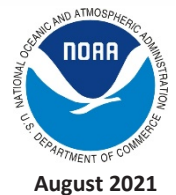


# Uncrewed Aircraft Systems Hurricane Response Job Aid

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



# Uncrewed Aircraft Systems Hurricane Response Job Aid

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



**U.S. DEPARTMENT OF COMMERCE** • National Oceanic and Atmospheric Administration •  
National Ocean Service • Office of Response and Restoration • Emergency Response Division

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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](#)"<sup>1</sup>, "[NOAA Aircraft Operations Center \(AOC\), Uncrewed Aircraft Systems Policy 220-1-5](#)"<sup>2</sup> (AOC Policy 220-1-5), and "[NOAA UAS Handbook](#)"<sup>3</sup>. 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"](#)<sup>4</sup>. Users from other agencies will need to ensure that their activities are conducted in accordance with their agency's policies and procedures.

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<sup>1</sup> <https://www.noaa.gov/organization/administration/nao-216-104-management-and-utilization-of-aircraft>

<sup>2</sup> <https://www.oma.noaa.gov/find/media/documents/policy-220-1-5-unmanned-aircraft-systems-uas-operations>

<sup>3</sup> <https://www.oma.noaa.gov/find/media/documents/noaa-unmanned-aircraft-systems-handbook-june-2017>

<sup>4</sup> <https://www.oma.noaa.gov/learn/aircraft-operations/aircraft/uncrewed-aircraft-systems>

## Hurricane Response

When a hurricane results in large-scale damage to coastal areas, including sunken and displaced vessels and other types of hazardous materials, the US Coast Guard (USCG) may receive funding from the USCG National Pollution Fund Center or an Emergency Support Function (ESF) 10 Mission Assignment from the Federal Emergency Management Agency (FEMA) to manage the assessment and removal of debris items that pose potential pollution risks. NOAA's Office of Response and Restoration (OR&R), Emergency Response Division (ERD) staff provide scientific support and data management for hurricane responses. This support includes rapid mapping of potential oil and hazardous material debris (vessels, tanks, drums, etc.) using NOAA National Geodetic Survey (NGS) post-storm imagery, generating tools for field data collection, tracking the status of debris removal operations, documenting damages during removal operations, and providing a common operating picture. Hurricane debris can be stranded in areas difficult to access by field assessment teams.

This job aid was developed to supplement hurricane response activities (post-storm derelict vessel and HAZMAT identification and removal), providing a guide for the use of consumer-grade small UAS (sUAS) with photo and video capability. sUAS refers to a system with an aircraft weighing less than 55 pounds, including any attached accessories.

A portable and easily deployable sUAS is a valuable tool during hurricane response. It can be used for reconnaissance overflights to detect hurricane debris, thus providing significant cost savings when compared with traditional overflights. A sUAS can be quickly deployed by the field teams to get closer to debris for gathering key information. A sUAS is also a good tool for monitoring injury to the surrounding habitat caused by stranding or removal of vessels and other hurricane debris.

## 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](#)<sup>5</sup> 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

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<sup>5</sup> <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. These 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](#)<sup>6</sup> 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 caused by falling objects;
- Impact with buildings, vessels/vehicles, aerial objects, water, or ground;

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<sup>6</sup> <https://www.oma.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 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 hurricane 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 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 from damaged or derelict vessels.

## 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](https://www.faa.gov)<sup>7</sup> and [Electronic Code of Federal Regulations](https://www.ecfr.gov)<sup>8</sup> (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:

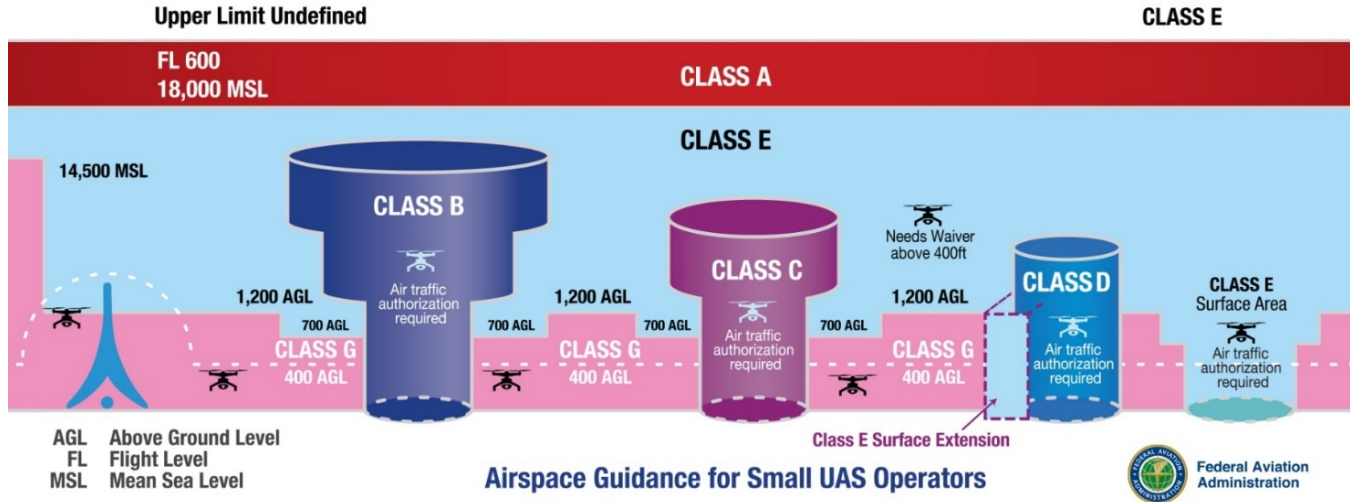
- For any commercial flight operations, a FAA-certified remote PIC must be present but is not required to be the pilot in control of the aircraft.

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<sup>7</sup> [https://www.faa.gov/news/fact\\_sheets/news\\_story.cfm?newsId=22615](https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22615)

<sup>8</sup> <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 pilot in command 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 operator 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 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](#)<sup>9</sup>.

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](#)<sup>10</sup>. For UAS Facilities not covered by the LAANC system, authorization must be requested by filling out an application on the [FAA Drone Zone website](#)<sup>11</sup>. 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](#)<sup>12</sup>.

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<sup>9</sup> [https://www.faa.gov/uas/commercial\\_operators/uas\\_facility\\_maps](https://www.faa.gov/uas/commercial_operators/uas_facility_maps)

<sup>10</sup> [https://www.faa.gov/uas/programs\\_partnerships/data\\_exchange](https://www.faa.gov/uas/programs_partnerships/data_exchange)

<sup>11</sup> <https://faadronezone.faa.gov>

<sup>12</sup> <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

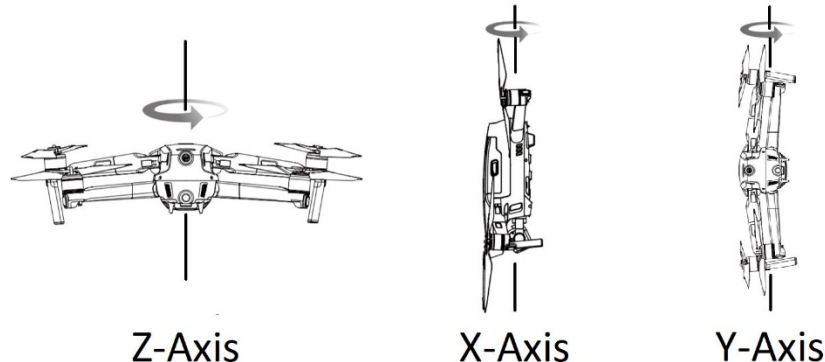
Upon arriving at the mission location, several factors must be considered before launching. Current weather, new airspace restrictions (TFRs), presence of people and animals, and potential obstacles are all factors that affect the safety and success of the mission.

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 hurricane 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 hurricane 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 (camera points directly downward) photos is best for creating image mosaics. Oblique (camera points at an angle to nadir) images are best for shoreline reconnaissance and field-level, operational context. Nadir-view is  $-90^\circ$  in the illustration below. However, some apps define nadir as  $0^\circ$ , 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 hurricane response but can be useful for documenting processes such as 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. 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.

If automatically collecting photos at the waypoints, it is important to set enough waypoints to get the desired photo spacing as shown in the adjacent illustration. Otherwise, select as few points as needed to create the desired path.

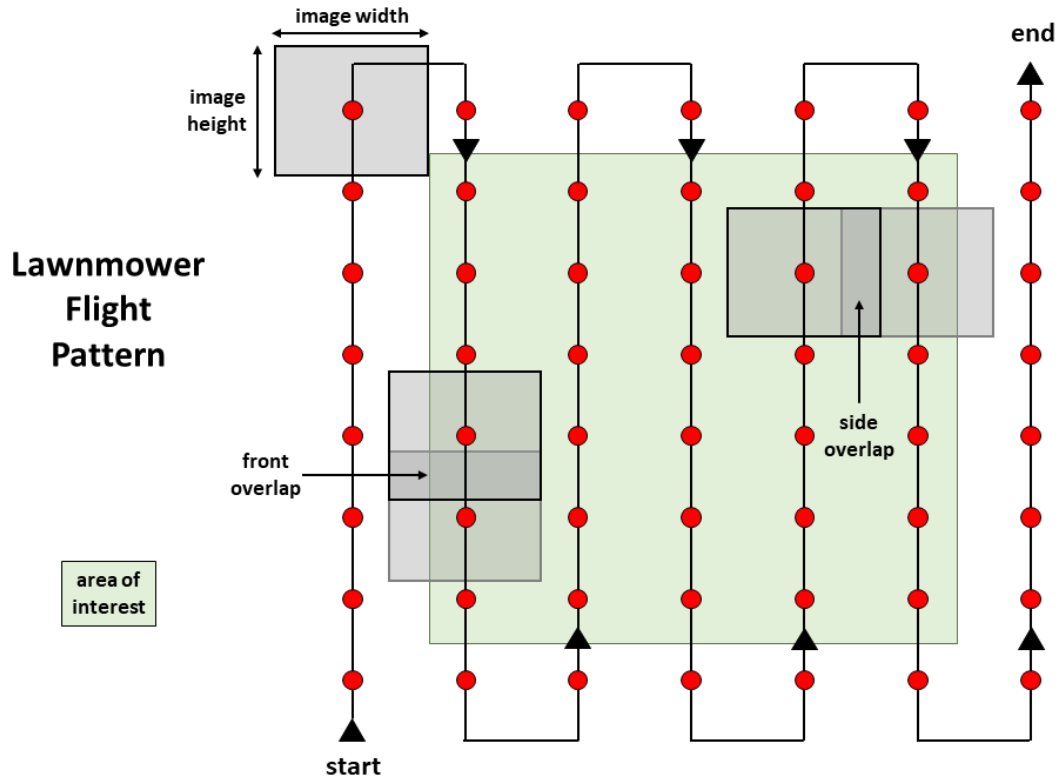




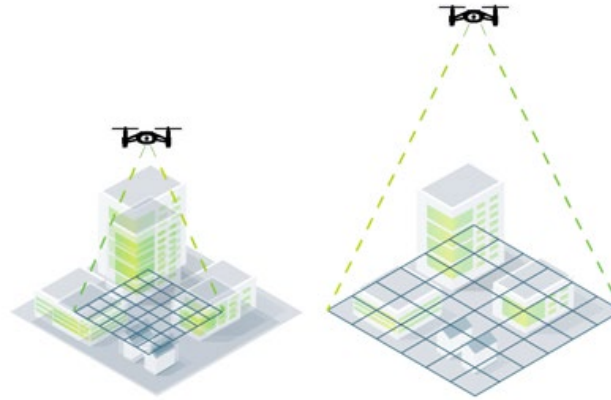
## Grid Flight for Mosaic

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).



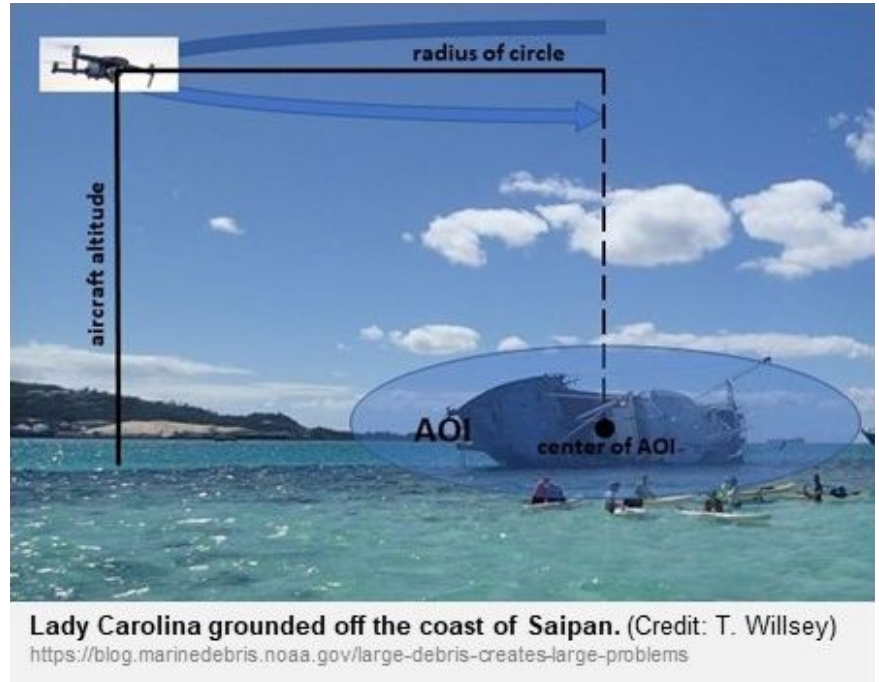
The ground sample distance (GSD) of an image is the distance between the center of two consecutive pixels measured on the ground. The GSD varies with the altitude of the aircraft. The lower the altitude, the smaller footprint on the ground, and the more photos needed to cover an area (see illustration 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 an area with a lot of debris. 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.



# Hurricane Response sUAS Operations

Hurricanes usually cause destruction that can leave behind large amounts of debris in water and on land. These debris items pose hazards to navigation, commercial fishing grounds, and sensitive ecosystems. Although imagery collected immediately after the storm has passed is used to detect debris, a sUAS may be useful in getting detailed information regarding the debris, such as: debris/vessel type; vessel registration number; proximity to and/or damage to sensitive habitat; potential pollution threats; and more.

Imagery and video collected by sUAS are also valuable aids for planning the removal of stranded vessels or other debris and for documenting and monitoring any injury caused by stranding or removal of the debris. Utilizing a sUAS allows responders to gain visual access to vessels and HAZMAT debris that otherwise present significant challenges for a visual assessment: located deep within a marsh or mangrove, other debris is preventing access, or due to safety concerns. Imagery and or video collected can also be used as a baseline for restoration of damaged sensitive habitats.

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.).

## Debris Detection/Identification

---

Objective: Perform high altitude overflights to search for areas with stranded debris/vessels.

**Flight Method:** Waypoint Path Flight

Altitude: 100 – 200 ft AGL

Speed: 3 – 10 mph

Gimbal Angle: -90° (nadir) to -45°



Camera Mode: 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

## Debris Detection/Identification (cont.)

---

Objective: Cover large area in search of stranded debris/vessels

**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 a Point

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; fly manually and at higher speed to and from automated flight path endpoints

## Debris Detection/Identification (cont.)

---

Objective: Collect detailed information regarding stranded debris/vessels.

**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  
Video: multiple short segments

Camera Settings: Autofocus; exposure set and lock

Notes: Always maintain VLOS; keep speed consistent when collecting video; use slow speed if collecting photos at intervals



## Environmental Injury Assessment (debris/vessel removal)

---

Objective: Document injury caused by stranding and removal of debris/vessel.

**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

## Environmental Injury Assessment (cont.)

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Objective:	Document injury caused by stranding and removal of debris/vessel.
<b>Flight Method:</b>	<b>Orbital Flight</b>
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
Radius of Orbit:	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

## Environmental Injury Assessment (cont.)

---

Objective: Create an imagery mosaic of the area of interest 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: Aircraft should hover after completion of pattern and fly to base manually

# Data Processing and Management

Data resulting from hurricane 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 hurricane 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 hurricane response data such as imagery and flight tracks are uploaded to the [Data Integration Visualization Exploration and Reporting](#)<sup>13</sup> (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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<sup>13</sup> <https://www.diver.orr.noaa.gov/>

## GIS files:

- TRGT\_yyyymmdd\_pt - Target locations, point features.
- TRK\_yyyymmdd\_time\_In - Tracklines for individual missions (multiples by day).
- WPT\_yyyymmdd\_misc\_pt - Miscellaneous waypoint collected for special feature or purpose.

## **ERMA**

[Environmental Response Management Application](#)<sup>14</sup> (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. Hurricane 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.

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<sup>14</sup> <https://response.restoration.noaa.gov/resources/maps-and-spatial-data/environmental-response-management-application-erma>

## Website References

<sup>1</sup><https://www.noaa.gov/organization/administration/nao-216-104-management-and-utilization-of-aircraft>

<sup>2</sup><https://www.oma.noaa.gov/find/media/documents/policy-220-1-5-unmanned-aircraft-systems-uas-operations>

<sup>3</sup><https://www.oma.noaa.gov/find/media/documents/noaa-unmanned-aircraft-systems-handbook-june-2017>

<sup>4</sup><https://www.oma.noaa.gov/learn/aircraft-operations/aircraft/uncrewed-aircraft-systems>

<sup>5</sup><https://www.noaa.gov/organization/information-technology/privacy>

<sup>6</sup><https://www.oma.noaa.gov/find/media/documents/aircraft-operations-center-aoc-aircraft-operations-manual>

<sup>7</sup>[https://www.faa.gov/news/fact\\_sheets/news\\_story.cfm?newsId=22615](https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22615)

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

<sup>9</sup>[https://www.faa.gov/uas/commercial\\_operators/uas\\_facility\\_maps](https://www.faa.gov/uas/commercial_operators/uas_facility_maps)

<sup>10</sup>[https://www.faa.gov/uas/programs\\_partnerships/data\\_exchange](https://www.faa.gov/uas/programs_partnerships/data_exchange)

<sup>11</sup><https://faadronezone.faa.gov/>

<sup>12</sup><https://tfr.faa.gov>

<sup>13</sup><https://www.diver.orr.noaa.gov/>

<sup>14</sup><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.

AOI: Area of Interest

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 includes:

- 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 <i>(required for Phantom 3)</i>	✓		T	✓
DJI GO 4 <i>(required for Mavic 2 &amp; Phantom 4)</i>	✓		T	✓
DJI Ground Station Pro <i>(iOS only)</i>	✓	✓		
DJI Fly <i>(required for Mavic Mini &amp; Mini 2)</i>			T	✓
DroneDeploy		✓		
Parrot FreeFlight 6 <i>(required for Anafi)</i>	✓		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