299555
2014 INTERNATIONAL OIL SPILL CONFERENCE

A Field Evaluation of Unmanned Aircraft Systems for Oil Spill Response

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ABSTRACT 299555:

A key component of any oil spill response operation is the ability to identify and describe the characteristics of the spill and ultimately direct the resources necessary for clean up. Currently, this task is primarily performed by trained personnel in manned aircraft. With the recent advances in Unmanned Aircraft Systems (UAS) it may be possible to obtain the same high quality field reports and provide detailed guidance for surface assets without the high cost and risk associated with manned flight.

In early March 2013 a group of interested parties convened in Astoria, Oregon to evaluate the feasibility of using a UAS as an observation, documentation, and control platform in an oil spill response environment. The test was conducted over three days and included participants from Chevron Shipping, AeroVironment, University of Alaska, and a wide variety of Oil Spill Response organizations. Operations were based out of the Clatsop Community College MERTS campus near Astoria, Oregon with flight operations conducted from a 34 ft vessel near Rice Island and Grassy Island on the lower Columbia River.

The investigative team included a trained oil spill Aerial Observer, a UAS Technical Team, and an Oil Industry Environmental Compliance Manager. The primary goal of the test was to evaluate the feasibility of UAS technology as an oil spill response tool. The exercise not only provided an opportunity for the Oil Spill Response community to evaluate first-hand the technical and operational capabilities of the Unmanned Aircraft System, but it also helped introduce the UAS industry to the requirements and expectations of the Oil Spill Response community.

INTRODUCTION AND BACKGROUND:

Small Unmanned Air Systems (UAS)

Chevron Shipping and AeroVironment were first introduced at the Clean Gulf Oil Spill Conference in 2005 at Galveston, TX. The AeroVironment Unmanned Air Vehicles' capabilities in a marine environment were readily evident as a result of their long time development efforts to

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support the U.S. Military. AeroVironment had a 1.5-meter wingspan UAS, the Raven, which appeared well-suited to low level, unmanned surveillance over land or air support for Shore Line Cleanup Assessment Teams (SCAT) to expedite their inspection of potential areas impacted or covered by oil. A second two-meter wing span UAS, the Puma, used the identical operator control package but had the added capability of landing on water and a longer 2 hour flight time which made this an invaluable air asset for the on water supervisor to guide the surface oil recovery/response assets. These small, hand launched, lithium battery powered UAS's also carried an infrared camera capability permitting them to fly at night or in reduced visibility to track movement of the oil over night versus reacquiring position info of the oil at first light.

At Chevron's request, AeroVironment performed fight testing under daylight conditions in early 2006 in the Santa Barbara Channel near Carpenteria, CA where there are active natural oil seeps from the seabed (Figure 1). The flight test validated that Raven model UAS's could collect live video and position information from field locations and transmit the data to an Incident Command Post or other responders in the field via vhf radio. More notably, the UAS infrared camera worked very well at differentiating the streamers of oil from the surrounding surface seawater (Figure 2). Due to FAA flight restrictions, no flights have yet been conducted over the natural seeps to test the UAS infrared capability under night time conditions.

Natural Oil Seeps off shore Carpinteria, California, February 2006

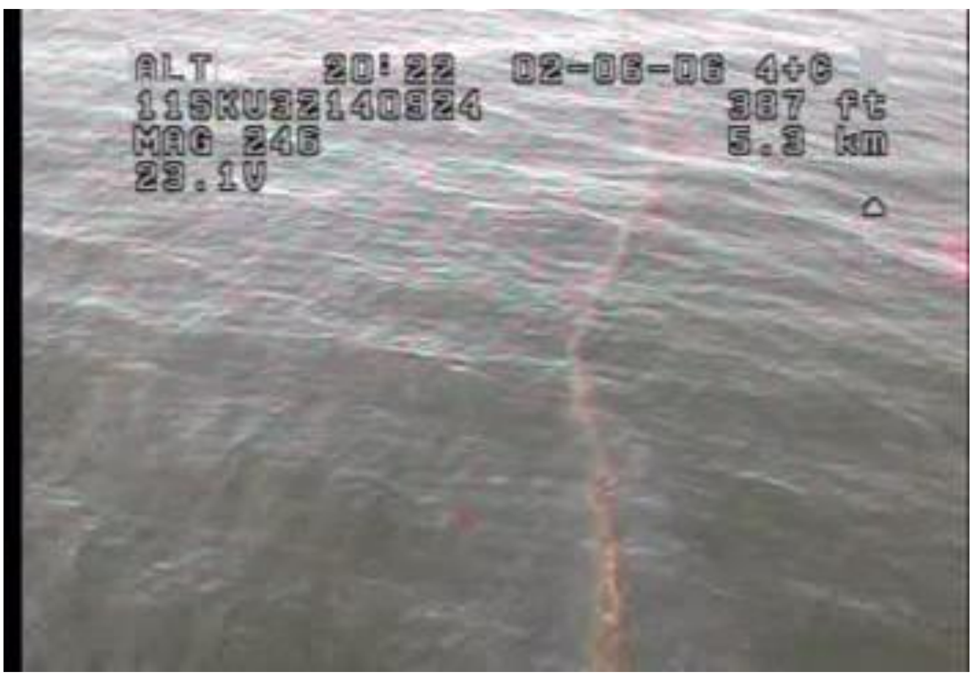

Figure 1: Oil streamer photo with normal video lens (387 ft altitude)

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Figure 2: Oil streamer photo with Infrared lens (436 ft altitude)

Later in May 2006, AeroVironment flew the Raven again to document sensitive site strategy testing conducted by CA Department of Fish and Wildlife personnel and Marine Spill Response Corporation boats in the Sacramento River (Figure 3).

Figure 3: Sacramento River – simulated oil (rice hulls) containment photo (144 ft altitude)

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In September 2006, AeroVironment participated in ConocoPhillips oil spill response exercise in Rodeo, CA by collecting real time aerial surveillance video of sensitive shorelines for review by the Environment Unit. Additional overflights of response boats conducting booming and skimming of rice hulls simulating oil were used to provide live video to personnel in the Incident Command Post and the On Water Supervisor controlling the recovery boats efforts (Figure 4).

Figure 4: San Francisco Bay Exercise – simulated oil skimming photo (538 ft altitude)

Both the Chevron and the ConocoPhillips exercise validated that the UAS's could often provide equal air surveillance capabilities as manned aircraft to command post and field oil spill responders for situational awareness and documentation purposes. In some circumstances the UAS capabilities were better than manned aircraft in terms of rapid response, flexibility, and

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access to real-time video in the command post and field. This was now an aerial surveillance asset with a very small logistics footprint capable of being totally managed by responders on boats or in the field when and where required. Low-level flights at night or in low visibility using infrared cameras were also now possible without the safety issues posed by using manned aircraft.

FAA Regulation Changes 2007 – Industry testing stops

In the absence of specific FAA regulations for UAS's employed to support Emergency Response operations, UAS operators in the United States used long standing radio controlled model aircraft safety guidance to remain lower than 400 ft above ground level and outside 3 miles from airfields engaged in active air operations. This proved safe and practical for nearly all Emergency Response purposes but the FAA stopped commercial use of UAS's in February 2007 after two near miss events by law enforcement unit drones flying close to major airports. In place of the "radio controlled modelers rules" guidance the UAS community previously used, the FAA instituted a formal, lengthy "Certificate of Approval" (COA) process typically reserved for experimental aircraft. This limited the use of UAS's to only very remotely populated areas of the U.S. or over military controlled airspace until the FAA developed specific rules on how, when, and where UAS's could be used in the commercial sector for Emergency Response, mapping surveys, facility security over flights, etc.

Several months after the FAA restricted UAS flights without COA approval, the FAA formed an aviation industry/government work group to formulate draft regulations for commercial UAS use. While this initially appeared promising, there was no visible progress toward draft or final rules for commercial UAS use until the U. S. Congress passed H.R. 658 into law in February 2012, requiring the FAA to complete procedures for commercial UAS use by 2015. Chevron attempted to gain permission for UAS flights in oil spill response exercises several times after 2007 using the COA application process without success.

Astoria, Oregon 2013 - FAA approves industry COA request

In March 2013 an approval was obtained for UAS flights over the Columbia River east of Astoria, Oregon in conjunction with an oil spill response exercise. The area in Figure 5, which the FAA approved, was exactly the same as submitted by the exercise planners. The exercise planners only requested the COA for the week of March 11-15, 2013, however the approved COA is valid until March 10, 2015. There has been no follow-up on use of the approved airspace for UAS's since 2013. Before flying the UAS's there again, the FAA would have to be notified 48-72 hrs in advance to publish Notice to Airman (NOTAM) safety warnings advising other aircraft to remain clear of the COA area.

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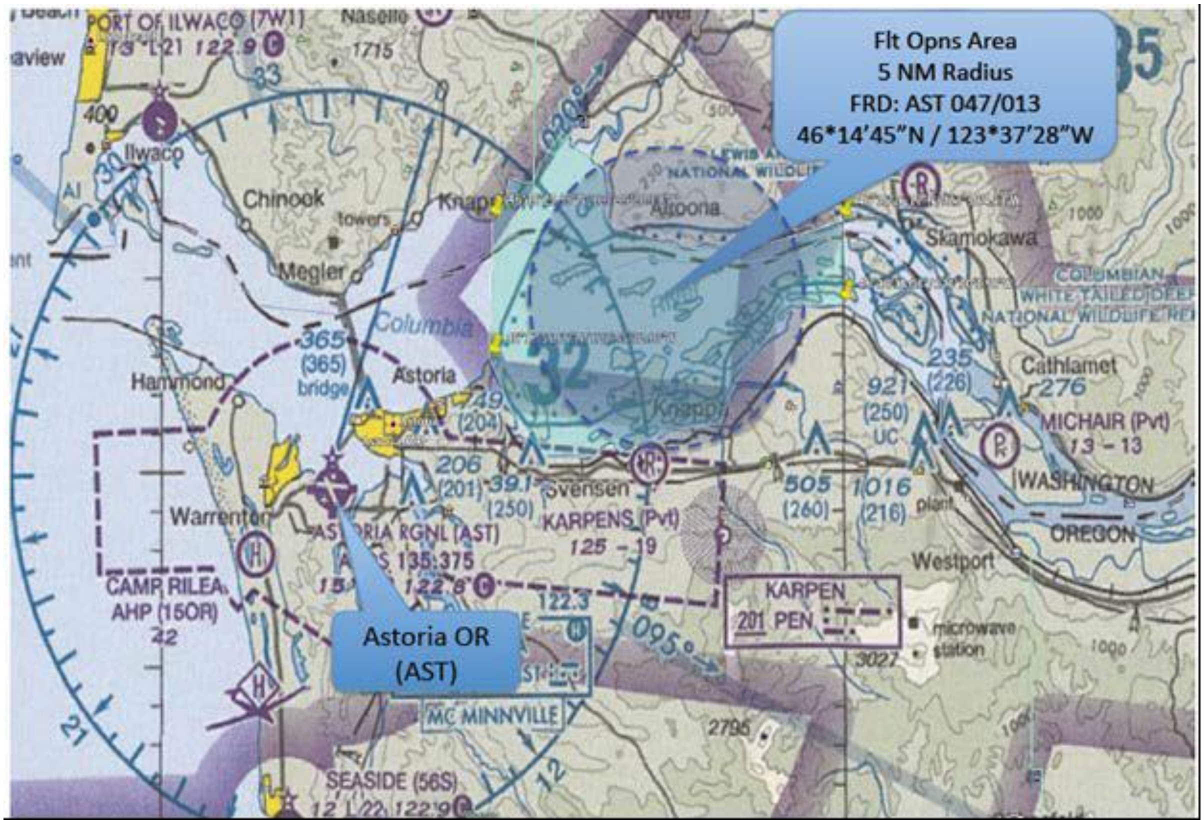

Figure 5: FAA approved COA site east of Astoria, Oregon

Note: Nearby Astoria Airport (AST) was also highlighted on the chart but only as an area to be avoided due to manned aircraft traffic.

Later in July 2013, leveraging the directives in Congressional Bill H.R. 658, AeroVironment applied for and received an FAA type certificate for a hand launched UAS enabling flight operations for commercial hire. Although currently limited to flight over water in the Beaufort, Chukchi, and Bering Sea off the coast of Alaska, this represents a significant first step forward to integrating UAS's into U.S. National Airspace for non-military purposes.

Astoria, Oregon Oil Spill Exercise – March 2013
Puma AE (All Environment) characteristics and specifics

Since the UAS testing stopped in 2006, UAS's from the different manufacturers continued to grow in numbers and their capabilities. The AeroVironment Puma airframe was modified and now carried a waterproof, retractable belly camera with pan, tilt, zoom, and infrared capability. An improved battery now permitted flights up to 3.5 hours.

The operating footprint to store, assemble, launch, and recover the Puma AE on land or water is very small. A mission operator and a vehicle operator with one UAS can operate in the field flying several times per day for a period of several days providing they have a pickup truck or SUV for transportation, a battery charger or generator for UAS batteries and access to food and shelter. For operating on the water, a 30 ft boat with about 10 ft by 10 ft of unobstructed

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deck space is usually sufficient to operate from protected waters during reasonable weather. Longer periods in the field (or 24/7 type operations) can be sustained by adding additional UAS's, spare parts, and operators. This could also be done for on water operations with larger size boats having extra accommodations to house the UAS operators.

The shipping footprint for one UAS, Ground Control Station, Mission Planning laptop, and critical spares is two large hard shell cases (6 ft by 2 ft by 1 ft; 60 lbs each) and one medium hard shell case (3 ft by 2 ft by 2 ft; 90 lbs). This equipment can travel with the operators as excess luggage. The batteries are shipped airfreight separately due to aircraft regulations.

RANGE	**15 km**
ENDURANCE	**3.5 hours**
SPEED	**20 to 45 knots**
OPERATING ALTITUDE (Typical)	**500 ft (152 m) Above Ground Level**
WING SPAN	**9.2 ft (2.8 m)**
LENGTH	**4.6 ft (1.4 m)**
WEIGHT	**13 Ibs (5.9 kg)**
GCS	**Common Ground Control Station – encrypted vhf radio**
LAUNCH METHOD	**Hand-launched**
RECOVERY METHOD	**Autonomous or manual deep-stall landing**
MAX WINDS	**Approx 25-30 knots**

WEIGHT	**650 gram**
BALL DIAMETER	**5.8 inches**
OPERATING TEMPERATURE	**–20C to 50C**
WEATHERIZATION	**Waterproof**
CAMERA 1	**Daylight 5 Megapixels**
CAMERA 2	**Thermal IR 640 x 480**
ZOOM LEVELS	**4**
ROTATION LIMITS	**Continuous**
TILT LIMITS	**+10 to –95 degrees**
CONTROL	**High Speed Serial**
VIDEO	**MPEG**

Figure 6: Specifications for Puma AE UAS and Gimbled Sensor / Mantis i25 AE camera

Typical operator training for the Puma AE system consists of 10 days of orientation on UAS's in which students learn basic flight theory, airspace safety and how to assemble, fly, and maintain the UAS airframe and its control elements. Most of the second week is actual hands on

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flying time under the guidance of qualified instructor pilots. After successfully completing training, an operator must complete the FAA ground school/written test and the 2nd Class Airman Medical Exam. Vehicle operators continue to maintain equipment skills and flight proficiency by flying the UAS at least once a month or utilizing a compatible platform to perform a launch, recovery, and 15 minute flight every 150 days.

UAS evaluation team composition

In testing during earlier years, much of the effort was spent trying to demonstrate to oil companies, federal and state regulators, and oil spill responders that a new tool was becoming available to augment what already existed. Those efforts were valuable to help scope where UAS's could add value but lacked the validation of experienced spill responders, particularly since UAS's have not yet been used in any of the significant oil spills in the United States since they have become readily available.

For the Astoria, Oregon oil spill exercise, a deliberate decision was made to place the UAS operation under the control of a trained oil spill Aerial Observer to evaluate and compare the UAS's capabilities with typical aerial observation results using a manned aircraft. Brian Parscal, the Aerial Observer chosen, was trained by Al Allen of Spiltec and Kim Beasley of Clean Islands Council in Hawaii. Mr. Parscal is familiar with the Aerial Observation protocols of both the National Oceanic and Atmospheric Administration (NOAA) and the Bonn Agreement. Additionally, he has performed actual Aerial Observation flights over oil spills multiple times in Hawaii.

AeroVironment provided two UAS's with spare parts and a three-person team to operate the UAS's. The Mission Coordinator for the team was a former U.S. Navy pilot and the Mission Operator and Vehicle Operator were two UAS instructor pilots, all AeroVironment employees.

On site planning

The Astoria, OR Unmanned Aircraft Systems exercise began with a meeting between the operational participants at the Clatsop Community College Marine and Environmental Research and Training Station (MERTS) located near Astoria, Oregon. During this meeting, the Aerial Observer provided a briefing of the objectives and techniques of Aerial Observation and Spotting for oil spills and described the technical requirements for such operations; the UAS manufacturer, AeroVironment, described the technical capabilities of their Puma UAS platform (Figure 7), and gave an indoor demonstration of the control and monitoring equipment associated with the aircraft. Afterward a general operational plan was developed and participants were briefed on their respective responsibilities and safety considerations.

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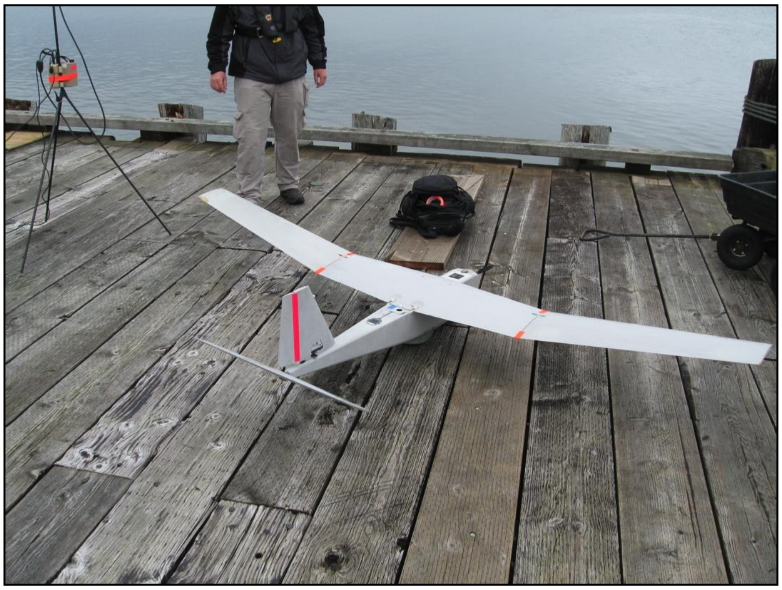

Figure 7: Puma UAS, assembled and ready for flight operations

After the initial briefing in the MERTS conference room, the team moved to the Clean Rivers Cooperative Command & Communications trailer (Figure 8) that had been staged in the parking lot of the MERTS facility. Although far larger than what is usually needed, it proved to be an ideal facility for the base of operations and was utilized for the remainder of the exercise. Clean Rivers Cooperative also provided a 34ft vessel and a crew of two for the duration of the exercise. The FRV Protector (Figure 8), with a 35 knot speed and shallow draft, proved ideal for maneuvering in the shallow waters around the Columbia River islands. The crew, with their many years of combined local knowledge, was invaluable in keeping the participants safe and on location.

Figure 8: Clean Rivers Coop Communications Trailer and FRV Protector / Crew

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The flight operations were conducted on the lower Columbia River in an area near Rice Island and Grassy Island. These flight operations provided an ideal opportunity for the participants from the Oil Spill Response community to experience first-hand the capabilities and limitations of the Puma UAS platform and for the UAS team to more fully understand the Oil Spill Surveillance and Spotting missions. It also provided an opportunity to practice the coordination between the Aerial Observer, vessel crew, and the UAS operators.

RESULTS AND DISCUSSION:

Field Operations

The Aerial Observer, vessel crew, and UAS operators were quickly able to establish an effective working relationship with well-defined roles and responsibilities. The core operational group consisted of oil spill Aerial Observer, UAS Mission Operator, UAS Vehicle Operator, and Vessel Captain. All participants were well trained and displayed a high level of expertise in their respective fields. The Aerial Observer was provided a separate video display (Figure 9) and could see the same imagery as the UAS Mission Operator and UAS Vehicle Operator. This proved quite valuable in providing the Aerial Observer with total situational awareness. Close coordination between all parties proved essential for safe and effective operations. The vessel FRV Protector proved to be a suitable platform for the on water operations. The vessel had a small cabin that provided the team shelter and allowed for easy communications between participants. Although the vessel had good deck space, much of it was taken up by oil boom storage. This was not a significant issue for this exercise but for future operations it would be recommended that any unrelated equipment be removed from the vessel to maximize deck space.

Figure 9: Mission Planning Laptop

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On Board Image Quality

The real-time video available to the on board Observer was of good quality and adequate for the mission. Despite the overcast and intermittent foggy conditions, the video provided enough definition and resolution to fulfill the mission. In addition to real-time video, the Puma has the capability to take high-resolution still photos (Figure 10) that can be reviewed on board immediately after capture.

Figure 10: High definition photo with position, altitude, and azimuth data (lower left)

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Documentation

Because all imagery and flight information is automatically captured and recorded by the control equipment, documentation is a strong point with the UAS platform. Every video frame and still photo is geo-referenced and contains a wealth of information including the location, altitude, and angle of view (Figure 10). The Center Field of View (CFOV) feature inherent in the video imagery displays the ground-based position for the center cross hairs displayed on image. This feature can provide the position of any target simply by aiming the camera at that target. This feature allowed the team to identify the position of a target without the need to fly the aircraft to the target. The Aerial Observer found this feature quite valuable. In addition to the imagery and associated data, the UAS also logs the flight path and altitude of the aircraft, which the Observer also found quite valuable (Figure 11).

Figure 11: UAS flight track imported into Google Earth

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Figure 12: Shoreline high definition photo imported into Google **Earth**

Unfortunately, all this flight data and imagery was recorded in the National Imagery Transmission Format (**NITFS**), a format that was unfamiliar to the Oil Spill Response members of the group. The AeroVironment members were able to convert the still images to a jpeg format, the video to an mpeg format, and flight information to a .KMZ (Google Earth) format (Figure 12) but some information was lost in the conversion.

CONCLUSIONS AND RECOMMENDATIONS:

Overall, the Unmanned Aircraft Systems show promise as a tool in oil spill response observation and spotting. The technology is such that a small team can deploy and operate the system in the field and can potentially provide Command with additional real-time situational awareness.

Imagery

During this exercise, the real-time imagery available to the Aerial Observer using a 5 megapixel, 4X zoom was quite good. The Observer’s initial concerns about the narrow field of view inherent in the on board optical package were mostly alleviated by the skill of the camera operator. It was demonstrated that a wider field of view could be simulated by having the Operator slowly pan the camera from side to side. Again, close coordination between the Aerial Observer and Camera Operator is critical.

The Internet has many other UAS vendor options with larger and smaller UAS's airframes and cameras of higher and lower resolution and zoom capabilities. Determining the

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data/photography quality necessary for the mission aids selection of acceptable UAS's without over or under buying in terms of capability. Higher quality photography beyond the 5 megapixel, 4x zoom camera used could benefit wildlife identification or shoreline clean up assessments but may add little to Aerial Observation operations typically performed at 200 to 400 ft altitude. This would be especially true if the increased capability camera has increased weight or power consumption and reduced the UAS flight time.

Equipment

The UAS package for this exercise included two complete Puma systems and enough redundant equipment to minimize the likelihood of downtime due to equipment failure. During the three days of operation the team experienced no mechanical or instrumentation problems. These particular UAS's were built to military standards designed to ensure continuous operation with minimum maintenance in rigorous conditions. When supporting oil spill response efforts near areas with ready access to logistics, these same UAS's could remain operating days or weeks in the field when receiving routine maintenance and minor field repairs.

The UAS's simplicity and ruggedness comes with a higher cost to be considered when weighing the vehicle choices against mission requirements and field conditions. Far cheaper, smaller UAS's used by the real estate and film industry can capture remarkable video using sport videocams mounted to foam wing airframes or quadcopters. Their more fragile airframes, short range and minimalist avionics, data capturing, and communications capability however implies they would have a limited life span and could not be used in a wide range of missions supporting oil spill response. UAS vehicles which offer longer flight times are also available but their larger size usually also includes a higher vehicle cost, larger logistics requirements for transportation and a dedicated support team of several people to service the vehicle routinely. Smaller UAV's using electric motors for propulsion may have logistics issues shipping batteries. Larger UAV's can also experience logistics problems in remote areas obtaining or transporting petroleum based fuels for propulsion in internal combustion engines.

Communications

As with manned flight, communication from the field to Command is always a major concern. For this exercise the 5 to 6 miles distance from the area of operation to the Command Trailer allowed for the streaming of real-time video. This was accomplished through an encrypted direct vhf radio link between the aircraft and the viewing station in the Command Trailer. Of course, this close proximity will rarely be the case in a response situation. Additional distance can be obtained by retransmitting the video through an additional Ground Control Station. Alternatively, flying a second UAS to serve as an airborne video retransmission site also adds the ability to reroute the vhf signal around or over buildings or hills which could block signal reception. A reliable communications system capable of providing the necessary bandwidth for streaming video is an important component of the system and should be in place on Day One of operations. It is recommended that AeroVironment regularly offer extended range communication capability as part of their overall service.

Data Format

Data format was also an issue identified early in the exercise. The end product (or data output) of the AeroVironment system is geared towards the DOD/Homeland Security

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community and not currently in a format easily handled by the Oil Spill Response community. The AeroVironment operators were able to locate software that could convert their data to a more universal format (i.e. KML) but some data was lost in the process. It is recommended that AeroVironment develop a method for providing the Oil Spill Response community the complete data package in a more usable format.

With more pure commercial UAS's entering the field of choices, digital data link options have become available that integrate transmitter/receivers into networks using IP (internet protocol) and a web based interface. Video capture using the industry standard H.264 encoding is also available to improve image quality and stabilization. Some UAS's feature cameras that collect high resolution photos which are geo-referenced into 2D/3D maps and then accessed with well known GIS and photography software for generating layered maps or publishing to websites.

FAA Authorization/Approval

Flight area approval is another issue that arose early in the planning process for this exercise. The 60 day lead time required by the FAA to process a COA request under their current policy is overly burdensome and deters the UAS's from being seriously considered for use in oil spill exercises or real events. In a response scenario, an approval process that can react in hours, not days or weeks, is required. It is recommended that AeroVironment secure FAA authorization for flight operations as part of their overall service.

Complete UAS Package

For an Unmanned Aircraft Systems package to be oil spill response ready it is recommended that a complete package should include:

- All the UAS hardware and spare parts necessary for prolonged uninterrupted operations.
- UAS operators familiar with oil spill response operations.
- FAA approval for flight operations.
- A communications system suitable for long-range data transmission with the capability to display streaming video to the Command Center.
- A final data package formatted to the client's specifications.

Summary

Small unmanned aircraft systems are a proven reliable technology well suited for aerial surveillance and oil spill response. Autonomous control of real time video and enhanced situational awareness to responders in the field will significantly improve efficiency and reduce the risks of manned aircraft. The distribution of geo-located time stamped imagery to the Command Center and beyond will significantly improve the Common Operating Picture (COP) and decision-making. Complimentary to real time streaming video, high definition visual imagery, LiDAR, and multi-spectral data collection can also provide additional post processed GIS mapping and data analysis into the COP. These capabilities are available today and with the recent progress in FAA acceptance of small UAS into National Airspace, we believe UAS will soon play a significant role in oil spill response and disaster preparedness.

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