 

Uncrewed Aircraft Systems Oil Spill Response Job Aid

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Response and Restoration
Emergency Response Division

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A Guide to provide application-specific guidance for effectively using small Uncrewed Aircraft Systems (UAS) to collect data in support of oil spill response.

U.S. DEPARTMENT OF COMMERCE • National Oceanic and Atmospheric Administration •
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Introduction

Disclaimer

The information contained within this document is intended to provide application-specific guidance for effectively using Uncrewed Aircraft Systems (UAS) to collect data in support of certain emergency and disaster response missions. However, the content is not intended to exhaustively cover or supersede existing regulatory and policy frameworks. This information is provided to help develop and execute the most efficient UAS missions in challenging response environments while also ensuring compliance with existing NOAA policies. It is advised that the information provided herein should be used in conjunction with these other resources: "NAO 216-104A: Management and Utilization of Aircraft[1]", "NOAA Aircraft Operations Center (AOC), Uncrewed Aircraft Systems Policy 220-1-5[2]" (AOC Policy 220-1-5), and "NOAA UAS Handbook[3]". For more information regarding specific NOAA UAS operational policies and procedures, the reader is encouraged to reach out to the NOAA Office of Marine and Aviation Operations (OMAO) "UAS Division"[4]. Users from other agencies will need to ensure that their activities are conducted in accordance with their agency's policies and procedures.

[1] https://www.noaa.gov/organization/administration/nao-216-104-management-and-utilization-of-aircraft
[2] https://www.omao.noaa.gov/find/media/documents/policy-220-1-5-unmanned-aircraft-systems-uas-operations
[3] https://www.omao.noaa.gov/find/media/documents/noaa-unmanned-aircraft-systems-handbook-june-2017
[4] https://www.omao.noaa.gov/learn/aircraft-operations/aircraft/uncrewed-aircraft-systems

Oil and Hazardous Materials Spill Response

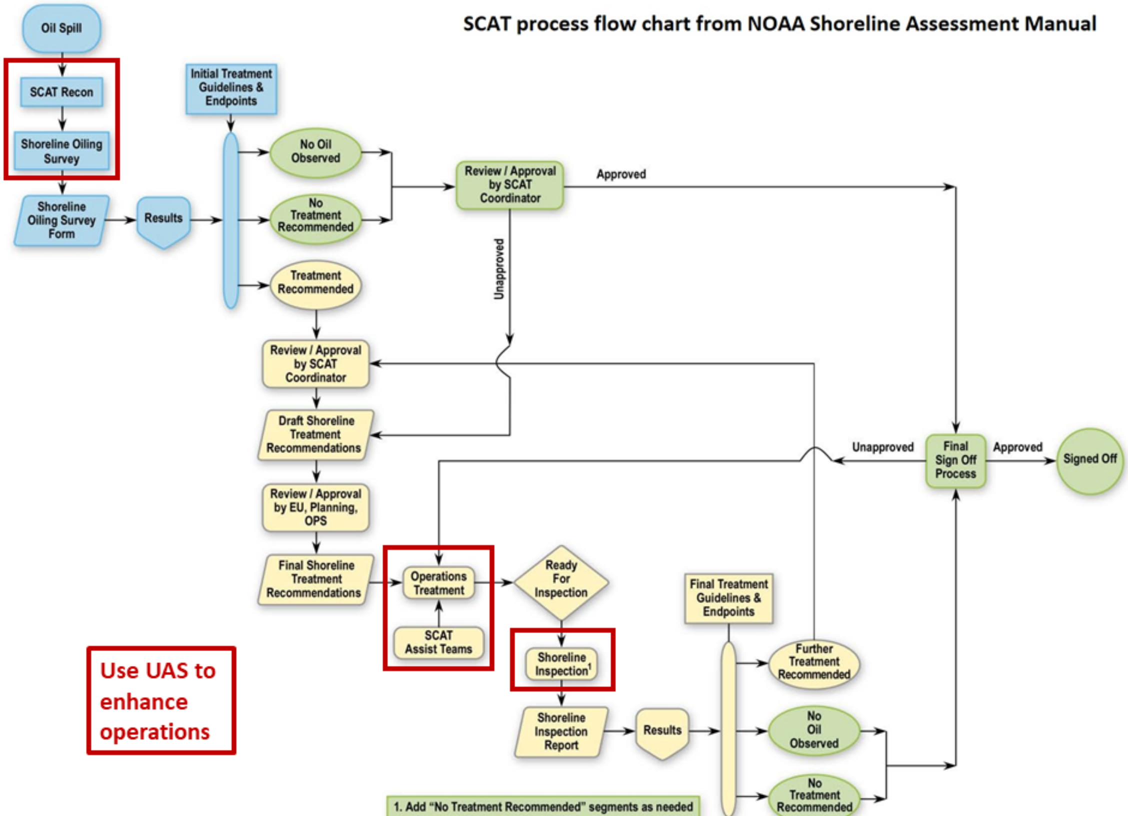
When spilled oil or other hazardous material contaminates shoreline habitats, responders must survey the affected areas to determine the appropriate response. NOAA published the Shoreline Assessment Manual (4th Edition, 2013) which outlines methods for planning and conducting shoreline assessment and incorporating the results into the decision-making process for shoreline cleanup at oil spills.

This job aid was developed to supplement the Shoreline Assessment Manual, providing a guide for the use of consumer-grade small UAS (sUAS) with photo and video capability during oil spill response. Though this guidance is written for oil spills, it may also be useful for hazmat discharges or marine debris events as well.

A portable and easily deployable sUAS is a valuable tool during spill response. It can be used during different phases of the Shoreline Cleanup Assessment Technique (SCAT) process (see illustration below) and can provide significant cost savings, particularly when used in place of traditional aircraft for reconnaissance overflights. During a shoreline survey, some shorelines may be inaccessible to field teams on foot for reasons including tide levels, environmental hazards, sensitive habitats, etc. A sUAS can be quickly deployed to look for moderate to heavy oil in inaccessible areas. Light oiling of marshes is usually not easily visible in sUAS imagery unless suitable conditions exist, such as a continuous band across the vegetation.

A sUAS is also useful for monitoring and recording response strategies, such as shoreline treatment or proper deployment of sorbents. It provides a unique perspective and can even be used to help plan and direct operations.

SCAT process flow chart from NOAA Shoreline Assessment Manual



Operational Requirements

All UAS missions where NOAA has responsibility for flight safety must adhere to the requirements as described in AOC Policy 220-1-5. This includes operations in which NOAA personnel serve as the Pilot in Command (PIC) or Mission Commander (MC) or when NOAA property is utilized; NOAA vessels or aircraft are used as deployment platforms; and/or when missions are directed by NOAA personnel. All NOAA UAS operations must be approved by the OMAO UAS Division (UASD) through the issuance of a Flight Authorization Memorandum (FAM). An approved Operational Risk Management (ORM) assessment is required to be on file and available to the UASD.

UAS operations that AOC Policy 220-1-5 may not apply to include: demonstration flights where NOAA personnel are observers only; UAS operations conducted by another governmental organization that has an established UAS management program and assumes responsibility for the operation; and UAS operations owned and operated by external contractors and operated under a contract for UAS services or as part of a NOAA "data buy."

Privacy is of utmost importance to NOAA. Because NOAA's use of UAS may unintentionally collect Personally Identifiable Information (PII), the protections of NOAA's Privacy Policy and Unmanned Aircraft Systems Privacy Policy[5] are necessary. Data handling complies with the Privacy Act of 1974 (5 U.S.C. 552a) (the "Privacy Act"), which, among other things, "restricts the collection and dissemination of individuals' information that is maintained in systems of records, including PII, and permits individuals to seek access to and amendment of records". When PII is collected as part of an emergency response at the direction of the USCG, these data are maintained and managed by

[5] https://www.noaa.gov/organization/information-technology/privacy

the U.S. Coast Guard (USCG) Owner Outreach Program in a secure non-public-facing database/location. The UAS team must work closely with the USCG to define how PII would/should be handled during a response.

UAS operations must also adhere to the requirements of Title 14 Code of Federal Regulation (CFR) Part 107 (hereafter referred to as Part 107). These rules are summarized below in the Flight Planning and Preparation section.

Safety

Safety is the principal consideration in all aspects of UAS operations. A safe UAS operation depends on accurate risk assessment and informed decision-making.

Risk levels are established by the severity of possible events and the probability that they will occur. Risk assessment identifies hazards and associated risks and their relationship to the mission. The risks must be weighed against the benefit of the mission to decide whether the risks are acceptable.

Safety is the inherent responsibility of all members participating in UAS operations. All UAS missions must have a FAA Part 107 certified PIC. The PIC has the overall responsibility and the authority to decline a flight mission that they consider excessively hazardous.

Hazards and Mishaps

Hazards must be identified and analyzed for the associated degree of risk to the mission and minimized or mitigated prior to operations. Hazards may include risks to performance of flight as well as risk of injury to personnel.

A mishap is defined as an unplanned event or series of events, directly involving the UAS in operation, which results in damage to property and/or injury. Please refer to the AOC Safety Policy 220-1-4 in the AOC Aircraft Operations Manual[6] for definition of damage and injury.

Reporting Mishaps and Injuries

Mishaps that occur during UAS operations shall be reported as required by FAA and Aircraft Operations Center (AOC) policy. Part 107.9 states that mishaps must be reported no later than 10 calendar days after an incident if any person experienced serious injury or loss of consciousness, or if property other than the UAS was damaged and the cost of repair or the fair market value in the event of total loss exceeds $500. For any mission that NOAA is directly responsible for (i.e., not a "data buy"), all further reporting and response will adhere to the procedures described in AOC Policy 220-1-4.

Operational Risk Management (ORM)

The PIC must ensure that UAS operations do not pose unacceptable risks to persons and property. Operational Risk Management (ORM) considers all potential hazards and implements mitigations to manage the risk posed by the hazards. Hazards that should be considered when conducting a risk assessment include:

- Laceration injuries caused by propellers;
- Impact injuries cause by falling objects;
- Impact with buildings, vessels/vehicles, aerial objects, water, or ground;

[6] https://www.omao.noaa.gov/find/media/documents/aircraft-operations-center-aoc-aircraft-operations-manual

- Weather;
- Fly-away of aircraft;
- Battery fire;
- Lack of proper airspace coordination (due to a large and/or complex operational area); and
- Frequency interference (loss of link with remote controller).

Possible mitigation measures for the hazards listed above include:

- The PIC will be skilled in piloting the UAS and the Visual Observer (VO) will be trained in hand launch and recovery (refer to NOAA restrictions regarding which sUAS can be caught by hand).
- Only allow the VO to hand launch and recover the aircraft while wearing appropriate PPE including long sleeves, gloves (Kevlar or thick leather), glasses, and hat.
- Only allow the flight team within the vicinity of the aircraft during operations and alert all personnel prior to commencing and immediately following each flight.
- The PIC and VO will ensure the UAS stays clear of and does not fly directly overhead of all personnel (except VO during launch and recovery).
- The PIC will not operate the UAS within the vicinity of other vessels that are not involved in operations and will terminate operations if another vessel approaches.
- The VO will maintain a constant lookout for aircraft in the operational airspace and the PIC will immediately reduce altitude to 50 feet (15 meters) if an aircraft approaches and land as soon as possible.
- All UAS lithium batteries will be stored and transported in a safe manner.
- When operating from a vessel or other vehicle, it will be equipped with a dry chemical extinguisher.

An approved ORM assessment is a requirement for any mission NOAA is directly responsible for as described in the Operational Requirements section above. Consult the NOAA UAS Handbook for more information.

Emergency Procedures

Emergency procedures are used in instances where, despite implementing mitigation measures, there is a lost link, loss of visual contact, loss of GPS, or there are other aircraft or obstructions in the flight path. Some emergency procedures are specific to the UAS as outlined in the operations manual provided by the UAS manufacturer. Many UAS have failsafe options including stabilization options, Return to Home (RTH) procedures, and a Combination Stick Command (CSC) for stopping the motors. Having an emergency procedures checklist on-site is recommended; an example can be found in Appendix C.

Some emergency procedures include:

- If the link between aircraft and RC is lost for a set amount of time (e.g., 10 seconds), the aircraft is programmed to return to a set home point.
- If GPS is lost following a loss of link, the aircraft will hover in place for a set amount of time (e.g., 60 seconds) and will return to a set home point if GPS is not regained.
- If the UAS begins to perform abnormally and/or becomes unresponsive to controller commands, the PIC will land or the VO will hand-capture the aircraft immediately.
- A dry chemical extinguisher can be used to suppress and contain a lithium battery fire, and water can be used when an extinguisher is not available.

The PIC should brief all persons involved in the UAS operations about emergency procedures and should be prepared to implement them when deemed necessary. Any emergency should be thoroughly documented once the aircraft is retrieved (if possible) and any injuries have been assessed and tended to.

Equipment

A wide variety of sUAS exists that includes fixed-wing, rotary-wing, and fixed-wing hybrid with vertical take-off and landing (VTOL) capability. Small multi-rotor aircraft are ideally suited for many discrete spill response activities because of their ease of use, excellent control over camera view and positioning, and relatively low cost. This job aid is designed to be used with consumer-grade multi-rotor sUAS mounted with a digital RGB camera.

Required

Required base equipment includes: the aircraft; remote controller (RC); tablet/smartphone and RC cable if the RC does not have a built-in screen; aircraft battery; battery charger; strobe lights; and storage card, typically a microSD card. All sUAS weighing more than 0.55 pounds must be registered with the FAA (see section on Part 107 Rules below). Supplemental equipment includes at least two extra aircraft batteries; spare propellers; car or solar charger for batteries; spare microSD cards; and landing pad. Most multi-rotor sUAS have a maximum flight time per battery of 20-30 minutes, thus multiple batteries are essential for more lengthy or remote operations. The ability to charge batteries while in the field will further extend operational time. A computer for downloading and processing imagery is needed for post-flight data management but may not be required in the field.

Optional

LED strobe lights mounted on the struts or undercarriage of the aircraft are highly recommended to increase visibility. A sunshade for the smartphone or tablet screen will increase the visibility of the screen. A mobile hotspot for internet connectivity might be useful for loading maps to the device used to control the aircraft while in remote areas where cell service is available or to deliver data to a command post during emergency operations. Rapid chargers that charge more than one aircraft battery at a time are very useful for charging batteries between flights, especially when in a remote area. A portable power source is recommended for powering the rapid charger. Binoculars are also useful but should not be used to maintain visual line of sight (VLOS) of the aircraft (see Part 107 Rules below). If operating from a boat, each person should be wearing a personal floatation device (PFD). A structure or device to provide shade for participants is recommended for operations in high temperatures. Finally, a need may arise to capture the sUAS by hand. Follow the appropriate safety procedures such as wearing gloves and eye protection to protect from injury due to the propellers.

Limitations

While there are many advantages to using a small, rotary-wing, uncrewed aircraft system, there are also some limitations when compared to other UAS (e.g., larger UAS, fixed-wing):

- Flight time is usually at most 20-30 minutes per battery;
- Visibility of the aircraft is limited due to its small size;
- Sun glare on the RC, smartphone, or tablet can make the screen difficult to see;
- High winds, gusts, and sudden changes in wind speed may make flying impossible and are common in coastal environments;

- Precipitation can ground the aircraft;
- Risk of the aircraft landing or falling into water is high in coastal environments;
- Flight failure can occur if the battery completely discharges during flight; and
- Camera resolution is typically not sufficient to detect light oiling.

Flight Planning and Preparation

A critical part of the process of using UAS for any purpose is planning the flight operations.

Part 107 Rules

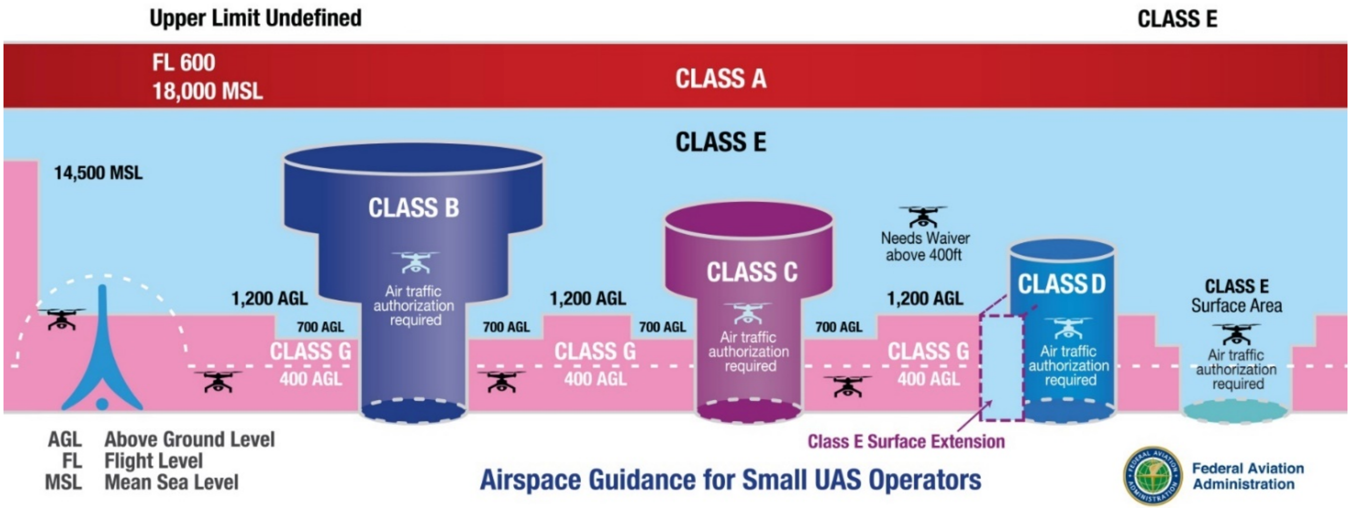
The FAA requires that operation of a sUAS (weighing less than 55 pounds) for a purpose other than recreation or hobby is governed by Part 107. Adherence to these regulations must be considered during flight planning. These regulations should be reviewed on the FAA[7] and Electronic Code of Federal Regulations[8] (e-CFR) websites.

Part 107 regulations require any aircraft greater than 0.55 pounds be registered with the FAA prior to flight and the registration must be displayed on the exterior of the aircraft. Some major provisions of Part 107 to be aware of include the following:

- For any commercial flight operations, a FAA-certified remote PIC must be present but is not required to be the pilot in control of the aircraft.

[7] https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22615
[8] https://www.ecfr.gov/cgi-bin/text-idx?node=pt14.2.107&rgn=div5

- No operations are allowed in Class A airspace. Operations in Class B, C, D, and E airspace are allowed with the required Air Traffic Control (ATC) permission (see illustration below). Operations in Class G airspace are allowed without ATC permission.



- sUAS may be operated after daylight hours (official sunrise to official sunset, local time) provided the aircraft is equipped with FAA-approved anti-collision lighting and the remote PIC has completed an initial knowledge test or recurrent training after April 6, 2021.

The following regulations may be waived upon approval of the FAA:

- The uncrewed aircraft must always remain within VLOS of the pilot or VO during operation without the use of devices other than corrective lenses.
- No person may act as the PIC, a VO, or a person manipulating the controls for more than one uncrewed aircraft operation at a time.
- Right-of-way must be yielded to all other aircraft, crewed or uncrewed.
- sUAS may not be operated over any persons not directly involved in the operation. This rule was amended on April 6, 2021, to allow operations over people in some circumstances subject to requirements based on the level of risk the sUAS presents to people on the ground.
- Operations from a moving land or water-borne vehicle are allowed only when flown over a sparsely populated area. Operations from a moving aircraft are not allowed.
- The maximum allowable altitude is 400 feet above ground level (AGL) or 400 feet above a structure when flown within a 400-foot radius of the structure.

Airspace Restrictions

As mentioned above, ATC permissions are required for flying in Class B, C, D, and E airspace. The PIC is responsible for checking the flight area for any airspace restrictions including temporary flight restrictions (TFR) and Notice to Airmen (NOTAM) alerts for the day and time of operations. Airspace classifications can be viewed on FAA UAS Facility Maps that also show the maximum altitudes around airports where FAA automatic authorization for Part 107

UAS operations may be requested without additional safety analysis (see the next paragraph for a description of the authorization system). A link to the maps can be found on the FAA UAS Facility Maps website[9].

The Low Altitude Authorization and Notification Capability (LAANC) system, a collaboration between FAA and Industry, automates the application and approval process for airspace authorizations. Requests made through LAANC are checked against multiple airspace data sources in the FAA UAS Data Exchange such as UAS Facility Maps, Special Use Airspace data, Airports and Airspace Classes, as well as TFRs and NOTAMs. If approved, pilots can receive authorization for an altitude at or below 400 feet AGL in near-real time. As of September 2021, night operations can be requested via LAANC. For a list of FAA-approved LAANC UAS service suppliers, see the FAA UAS Data Exchange website[10]. For UAS Facilities not covered by the LAANC system, authorization must be requested by filling out an application on the FAA Drone Zone website[11]. Individuals who request a Part 107 airspace authorization via the FAA Drone Zone are encouraged to consult the FAA UAS Facility Maps prior to submitting a request to determine locations and altitudes that can be approved quickly. Processing the application can take up to 90 days.

New TFRs may be announced at any time and may not necessarily be noted in the mobile app used to request LAANC authorization, thus it is important to check for these several times before starting operations. TFRs are announced on the FAA Graphic TFRs website[12].

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9 https://www.faa.gov/uas/commercial_operators/uas_facility_maps
10 https://www.faa.gov/uas/programs_partnerships/data_exchange
11 https://faadronezone.faa.gov
12 https://tfr.faa.gov

Other Flight Restrictions

It is up to the PIC to determine if there are any other potential restrictions for flight and to request permission to fly from the organization or agency managing the restricted area. Processing applications for permits may take weeks to months. Examples include critical infrastructure; designated wilderness areas; Wildlife Sanctuaries; National Parks; and areas where wildlife disturbance may be a concern, such as marine mammal haul-outs and nesting bird colonies.

Mission Planning

It is highly recommended to plan missions while Internet connectivity is available. In emergency situations, this may not be possible due to location and time constraints. After the mission location is determined, check for airspace restrictions, TFRs, NOTAMs, and any other restrictions in the area and request authorization as needed. Also check that forecasted weather conditions are permissible for the specific aircraft to be flown. Different aircraft have different windspeed and temperature limits. Most consumer-grade sUAS are not water resistant and thus precipitation should be avoided.

Develop a plan that includes the objective for the mission, the staffing and equipment requirements, and the appropriate flight methods to be used. If the mission includes flying a pattern or other semi-autonomous flight, setting this up in the controller app in advance and with an Internet connection is recommended. Maps of the area can be uploaded or cached for viewing remotely when no connection is available. A list of common controller apps is in Appendix B.

Equipment Preparation

Before heading to a remote area with the equipment, the equipment must be inspected and prepared. It is recommended to have a pre-mission checklist (see Appendix C for sample checklists) with the following tasks listed:

- Charge aircraft batteries, remote controller, tablet/smartphone, strobe lights, and all other batteries;
- Check for firmware and software updates to sUAS and apps;
- Clear storage (microSD) cards and format if necessary; and
- Inspect propellers, aircraft, and RC for damage that might interfere with operation.

Preparation for Flight

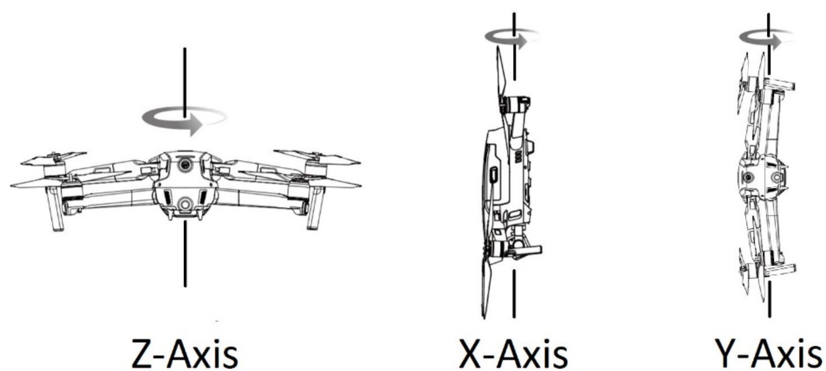
Upon arriving at the mission location, several factors must be considered before launching. Current weather, new airspace restrictions (TFRs), presence of people and animals, and potential obstacles are all factors that affect the safety and success of the mission.

There are also steps to take for preparing the sUAS equipment for flight. These include but are not limited to:

- Place and secure the launch pad in an appropriate position upwind of observers;
- Inspect the airframe, landing gear, and propellers;
- Install the battery, storage card (microSD), camera filter, and strobe lights onto the aircraft;
- Remove the gimbal protector;
- Ensure the registration number is visible on the aircraft; and
- Connect the tablet or smartphone to the controller.

After these tasks have been performed, it is time to turn on the aircraft and place it on the launch pad, then turn on the RC and position the antennas properly. Turn on the tablet or smartphone, if using one. Open the flight app and load the flight plan if there is one. The app will alert the pilot if compass or Inertial Measurement Unit (IMU) calibration is needed. Compass calibration is common if flying in a different region than where the aircraft was last flown. IMU calibration is critical for keeping the aircraft straight and level while flying. Follow the sUAS manufacturer's recommendations on how often to perform calibrations and the process for calibration. Some sUAS require compass calibration before each flight.

The process for calibrating the compass is common among most sUAS. Horizontal (z-axis) calibration is carried out by keeping the aircraft level and turning the aircraft clockwise (or counterclockwise) in a 360° circle. For vertical (x-axis) calibration, the aircraft is tilted 90° forward with the camera pointing down and turning the aircraft in a 360° circle. Some sUAS require calibration in the y-axis by tilting the aircraft on its side with the camera pointing to one side and rotating the aircraft in a 360° circle. See the illustration below.



Other items to check before flying the aircraft:

- Verify the gimbal is level and can move unobstructed;
- Check all battery levels;
- Check the aircraft status LEDs;
- Check GPS satellite and compass status;
- Check the flight mode switch (typically located on the RC);
- Verify the camera is on and the settings are appropriate for the mission;
- Check RTH behavior (set to return to RC or pilot if working from a boat); and
- Make sure launch site is clear for takeoff and all participants are standing upwind.

Once everything checks out, the aircraft motors can be started. Take off and hover the aircraft nearby to verify the aircraft is stable while hovering. Move the aircraft in all directions briefly to confirm the flight controls are working properly, and then begin the mission. Repeat these steps at the beginning of each new flight during a mission.

Post-Flight

All environmental conditions and activities during flight should be recorded in a mission log that also includes a description of the location, the date and time of all flights, the app(s) and flight methods used, the type of mission, and notes regarding any significant events that occurred during the mission or details that may be of importance when reviewing the data captured. If a mission is flown at a set altitude, such as when collecting imagery for a mosaic, the altitude should also be noted in the mission log.

Once the mission has been completed and the data sync between aircraft and RC/mobile app has finished, turn off the aircraft and RC. Remove the camera filter (if using one) and install the gimbal protector. Remove the battery, strobe lights, and storage card from the aircraft. Inspect the aircraft, batteries, and propellers. Store all equipment properly and complete the mission log. Back up the storage card as soon as possible and be sure to safely store the card when finished. Download and back up the flight tracks (see Data Processing and Management section for instructions).

sUAS Flight Methods

Several methods for flying a sUAS are used during spill response activities. The methods are explained here and will be referenced in later sections that discuss best methods to use for each type of operation. Some common terms and acronyms are explained in Appendix A.

Imagery Collection Methods

Some spill response sUAS operations will not require collecting imagery and will instead rely on simply viewing from the camera point of view (POV) on the RC, tablet, or smartphone screen. This section provides guidelines for collecting photos and video with the aircraft during flight.

Photo Collection

Camera settings are critical when collecting photos and vary for each sUAS and mobile controller app. Settings to pay attention to include exposure, shutter speed, and focus. Many sUAS have a mode where these settings are automatic and adjust according to the ambient lighting and distance to the object or area the camera is pointing at.

However, for some operations, these parameters should be set and locked. The PIC should be familiar with how to set these parameters for each sUAS and mobile controller app being used.

Collecting nadir (when the camera is pointing directly downward) images is the best method for creating image mosaics. Oblique images are the best for shoreline reconnaissance and field-level, operational context. Nadir-view is -90° in the illustration below. However, some apps define nadir as 0°, so attention must be paid to this setting when creating a flight plan.

Automated Photo Collection

Photos can be collected automatically at selected waypoints or at set distance or time intervals. Distance intervals are set in horizontal and/or vertical directions for automatic collection of photos. Distance interval mode is a feature included in some controller apps and may be called “GPS Lapse”, “Free Flight”, etc. Time interval mode is also included as a feature in many controller apps and may be called “Timelapse”, “Timed Shot”, “Hyperlapse”, etc. For each instance of the elapsed time interval, an image is captured. Some apps require a semi-autonomous mode to automatically capture photos at intervals (see Waypoint Path Flight below). When possible, setting the aircraft to stop and hover before capturing a photo helps reduce motion blur.

Video

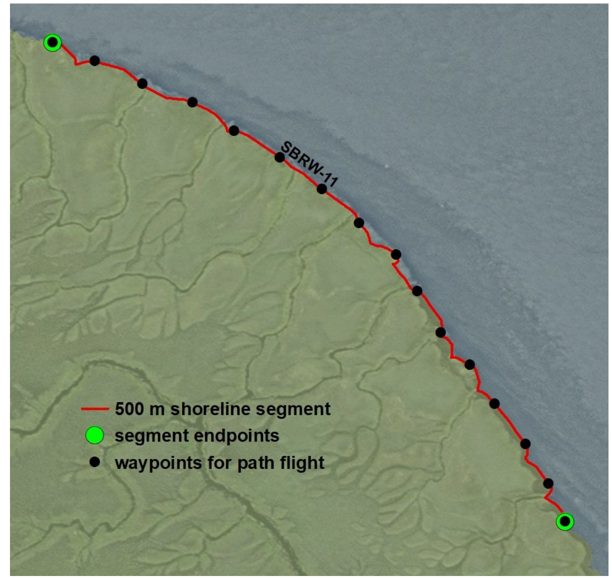
Video collection is less common in spill response but can be useful for documenting processes such as shoreline operations, environmental monitoring, and debris removal. Collecting short, sequential videos is recommended to make the resulting files more manageable. Photos, which are geotagged by the sUAS, can be collected before and after each video segment to help locate where the segments were collected during processing. The Waypoint Path Flight method described below is especially useful for collecting video. The recording is automatically started at the beginning of the flight path and stopped at the end.

Manual Flight

During manual flight, the aircraft is flown directly by the pilot using the RC without any automation. The camera is also manually operated. This is the preferred method for takeoff and landing because it allows for complete control of the aircraft, especially when the launch site may have moved, such as when operating from a vessel. This is also the best method to use for exploratory missions when there is not enough information to plan flights before being in the field.

Waypoint Path Flight

Waypoint-derived flight methods are semi-autonomous. Waypoints are usually determined by selecting points on a map or by flying the aircraft to each point. Waypoints can be selected to follow a path for automated flight. This method allows the pilot and/or an observer to focus on the camera POV, while a VO maintains VLOS with the aircraft.



During the initial phase of a spill response, an accurate shoreline vector dataset, such as an ESI shoreline[13], is segmented into regular lengths (typically 500-1000 meters) and by dominant shoreline type. Shoreline segment data may be provided by SCAT data managers for uploading to the sUAS flight planning software, if applicable. Otherwise, a shoreline dataset can be used as a visual guide to select points along a path that follows the shoreline closely. If automatically collecting photos at the waypoints, it is important to set enough waypoints to get the desired photo spacing. Otherwise, select as few points as needed to match the shoreline as shown in the adjacent illustration.

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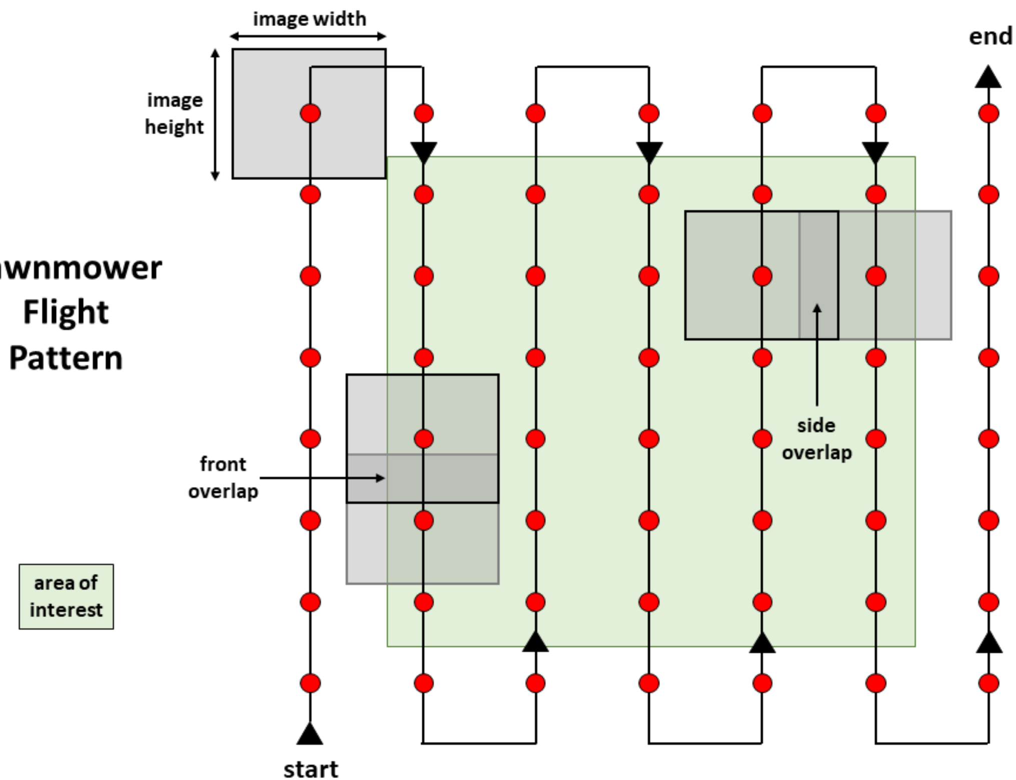
[13] https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/download-esi-maps-and-gis-data

Grid Flight for Mosaic

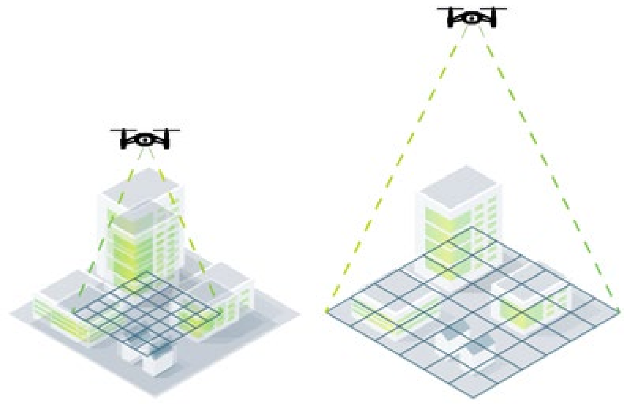
Waypoints are selected to form the boundary of a polygon. The operator then inputs various parameters to create a “lawnmower pattern” that covers the polygon (see illustration on the next page). Common parameters include aircraft altitude AGL, front and side overlap, and aircraft speed. Once the parameters are specified, the controller app will automatically create a pattern to satisfy the requirements and adjustments can be made to the pattern and parameters to reduce/increase the overall time required to complete the pattern or to reduce/increase the total number of photos to be collected. Camera parameters such as gimbal angle, exposure, and focal length (or autofocus) may also be specified. Camera gimbal angle should always be set to nadir (pointing directly downward).

Focus distance is typically set and locked, but auto-focus can be used if the terrain varies significantly. Exposure should also be set and not allowed to automatically adjust. Plan to cover an area larger than needed because the edges of the processed mosaic may be warped. Flying at least three parallel lines in a grid is recommended for good overlap. A cross grid pattern is not recommended because it does not significantly improve the resulting mosaic and it adds flight time and processing time due to added imagery. If using a sUAS with a rolling shutter camera, it is best to set the aircraft to stop and hover briefly while capturing the photo to reduce distortion introduced by motion. Suggested minimum overlap is 75% / 75% (front/side).

Lawnmower Flight Pattern



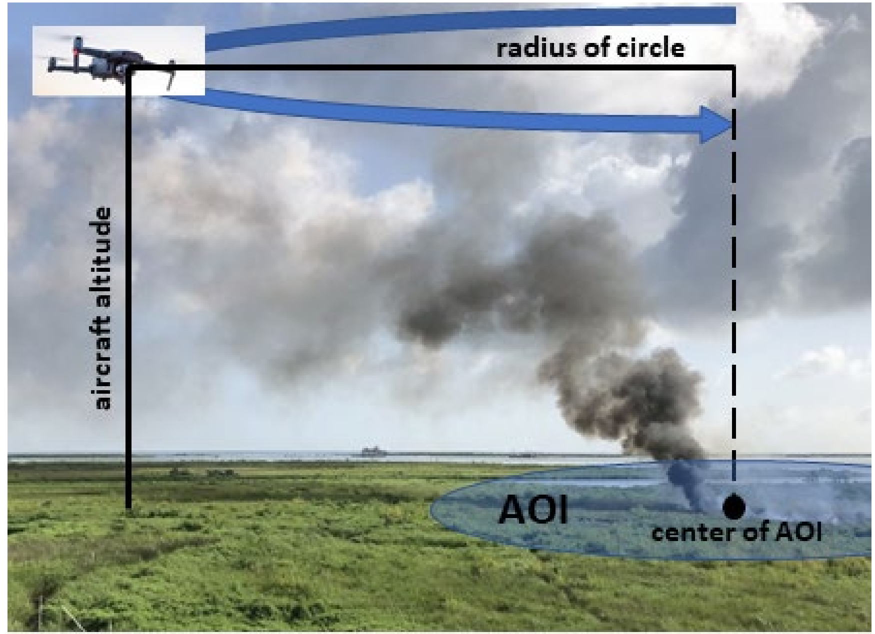
The ground sample distance (GSD) of an image is the distance between the center of two consecutive pixels measured on the ground. The GSD varies with the altitude of the aircraft. The lower the altitude, the smaller the footprint on the ground and the more photos needed to cover an area (see illustration below). Also, GSD varies with the size of the camera sensor being used and the output image resolution. Thus, one set of parameters for a lawnmower pattern will produce varying results for each sUAS.



Flying a second pattern that covers the same area at a different altitude (usually 20% higher) may improve mosaic georeferencing accuracy. Processing software is required for producing orthomosaics and processing time increases greatly with an increase in the number of photos used. The most common processing software packages are listed in Appendix B.

Orbital Flight

This method is used to circle around an area of interest (AOI), as shown in the adjacent illustration. An AOI target must first be defined. This is usually an object, but it can also be a point of interest (POI) on the ground or discrete oiled area. Once the target is selected, the altitude and radius of the circular orbit and the speed must be set, though these settings can usually be changed while the orbit is in process. The radius and altitude may be set by flying the aircraft to a position and pointing the camera towards and locking on to the center of the AOI, making sure the entire AOI is visible in the camera view during orbit. Some controller apps allow for direct input of radius and altitude values. Set and lock the focus once the altitude and radius are determined.



In-situ burning in Louisiana (NOAA OR&R)
https://blog.response.restoration.noaa.gov/index.php/incident-responses-august-2019

Spill Response sUAS Operations

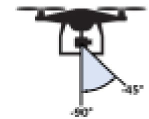
This section describes the spill response activities where use of sUAS has proven to be useful. Specific flight methods are recommended for each response activity. As described in the introduction, there are four areas of the SCAT process where sUAS is particularly useful for supplementing shoreline surveys and clean-up operations: reconnaissance; SCAT shoreline surveys (including marsh interiors); operations treatment (i.e., sorbent, boom, vegetation cutting); and post-treatment shoreline inspection. sUAS can be used in place of traditional aircraft for reconnaissance overflights to search for moderate to heavy contamination. If oil or some other hazardous material is detected during an overflight, the sUAS can easily be flown in for a closer look before returning to base.

Once the shoreline is segmented and SCAT teams are deployed, teams can use sUAS to create overview maps of segments to be used later in the planning process. sUAS can also be deployed to survey shorelines that are otherwise inaccessible due to tides, hazardous terrain, sensitive habitat (e.g., marsh interiors), etc.

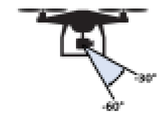
Imagery and video collected by sUAS are also valuable tools for planning operations treatment and can be used to monitor and record treatment application as well as inspection of areas post-treatment.

Suggested flight parameters for each of these operations are listed in the following pages. These parameters include but are not limited to flight altitude, aircraft speed, camera pointing angle (gimbal angle), camera mode (still image or video), and camera settings (focus, exposure, etc.).

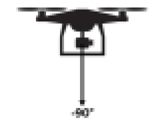
SCAT Reconnaissance

Objective:	Perform high altitude overflights to search for areas with moderate to heavy oil.
Flight Method:	**Waypoint Path Flight**
Altitude:	100 – 200 ft AGL
Speed:	3 – 10 mph
Gimbal Angle:	-90° (nadir) to -45° 
Camera Mode:	Photos: distance or time interval automated image collection
Interval Settings:	Distance (horizontal): 35 ft (at 100 ft AGL) – 70 ft (at 200 ft AGL) Time (5 mph): 5 secs (at 100 ft AGL) – 10 secs (at 200 ft AGL)
Camera Settings:	Autofocus; exposure set and lock
Notes:	Fly manually and at higher speed to and from automated flight path endpoints

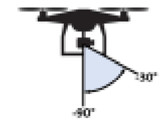
SCAT Reconnaissance (cont.)

Objective:	Take a closer look at potential areas of interest identified during reconnaissance.
Flight Method:	**Manual Flight**
Altitude:	10 – 25 ft AGL
Speed:	3 – 10 mph
Gimbal Angle:	-60° (at 25 ft AGL) to -30° (at 10 ft AGL) 
Camera Mode:	Photos: collected manually
Camera Settings:	Autofocus; exposure set and lock
Notes:	Always maintain VLOS

SCAT Segment Mapping

Objective:	Create an imagery mosaic of a segment for use in an overview map.
Flight Method:	**Grid Flight for Mosaic**
Altitude:	100 – 200 ft AGL
Speed:	3 – 10 mph: slower speed recommended if time and battery capacity allow
Gimbal Angle:	-90° (nadir) 
Minimum Overlap:	Side 75%, front 75%
Camera Mode:	Photos: hover and capture at waypoints
Camera Settings:	Set focus using autofocus, then switch to manual focus to lock; set exposure and lock
Shooting Angle:	Course aligned
Notes:	Aircraft should hover after completion of pattern and fly to base manually; there might need to be more than one grid pattern to cover a segment to maintain VLOS during flight; fly manually and at higher speed to and from automated flight path endpoints

SCAT Shoreline Survey

Objective:	SCAT surveys of inaccessible areas.
Flight Method:	**Manual Flight**
Altitude:	10 – 50 ft AGL
Speed:	3 – 10 mph: slower speed recommended if time and battery capacity allow
Gimbal Angle:	-90° (nadir) to -30° 
Camera Mode:	Photos: collected manually or automatically at distance intervals
Camera Settings:	Autofocus; exposure set and lock
Shooting Angle:	Parallel to flight path
Notes:	Always maintain VLOS

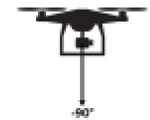
Operations Planning/Monitoring

Objective:	Planning for and monitoring of shoreline operations and inspection.
Flight Method:	**Manual Flight**
Altitude:	High enough to avoid interfering with operations on the ground and to maintain a good perspective, but less than 200 ft
Speed:	3 – 10 mph
Gimbal angle:	Varies, depending on altitude and flight path
Camera Mode:	Photos: collected manually or automatically at distance intervals Video: multiple short segments
Camera Settings:	Use autofocus if varying the distance between aircraft and target area – click on view screen (controller app) to focus on an object or area
Notes:	Always maintain VLOS

Operations Planning/Monitoring (cont.)

Objective:	Planning for and monitoring of shoreline operations and inspection.
Flight Method:	**Orbital Flight**
Altitude:	Just high enough to keep the entire area in the camera view, but less than 400 ft; should be set along with radius to avoid interfering with operations
Flight Radius:	Varies, depending on altitude and size of the target/area of interest; should be set along with altitude to avoid interfering with operations
Gimbal angle:	Will be set automatically by locking onto the target object or area
Speed:	5 – 15 mph; faster speeds for larger orbit radius
Camera Mode:	Video: multiple short segments
Camera Settings:	Set focus using autofocus, then switch to manual focus to lock; set exposure and lock
Notes:	Avoid flying over people on the ground when possible

Operations Planning/Monitoring (cont.)

Objective:	Create an imagery mosaic of the operations area for use in an overview map.
Flight Method:	**Grid Flight for Mosaic**
Altitude:	50 – 200 ft AGL, depending on size of area
Speed:	3 – 10 mph: slower speed recommended if time and battery capacity allow
Gimbal Angle:	-90° (nadir) 
Minimum Overlap:	Side 75%, front 75%
Camera Mode:	Photos: hover and capture at waypoints
Camera Settings:	Set focus using autofocus, then switch to manual focus to lock; set exposure and lock
Shooting angle:	Course aligned
Notes:	Fly manually and at higher speed to and from automated flight path endpoints

Data Processing and Management

Data resulting from spill response sUAS operations may include flight tracks, images, video, waypoints, mission logs, observation notes, and perhaps even relevant response forms. Storage cards should be removed from the sUAS and data copied to a computer and/or an external drive.

Flight tracks are usually recorded within the mobile controller app being used to perform a flight mission. Flight tracks should be downloaded for all missions as soon as possible because they may get overwritten as more missions are completed. The method for extracting flight tracks varies with the controller app, sUAS model, and mobile controller device. Downloaded flight tracks usually must be converted into a format that can be visualized in a Geographic Information System (GIS). Consult the manufacturer’s manual for the controller app used.

Images collected for creating a mosaic will need to be processed, and the person creating the mosaic should be familiar with the process in the software application being used. Common processing software applications are listed in Appendix B. Images collected over more complex terrain will require higher-resolution processing. Images with a significant area covered by water may not align and thus the water portions may be left out of the resulting mosaic.

Videos for spill response require minimal processing but tend to be very large files. As mentioned in the sUAS Flight Methods section, keeping videos short and recording in sequential segments are recommended and help keep processing to a minimum.

DIVER

NOAA manages data associated with the evaluation and restoration of environmental injuries from hazardous waste releases, oil spills, marine debris, and vessel groundings in its role as a steward for the nation's coastal and marine resources. sUAS spill response data such as imagery and flight tracks are uploaded to the Data Integration Visualization Exploration and Reporting[14] (DIVER) tool maintained by OR&R. The DIVER Explorer then allows users to search and download these and other environmental and project planning data specific to geographic regions or activities.

sUAS data uploaded to DIVER should follow a standard naming convention based on guidelines in the NOAA Data Sharing Plan which will be shared with the sUAS pilot during the response. All folder and file names should use underscores, not spaces, dashes, or any other character, to split naming description. Filenames must include the type and date and time of observation/mission.

Imagery:

- RAW_yyyymmdd_img - Individual images that go into a mosaic.
- MSC_yyyymmdd_img - Mosaic images by day. If there is more than one mosaic per day, add another qualifier after the date, such as "a", "b", and so on.
- TRGT_yyyymmdd_img - Target images for geo-tagging (non-nadir, oblique). Ideally these will have coordinates embedded into the EXIF metadata for each image; images should be zipped into a data package so that the geotagging can be handled automatically by DIVER.

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[14] https://www.diver.orr.noaa.gov/

GIS files:

- TRGT_yyyymmdd_pt - Target locations, point features.
- TRK_yyyymmdd_time_ln - Tracklines for individual missions (multiples by day).
- WPT_yyyymmdd_misc_pt - Miscellaneous waypoint collected for special feature or purpose.

ERMA

Environmental Response Management Application[15] (ERMA®) is an online mapping tool that serves as a Common Operational Picture (COP) providing situational awareness to NOAA and USCG responders. The ERMA COP integrates both static and real-time data, such as Environmental Sensitivity Index (ESI) maps, incident-specific field data, ship locations, weather, and ocean currents, in a centralized, easy-to-use format for environmental responders and natural resource decision makers. Spill response data uploaded to DIVER are visualized in ERMA®.

References

NOAA (2013). Shoreline Assessment Manual. 4th Edition. U.S. Dept. of Commerce. Seattle, WA: Emergency Response Division, Office of Response and Restoration, National Oceanic and Atmospheric Administration. 73 pp + appendices.

[15] https://response.restoration.noaa.gov/resources/maps-and-spatial-data/environmental-response-management-application-erma

Website References

[1]https://www.noaa.gov/organization/administration/nao-216-104-management-and-utilization-of-aircraft

[2]https://www.omao.noaa.gov/find/media/documents/policy-220-1-5-unmanned-aircraft-systems-uas-operations

[3]https://www.omao.noaa.gov/find/media/documents/noaa-unmanned-aircraft-systems-handbook-june-2017

[4]https://www.omao.noaa.gov/learn/aircraft-operations/aircraft/uncrewed-aircraft-systems

[5]https://www.noaa.gov/organization/information-technology/privacy

[6]https://www.omao.noaa.gov/find/media/documents/aircraft-operations-center-aoc-aircraft-operations-manual

[7]https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22615

[8]https://www.ecfr.gov/cgi-bin/text-idx?node=pt14.2.107&rgn=div5

[9]https://www.faa.gov/uas/commercial_operators/uas_facility_maps

[10]https://www.faa.gov/uas/programs_partnerships/data_exchange

[11]https://faadronezone.faa.gov/

[12]https://tfr.faa.gov

[13]https://response.restoration.noaa.gov/oil-and-chemical-spills/oil-spills/download-esi-maps-and-gis-data

[14]https://www.diver.orr.noaa.gov/

[15]https://response.restoration.noaa.gov/resources/maps-and-spatial-data/environmental-response-management-application-erma

Appendix A: Definitions and Abbreviations

AGL – Above Ground Level: the altitude of an aircraft above the level of the ground.

AOC: the NOAA Aircraft Operations Center.

Autonomous flight: internal programming that instructs a UAV on where to fly.

BLOS – Beyond Line of Sight: when the aircraft is no longer visible.

Camera gimbal: keeps the UAV camera at the same angle regardless of the movement of the drone by automatically compensating using calibrated and often remotely controlled electric motors.

COA – Certificate of Authorization: an FAA authorization issued by the Air Traffic Organization to a public operator for a specific UAS activity.

CSC – Combination Stick Command: a feature some UAS have for starting and stopping the motors. The CSC can also be performed in the event of an emergency.

Fly-away: unintended flight outside of operational boundaries as the result of a failure of the control element or onboard systems, or both.

Georeferencing: the internal coordinate system of a digital map or aerial photo can be related to a ground system of geographic coordinates.

Gimbal angle: the vertical tilt angle of the camera with respect to pointing directly forward. Also called gimbal pitch.

GIS – Geographic Information System: a framework for gathering, managing, and analyzing data.

Ground control points: points on the ground surface of known or measured location used for geo-referencing.

GSD – Ground Sample Distance: the distance between center points of each sample (image pixel) taken of the ground.

IMU – Inertial Measurement Unit: an electronic device that uses accelerometers and gyroscopes to measure acceleration and rotation, which can be used to provide position data.

MC – Mission Commander: a NOAA employee with final oversight and responsibility to ensure all applicable statutory requirements are met during all NOAA-sponsored UAS operations.

Nadir: the point vertically beneath the camera center at the time of exposure.

No Fly Zone: areas where flying a UAS is restricted by government regulations.

OMAO: the NOAA Office of Marine and Aviation Operations.

ORM – Operational Risk Management

Orthomosaic: a photogrammetrically orthorectified image product mosaicked from an image collection, where the geometric distortion has been corrected and the imagery has been color balanced to produce a seamless mosaic dataset.

PFD: Personal floatation device.

PIC – Pilot in Command: A FAA Part 107 certified remote pilot responsible for all UAS operations.

Pitch: the angle the UAS tilts upwards or downwards along the axis that runs left to right.

PPE – Personal Protective Equipment: equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses.

POI – Point of Interest: a location or object designated for the UAV to keep its camera focused on.

POV: Point of View.

RC – Remote Controller: The unit used to remotely control the UAV. It may have a built-in screen or a clamp for holding a tablet or smartphone. Also called a transmitter.

Roll: the angle the UAS moves from side to side along the axis that runs in the forward and backward direction.

Rolling shutter: a method of capturing an image that does not expose the entire sensor at a single instant in time but rather by scanning across the scene rapidly, either vertically or horizontally.

RTH – Return to Home: a point for the UAV to return to, often the location where it took off.

SCAT – Shoreline Cleanup and Assessment Technique: a systematic method for surveying an affected shoreline after an oil spill.

Semi-autonomous: a mode of operation in which the UAS accomplishes a subset of its defined tasks without operator interaction.

Shooting angle: the horizontal angle of the camera when flying a path or pattern.

sUAS – small Uncrewed Aircraft System

UAS – Uncrewed Aircraft System: an uncrewed aircraft (UAV) and the equipment to control it remotely.

UASD – OMAO UAS Division

UAV – Uncrewed Aerial Vehicle: any aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board.

VLOS – Visual Line of Sight: the ability to see an aircraft unaided by any device other than corrective lenses.

VO – Visual Observer: a crewmember in direct communication with the UAS pilot that assists in keeping the aircraft within VLOS.

WAAS – Wide Area Augmentation System: a system of satellites and ground stations that provide GPS signal corrections, giving up to five times better position accuracy than uncorrected GPS.

Waypoint: a point of reference (latitude and longitude) that can be used for location and navigation.

Yaw: the direction the front of the UAS is facing when rotating either clockwise or counterclockwise on its vertical axis.

Appendix B: UAS Toolkit

Small Uncrewed Aircraft Systems

The specific sUAS equipment and accessories used to develop this job aid include:

- DJI Phantom 3 Pro
- DJI Mavic 2 Pro
- DJI Mavic Mini
- DJI Mini 2
- Parrot Anafi
- Apple iPad Mini
- Apple iPhone
- Firehouse LED strobe lights
- Lume Cube LED strobe lights
- PolarPro ND and CPL lens filters for DJI Mavic 2
- Freewell ND and CPL lens filters for Parrot Anafi

Controller Apps

Several smartphone/tablet apps are available for controlling sUAS. Some are platform-dependent, but most work on Android and/or iOS. Apps and their associated flight methods tested for development of this job aid include:

Controller Mobile App	Flight Methods Available			
	Waypoint Path	Grid for Mosaic	Distance (D) / Time (T) Lapse	Orbit
DJI GO *(required for Phantom 3)*	✓		**T**	✓
DJI GO 4 *(required for Mavic 2 & Phantom 4)*	✓		**T**	✓
DJI Ground Station Pro *(iOS only)*	✓	✓		
DJI Fly *(required for Mavic Mini & Mini 2)*			**T**	✓
DroneDeploy		✓		
Parrot FreeFlight 6 *(required for Anafi)*	✓		**D, T**	✓
Litchi	✓	✓	**D, T**	✓
Pix4Dcapture		✓	**D**	✓
ESRI Site Scan LE		✓		

UAS Image processing software

The processing software for creating orthomosaics and DEMs or other 3D products that were tested for development of this job aid include:

- Agisoft Metashape
- Pix4Dreact
- ESRI Site Scan for ArcGIS
- ESRI ArcGIS Pro

Appendix C: Checklists

PRE-MISSION

EQUIPMENT PREP:

_____AIRCRAFT BATTERIES CHARGED
_____REMOTE CONTROLLER CHARGED
_____STROBE LIGHTS CHARGED
_____TABLET/PHONE CHARGED
_____UAS FIRMWARE UP-TO-DATE
_____APPS UPDATED
_____MAPS FOR FLIGHT AREAS CACHED IN APPS
_____MICROSD CARD BACKED UP & CLEARED

MISSION PLANNING:

_____FLIGHT PLAN
_____AIRSPACE RESTRICTIONS & APPROVALS
_____NOTAMs/TFRs
_____ORM ASSESSMENT
_____WILDLIFE AVOIDANCE
_____OBSTACLES (RTH, TAKEOFF LOCATION, ETC.)
_____WEATHER
_____SCAT SEGMENT MAP
_____BLANK SCAT SURVEY FORM(S)

PACKING LIST:

_____AIRCRAFT W/ GIMBAL PROTECTOR INSTALLED
_____REMOTE CONTROLLER
_____MICROSD CARD(S)
_____TABLET/PHONE W/ APPS
_____STROBE LIGHTS
_____CAMERA FILTERS
_____PROPELLERS (4 PLUS SPARES)
_____REMOTE CONTROLLER PHONE/TABLET CABLE
_____CAMERA FILTERS
_____LAUNCH PAD

PRE-FLIGHT

AIRCRAFT INSPECTION:

_____CHECKED FOR CRACKS OR SEPARATION
_____CHECKED FOR LOOSE OR DAMAGED SCREWS
_____CHECKED FOR LOOSE OR DAMAGED WIRING
_____PROPELLERS CHECKED
_____CAMERA LENS & OBSTACLE SENSORS CLEANED

BEFORE TAKEOFF:

_____LAUNCH PAD PLACED (OPTIONAL)
_____REGISTRATION NUMBER IS VISIBLE
_____GIMBAL PROTECTOR REMOVED
_____GIMBAL IS LEVEL & CAN MOVE UNOBSTRUCTED
_____CONTROLLER CONNECTED TO TABLET/PHONE
_____FLIGHT MODE SWITCH IS SET (USUALLY P-MODE)
_____ANTENNAS PROPERLY POSITIONED
_____MICROSD CARD INSTALLED
_____STROBE LIGHTS INSTALLED AND TURNED ON
_____CAMERA FILTER INSTALLED (OPTIONAL)
_____AIRCRAFT AND CONTROLLER TURNED ON
_____COMPASS CALIBRATED
_____BATTERY LEVELS CHECKED

BEFORE TAKEOFF (cont.):

_____GPS STATUS CHECKED
_____CAMERA SETTINGS CHECKED
_____LAUNCH SITE CLEARED AND PARTICIPANTS UPWIND
_____RETURN TO HOME (RTH) BEHAVIOR AND ALTITUDE SET

TAKEOFF & HOVER – BEFORE FLIGHT:

_____AIRCRAFT IS STABLE
_____FLIGHT CONTROLS CHECKED
_____START VIDEO RECORDING (OPTIONAL)
_____CHECKED FOR OBSTACLES/INTERFERENCE

POST-FLIGHT

_____DATA SYNCED TO REMOTE CONTROLLER APP
_____AIRCRAFT TURNED OFF
_____REMOTE CONTROLLER TURNED OFF
_____CONTROLLER TO TABLET/PHONE CABLE REMOVED
_____GIMBAL PROTECTOR SECURED
_____CAMERA FILTER REMOVED (OPTIONAL)
_____MICROSD CARD REMOVED
_____MICROSD CARD BACKED UP
_____RECORDED FLIGHT TRACK DOWNLOADED
_____RECORDED FLIGHT TRACK BACKED UP
_____AIRCRAFT & PROPELLERS INSPECTED
_____AIRCRAFT BATTERY REMOVED
_____AIRCRAFT BATTERY INSPECTED
_____PROPELLERS REMOVED (OPTIONAL)
_____MISSION LOG COMPLETED
_____LAUNCH PAD RETRIEVED (OPTIONAL)
_____EQUIPMENT STORED PROPERLY

EMERGENCY PROCEDURES

LOST LINK (CONTROLLER CONNECTION):
- MAINTAIN VISUAL CONTACT
- PAUSE AUTONOMOUS FLIGHT IF NECESSARY
- HOVER UAV FOR UP TO 2 MINUTES
- RTH SHOULD AUTO-INITIATE
- ATTEMPT TO RE-ESTABLISH LINK IF RTH FAILS, MOVE RC TOWARDS AIRCRAFT OR TO HIGHER POSITION, REPOSITION ANTENNAS

LOSS OF GPS:
- MAINTAIN VISUAL CONTACT WITH UAV
- MANUALLY OPERATE UAV UNTIL GPS REACQUIRED
- LAND UAV AS SOON AS POSSIBLE IF STILL NO GPS
- CSC (ENGINE KILL) IF UNABLE TO REGAIN CONTROL

LOSS OF VISUAL CONTACT:
- PAUSE AUTONOMOUS FLIGHT IF NECESSARY
- ATTEMPT TO RE-ESTABLISH VISUAL CONTACT
- INITIATE RTH UNTIL UAV IS VISIBLE OR HAS LANDED

APPROACHING AIRCRAFT:
- IMMEDIATELY DESCEND UAV TO SAFE ALTITUDE

LOW BATTERY WARNING:
- PAUSE AUTONOMOUS FLIGHT IF NECESSARY
- INITIATE RTH OR FLY UAV MANUALLY TO RETURN

POWER FAILURE:
- WARN ANY PERSONS IN THE VICINITY
- CLEAR THE AREA IF POSSIBLE
- MAINTAIN VISUAL CONTACT WITH UAV
- RETRIEVE AIRCRAFT IF POSSIBLE