JEFFREY BARTKOWSKI, ALEX LORMAN & MICHAEL JOHNSON, SEA MACHINES, LOOK AT HOW TO IMPROVE THE SAFETY AND EFFICIENCY OF SPILL RECOVERY AND OTHER OPERATIONS.

UNMANNED WORK BOATS

The recovery of spilled oil in an open water marine environment is a significant task, yet it can be extremely hazardous for the personnel involved. While various recovery tactics are available including booms, skimmers, and in-situ burning, generally all involve the use of human-occupied small craft that place the operators in close contact with oil. Health and safety hazards exist due to exposure to volatile organic carbons (VOCs), including benzene and other toxins, evaporating from the oil and dispersants, as well as physical hazards from excessive heat, cold, and general small boat operations in open seas.

Sea Machines Robotics sees these health and safety hazards as reason to use the latest autonomous technology in developing unmanned work boats, which will allow operators to be relocated to larger vessels while cleaning up the spill. The autonomous boats are designed to increase safety, while improving response time and the efficiency of operations during a spill response.

Health and safety concerns with spill recovery

Crude oil can contain over 1000 different hydrocarbons which vary in concentration depending on the source of the oil. Many of these compounds are volatile and can cause respiratory, hepatic, renal, endocrine neurologic, hematologic and other problems at high levels of exposure. Furthermore, mutagenic effects from volatile organic compounds (VOCs) such as benzene and polycyclic aromatic hydrocarbons (PAHs) found in crude oil can theoretically be induced by exposure to very low concentration of these compounds.[1] Benzene is a known hematotoxicant and hematocarcinogen,[2] and research has shown to cause effects on blood cells in workers exposed to levels below occupational exposure limits (OELs),[3] as well as reproductive hazards.[4]

During the Deepwater Horizon spill, a vessel of opportunity (VOO) programme was employed utilising local fisherman and their boats to aid in the recovery tactics of booming and skimming, and in-situ burning of spilled oil. This put operators whose expertise was not spill cleanup, in direct exposure to crude oil, dispersants and burning. Within the first month, several of these fisherman were hospitalised due to symptoms such as headaches, upper respiratory irritation, and nausea, with some cases so severe as to require hospitalisation for up to six nights.[5] Health hazard evaluations of the various working environments were conducted by NIOSH in response to these hospitalisations. Personal breathing zone and area air samples were taken for VOC's glycol ethers, total particulate matter, PAHs, benzene, and other toxins during recovery and decontamination procedures and found concentrations to be below occupational exposure limits for these toxins at the sites tested. However, the daily infirmary logs reviewed from 1 - 30 June, 2010, showed that of the 1004 visits, 363 (36%) were ear nose and throat respiratory complaints.[5] Additionally, from 7 - 22 June, 2010, 826 voluntary health symptom surveys completed indicating that the most frequently reported symptoms were headaches, upper respiratory symptoms and symptoms of heat exposure. Workers who reported they had direct contact with oil, dispersants, and in-situ burning reported a higher instance of upper respiratory symptoms and coughs than those not exposed.[5] While PBZ and area air sampling at sites during specific activities revealed levels below OELs of individual chemicals, the authors of the NIOSH report conclude that mixed low level exposures to crude oil, dispersants and other chemicals combined with the heat stress and psychological strains experienced during oil recovery exercises may have contributed to the health symptoms reported.[5]

Due to location of the Deepwater Horizon spill, responders engaged in recovery efforts from spring through summer routinely experienced temperatures ranging from 90 - 100 ˚F and high humidity, which would make strenuous work difficult if not dangerous on its own. With these conditions, and the required use of personal protection equipment (PPEs) including full coveralls, boots, gloves, and respirators the potential for heat related injuries and illness was greatly increased. In response, various heat stress management plans were utilised depending on job task, with a common rotation being 20 minutes of work, followed by 40 minutes of rest.[5] This schedule, which is required to keep human responders safe, effectively triples the man-hours required to complete an individual task during these management cycles.

Figure 1. *The autonomous work boat is Sea Machine's first production hull. While primarily designed for heavy work such as towing and barge moving, the V1 also has the capability for extended survey operations and station keeping/standoff applications.*

Figure 2. *The Sea Machines V1 is designed for the the J-towing of booms for oil spill response. In this application the V1 runs in a supervised autonomy mode, following the main vessel and standing off at pre-determined distances set by the operator.*

Advantages of using unmanned work boats

Safety

By utilising unmanned, and therefore intrinsically safe, marine platforms, the company proposes relocating the human operator from the spill boom-towing work boat back to the enclosed bridge of a primary spill response vessel. An autonomous work boat is an extremely resilient and safe platform equipped with all necessary sensors and communications equipment, and has the ability to run fully on battery propulsion if needed. The unmanned boat can venture into spill areas too dangerous for human operators. The boat can also act as an advanced sensor suite to relay potential hazards about the environment to the primary spill response vessel. Thus, providing data on VOC and other airborne toxin levels prior to any human occupied vessels approaching a specific spill area.

Efficiency

While safety is the main priority in an oil spill cleanup operation, the ability to efficiently and quickly contain and remove the contaminates from the water is the ultimate goal. A faster clean up creates less working risk for the operators and reduces overall cost while returning the maritime environment to its prior state as fast as possible. As stated above, a 20 minute on, 40 minute off work schedule necessitates three times as many workers to accomplish the same tasks without even accounting for the time lost during personnel changeover. An autonomous boat requires no breaks other than refueling and can continue operating in hazardous and challenging conditions just as easily. This alone saves time and money while allowing

the spill cleanup to be executed more quickly, thereby reducing the overall environmental impact.

In addition to an enhanced work schedule, Sea Machines platforms do not need refresher training courses or to be paid, fed, and accommodated while on standby. Quite simply; an autonomous workboat is a piece of equipment that can remain on long term standby, with minimal maintenance, be deployed on short notice and readily shipped to locations around the world.

Development

The idea behind Sea Machines Robotics was conceived when the founders were working on salvage operations of large vessels. The wreck occurred in a pristine and protected maritime conservation zone off the coast of Italy. Environmental protection was paramount to every operation and great care was taken to leave the environment undisturbed. Oil boom was deployed at all times around the wreck to contain any floating contaminates. While a necessary and prudent protection, the management of this boom quickly became a never ending, arduous task. Tugboats, supply boats, and small crew boats were constantly going through, around and sometimes over the boom in their daily activities. This at times left the boom either ineffective or even damaged. The founders envisioned the solution to this being some level of autonomous active boom management system, which could safely and easily interact with all the other marine traffic around it. Allowing the environment to stay protected, while providing the means for other manned boats to efficiently transit in and out of the protected area.

Autonomy

Unlike some of the current trends in the autonomous world, the goal of Sea Machines has never been to have a 'fire and forget' style of autonomous vehicle. The company's autonomous systems work closely with a human operator, while utilising levels of 'managed autonomy' to allow the operator to focus on the work at hand rather than directly navigating the unmanned vessel. The company was born from a need for tasks to be made easier and safer in the offshore world. Autonomy was the solution to that need, rather than a solution in search of a problem. This philosophy has been key in every step of development by the company, allowing it to develop a system that is aimed at efficiency, safety, and automation rather than an unproven concept.

Sea Machines has a 'man in the loop' at all times. This method allows for both greater efficiency and less operation risk in several ways. With a human supervisor always in sight of the vehicle, and providing positive control over positioning, COLREGS can be maintained. Both autonomous and manned platforms can then work in harmony with other vessels on the waterways. Not only does this allow the insight and perception of a human captain, it avoids the nearly impossible problem of a sensor suite capable of detecting any and all navigational challenges and knowing how to respond in kind. This sort of managed supervision will be most familiar to those who have operated dynamically positioned ships. While the dynamic positioning officer can drive the thrusters individually, in most cases they do not have to; the operator programs the computer with the position coordinates and the supervised system then actuates the thrusters to match the commands. Sea Machines managed autonomy systems provide a similar level of input, allowing the operator to concentrate on the tasks at hand, rather than commanding the individual drives on the autonomous boat.

This managed autonomy is particularly applicable in the first planned application of this platform.

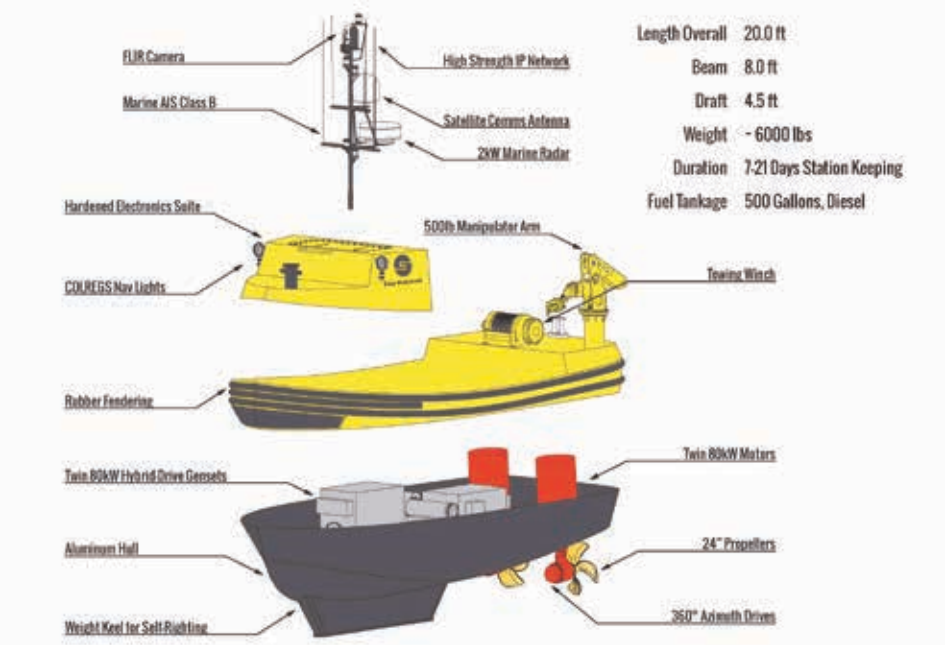

Figure 3. *Diagram showing the internal and external components of the V1 autonomous work boat.*

Figure 4. *The Sea Machines V1 makes an ideal small fire boat, allowing the vehicle to get closer to, or under hazardous fires than would normally be safe with operators aboard. The V1's accurate stand off and station keeping capabilities will keep the vehicle where the operators set it, while allowing them direct control of the fire pump.*

J-Towing

In order to demonstrate the effectiveness of unmanned marine systems, the company has chosen to demonstrate the collaborative vessel J-Towing of oil boom

as its first application. This workflow is frequently carried out by a set of operators on two separate manned boats with resulting risk and a lack of efficiency known to be some of the concerns from oil spill response organisations and their members. By demonstrating improvements to an existing and familiar workflow, it can be proven and quantified, to the ordinarily staid offshore market, exactly how useful unmanned systems can be.

Additional uses for unmanned workboats in oil and gas

Sea Machines has also identified other applications in the oil and gas sector for heavy duty unmanned vessels.

FiFi

Marine firefighting can potentially be a hazardous operation for the fireboat crews depending on the local conditions and structure, type, and severity of fire being fought. A heat-shielded unmanned workboat with remote control and station keeping capabilities can be advantageous in getting a fire pump closer to dangerous hazmat or overhead fires, while providing a safe standoff distance for the operators aboard another vessel. Sea Machines platforms are well suited for fire boat applications due to their twin azimuthing thrusters, which will allow the boats to keep station and move fore, aft, and to the side. Furthermore, by using an on-board IR thermal cameras they can transmit real time imagery of the heat situation to the operators and more importantly the automated controls will enable the boat to keep the fire water stream continuously aimed at the highest heat areas without the assistance of the operators.

Survey

Hydrographic surveys are being identified as a potential use of unmanned surface vessels in efforts to increase efficiency and reduce costs of the survey. Unmanned vehicles can proceed in weather and sea conditions that would generally be unpleasant to crew onboard small launches. Additionally, an unmanned vessel can operate continuously for extended periods of time and overnight by not requiring crew breaks or changes. The unmanned work boats have enough space and power available for the real time processing requirements of today's hydrographic multibeam sonars. Through the use of industrial hardened WiFi or maritime broadband radio, surveyors can provide overwatch of sonar settings and system health, while receiving truncated, processed data back in real time to ensure quality and coverage of the survey. In a supervised autonomy scenario, one primary survey vessel could oversee multiple unmanned survey work boats, increasing the number of sonars in the water, and therefore reducing survey times, while using the same number of crew typically required for one survey vessel.

Marine mammal monitoring

Marine Geophysical survey operators work under strict rules regarding the ramp up and use of seismic sources to protect marine life during survey operations. Survey operators are required to monitor various exclusion zones, and the sound levels within them, for marine mammals and turtles entering them. An exclusion zone for areas of sound levels of 180 dB or higher and around the seismic source must be monitored for marine life and operations halted if mammals or turtles enter into this zone. Additionally a safety zone limited to 160 dB maximum is maintained and the seismic vessel must alter course if mammals are detected within.[6] During daylight hours, trained protected species observers (PSOs) are required to keep watch for any mammals entering the exclusion zone. However their ability to spot animals becomes limited at night and in poor weather. Incorporating an unmanned work vessel utilising passive acoustic monitoring (PAM) techniques out in front of the seismic vessels can monitor sound levels in exclusion zones and identify mammal activity long before visual confirmation. This will allow operators more time to make decisions regarding survey operations.

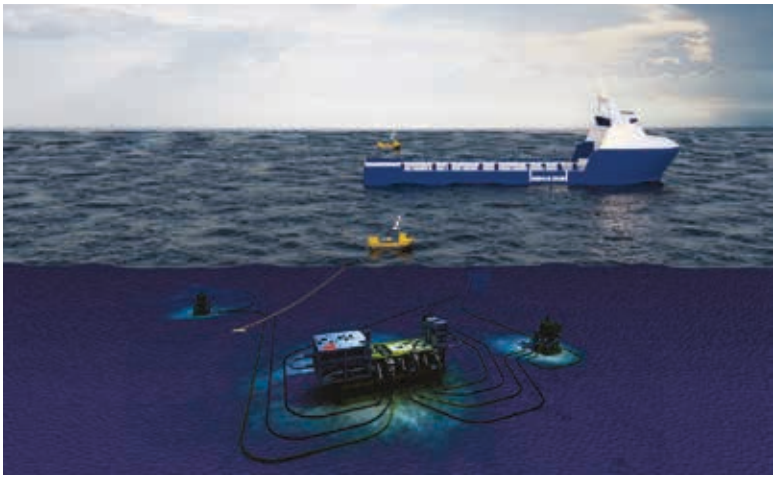

Figure 5. *The Sea Machines V1 is capable of running extended survey grids due to its duration, available power, and room for onboard processors and storage. Hardened WiFi will allow surveyors to operate and modify settings of multibeam or side scan sonar systems from aboard another vessel. Running a Sea Machines V1 in conjunction with a survey boat is a force multiplier which will effectively double coverage rates. The twin azimuthing propellors of the V1 allows for accurate survey lines in the most challenging conditions and cross winds.*

AeroStat/ROV operations

Unmanned work vessels make ideal platforms to launch and recover tethered unmanned vehicles. During an oil spill response scenario, unmanned aerostats are useful as low cost, consistent aerial surveillance adding to the situational awareness of the recovery operations. Using an unmanned vessel to position and host an Aerostat frees up other operational boats on site, as well as crew members. The USV can hold a station within a spill zone without concerning crew members onboard, and by using optical and radar sensors onboard the aerostat, provide location and tracking information of the spill continuously day and night.

Conclusion

Through the use of unmanned work boats, Sea Machines Robotics envisions improving safety and efficiency related to oil and gas operations, emergencies, and spill response. Through development of the V1 autonomous workboat applications will continue to be identified which can benefit from relocating humans from the active worksite, to a safer or more habitable vessel nearby. As the acceptance and adoption rate of autonomy into offshore operation increases, the company foresees the use of unmanned workboats in multi vehicle, collaborative scenarios further improving the safety during moving of heavy barges and infrastructure, and other over the horizon operations.

References

1. Goldstein, B., Osofsky, H., Lichtveld, M., 'The gulf oil spill,' New England J Med 364(14) (2011) pp. 1334 – 1348.
2. Goldstein, B., Witz,. D, G., Benzene. 'Lippmann M, eds. Environmental toxicants: human exposures and their health effects'. 3rd ed. Hoboken, NJ: John Wiley, (2009) pp. 459 - 98.
3. Lan, Q., Zhang, L., Li, G., et al. 'Hematotoxicity in workers exposed to low levels of benzene' 306 (2004) pp. 1774 - 1776.
4. Xing C, Marchetti F, Li G, et al. Benzene exposure near the US permissible limit is associated with sperm aneuploidy. 'Environ Health Perspect' (2010)118: 833 - 839.
5. King B, Gibbins J. 'Health Hazard Evaluation of Deepwater Horizon Response Workers', NIOSH HETA 2010-0115 & 2010-0129-3138, (2011).
6. Seismic Survey Mitigation Measures and Observer Reports (2012) - Bureau of Ocean Energy and Management report - OCS Study BOEM (2012 - 2015).