detects electromagnetic energy that is reflected by capillary microwave waves on the ocean and measures the backscatter from the ocean's surface. Oil dampens the amphitude of the capillary waves hence, these sensors detect the calming of the ocean's surface.	May potentially show the presence/absence of oil; location and extent of oil spill.	All-weather; far range (40km radius); processing time; high resolution; big picture; day and night monitoring; can detect through clouds, rain and fog.	Cannot detect oil if in calm seas (i.e. cannot detect calm inside of calm); sea state limitations (between 0.5-7 on the Beaufort scale); potential for false positives (i.e. wave or algal blooms, biogenic substances); no thickness detection; needs proper ground truthing.	Airborne platform; most common radar method of detection.
Synthetic Aperture Radar (SAR)	Same as above.	May potentially show the presence/absence of oil; location and extent of oil spill.	All-weather; exptreme far range; high resolution; big picture; day and night monitoring; can detect through clouds, rain and fog.	Cannot detect oil if in calm seas (i.e. cannot detect calm inside of calm); sea state limitations (between 0.5-7 on the Beaufort scale); potential for false positives (i.e. wave or algal blooms, biogenic substances); no thickness detection; needs proper ground truthing.	Airborne and satellite platform common radar method of detection; far range capability.
Laser Fluorosensors which include Light Detection and Ranging (LIDAR) sensors	Illuminates the ocean surface with a UV laser oil absorbs and emits electromagnetic energy in the form of visible light.	Oil classification; thickness of 0.1-20μm; if a scanning device is attached, one can determine aerial extent and volume; detects presence/absence.	Course oil classification; distinguish between natural oil, biogenic oil, mineral oils, etc.; does not need a specialized aircraft; day and night monitoring; transect of points instead of sampling; potential for submerged oil.	Has to be operated in low altitudes; cannot detect through fog and cloud cover; limited to sea state; can only detect oil spill on the surface water (i.e. must obtain an oil sample to calculate thickness); thermal acclimation of oil; needs proper ground truthing .	Airborne; laser acoustic sensors are available but only in developmental stages but have similar capabilities as laser fluorosensors; near range.
Forward Looking Infrared Radar (FLIR)	Thermal infrared detection method that measures different heat signatures by evaluating the brightness temperature of the ocean's surface. Brightness temperature is a function of emissivity.	May potentially show the presence/absence of oil; location of oil spill; oil extent; relative thickness.	Can search for ships; day and night monitoring; common method of detection; can detect through light fog; works on oil covered snow/ice.	Nighttime observations can be slightly ambiguous; false positives; unable to detect emulsions in water; needs proper ground truthing.	Airborne platform.

Appendix D: Remote Sensing Sensors and Their Qualitative Assessments (cont'd)

Table 2: Current remote sensing hydrocarbon sensors currently used by resource managers and scientists. Qualitative assessments of their performance is provided.

Hydrocarbon Sensor Type	Measurement	Information Provided	Strengths	Weaknesses	Remarks
Aerial Video and Photography (includes night vision)	Visually detects the presence of oil in the visible electromagnetic spectrum through observations of color change.	Distribution of oil; detects absence/presence of oil; rough thickness estimates based by color scheme.	With night vision goggles can detect during night; easy to use; quick response to assemble and get information; readily available.	Cannot detect oil through cloud cover or fog; some false positives but w/ training can reduce this; limited thickness info as color scheme is a subjective method of determination	Airborne; most common method of detection; relative estimate.
UV/IR Scanner	Measures the material's ability to absorb and radiate energy at the ultraviolet and infrared wavelengths.	Oil extent; location; presence/absence of oil; relative in thickness.	Ability to see very thin when it comes to thickness; can determine different sources of oil; combining both UV/IR methods of detection to negate false positives; day/night observations; easily available; proven; rugged; good under snow.	Weather conditions such as fog or cloud cover; limited thickness; prone to false positives; night observations limited; not a true oil detector; need proper ground truthing; passive system utilizing the sun as the UV source.	Airborne platform.
UV Camera Illuminated	Utilizes a camera equipped with filters that block out parts of the electromagnetic spectrum and proper illumination either visible or UV to record the emissivity of material.	Detects presence/absence of oil.	To help keep the response unit on the oil for proper containment; simple; low-tech; real-time.	Limited field of view as only strong as the searchlight; use in a restricted area not necessarily open ocean; meant only for use on a ship or helicopter.	Ship or helicopter.
Radio microwave Imaging System	Passive imaging sensor that detects the emission of oil at the microwave wavelength in the electromagnetic spectrum.	Detects presence/absence of oil; distribution; thickness; aerial extent; volume.	All weather; day/night observations; passes through clouds; absolute thickness (50μm-3mm); instantaneous information delivered in real-time; very powerful; can calculate oil volume.	Sea state limitations (white caps will give microwave signatures but oil spill will have likely dispersed at that sea state); dedicated aircraft; low spatial resolution; low availability.	Airborne; near range.

Appendix D: Remote Sensing Sensors and Their Qualitative Assessments (cont'd)

Table 2: Current remote sensing hydrocarbon sensors currently used by resource managers and scientists. Qualitative assessments of their performance is provided.

Hydrocarbon Sensor Type	Measurement	Information Provided	Strengths	Weaknesses	Remarks
Ground Penetrating Radar (GPR)	Geophysical method that uses radar pulses in the 10 m microwave frequency of the electromagnetic spectrum to image the subsurface.	Detect presence/absence of oil; oil extent; possible thickness; location; detects oil under ice.	Possible calculation of oil volume; tested fairly well in Arctic climates.	Requires ground team to operate unit above ice; not an airborne or satellite method yet; helicopter cannot detect under snow; needs proper ground truthing.	Airborne (future technology); towed system on belly of helicopter; near range.
Multispectral Scanning Systems	Passive scanning system that collects emitted radiation over a variety of different wavelengths at several discreet spectral band.	Detects presence/absence of oil; distribution; oil extent; location.	Covers large areas; good resolution; able to discriminate between sheens and thick oil; aircraft can go under clouds.	Difficult data interpretation; have to be able to acquire the imagery; sun angle, cloud cover limitations; potential for false positives; need proper ground truthing; need good visibility.	Airborne and satellite; most commonly used scanning system; optical near and far range.
Hyperspectral Imaging	Passive scanning system that collects emitted radiation over the continuous spectrum, visiable and near infared sample at very high spectral resolution.	Detects presence/absence of oil; distribution; oil extent; location; classification.	Covers large areas; good resolution; able to discriminate between sheens and thick oil; aircraft can go under clouds, potential for submerged oil detecting.	Difficult data interpretation; have to be able to acquire the imagery; sun angle, cloud cover limitations; potential for false positives; need proper ground truthing; need good visibility.	Airborne platform; still in the research and development stage; satellite resolution too coarse.
High Frequency (HF) Radar/Coastal Dynamics Radar (CODAR)	Measures wave state and surface current velocity fields near the coast by analyzing the doppler of reflected radio waves.	May potentially detect the presence/absence of oil; possibly movement.	Shore based 24/7 operation; all weather.	Based on theory and adapted for oil spill response; originally intended for the measurement of currents; potential for false positives; need proper ground truthing; need good line of sight; weather limitations; requires multiple base stations.	Commercially available is potential issue.
Nuclear Magnetic Resonance (NMR)	Rather than exciting electrons of particles into a higher energy state as in other hydrocarbon techniques, NMR excites the nucleus in its magnetic field using electromagnetic radiation .	Detect presence/absence of oil; possible thickness; classification.	Potentially good detection method under snow/ice.	Laboratory based unit; not portable but has the potential to become a remote sensing device.	Future applications for hydrocarbon sensing; In experimental testing phase of development.

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