Integrating Unmanned Aircraft Systems into Alaskan Oil Spill Response – Applied Case studies and Operational Protocols

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ABSTRACT

(PS1-02) Unmanned Aircraft Systems (UAS) have a high potential value to support oil spill response activities due to their capabilities to provide real-time situational awareness. A variety of UAS are available to support response activities, and determining the precise aircraft, sensor payload and flight patterns will depend on the operational need for surveillance. In support of UAS integration into America's airspace, the FAA has defined general protocols for the commercial use of small UAS (less than 55 lbs. total take-off weight) in 14 CFR Part 107. However, these regulations do not address any other concerns associated with flight of these small aircraft, such as shared operational airspace within a temporary flight restriction area, or regulations for flight over animals that fall under state or federal management. To address this lack of policy, a UAS protocol for flights of small UAS during oil spill response activities was developed and integrated into a series of tabletop oil spill exercises conducted in Alaska during 2018. The UAS protocol was vetted with state and federal agencies responsible for wildlife management both on and off-shore, was modified for execution in remote as well as urban locations, and has been integrated into Area Contingency Plans in Alaska. This presentation will highlight the operational

components of the UAS operational protocol, as well as the challenges, both perceived and actual, to UAS integration into the incident management structure of an oil spill response.

INTRODUCTION

Remote-sensing (RS) tools are able to support oil spill response activities without exposing people to the numerous dangers and environmental concerns associated with assessing an oil spill directly (Adams et al, 2014). RS tools also allow access to remote areas to characterize the environment in which an oil spill can or has occurred which would otherwise be inaccessible, extremely challenging to get to, or inherently environmentally sensitive to human disturbance (Chou et al, 2010; Giordan et al, 2017). Being able to ascertain such remote environments is important for monitoring off-shore oil exploration and production activities, and especially important for observing ecosystems, changes and disasters in the population-sparse Arctic (Thamm et al, 2013). The value of RS the environment is clear, but the integration of the data collected by the sensors into decision-making in the short and long-term remains pocked with gaps in efficiency. Capitalizing on RS requires the use of the correct sensor to collect the data decision-makers care about and can act upon, as well as data that can be interpreted by those decision-makers and their support teams; not all data is created equal. An additional hurtle can be the delay in data delivery from whatever platform is being used to collect data over the remote site (e.g. satellite, airplane, boat, etc.), to the location where decision-makers can access the informational product, such as an incident command post (ICP) during an active oil spill response.

Unmanned aircraft systems (UAS) are known for their utility to provide real-time data (i.e. live) during data-collection flights and are relatively easy to task for flight in comparison with earth-observing satellites, or specialized airplanes outfitted with multiple sensor packages. During an oil spill response, the real-time, or near-real-time (less than 60 minutes after collection), data delivery of UAS data collections can provide the situational awareness needed to develop tactical response strategies (Giordan et al, 2018; Gowravaram et al, 2018). However, not all data that is captured is useful, and not all UAS can capture useful data for decision-makers. Choosing the correct platform and sensor package to gain situational awareness should be dictated by operational capacity to consume those data to create informational products for decision-makers in a timely fashion.

In parallel to the efforts to integrate quality UAS-collected information into oil spill response decision-making, the Federal Aviation Administration (FAA) is working to integrate UAS safely into United States airspace. The FAA has established seven UAS test sites across the nation, the Alliance for System Safety of UAS through Research Excellence (ASSURE), and has partnered with the Department of Transportation to establish the Integrated Pilot Program (IPP), with the directive to identify and rectify hurtles to integrating UAS into US airspace; the University of Alaska Fairbanks' Alaska Center for Unmanned Aircraft Systems Integration (ACUASI) is a member and key player in all three of these defining efforts. Through these efforts, and the incredible popularity and accessibility of UAS, new operational requirements are being added and removed by the FAA on a regular basis. Other federal agencies, and many state agencies, have been hesitant to embrace UAS technologies due to a lack of publicly available airworthiness test data, and the lack of use of these technologies in support of their programs to date. This hesitancy has created ambiguous UAS policies outside of the FAA regulations required for safe flight.

A set of operational guidelines was developed for use of small-UAS during marine oil spills over Alaskan waters and coastlines during five Alaskan oil spill exercises in 2018 to reduce ambiguity in UAS use to support oil spill responses and exercises. The operational guidelines were vetted as part of the industry-led exercises with federal, state and municipal agency representatives, and in one case industry lawyers, in exercise real-time (during the exercise) and after compilation as an operational protocol. The operational, *Protocol for Using Unmanned Aircraft Systems (UAS) During an Oil Spill Response or Exercise* (Garron, 2019), was developed for the use of small (less than 55 pounds) UAS in support of oil discharges, or hazardous substance release, responses and exercises in Alaska. These specific types of environmental responses the protocol was designed for are authorized by the National Oil and Hazardous Substances Pollution Contingency Plan 40 CFR Part 300 (National Contingency Plan or NCP). The NCP establishes the National Response System (NRS) and this protocol describes the roles and responsibilities for UAS integration into the incident command structure of authorized NRS actions that may include UAS flight requirements and UAS-relevant agency requirements in the presence of wildlife in marine and terrestrial environments. This protocol has been integrated into the Arctic and Western Alaska Area Contingency Plan (AWA ACP) by the plan stewards, US Coast Guard Sector Anchorage.

This presentation describes the components and the process of developing and integrating an operational UAS protocol into oil spill response exercises and the contingency plans used to guide response and exercise activities in Alaska.

MATERIALS AND METHODS

This effort focused on the exclusive use of small-UAS (less than 55 lbs.), carrying off-the-shelf sensor payloads that were intrinsically integrated with the aircraft. The purpose for this specificity is the based on the accessibility of these types of UAS for immediate deployment as compared to small fixed-wing UAS or large-UAS which require additional skills and licensing for flight, and the reality that most oil spill removal organizations (OSROs) are experimenting with small, multi-rotor vehicles. Data collections were limited to optical sensors, as were the simulated data sets. All UAS pilots and UAS observers were certified by the FAA under 14 CFR Part 107 of the Federal Aviation Regulations as qualified UAS operators, knowledgeable on air safety and restrictions governing small-UAS flights.

UAS-based data collection

UAS-collected data was used for four of the six exercises using UAS of opportunity (i.e. already in possession by the OSROs supporting the exercises). These data were used in the exercises as baseline data and background layers for trajectory maps and tactical operations. For all of the exercises, simulated UAS flights were reported to the exercise controllers who then decided what conditions were observed, or information collected, during the simulated flights. Data for the two Fall 2018 exercises were collected using the DJI Mavic Pro operated by Alaska Clean Seas (ACS). Both still images and videos were collected with visible spectrum (Red, Green, Blue/RGB) sensors. Data was collected at nadir (0º) and oblique angles (-10º to -20º) at altitudes ranging from 200 to 390 feet above ground level (AGL) and was used as baseline data and background imagery for simulated trajectory analysis. Data collected for the Spring 2019 exercises was collected using a DJI Phantom 4 UAS operated by CISPRI (for McArthur River footage) and the State of Alaska Department of Natural Resources (for Seaview production pad footage) at variable oblique angles. Additional sensors were not employed, as they were not available on the UAS of opportunity. No post-processing was performed on any of the data sets prior to introduction into the command post of the exercises. All UAS-collected data used for the exercises were provided via hard drive directly to the GIS specialist in the command post who was also responsible for providing the operational maps, inclusive of trajectory analyses. No data was collected or delivered in real-time for the exercises as they were tabletop in nature, with no tactical deployments. This information was used to define UAS-based data management procedures incorporated into the UAS protocol for spill response and exercises (Garron, 2019).

UAS integration into incident command system (ICS)

Roles and responsibilities for UAS teams working on oil spill responses or exercises were compiled from relevant Federal Emergency Management Agency (FEMA) guidance documents for Incident Command System (ICS) and the Code of Federal Regulations (CFR) for protocol integration. The operational guidelines were used to define an operational checklist, that was combined with UAS team roles and responsibilities to form the basis of the operational protocol (Garron, 2019). A UAS Technical Specialist from the research team was embedded in the command post and worked directly within the Air Branch Director, coordinating aircraft into the airspace in and around the simulated temporary flight restriction (TFR) zone designated as part of the oil spill response exercise, and in the Environmental Unit as shoreline cleanup and assessment technique (SCAT) support for one exercise. Embedding the researcher allowed for direct access to the members of state and federal agencies acting as stewards for the animals and environment potentially impacted as part of the exercises to inform flight guidelines. FAA guidance for use of small UAS during an emergency response was defined by the research team prior to the exercises and was practiced through execution for each scenario (Table 1).

Table 1. UAS Team Activation and FAA Requirements for UAS Flights (*adapted from Garron, 2019)*
• The Air Operations Branch Director activates the UAS Technical Specialist. If the NRS response action does not immediately have an Air Ops Branch Director, the UAS Technical Specialist shall report to the Operations Section Chief or other authorized response personnel as determined by the federal and/or state on-scene coordinator. • The UAS Technical Specialist requests and contacts UAS pilot/observer teams for mobilization. • The Air Operations Branch Director or other authorized incident response personnel for the Responsible Party or the federal and/or state on-scene coordinator requests a temporary flight restriction (TFR), inclusive of proposed UAS activity, over the area of operations from the Federal Aviation Administration (FAA) Flight Center Watch Supervisor. • UAS Technical Specialist applies for Special Governmental Interest (SGI) amendment process (formally known as Emergency-Certificate of Authorization or E-COAs) via

the Emergency Operation Request Form, if standing COAs or Part 107 waivers for the area of operations are determined insufficient to support response or exercise.
  - The SGI can be requested by either a 107 operator or a public entity with a COA.
  - The UAS Technical Specialist submits E-COA application via email to the FAA System Operations Support Center at 9-ator-hq-sosc@faa.gov
    - If approved, the FAA will add an amendment to the pilot's existing COA or Remote Pilot Certificate authorizing flights under the certain conditions specified in the waiver application.
    - If denied, operators can only fly within the provisions of their existing COAs or Part 107 waivers.
- Air Operations Branch Director and UAS Technical add response specific UAS information to ICS-220 form (UAS N#s, UAS operational frequencies, UAS communication frequencies, UAS type, UAS model, COA/waivers in use).
- All UAS flights must be conducted by certified UAS pilot/observer teams as defined by 14 CFR Part 107 or 49 US Code 40102(a) and 40125 COAs in coordination with the Air Operations Branch Director and/or the UAS Technical Specialist.
- UAS Pilots can operate a maximum of 8 consecutive hours and a maximum of 14 hours per day under specific direction and permission from the Air Operations Branch Director and the UAS Technical Specialist (Augmented Operations as per 14 CFR Part 117). Each UAS pilot will have one alternate to allow sufficient breaks during response operations.

For exercises, UAS technical specialist submits a Notice to Airmen (NOTAM) for UAS flight operations for the defined exercise area.

Prior to each exercise flight (real and simulated), the UAS Technical Specialist coordinated flight parameters with the embedded representatives of the U.S. Fish and Wildlife Service (USFWS), National Ocean and Atmospheric Administration's National Marine Fisheries Service (NMFS), the State of Alaska Department of Fish and Game (ADF&G), and a representative from the Alaska State Historical Preservation Office (SHPO; not embedded). Lessons learned about agency permitting and airspace coordination were integrated into the UAS operational protocol after the exercises, and was provided to the AWA ACP subcommittee for review. Comments were discussed via teleconference and provided via written submission for integration into the UAS protocol (Garron, 2019). The protocol was adapted into version 2020.0 of the AWA ACP via the review and adoption process previously established by the AWA Area Committee's Steering Committee. The Steering Committee is made up of the relevant federal and state on-scene coordinators.

RESULTS/DISCUSSION

UAS-based sensors to support oil spill response

The UAS-collected data for these exercises were only from the visible light spectrum, recordable by electro-optical cameras. These cameras, capable of still image collection as well as video, were fully integrated into the UAS of opportunity, thus making their use seamless, and their output intuitive. However, there are many other sensors that can be carried on a UAS that can support tactical decision-making during an oil spill response (Fingas & Brown, 2012; Huang et al., 2017; Jha et al., 2008; Messinger & Silman, 2016). Infrared sensors, finer resolution electro-optical cameras, multispectral sensors (Dufek et al., 2019; Gowravaram et al., 2018) and hyperspectral sensors (Alam & Sidike, 2012; Andreoli et al., 2007; El-magd et al, 2014) all can answer different specific tactical questions during an oil spill response. Complex sensors capable of providing detailed information often require large amounts of energy to run, and are not typically integrated in off-the-shelf UAS products, which is a risk for any operation in investment. In practice, specific data collection platforms need to be paired with sensors they are able to carry and power during data collection efforts, and if those UAS have been tested and established in the commercial market, there is a higher likelihood that operators and data managers will be able to create tactical informational products for decision-makers from the UAS-collected data. Depending on the sensor chosen, different post-processing methods will need to be employed to provide a useful informational product to decision-makers in a timely fashion. Creating an informational product that can be used by decision-makers is a significant task that increases in time the more intricate the sensor, and the more abstract the data. Finding an operational balance of sensors, some capable of providing easily consumable real-time data, and others capable of providing detailed information about the spill itself in near real-time, is a new facet to the same operational problem of speed vs. detail. The correct sensor to use during an oil spill response is the one that is able to answer the question being asked in an acceptable amount of time for decision-makers to act upon the information.

UAS operational flight requirements

For the case study exercises, UAS operations were coordinated through the Air Operations Branch of the Operations Division of the Incident Command, as would be the case during an actual response. The Air Operations (Air Ops) branch is responsible for managing the airspace and the aircraft operating within the area of interest. Often there will be a TFR put in place, which also would be under the managerial authority of the Air Ops Branch Director, though the FAA maintains ultimate control of all airspace in the U.S. For four of these exercises, there was a UAS Technical Specialist (FEMA, 2017) embedded within the Air Ops branch. This role reported to the Air Ops Director and was responsible for all UAS coordination as part of the exercises, with a focus on safety and operational data collection of the simulated UAS flights. For the fifth exercise, the UAS Technical Specialist was embedded in the Environmental Unit to support the SCAT teams.

During a real oil spill, it is likely that multiple branches of the incident command will have access to UAS for acquiring various data, but it is of paramount importance that all flight activities, UAS and otherwise, be coordinated through Air Ops to insure the safety of all members of the response. To cement this concept, all utilized UAS were included on the ICS 220 (Air Operations Summary) for all of the exercises. A TFR was put into place by the Air Ops Branch Director, allowing for direct coordination of UAS with all other air assets being utilized as part of the simulated response. When a TFR has been established, there still maybe the requirement for an Emergency Certificate of Authorization (eCOA) to access the TFR airspace. For example, if a small, fixed-wing UAS was being launched from shore, and the TFR was some distance away, a corridor would need to be set-up under an eCOA for the UAS to get to the TFR. An eCOA can be used to request variances to any of the inherent Part 107 flight regulations from small-UAS, such as temporarily flying beyond visual line of sight.

Legal concerns of the responsible parties (industry partners hosting exercises) for the use of UAS during a spill response or exercise were taken into consideration. Vetting of the UAS teams was a requirement of the industry partners leading the exercises through the legal liaison of the responsible party. In an actual response, UAS team vetting could include background checks, past performance records, FAA inquiries and other formal agreements. The only mandated operational permissions for UAS flights in a TFR over an oil spill response are those dictated by the Air Ops Branch Director. However, all of the regulation compliance guidance provided to pilots that complete the FAA Part 107 certification, or as defined as part of the certificate of authorization in use, will likely be a requirement to work in the airspace of any response.

Wildlife agency coordination

During the first two exercises in 2018, the simulated UAS pilot teams (pilot and observer) were underutilized for tactical decision-making due to a lack of understanding of UAS capacity to support tactical requirements. In an effort to observe baseline perceptions about UAS integration into the ICP, no suggestions for UAS use were made by the UAS Technical Specialist embedded in Air Ops during these exercises. As a result, no UAS overflights for oil footprint were requested by anyone in the ICP. However, the Operations Section Wildlife Branch was quick to utilize the simulated real-time nature of the UAS-based data collections. UAS were used by the Wildlife Branch to identify marine mammals nearing the simulated oil spill that would need to be hazed, identify the location of nesting shorebirds in the area of impact and projected impact, and to provide simulated real-time data viewing to trained protected species observers.

The coordination of UAS operational flights included addressing flight requirements, and requests from state and federal agencies responsible for the welfare of animal and cultural resources participating in the exercises, specifically National Oceanic and Atmospheric Administration (NOAA), NOAA Fisheries (NMFS), U.S. Fish and Wildlife Service (USFWS), and the State of Alaska Department of Fish and Game (ADF&G) (collectively referred to here as "wildlife agencies"). Policy nuances about UAS use during oil spill responses versus oil spill response exercises were revealed through these exercise-based discussions, and solutions to these nuances were developed to remove ambiguity for UAS use in Alaskan spill and exercises. The most stringent flight parameters from these agencies were those defined through the endangered species Section 7 consultation process relating to animals under the purview of NMFS.

UAS flight guidelines reported here were designed to meet FAA requirements and wildlife agency recommendations for UAS flights in most locations along Alaska's coast and waters, and to provide operational guidelines for UAS flight planning. UAS flight guidelines were vetted by wildlife agencies during the exercises were codified during review of the UAS use in oil spill protocol (Garron, 2019). These flight guidelines pivot around the central idea that wildlife are protected from harm and harassment under a variety of laws (e.g., Endangered Species Act, Marine Mammal Protection Act, Bald and Golden Eagle Protection Act), and are intended to reduce the likelihood that wildlife will be harmed or harassed by UASs during spills and drills. Though no specific legal mandate exists requiring UAS operators to consult with agencies other than the FAA prior to flights, if UAS resources are used during an NCP type incident, all response related action taken must be authorized by the federal on-scene coordinator. Further, as directed by the NCP, the federal on-scene coordinator must consult with various trustee agencies via pre-defined processes, e.g. the section 7 consultation. Therefore, the responsible party, their contractors and the UAS operators must ensure, to the maximum extent practicable, that they operate consistent with the AWA ACP version that includes the UAS operational protocol, as lack of doing so will likely result in fines and other indirect consequences.

During a spill response, wildlife agencies should be contacted as soon as possible to coordinate response activities in a way that reduces impact to wildlife. In Alaska, the Wildlife Protection Guidelines for Oil Spill Response in Alaska (WPG) within the Alaska Area Contingency Plans provides wildlife agency contacts, wildlife observation forms, and other information. To ensure compliance with wildlife laws during exercises, contact wildlife agencies as soon as the exercise has been planned. If conducting exercises in an area with known NMFS species of concern, NMFS consultation should be conducted to determine if an incidental take authorization needs be obtained for the unintentional "take" of marine mammals incidental to the exercise. This guidance may or may not be accepted outside of Alaska and should be confirmed locally prior to implementation. Creating the operational protocol, having it vetted by all involved agencies, followed by integration into the AWA ACP was an attempt to curtail future redundant and cyclical discussions about efficient integration of UAS in oil spill response.

The Operations Checklist (Table 2) is designed to reduce potential disturbance and harm to wildlife during UAS flights as part of an oil spill response or exercise in Alaska. The UAS operational protocol shall be followed unless alternative, incident-specific, wildlife impact mitigations are defined as part of an authorized NCP response action. UAS flight operations performed in support of an authorized NCP response action or other emergency response should be coordinated with input from wildlife agencies, and additional protection measures may be developed as the response continues. Permits may be required to take off and land a UAS on State Special Areas (Critical Habitat Areas, Refuges, Sanctuaries, or Ranges), or other public lands. These permits can be efficiently obtained from state or federal agencies during a spill response, but should be obtained in advance of exercises. Additional recommendations for the use of UAS near wildlife during spills and exercises can be found in Garron, 2019.

Table 2. Operations Checklist (*adapted from Garron, 2019*)

- **[PRE FLIGHT]** Start new Flight Log for specific flight, including UAS team and response specific roles of members,
- **[PRE FLIGHT]** Establish a UAS ground-station for flight operations (land owner consultation/permitting may be required),
- **[PRE FLIGHT]** Establish real-time flight monitoring station,
    - Real-time video display via the UAS flight controller, laptop streaming of flight data, or external monitor, as available
    - Wildlife observers should be co-located with pilots at UAS ground station to monitor the live UAS video feed and scan surroundings for the presence of wildlife
- **[PRE FLIGHT]** Perform pre-flight safety and security checks of aircraft; inform UAS technical specialists and observers of any potential safety concerns,
- **[PRE FLIGHT]** Perform pre-flight safety and security checks of on-board data gathering and streaming equipment; inform pilots and observers of any potential safety concerns,
- **[PRE FLIGHT]** Ensure data recording and streaming equipment is operational, **[PRE FLIGHT]** Provide operational safety briefing,

- **[IN FLIGHT]** Conduct all UAS flights following the express regulations of 14 CFR Part 107 or 49 US Code 40102(a) and 40125 COA (see UAS Team Roles and Responsibilities for UAS Pilots above).
- **[IN FLIGHT]** Conduct UAS operations between 150 and 400 feet above the coastline/water, or as agreed upon in coordination with wildlife agencies, to reduce wildlife disturbance.
    - Do not use raptor shaped UAS if the potential for bird encounters exists
    - Approach flocks of birds from high altitudes, and reduce altitude from directly above
    - Do not conduct flights lower than 150 feet over birds
    - Do not fly within 300 feet of bald eagle nests
    - Avoid flights near perched or flying eagles
        - Ground aircraft or move aircraft away if perched or flying eagles encountered
- **[IN FLIGHT]** UAS will avoid buzzing, hovering, landing, taking off, taxiing, excessive speed or sudden changes in speed or direction near wildlife on land or in the water.
- **[IN FLIGHT]** When an animal sighting is made, species, group size, age categories (if determinable), heading (if consistent), and bearing and distance from the spill will be recorded by wildlife observers, the Wildlife Observation Form found in the WPG.
    - If no wildlife observers are co-located with UAS pilots/observers, the UAS pilots will contact the wildlife observers or wildlife branch of IMT via radio or phone when impacted shoreline or animals are sighted once they are safely able to do so.

- **[POST FLIGHT]** Complete Flight Log for specific flight.
- **[POST FLIGHT]** Perform post-flight safety and security checks of aircraft; inform UAS technical specialists and observers of any potential safety concerns,
- **[POST FLIGHT]** Perform post-flight safety and security checks of on-board data gathering and streaming equipment; inform pilots and observers of any potential safety concerns,
- **[POST FLIGHT]** Check data recorded, create back-up copy, and forward original data to the Situation Unit for integration into the common operating picture, and any other designated recipients, as required by the incident data management and sharing plan.
- **[POST FLIGHT]** Report wildlife sightings to wildlife agencies or incident-specific designated IMT positions.

UAS ICS integration challenges

A primary benefit of off-the-shelf UAS technology, is the ability to provide real-time data collections for tactical operations and wildlife situational awareness. Most commercially available UAS can live-stream visible data (electro-optical/RGB) as it is being collected. Whether this live-streaming is only to the pilot and the nearby observers, or to the ICP is a function of communication networks, which in themselves are often dictated by the relative remoteness (or nearness) of the area of interest to established communication infrastructure like cell networks or broadband internet access points. In the highlighted exercises, no data was being collected during the tabletop exercises, so demonstration of real-time data delivery into the command post was not achievable. However, the previously collected footage was displayed in the ICP, and was used for tactical decision-making, specific to the conditions observed in the UAS-collected imagery.

One of the most significant challenges to UAS integration is data management for efficient use in decision-making. UAS-collected data has the capacity to be very intuitive, or very complex, and the complexities of the data and desired data products will dictate post-flight processing requirements. Data managers that had not been trained to specifically handle UAS data were unable to integrate the baseline videos or images into the GIS-based common operating pictures (COP) in use during the exercises. Manual data workarounds were performed during the exercises to provide quality images to the tactical decision-makers of the incident command, but the value of the images collected was not fully utilized. This significant challenge can be overcome with training or by adding additional RS experts to the COP team, but should be addressed by all operators conducting regular oil spill drills for which they are flying UAS for situational awareness of any kind. In order to achieve maximum efficacy of any UAS asset, the UAS team should deploy with a pre-packed and self-contained logistics that can integrate data and video feeds directly into the Unified Command or ICP.

Rogue UAS operations

This study focused on the integration of UAS into oil spill response exercises, specifically through flight operational guidance aimed to provide decision-makers in incident command with the information they need to make quality response decisions. This study did not focus on "rogue" UAS operations, by members of the response or otherwise, that may be operating UAS legally, but outside of the bounds of the incident command structure of the response. It is recognized that rogue flights will likely occur during an actual response (rogue flights were often presented as problem injects throughout each of the exercises). Defining management strategies of these rogue aircraft and operators during an exercise, allows for a basis from which to manage rogues during an actual response can be established. The primary management tool to prevent rogue operations during an oil spill response is the establishment of a TFR over the area of operations. Part 107 certified pilots are required to check for any notice to airmen (NOTAMs), designed to provide information essential to personnel concerned with flight operations but are not known far enough in advance to be publicized by other means (i.e. real-time abnormal status indicators), which are applicable to their area of flight, and through this process will be made aware of the closure in operational airspace (U.S. Department of Transportation, 2019). Strategies to manage rogue UAS within a defined TFR during an operation includes deploying a security team to identify the operator of the UAS, and have UAS operations ceased immediately. This method assumes the UAS is being flown with line of sight of the operator as per Part 107 guidance, and that security teams will have physical access to the operator's location. Jamming devices for blocking UAS operational signals are not yet commercially available, nor legal for non-governmental use, thus if a rogue UAS is observed, the safest solution is to ground all aircraft in the TFR until the rogue UAS has left the area, voluntarily or not.

CONCLUSIONS

Visible spectrum baseline data provided by the UAS for these exercises was intuitive to consume and of high enough quality to make tactical decisions (e.g. boom placement in small streams). These major advantages of visible sensors should not be overlooked when considering other RS packages capable of more detailed analysis of the environment. There is no operational response value in a sensor that produces data that is too complicated to be understood quickly by decision-makers. The balance of detail vs. time will continue to improve as computing power becomes more efficient by weight. It is important that the computing infrastructure be in place to support voluminous RS data sets collected during a response (or exercise), and that the end users have the training needed to take full advantage of the products. Uncertainty in the data products needs to be eliminated or defined up front so that credibility will not be lost. Long-term data accessibility needs to be considered during design, implementation and evaluation of the products if there is to be hope of creating a product that will remain viable longer than the operational response phase.

Embedding a UAS Technical Specialist into the Air Operations Branch of Operations proved to be effective for safe airspace management, to coordinate with the needs of the tactical maneuvers of the Ops team, and to leverage the preliminary flight guidelines. The informal discussions within the incident management team of the oil spill response exercises allowed for clarification of UAS capacity as well as agency concerns about UAS flights over wildlife and their habitat. These direct discussions served to inform as well as to develop the UAS operational protocol that was subsequently integrated into the AWA ACP.

Once the operational support available from the simulated UAS was understood, the UAS were quickly integrated into routine overflights and specialized missions. There is still misunderstanding in the general operational environment on what UAS can and cannot do, thus continued education about these tools for potential responders is important to establish and maintain. Not being able to demonstrate real-time data delivery by the UAS in these exercises provided the opportunity to introduce expectation management about these modern tools, and an understood challenge for each ICP to overcome.

One component of UAS integration into oil spill response activities that needs to be included for a holistic response strategy development is stakeholder engagement when new tools become available to support a response. It is recommended to have training sessions on the RS imagery and video that is most likely to be used for decision-making in the command post so that decision-makers understand what data information is available with the RS collection tools at hand. Providing opportunities for feedback and iteration cycles will only improve the product and increase the legitimacy of the technology and team. Learning and training opportunities for staff in the ICP that work with the UAS (or any other RS platform)-collected data needs to be provided by any operator or responder interested in using tools beyond the human aerial observer for situational awareness during an oil spill response. This significant challenge can easily be overcome, but should be addressed by all operators conducting regular oil spill drills for which they are flying UAS for situational awareness of any kind.

Rogue operations, intrinsically safe UAS, citizen-created and publicly available UAS-collected data sets over sensitive targets, all need to be understood and addressed in the immediate future, and prior to the next significant oil spill response. As detailed challenges about UAS integration into airspace and operations of many sorts are identified and resolved daily, the oil spill response community has an opportunity and a responsibility to take advantage of this rapidly evolving tool to support quality oil spill response decisions.

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