Alternative Response Technologies: Progressing Learnings

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ABSTRACT

This presentation provides an update on the progress of oil spill technology development following the Deepwater Horizon (DWH) incident in the Gulf of Mexico during 2010. A number of new technologies were successfully tested and implemented via the Alternative Response Technology (ART) Program. The focus of this paper is spill response offshore, near shore, and on-shore; it covers technologies related to surveillance, in-situ burning, booming, skimming, mechanical oil/water separation, sand cleaning, and bioremediation.

More than 123,000 individual ideas were submitted to the ART program by the public during the DWH response. These ideas fall into two categories: source control (80,000) and spill response (43,000). After screening for potential, novelty, and utility (and a number of other qualities), ~ 100 spill response ideas were field-tested or evaluated in detail, and at least 45 ideas were recommended for use in response operations. Once a mere notion, these innovations are now tools in the industry's toolbox for oil spill response.

To further enhance technologies and capabilities in spill response, technology programs are being implemented by BP and other operators, oil spill response organizations (OSROs), and joint industry programs ("JIPs," such as API, OGP, and IPIECA). Some of these programs are being conducted in collaboration with key

government agencies, including NOAA, EPA, USCG, Environment Canada, Research Council of Norway, and others. As time progresses, these programs are merging because the participants are collaborating and communicating extensively.

This paper provides an update on the progress of current oil spill response technology programs and reveals early positive results.

INTRODUCTION

Oil spill response (OSR) technology progressed significantly as a result of innovations and experience gained during the DWH incident in the Gulf of Mexico in 2010, particularly in areas related to surveillance, controlled in-situ burning, booming, skimming, mechanical oil/water separation, and sand cleaning. During the response, the Alternative Response Technology (ART) team, under the direction of Unified Area Command (UAC), screened approximately 43,000 spill response technology ideas submitted by the public. The ART team's work was done alongside, and consistent with, the Federally directed Interagency Alternative Technology Assessment Program (IATAP).

One hundred of these 43,000 ideas were field-tested or evaluated in detail, and at least 45 of them were recommended for use, as needed, by response operations personnel. These innovations are now new tools in the industry's toolbox for oil spill response. The success of the ART program has been documented previously in various conferences and forums. One such paper presented on the program was "Alternative Response Technology for the Deepwater Horizon in the Gulf of Mexico—An Overview," which was presented October 5, 2011, at the 34th AMOP Technical Seminar on Environmental Contamination and Response, sponsored by Environment Canada and held in Banff, AB, Canada (Cortez 2011). The U.S. Coast Guard (USCG) previously summarized the IATAP program in an

August 2, 2011, release via its website (www.uscg.mil) and during an internal USCG Innovation Expo session on November 3, 2010 (USCG 2010).

Individual Industry Programs

At the conclusion of the DWH response activity, the BP members of the ART team conducted learnings workshops with their colleagues and other industry experts to cultivate technology advances and identify potential technology gaps in various areas of OSR. Using these learnings, the team embarked on an oil spill response technology R&D program for 2011 designed to further advance technologies in the areas of controlled in-situ burning, skimming, booming, and surveillance, as well as to codify the DWH experience, including waste management and sand cleaning.

Joint Industry Programs (JIPs)

To further enhance capabilities in spill response internationally, OSR technology development is also being led by various joint industry programs (JIPs), such as those led by the American Petroleum Institute (API), Oil & Gas Producers (OGP), and International Petroleum Industry Environmental and Conservation Association (IPIECA). Some of these programs are being conducted in collaboration with key government agencies, including the National Oceanic & Atmospheric Association (NOAA), Environmental Protection Agency (EPA), USCG, Environment Canada, Research Council of Norway, and others. BP and other major oil operators are actively leading, participating in, and contributing learnings to each of the industry technical working groups (TWGs) to further advance OSR technology and capabilities internationally (USCG 2011; API JITF 2011; Mullin 2011; Oil Spill Commission Report 2011; OGP 2011).

Oil Spill Response Organization (OSRO) Programs

Also taking on the challenge of pushing development forward are the oil spill response organizations (OSROs), such as Clean Gulf Associates (CGA), Marine Spill Response Company (MSRC), and Oil Spill Response Ltd (OSRL). Membership within these organizations includes most of the major international oil companies, as well as key service contractors of the oil and gas and OSR industry. The OSROs were key contributors to the DWH spill response operations and collectively, therefore, can help to advance OSR learnings in several key areas.

ALTERNATIVE RESPONSE TECHNOLOGIES

Alternative Response Technologies, or “ARTs,” are now considered an important part of the oil spill response “tool box.” The usefulness of research and testing of innovative technologies was acknowledged in the Oil Pollution Act of 1990. Early on, the Unified Area Command recognized that the evaluation and testing of ARTs would be an important component of the MC252 Deepwater Horizon response, and in the end, the ART team was able to screen more than 43,000 spill response ideas submitted by the public, and they field-tested or evaluated in detail 100 of the ideas, resulting in at least 45 ideas being recommended for use in response operations. The list of all of the successful ARTs is in **Attachment 1**.

Of significance during the ART program was the number of OSR ideas that came from other industries and were adapted to spill response needs. For instance, the ART team field-tested more than 10 different sand cleaners for beach cleanup, and the most notable one that was deployed was the Sand Shark (**Figures 1 and 2**), a technology that was adapted from the road maintenance industry (material loader). The Sand Shark could clean a mile of beach per day, using its sifting process, down to a depth of approximately 12 inches.

Another successful sand cleaning technology deployed was the Gravely Rapid E Sand Cleaner (**Figure 3**). The Chicago-area Gravely Co., which manufactures industrial lawn mowers, had adapted its technology into a one-person sand cleaning machine that could get in and out of hard-to-access beach areas for cleanup. Its use was proposed by a distributor in Illinois who saw the larger sand cleaning machines on a newscast and reasoned that the smaller Gravely would be useful to responders.

Yet another example is the Boom Blaster (**Figure 4**), a technology adapted from the car wash industry that was able to rapidly clean 600 feet of boom per hour, which far exceeded what could be cleaned manually. During the response, more than 13 million feet of boom was deployed, so this cleaning device was very advantageous in cleaning boom for storage.

These and other technologies adapted from other industries—including the Parachute Surf Skimmer (a pool and pond cleaner proposed for tar ball capture), Yates Boom Cleaner (another automated process with dishwasher-like water jetting), and the M-I SWACO sand cleaning plant (adapted from tar sands production operations)—are now successful new tools in the industry's toolbox. This is a key learning for future spills: Be open to searching for technology outside our industry and be willing to think a bit out-of-the-box.

BP: OSR AND TECHNOLOGY R&D

At the conclusion of the response, the ART team, which was composed of engineers and responders from BP, USCG, NOAA, EPA, and OSPR (Office of Spill Prevention & Response), demobilized and returned to their previous roles. The BP members of the team moved into BP's Gulf Coast Restoration Organization to continue the OSR technology development that had begun with the ART program.

One of the first missions for the team was to interview many of the key personnel from the response as they de-mobilized and were returning to their previous roles. By doing this, the team could capture key learnings and identify additional technology gaps that might have surfaced in the various OSR areas. After documenting these learnings through informal workshops and interviews, the team was able to craft a proposed 2011 OSR technology development program for BP in order to further advance technology in some key areas of OSR. The team's technology portfolio is focused on several themes: controlled in-situ burning (ISB), skimming, booming, surveillance (aerial, on-water, underwater, and beneath sand), and waste management.

In October 2011, the Technology team transferred into BP's Global Crisis Management department within the Company's Safety & Operational Risk group. With the team positioned in this corporate group, its mission is to spread the OSR technology learnings and development in a global fashion to other BP businesses, as well as to proactively participate and contribute in the many industry forums and JIPs that are ongoing in furthering OSR technology development.

There are several OSR technology development projects underway, and the following subsections each provide a short synopsis with examples.

Surveillance

Surveillance is a key theme for OSR technology development. Aerial tracking of the oil slick was utilized during the response; however, determining the thickness of the slick is a technology that could further improve the operational efficiency of the response operations. In addition, improving industry's capability to track and measure thickness of the oil slick would greatly enhance response operations and boat placement. Based on the learnings workshops, several technology opportunities were identified and projects are now underway. Here are four examples from the Surveillance theme:

- Wave Gliders™ (**Figure 5**): This technology was used during the Deepwater Horizon incident, and additional field tests are currently underway. The Wave Glider™ is an autonomous, remote-controlled vehicle that can be used to measure oil and dissolved oxygen in water, to detect marine mammal vocalizations, and to sense other indicator s that can for tracking spill response characteristics. They can also provide key information regarding oil seeps, which can then be utilized in regional modeling programs for marine scientists.
- Sonar for Non-floating Oil Detection: These projects have involved using side-scan sonar, sub-bottom profilers, Acoustic Doppler Current Profiling, and the USCG-provided Coda Octopus 3-D sonar (**Figure 6**) to search for possible submerged oil. All have been successful in tests to date.
- Aeryon Scout, an unmanned aerial vehicle (UAV) (**Figure 7**): This project is a battery-powered rotor-wing aircraft that weighs about 2.5 lbs and is 3 feet in diameter. It is equipped with high-resolution cameras designed for surveillance. Field tests are underway in BP's Alaska operations, where uses in production operations inspections have also been identified.
- Aerial Observation Spill Response Balloon (**Figure 8**): Already tested in both Alaska and the Gulf of Mexico, this project combines a vessel-tethered balloon with a specialized camera to capture images of a wide area from the air. Advantages include the elimination of support aircraft, an inherently safer operation, real-time image capture with specific location tagging, and the ability to continuously monitor over long periods of time.

Controlled In-Situ Burning

Controlled in-situ burning was one of the more successful OSR techniques utilized during the response. Between 220,000 and 310,000 barrels of oil were successfully burned, which exceeded the amount of oil that was skimmed, according to NOAA estimates (Allen 2011). Based on the learnings workshops, several technology opportunities were identified and related projects are now underway:

- Enhanced Fire Boom Project (**Figure 9**): This project is focused on designing, testing, and deploying a larger, enhanced fire boom, which is capable of operating in higher sea states. The enhanced boom would improve sustained containment capability in higher sea states and wind and would provide a higher success rate of removing spilled oil from the surface of the water.
- Remote-Controlled ISB Project **(Figure 10)**: This project utilizes remotely controlled boats to continuously tow fire containment boom. These boats can be operated from a command vessel or aircraft. If successful, this technology will eliminate personnel risks by removing the human element and creating a safer operation. By controlling the tow vessels remotely, operaters can also synchronize the vessels' motions, thereby allowing them to collect, burn, and remove more oil.
- Fixed-Wing Ignitor (**Figure 11**): This project utilizes an existing aerotorch ignition design to be retrofitted in a fixed wing aircraft. If successful, this project would allow for the ignition of gelled diesel released from the air at speeds two to three times faster than those commonly used with a helicopter. This concept would allow for further travel distances with a higher payload.

Skimming

In the area of skimming, learnings workshops reflected an opportunity to improve the encounter rate of vessels to the oil on the surface. One of the projects being developed is a High-Capacity Skimming System (**Figure 12**), which utilizes "buster" technology and focuses on the entire booming and skimming system to maximize recovery efficiency. Field tests, thus far, indicate that the enhanced skimming system would improve the ability to encounter, and hence, skim and recover more oil from the surface.

Common Operating Picture

The DWH response presented some challenges from the operations standpoint: During its peak, approximately 6,500 boats/vessels, 125 planes, 6 rigs, and 48,000 responders were engaged operationally, making real-time communications among the teams challenging at times (**Figure 13**). Although the entire operation was conducted safely, from an HSE standpoint, the learnings workshops reflected some opportunities for improvement in the technology area of the Common Operating Picture (COP). Using a systematic approach to enhancing the real-time communication links among the sea, air, and land theaters of the response operation, the COP project can improve the speed and accuracy of decision-making while reinforcing safey measures. Additional benefits from a comprehensive COP development program could include rapid collation and analysis of large quantities of raw surveillance data, sorting of the data, and targeting of appropriate audiences—all within the rapid cadence of twice-daily response operational periods.

Waste Management

During the DWH incident, a significant number of key learnings were captured in the area of waste management. As the table below reflects, significant volumes of various types of waste were handled and disposed of during the incident in an environmentally safe manner. To further the technology, the waste management team conducted proof-of-concept pilot studies on two novel approaches: a) “tarballs to asphalt”—a program that proposed converting a significant volume of tarballs that were recovered from the spill into asphalt for paving roads; and b) “booms to bumpers”—another innovation in collaboration with the auto industry, which took used boom and recycled them into the manufacturing process of automobile bumpers.

MC 252 Waste and Oil Recovery and Disposal—Cumulative Total to Date Period Ending 06 November 2011		
	Total	**Units**
Oily Liquid	**460,462.00**	**BBLs**
Liquids	**949,099.00**	**BBLs**
Oily Solids	**95,550.70**	**Tons**
Solid Waste	**14,003.80**	**Tons**
Recyclables and Recoverables	**4,761.30**	**Tons**

INDUSTRY JIPS: ADVANCING OSR TECHNOLOGY

The industry is also actively capturing learnings and developing technology as a result of the DWH incident. Similar to the continuing enhancements that industry has made historically in the areas of improved well design/control and capping/containment, the various OSR JIPs that are underway have been very active and working collaboratively to enhance procedures and technologies in spill response internationally. Here is a short summary of three key JIPs that are underway (OGP 2011):

- API: In September 2010, the API published the Joint Industry Task Force (JITF) report that outlined the establishment of 29 technical working groups (TWGs) designed to capture learnings, recommend potential changes, and enhance OSR technologies in various areas. Progress thus far has been excellent, marked by a collaborative effort from the industry reps on the committees. A recent API JITF report (November 2011) outlines progress made during 2011 and plans for 2012. **Table 1** contains the list of the TWGs in progress (API JITF 2010, 2011).
- IPIECA/OGP-GIRG: Internationally, IPIECA's oil spill working group (OSWG) is collaborating with OGP's global industry response group (GIRG) in order to identify potential improvement opportunities post-DWH in various areas of oil spill response. This JIP has developed 19 recommendation areas (listed in **Table 2**) that cover a variety of oil spill response technologies, and technical working groups have been formulated from the respective JIP memberships to study these recommendations. Of significance is the fact that IPIECA/OGP-GIRG recognizes that some of the same OSR areas are being addressed by the API's 29 TWGs, and hence, API representation and collaboration with the IPIECA/OGP-GIRG JIP is well underway to ensure consistency and linkage (OGP 2011).
- OGP's Arctic JIP: The OGP has also established a JIP focused on Arctic oil spill response issues**. Chart 1** contains the JIP organization as well as its focus areas. Industry representatives are actively progressing OSR learnings, procedures, and technologies and applying them to the Arctic arena specifically. Like IPIECA/OGP-GIRG, this OGP Arctic JIP also includes API members to ensure alignment with similar programs that are ongoing within the API TWGs (OGP 2011).

OSRO PROGRAMS: ADVANCING OSR TECHNOLOGY

The OSROs were key to the spill response effort during the DWH incident, and firms such as The Response Group, O'Brien's Response Management (ORM), Oil Spill Response Limited (OSRL), Clean Gulf & Associates (CGA), and Marine Spill Response Corporation (MSRC) were significant contributors to the clean up in the Gulf. The firms comprise a significant number of oil spill responders with global experience who, when not involved in spill response efforts, are engaged in advancing spill response technology in collaboration with key vendors and exploration and production (E&P) operator-members.

A recent survey of the OSROs resulted in a general tabulation of the spill response technology areas that the companies are pursuing, as shown in **Chart 2**. Most of the technology development is spurred by operator-members, many of whom are also active in some of the industry JIPs such as API and OGP-IPIECA, which will ensure alignment with some of the ongoing programs in industry.

SUMMARY

There has been substantial progress made since the DWH incident in various areas of oil spill response technology development and enhancements. The industry has responded by creating various forums focused on OSR technology, such as the API, IPIECA/OGP, OGP Arctic, and other JIPs, and the OSROs themselves have also embarked on advancing several OSR technologies with key vendors and operator-members.

The key, however, is sustainability. Historically, the industry responded similarly after other major spills—such as offshore Santa Barbara, California (1969), Ixtoc I (offshore Mexico 1979), and Exxon Valdez (Prince William Sound, Alaska

1989)—and dramatically ramped up funding while commissioning various forums to enhance OSR technology developments. In all instances, however, after a few years of progress, conditions changed in industry because of oil price volatility and other economic events, and spill response technology development and funding returned to their previous levels (Oil Spill Commission 2011).

As the industry moves to explore for hydrocarbons in harsher environments marked with deeper water, Arctic conditions, and more remote areas of the world, there is a corresponding need for cutting-edge oil spill response technology development.

ATTACHMENT, FIGURES, TABLES, AND CHARTS

Alternative Response Technology—Successes

During the DWH incident, there were at least 45 successes based on field test evaluations in three categories—offshore, near shore, and onshore—which were recommended for use by responders, as required.

Offshore

- Controlled In-Situ Burning (Spilltec Inc. - Woodinville, WA): Extended, field-scale implementation of in-situ burning techniques previously planned and practiced only on a limited basis.
- Laser Fluorometer Submerged Oil Detection (EIC Laboratories, Inc. - Norwood, MA - with funding from USCG): Uses laser fluorescence polarization to detect nonfloating oil.
- Coda Octopus 3-D Sonar (US Coast Guard R&D, New London, CT): In conjunction with EIC Laser Fluorometer, uses proprietary underwater sonar technology for detecting nonfloating oil.
- Side Scan Sonar (Fairweather Science LLC - Anchorage, AK): Calibration and use of side scan sonar to detect nonfloating oil.
- Acoustic Doppler Current Profiler (T&T Marine - Galveston, TX): Calibration and use of ADCP to detect nonfloating oil.
- Big Gulp Skimmer (LAD Services - Morgan City, LA): Barge equipped with wide weir skimmer and settling tanks for high-volume open water oil skimming.
- Wave Glider (Liquid Robotics Inc. - Sunnyvale, CA): Autonomous, self-propelled, remotely steered vehicle with capability to carry wide range of monitoring instruments.

Near Shore

- Tar Ball Net (Tobu Services - Montegut, LA): Modified shrimp net for capturing tar balls.
- V2 Vyper Platform (Vyper Adams Inc. - Carson City, NV): Four-wheel drive vehicle with superior stability and light footprint, for use in sensitive beach and shallow water operations.
- Parachute Surf Skimmer (Holen Synergy Group, Inc. - Orlando, FL): Hand-deployed pond/pool skimmer adapted for use in recovering shallow water tar balls.
- Helicopter Boom Removal (Various sources): Use of helicopter and grapple to vertically retrieve boom stranded in sensitive shoreline areas (e.g., marsh).
- Yates Boom Cleaner (Yates Construction - Biloxi, MS): Use of dishwasher-like assembly-line transport and spray system to streamline used boom cleaning operations (improved cleaning rate).
- Boom Blaster (Gulf Coast Environmental Resources, LLC - Marshfield, MO): Use of car wash concept (cleaner, spray, brushes) to streamline used boom cleaning operations (improved cleaning rate & reduced manpower).
- Opflex Buoyant Open-Cell Foam (Cellect Plastics LLC - St. Johnsville, NY): Bouyant polyolefin foam with high absorbency; re-usable and available in multiple forms (pad, boom, pom pom, etc.).
- Low-Pressure Marsh Flusher (Core 4 - KEBAWK Group LLC - Chalmette, LA): Barge equipped with low-pressure water wand for gently irrigating marsh areas to mobilize oil for recovery.

- Truxor Amphibious Tool Carrier (Megator - Pittsburgh PA): Versatile, trailer-able amphibious vehicle capable of tool transport, skimming operations, raking, pumping and other uses.
- Water Curtain (DO2E Wastewater Treatment - Pensacola, FL): Use of directed aeration pumps to create water positive flow barrier, for protection of inland waterway from advancing floating oil without impeding vessel ingress/egress.
- Oil/Water Separation (Ocean Therapy Solutions - Metarie, LA): High-volume centrifugal oil-water separator.
- "HOSS" Heavy Oil Skimming System (VOO Captain Gerry Matherne - Texas City, TX): Custom-designed frame and netting device deployed from vessel for highly efficient tar ball recovery.
- X-Tex® Silt Barrier Fence (UltraTech - Jacksonville, FL) and Eco-Barrier Fence (Trinity Industrial Services - Chamblee, GA): Hydrophilic textile material installed as in-water "fences" to stop and divert oil approaching shorlines.

Onshore

- Reflectance Spectrometer (Louisiana State University - Baton Rouge, LA): Use of portable reflectance spectrometer in conjuction with control samples and computer-modeled calibration to determine Total Petroleum Hydrocarbon estimation of shoreline sediments.
- Bio Energy Gasifier (Bio Energy Conversion Global, Inc. - Stanfield, NC): Use of a patented gasification control system to convert a wide range of organic feedstocks including oily waste (e.g., oiled boom) into combustible gas for power generation.

- Booms to Bumpers (General Motors - Detroit, MI): GM partnered with BP and recycling companies to convert 227 miles of used oil boom into air deflectors for the Chevrolet Volt.
- Soft Boom Recycling (Various response locations, circa 2 million feet): Recovery of fluids by centrifuge, shredding of remaining boom for polypropylene recovery and densification.
- Tar Balls to Asphalt (Superior Asphalt Company - Gulfport, MS): Proof of Concept demonstration for converting oily sand waste to asphalt meeting Mississippi Department of Transportation standards.
- Green Earth Sand Cleaner (Green Earth Technologies LLC - Mobile, AL): Mobile, high-volume sand washing plant for cleaning beach sand contaminated by oil.
- Petromax Sand Wash (AECOM - Chicago, IL): Engineered concept for high-volume sand washing plant for cleaning beach sand contaminated by oil.
- M-I SWACO Sand Cleaning (M-I SWACO - a Schlumberger Company) : High-volume, fixed-location sand cleaning plant incorporating Western Canada tar sands technology.
- STS-101 Solids Washing (Rolyn Environmental Services, Alberta Canada): High-volume, fixed-location sand washing plant based on Canada tar sand technology and experience.
- Vortex Beach Sand Washer (Eco-Oil Separator, LLC -): High-volume, fixed-location sand cleaning plant.
- Big Green Sand Machine (Gulf Shores Environmental LLC - Lakeland, FL): High-volume, mobile sand cleaning plant; uses hot water wash and GOLF Energy's RECOVERIT polymer to accomplish continuous water recycling.

- Gravely Sand Cleaner (Rapid Equipment Distribution Inc. - Palatine, IL) and Barber Sand Man (H. Barber & Sons, Inc. - Naugatuck, CT): Combination of a walk-behind industrial mower engine and a sand sifter, originally designed for trash pick-up but adapted during the response for in-situ oil cleaning in areas difficult to access with larger equipment.
- EZ-Zacks Ergonomic Beach Cleaning Tool (Panamor Business Group Inc. - Largo, FL): Innovative handle for debris bags, improving ergonomics for responders doing manual shoreline cleanup.
- Sand Shark (LeeBoy Inc. - Lincolnton, NC): High-performing adaptation of road paving material loader for mobile beach cleaning. Among similar equipment, was the most widely used during the DWH response.
- Ozzies OPP-200 (Ozzies Pipeline Padder, Inc. - Phoenix, AZ): Mobile sand cleaner from pipeline industry, used to clean Gulf Coast sand beaches.
- Beach Tech 2000, 2800 & 3000 for Beach Cleaning (BeachTech, Inc. - Laupheim, Germany): Tractor-towed sand cleaners using rotating sieve screen for capturing contamination (each with different sieve sizes).
- Cherrington 4600 & 5000 for Beach Cleaning: Mobile beach sand cleaners utilizing fixed sieve screen and rotating paddle; 4600 model towed by tractor and in 5000 model unit and tractor are integrated.
- RECOVERIT (GOLF Energy Services - Birmingham, AL): Nontoxic, biodegradable, re-usable polymer product that selectively binds to oil in sandy sediment; separation can be accomplished by portable centrifuge.
- Beach Restoration System™ (Clean Beach Technologies LLC - Houston, TX): High-volume, mobile sand cleaning system; suitable for final ‘polishing’ of beach sand.

- ChemStation "7248" Degreaser (ChemStation - Mobile, AL): Degreaser effective at cleaning vessels and equipment with encrusted heavy oil; proprietary blend of d-limonene and surfactant.

ıre 2. Before and After Sand Shark

After

Figure 1. Sand Shark

Before

Figure 3. Gravely Rapid E Sand Cleaner

Figure 4. Boom Blaster

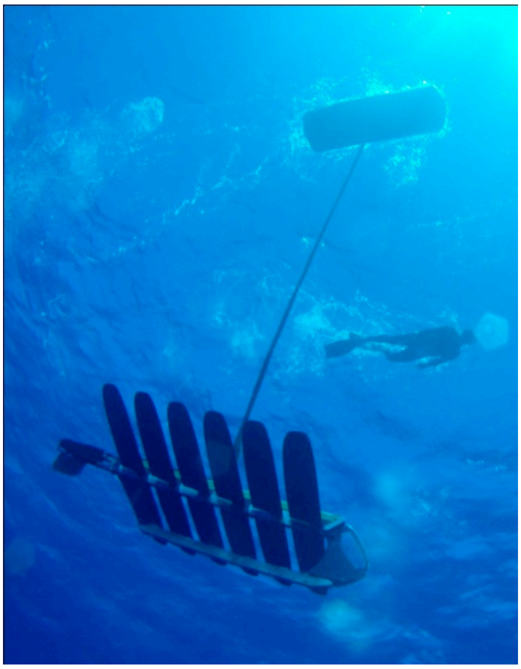

Figure 5. Wave Gliders

Coda Sonar Head **Coda & EIC Oscar on vessel**

Figure 6. Coda Octopus & EIC Oscar

Figure 7. Aeryon Scout UAV

Figure 8. Aerial Observation Spill Response Balloon

Figure 9. Fire Boom with Controlled Burn

Figure 10. Remote-Controlled ISB

Figure 11. Fixed-Wing Ignitor

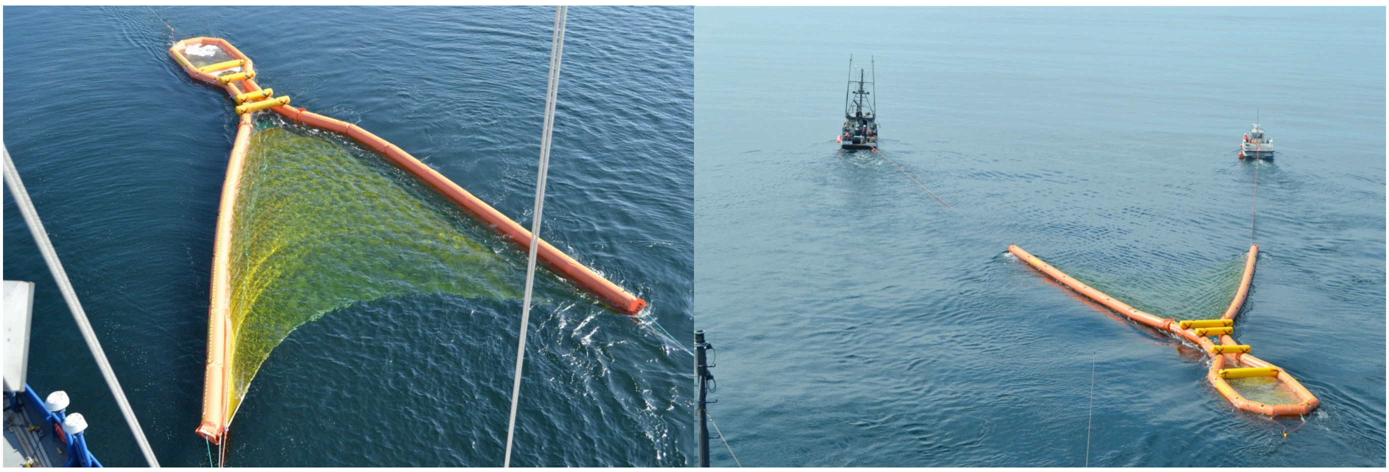

Figure 12. High-Capacity Skimming System