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sUAS Manual Flight Exercises

Practice Flight Drills for New Drone Pilots

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EXPERT REVIEWED

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Manual Flight Operations Guide for Small Uncrewed Aircraft Systems (sUAS): Practice Drills and Learning Skills

Small uncrewed aircraft systems are transforming earth observation in an array of fields, including agriculture, natural resource management, planning, public safety, and asset management. Not only do sUAS provide a unique bird's eye perspective of the Earth's surface, but these aerial vehicles are also more efficient, increasingly cost effective, and can provide customized 'data on demand' to enhance decision making. While sUAS are fairly user-friendly, acquiring some practice and experience under your belt is essential before conducting more advanced flight missions. This tutorial guide was developed to provide new drone operators with practice exercises (and other suggestions) to become safe and successful drone pilots. This guide provides an overview of rules for small unmanned aircraft systems (sUAS), information on drone safety, some tips and tricks, and suggestions for hands-on, manual flight tutorial exercises. By understanding regulations, safety procedures, and manual flight operations, you will be a better remote pilot.

Getting Started

Before you head out the door and push the "launch button," you must have a good command of sUAS rules and regulations as well as general drone safety precautions. After becoming familiar with federal and local regulations and reviewing your preflight safety checklist, you should be ready to start honing your manual flight skills.

Disclaimer

Operations involving sUAS carry some inherent risk. To help mitigate that risk, we have provided several safety tips and suggestions. Remote Pilots in Command (RPIC) should always follow all federal, state, and local regulations during flight operations. We also recommend following all manufacturer's recommendations and maintenance schedules for equipment. All information presented in this manual is intended for educational and informational purposes. It is not a substitute for legal or other professional advice. All exercises, learning lessons, flight operations, fieldwork, and associated missions are conducted at your own risk.

Overview: sUAS Rules and Regulations

Disclaimer: Please follow all local, state, and federal regulations for sUAS aircraft operations. In addition, consult with the administration of your facility to ensure all policies and procedures are followed. The following information is provided as suggested guidance. This information is not intended to be your only source for rules and regulations. For up-to-date Federal Aviation Administration regulations, see https://www.faa.gov/uas/, as rules and regulations frequently change. Questions, clarifications, and interpretations concerning regulations should be directed to the FAA.

Certificates and Registration

- All commercial sUAS pilots should obtain their Remote Pilot Certificate (RPC, aka FAA Part 107 certificate) or be under the direct supervision of a certificated pilot when operating an sUAS.
- The remote pilot in command (RPIC) will have all decision-making responsibilities during the flight.
    - The RPIC has the final authority and direct responsibility for the safe operation of the sUAS.
    - The RPIC should contact risk management or other authority before conducting flights on school grounds.
- Aircraft registration is required for recreational drones weighing 0.55 pounds (250 grams) or more and all drones flying under Part 107. Review the FAA's website (https://www.faaregisterdrone.com/) or the FAA DroneZone (https://faadronezone.faa.gov/) for additional information regarding drone registration.

Operating Requirements

- If operating within 30 minutes of morning or evening civil twilight, the aircraft must have an anti-collision light that is visible for at least 3 statute miles.

- Any equipment attached to the aircraft must be secure and not impact the flight performance (e.g., balance). All aircraft should be less than 55 pounds at takeoff.

- Airspace:

    - sUAS flights are only allowed in Class G airspace. Please check FAA Sectional Aeronautical Charts to ensure you will be flying in unregulated airspace.

    - The maximum allowable altitude is 400 feet above ground level (AGL), and the maximum aircraft speed is 100 mph.

    - You should check for Notices to Air Missions (NOTAMs) during flight planning and before takeoff to ensure there are no Temporary Flight Restrictions (TFRs). A few good sources are: http://www.faa.gov/, http://www.skyvector.com/ and http://www.1800wxbrief.com/. B4UFly (https://b4ufly.aloft.ai/) is recommended for recreational pilots but can be used in addition to official sources by commercial drone pilots.

    - The pilot must always maintain visual line of sight while operating the drone. The use of visual observers (VOs) as part of a flight plan is beneficial, but a pilot or an observer can only be responsible for one aircraft at a time and must have eyes on the sUAS at all times. Observation must be unaided (no binoculars).

    - Be aware that the Virginia High School League has issued a temporary flight restriction (TFR) for all sporting events.

FAA DroneZone

- Create an account with the FAA DroneZone (https://faadronezone.faa.gov/#/) to register your drone, request a waiver, and/or report an accident.

- Accident reporting (responsibility of the RPIC).

    - Report sUAS accidents that involve serious injury, loss of consciousness, or property damage of at least $500 to the FAA within 10 days.

    - Part 107 Accident Reports can be submitted and reviewed through FAA DroneZone accounts.

- FAA waivers.

    - The FAA can issue waivers to certain requirements of Part 107 when operators demonstrate they can fly safely under the waiver without endangering other aircraft, people or property.

    - Some examples are flying at night, beyond visual line of sight, or over people. For more information see https://www.faa.gov/uas/commercial_operators/part_107_waivers/.

    - Part 107 Waivers/Authorizations can be created and managed through DroneZone accounts.

Drone Safety

Disclaimer: Please follow all local, state, and federal regulations for sUAS aircraft operations. Consult with the administration of your facility (school or other entity) to ensure all policies are followed. The following information is provided as a set of recommendations and is not meant to be your only source of safety guidance.

Before Any sUAS Flight, Complete a Preflight Checklist

Follow all manufacturer recommendations before powering on the sUAS. A sample checklist has been provided after this section, but manufacturer recommendations always take precedence. Items to inspect typically include:

- Propellers – Ensure there are no nicks, cracks, or bends.
    - Damaged propellers should never be flown.
    - Never attempt to repair propellers.
    - Carbon fiber propellers should never be used when flying with students unless a specific mission would require their use. Carbon fiber propellers can cause serious injuries during an accident.
- Battery – Ensure the battery is fully charged and not damaged.
    - Ensure the battery is not swollen or hot.
    - Ensure the battery has a full charge.
- Equipment installations – Ensure all equipment is securely attached.
    - Check propellers to ensure they are securely and properly attached.
    - Check the battery to ensure is it properly attached.
    - Secure all panels, doors, or other latching devices.
    - Check cameras to ensure they are securely attached and that an empty SD card is installed (if applicable).
- Check the aircraft for obvious defects.
    - Be sure the landing gear is secure and straight.
    - Check to see that all lights are working.
    - If needed, be sure the strobe light is functional.
- Transmitter/controller – Make sure they are functioning.
    - Ensure batteries are fully charged.
    - Ensure software is updated.

Before Any sUAS Aircraft Flight, the Operational and Flight Areas Must Be Clear

- Be sure the operational area is safe and clear.
    - Ensure that the RPIC (remote pilot in command), as well as any other flight crew (such as visual observers), are in an area where they will not be disturbed or distracted.
    - Consider using caution tape to designate a crew area with a buffer to prevent people from entering the operations area or distracting crew members.

    - Ensure your flight will not travel over people unless they are crew members or an FAA waiver has been obtained.

- Check current and future weather conditions.
    - Ensure at least 3 statute miles of visibility.
    - Maximum flight altitude is 400 feet above ground level and at least 500 feet below clouds.
    - Flight pattern is at least 2,000 feet horizontally from clouds.
    - Print the most recent METAR (Meteorological Aerodrome Report) for your records.
    - Check to determine if temperatures could be lower than 40 degrees Fahrenheit, which will impact battery performance.
    - Assess the chance for icing at any flight altitude.
- Ensure that you are clear to operate in the airspace.
    - Ensure that you are operating in Class G airspace.
        - If not, acquire a Low Altitude Authorization and Notification Capability (LAANC) through one of the FAA-approved LAANC UAS service providers at https://www.faa.gov/uas/programs_partnerships/data_exchange/#approved or a apply for a waiver at https://www.faa.gov/uas/commercial_operators/part_107_waivers/.
        - Check for Notices to Air Missions (NOTAMs) at https://notams.aim.faa.gov/notamSearch/nsapp.html#/.
    - Acquire permission from owner if operating over private property.
    - Check for restrictions over public lands.
    - If operating a DJI, check the GeoZone Map (https://www.dji.com/flysafe/geo-map).

Safety When Not in Flight

- Secure all equipment when not in flight.
- Safely store LiPo (lithium polymer) batteries.
- Charge (or discharge) batteries for storage at recommended levels.

sUAS Operations in an Indoor Environment

Flying indoors can present different challenges than flying outside. In addition to following all safety recommendations, please be especially mindful of the following circumstances when flying indoors.

- Safe and clear operational area.
    - Aircraft flight and operational areas must be kept clear. This can be challenging in a small indoor environment. Make sure to have signage and markers to keep curious observers at a safe distance away from flight areas and operational areas.
    - Walk and scan the flight area before the flight to note any potential safety hazards. Sprinkler nozzles and fire detection equipment can be especially problematic for indoor sUAS flights.
- Communications.
    - Commercial and educational buildings may have strong Wi-Fi signals. These signals can potentially interfere with the communication between the transmitter and the aircraft. Many aircraft and transmitters use a 2.4 GHz frequency that is the same as Wi-Fi. You can use a frequency spectrum analyzer to determine potential interference before a flight.

sUAS Operations in an Outdoor Environment

- Many of your missions will focus on natural resources. Therefore, situational awareness will be critical for a safe flight.

- Walk the flight area before the flight to note any potential safety hazards. Trees and other tall vegetation could create issues during your flight. Please note the height of these structures.

- If your flight path proceeds between tall trees or buildings, please be especially aware of increased wind velocities between these structures.

- Wildlife can create hazards during the flight, but it's important not to impact wildlife negatively during your missions. Many species of birds could be territorial or inquisitive. Swallows and martins will often fly near sUAS. Mockingbirds, crows, and birds of prey could approach or dive at your sUAS. Please be cautious

Notes:

Flight Checklist for the DJI Mavic

This checklist was developed specifically for a DJI Mavic. It can be used for other types of drones, although some of the items may not be relevant to other makes and models.

Before you walk out the door...

- [ ] Check to make sure that you are flying in a safe flight zone.
    - Verify your flight location is in Class G airspace by checking SkyVector (http://www.skyvector.com/) and B4UFly (https://b4ufly.aloft.ai/).
    - Check flight services (https://www.1800wxbrief.com/) for:
        - TFRs.
        - NOTAMs.
- [ ] Check DJI's GeoZone to see if the drone requires unlocking (https://www.dji.com/flysafe/geo-map).
- [ ] Check weather conditions, wind, temperature, etc.
- [ ] Check for firmware updates.
- [ ] Check for DJI GO 4 app updates.
- [ ] Flight planning:
    - Plan flight route.
    - Review manual flight procedures.
- [ ] Make sure the flight area is free of obstacles above (e.g., tall trees, power lines) using a geographic viewer (such as Google Earth or city/county online GIS Mapper) to conduct a preliminary assessment of the area (also known as preliminary reconnaissance).
- [ ] Bring a takeoff/landing pad if needed (when working in tall grass, etc.).
- [ ] Confirm all items are fully charged:
    - Drone batteries.
    - Controller.
    - Tablet/iPhone.
- [ ] Erase data from the microSD card.
- [ ] Inspections:
    - Inspect overall aircraft/props/motors for damage.
    - Inspect battery for damage.

Supply list:

- [ ] Remote Pilot Certificate(s).
- [ ] Mavic Pro Drone.
- [ ] Batteries.
- [ ] Remote controller (RC).
- [ ] Extra propellers.
- [ ] Micro SD card.
- [ ] Phone or tablet with DJI GO 4
- [ ] Cable to connect RC to phone.
- [ ] First aid kit/fire extinguisher.

Prepare for operations (on-site):

- [ ] Conduct a more thorough on-site review by checking for obstacles and other safety concerns
- [ ] Unfold the propeller arms.
- [ ] Extend the propellers.
- [ ] Remove gimbal lock and cover.
- [ ] Attach camera filters (optional).
- [ ] Insert the micro SD card.

- [ ] Unfold the controller antennas.
- [ ] On the side of the RC, make sure "Sport" mode is off.
- [ ] On the Mavic Pro, make sure the mode switch is set to "RC."
- [ ] Set Mavic Pro on a flat, level surface.
- [ ] If using a phone, attach to the RC.
- [ ] If using a tablet, attach the tablet and tablet adapter to the RC.
- [ ] Make sure your team has been debriefed about the project.

Powering up:

- [ ] Turn on the phone and enter the DJI GO 4 app.
- [ ] Turn on the remote controller (before turning on the drone).
- [ ] Turn on the Mavic Pro.
- [ ] Lights will flash on the Mavic Pro.
- [ ] The Mavic Pro will make the "DJI beep-beep" sound.
- [ ] The gimbal will move.
- [ ] Connect Mavic Pro to DJI GO 4.
- [ ] Adjust camera settings.
- [ ] Wait for GPS and compass response on the DJI GO 4 App.
- [ ] Calibrate the drone if needed (aka "the drone dance", for a demonstration about the drone dance, view this video https://www.youtube.com/watch?v=5s9dhGUs4iY) (Ikopta, 2018)
- [ ] Establish the return to home point.
    - Check "READY TO GO GPS" in upper left of controller.
    - Check minimum "Return to Home Altitude" setting.
        - Take into account nearby trees/ structures/power lines.

Begin flight:

- [ ] Hold both of the sticks to the middle-center.
- [ ] Let Mavic Pro idle and inspect for irregular vibrations or movements.
- [ ] To stop the Mavic Pro, press the left stick down and the propellers will stop.
- [ ] To launch the Mavic Pro, press the left stick up and the Mavic will take off.
- [ ] Press record (video).
- [ ] Hover the drone to check for irregular vibrations/ movements/sounds.

Post Flight:

- [ ] Turn off the drone (battery) first.
- [ ] Turn off the controller (after turning off the drone).
- [ ] Inspect drone/batteries/propellers.
- [ ] Record anomalies.
- [ ] Record battery usage in the battery log.
- [ ] Document appropriately in the flight log.

Manual Flight Exercises

If you are just getting started, here are some potentially useful tips and reminders.

1. **Don't break the bank.** If this is your first manual drone flight, you might want to consider using a smaller, less expensive drone. New drone operators are more likely to experience a crash, especially if the flight path has trees, structures, or changes in the terrain. Crashing an expensive drone does not feel very good in any way, notably on the wallet. Learn on a cheaper drone and use prop guards if available.

2. **Get your Remote Pilot Certificate.** Even if you do not think that you will be operating a drone for commercial purposes, you still must learn a great deal of information about safe (and legal) operations. Becoming a licensed remote pilot is a good way to get started. More information is available from the FAA at https://www.faa.gov/uas/commercial_operators/become_a_drone_pilot/. If you are planning to operate a drone as a recreational pilot, complete the TRUST Certificate. More information is available at https://www.faa.gov/uas/recreational_fliers/knowledge_test_updates/.

3. **Start simple.** Start simple and build on your experience! The manual flight exercises were developed to help you start practicing. These exercises begin with basic maneuvers and increase in complexity. Do not proceed to the next exercise until you can confidently operate the sUAS in the current exercise. It is also recommended to operate the drone with a minimum altitude of approximately 15 feet AGL (the drone should operate above eye level in the event that something does go wrong) and a maximum ceiling of approximately 50 feet AGL. The ceiling can be increased after you have honed your skills and gained flight experience!

4. **Maintain consistent safety protocols.** Update your checklists regularly, keep your first aid kits nearby, and maintain safety zone setbacks consistently. Expect the unexpected! Bring a small fire extinguisher, just in case. It is important that these protocols become part of every flight operation. See figure 1 for an example of an operational configuration designed with safety in mind.

5. **The RPIC makes the call.** This guide suggests providing a safety area of 25 feet between the Operations Zone and the Flight Area (figure 1). This, and other setback recommendations/safety suggestions should be considered as minimum standards, or best-case scenarios. For example, recommendations assume the involvement of highly qualified and experienced RPICs, very small aircraft (less than 2 pounds), and a small group of experienced and attentive observers. The RPIC is encouraged to enhance (expand) the safety zone, increase other setbacks, modify flight altitude thresholds. and account for other safety protocols based on the specific situation associated with the flight mission. And, obviously, larger aircraft require larger setback distances and other safety protocols. We have even used a netted protected area when using larger aircraft for both the pilot and the observers. There is no such thing as "too safe."

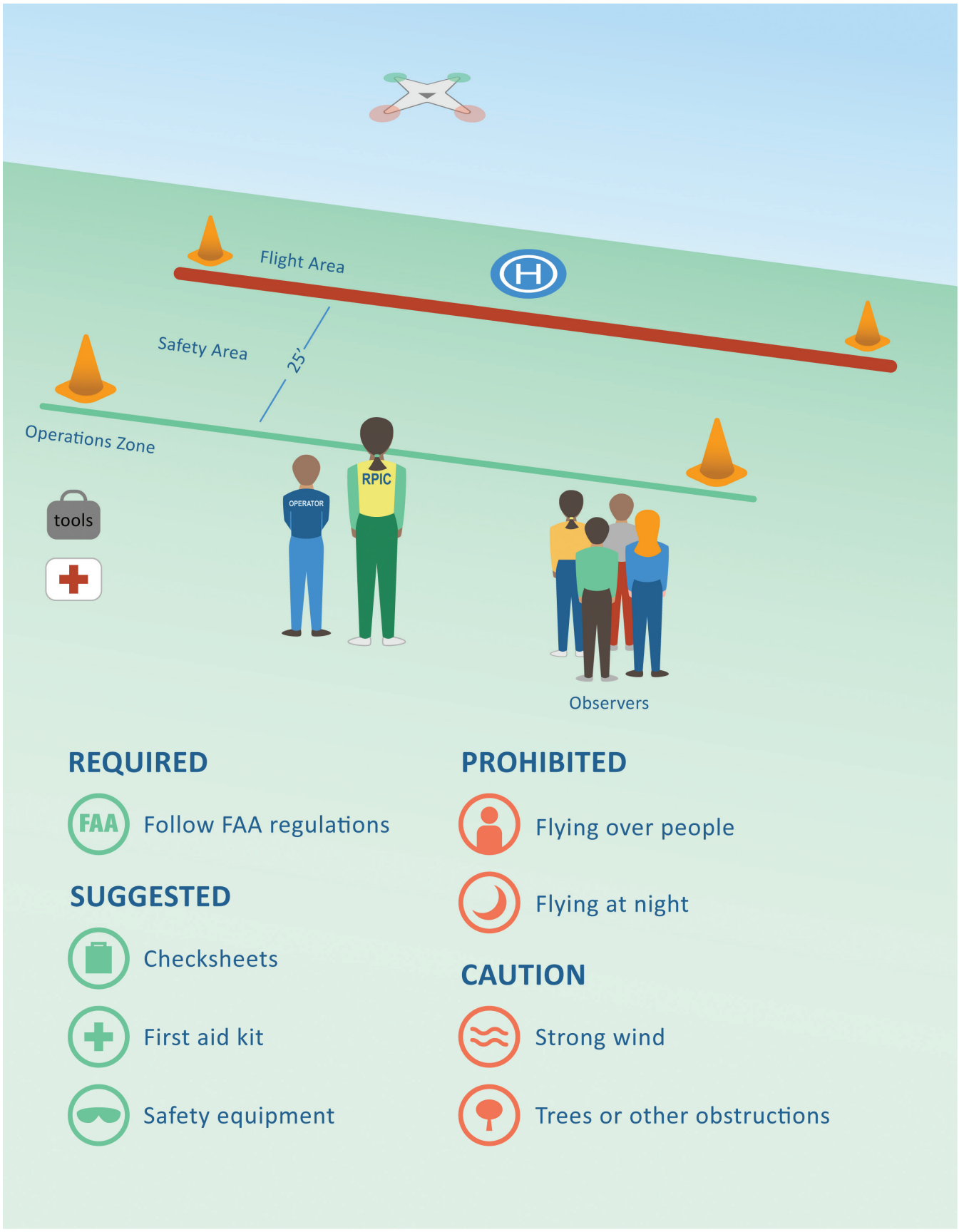


Figure1: Safety protocols such as those depicted here should be implemented consistently.

Get Control of the Controller!

Before launching, you will need to understand how the buttons and joysticks on your controller work (figure 2). This is vitally important. You will need to have confidence in your flight abilities as you will likely need to make split-second decisions. Every controller is unique to some degree, but typically, the joystick movements that control roll, pitch, yaw, and the throttle are consistent between drone models and manufacturers. Just be sure to reference your owner's manual as you practice.

Figure 2: Typical drone controller. (Photo by J. McGee.)

The joysticks on a multirotor aircraft, such as a quad copter, have four main operations (figure 3):

- **Yaw:** Moving the left joystick to the right or left rotates the drone clockwise or counterclockwise, respectively.
- **Throttle:** Moving the left joystick up or down increases/decreases the throttle. The throttle controls the rotational speed of the rotors, which causes the drone to go up or down (increase or decrease in altitude).
- **Roll:** By moving the right joystick to the left or right, the drone will tilt or "roll" to the left or right, causing the drone to travel to the left or right.
- **Pitch:** Moving the right joystick forward or backward tilts the drone forward or backward, causing the drone to travel forward or backward.

When operating a drone, you also need to remember that the remote pilot must assume the perspective of the drone (which way the drone is facing). If the drone is facing the pilot, the perspective is switched. A pilot needs to consider how the drone will respond to joystick commands given its orientation, not the pilot's.

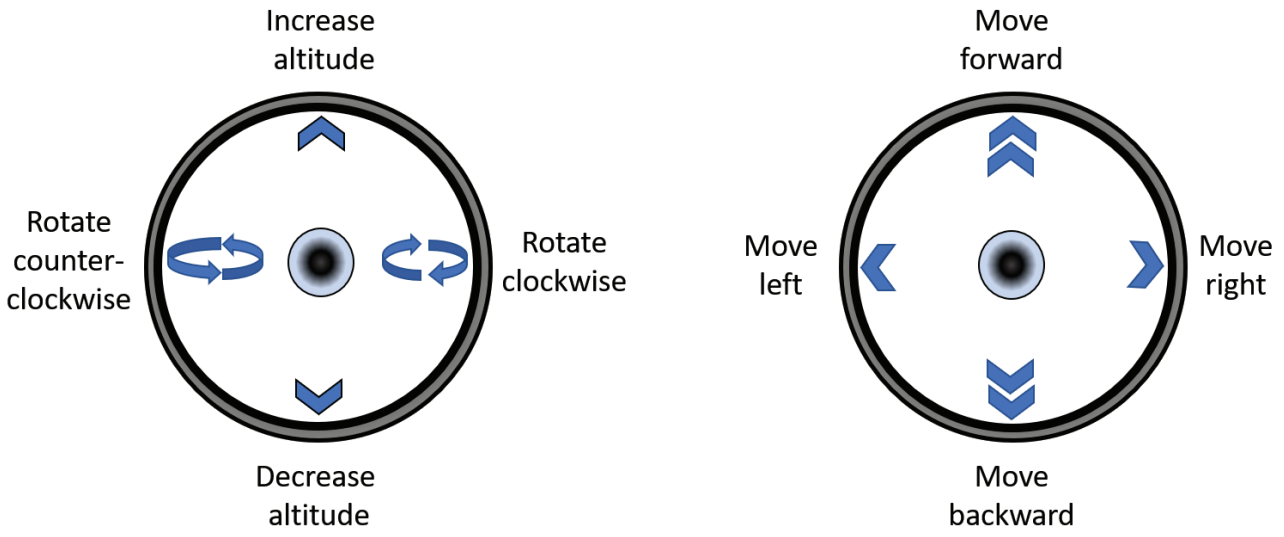


Figure 3: Typical responses of multirotor joystick controls. (Illustration by J. McGee.)

Notes:

Manual Flight Exercises

Hovering

The first two exercises will help to develop basic familiarity with the manual operation of your drone. Keep it simple at first and DO NOT operate your sUAS higher than 20 feet.

Exercise 1:

Set up your flying field as shown in figure 4 and start the drone (connect the controller, start the motors, etc.).

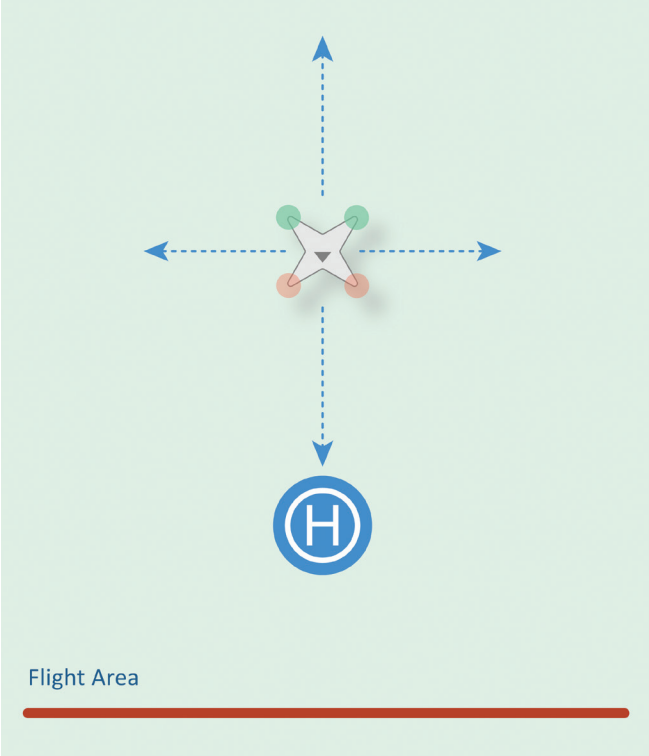


Figure 4: Hovering and lateral movement.

Skills: Takeoff, hover, move laterally, land.

1. Take off from your landing zone.
2. Keep the drone at a consistent altitude over the landing zone (20 feet above ground level, or AGL), and hover in place for 10-15 seconds.
3. Maneuver back above the landing zone and land in the middle of your landing target.

Exercise 2: Lateral Movement

Skills: Takeoff, maneuver in four lateral directions, land.

1. Take off again.
2. Climb to 20 feet AGL and hover.
3. Use both joysticks to maneuver left/right/forward/back. Move the drone laterally a few feet (10 or 15 feet) in all four directions as shown in figure 4 – forward, then back to midpoint; backward, then back to midpoint; left, then back to midpoint; and right, then back to midpoint.
4. Maneuver back above the landing zone and land in the middle of your landing target

Rectangular Patterns

The next flight exercises are designed to help develop awareness of the orientation of the drone. The key is to remember that the "left" and "right" joysticks on the controller are associated with the perspective of the drone, not of the RPIC. (Sometimes it helps to imagine that there is a little drone pilot sitting in the front of the drone.) During exercises 3 and 4, keep the drone at a maximum altitude of 20 feet. Feel free to go around the course several times prior to landing to help you master these skills.

Exercise 3: Navigation and Orientation

Skills: Take off, controller orientation while drone is facing the operator, land.

1. Take off from the landing zone and navigate laterally in a square or rectangular pattern (figure 5).

2. Keep the front of the drone *facing the operator* at all times.

3. Land in the middle of the landing zone.

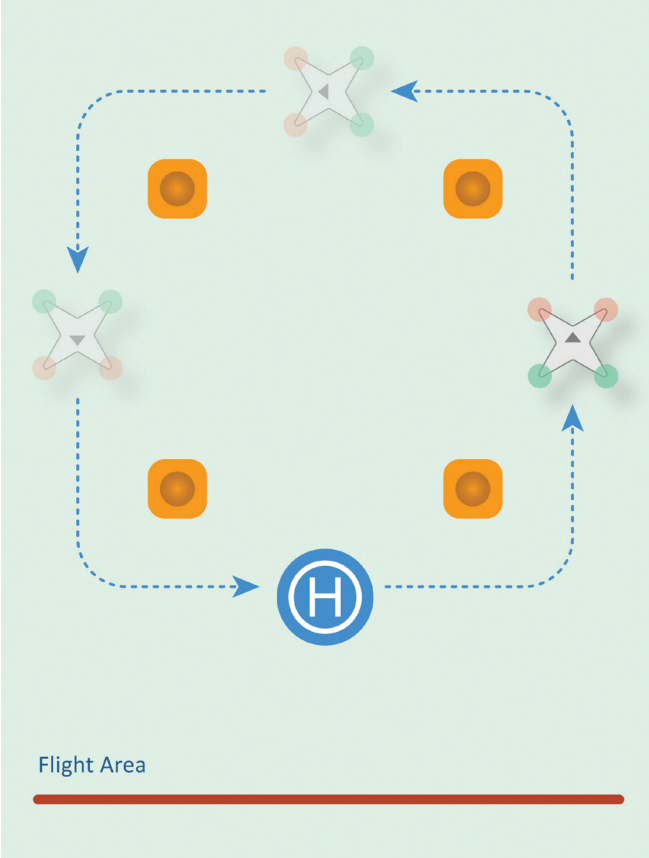


Figure 5: Flying rectangular patterns.

Exercise 4: Navigation and Orientation

Skills: Take off, controller orientation while drone is facing the direction of travel, land.

1. Take off from the landing zone and navigate laterally in a square or rectangular pattern.

2. Keep the front of the drone *facing the direction of travel* at all times.

3. Land in the middle of the landing zone.

Going in Circles

These exercises will help train you to use the two joysticks on the controller at the same time. Cones can be placed at various locations along the periphery of the circle as a guide for the pilot. You will know that you have mastered this exercise when you can keep the speed of the drone at a consistent pace. Your circle does not have to be perfectly round (oblong is fine) but it should not be jagged. Keep your drone at a maximum altitude of 20 feet for exercises 5 and 6.

Exercise 5:

Skills: Take off, control orientation while drone operating in a circular pattern (facing the operator), land.

1. Take off from the landing zone and navigate (laterally) in a circular pattern (figure 6).

2. Keep the front of the drone facing the operator at all times.

3. Land in the middle of the landing zone.

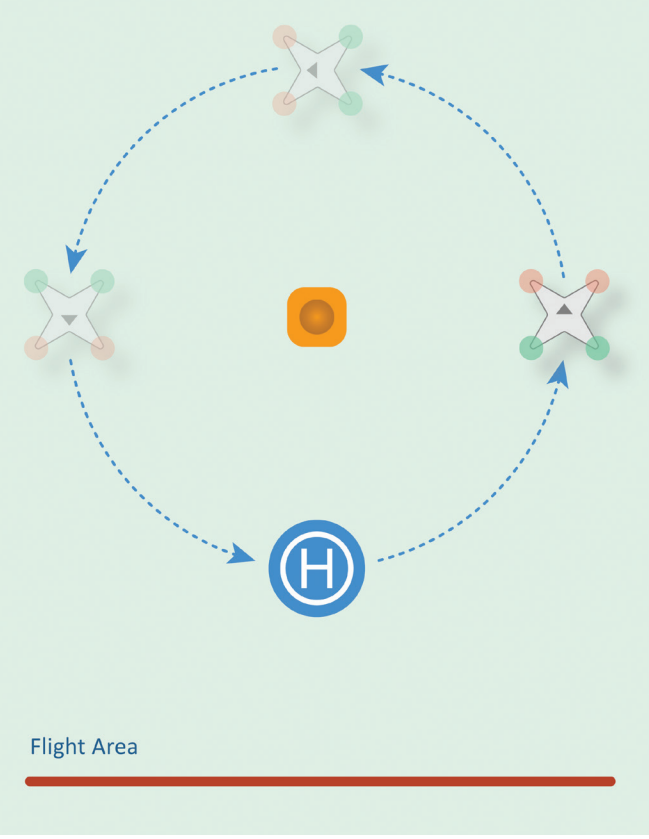


Figure 6: Flying in circles.

Exercise 6:

Skills: Take off, control orientation while drone operating in a circular pattern (facing forward), land.

1. Take off from the landing zone and navigate (laterally) in a circular pattern.

2. Keep the front of the drone *facing the direction of travel* at all times.

3. Land in the middle of the landing zone.

As in the previous exercises, go around the course several times prior to landing to help you master these skills.

Out and Back

These exercises will help you to assess your drone's orientation and your own depth perception. If you have difficulty manually navigating the drone back to the landing zone, you can always rely on the return to land (RTL) function if your controller has one, or just land it anywhere and pick it up afterwards. Keep the drone below 20 feet AGL. For these exercises, set up the flight area with three cones each set thirty feet apart (figure 7).

Skills: Take off, control orientation while drone operating a drone laterally (facing the operator), track visual depth of field, land.

Exercise 7:

1. Take off from the landing zone and navigate laterally around the first cone.
2. Keep the front of the drone *facing the operator* at all times.
3. Return to the starting point but do not land before heading out to the second cone.
4. Continue until you have passed around all of the cones.
5. Land in the middle of the landing zone.

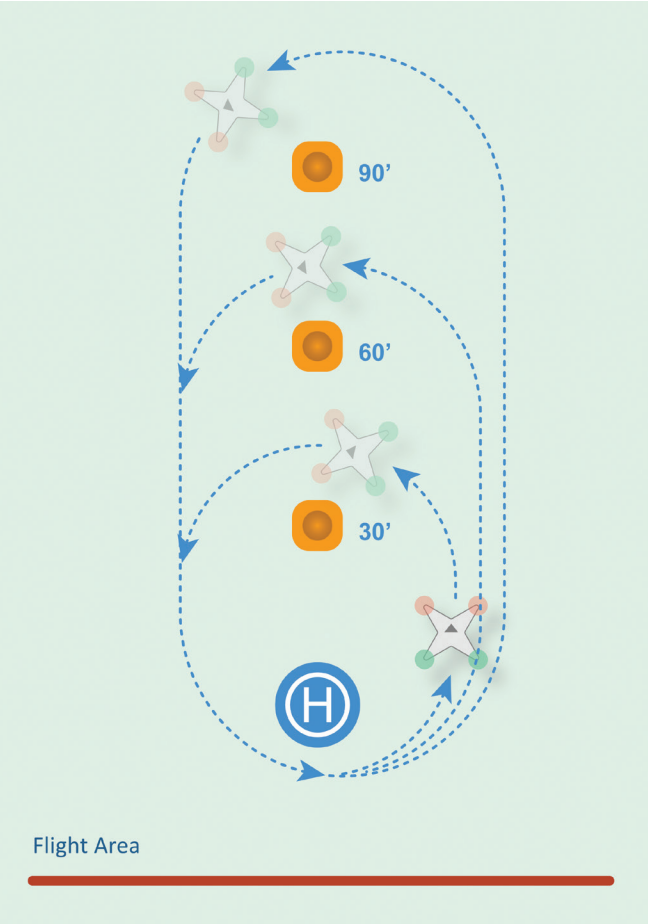


Figure 7: Out and back.

Exercise 8:

Skills: Take off, control orientation while drone operating a drone laterally (facing the direction of travel), track visual depth of field, land.

1. Take off from the landing zone and navigate laterally around the first cone.
2. Keep the front of the drone facing the direction of travel at all times.
3. Return to the starting point but do not land before heading out to the second cone.
4. Continue until you have passed around all of the cones.
5. Land in the middle of the landing zone.

The Beginner Drone Weave

This exercise helps you to learn to control your drone with various orientations and helps you to assess your own depth perception while applying more difficulty to the flight maneuvers. Keep the drone below 20 feet AGL.

Increase complexity by adding distance between the cones, adding more cones, or increasing the total distance of the flight.

Skills: Take off, control orientation while drone operating a drone laterally (facing the operator), track visual depth perception, land.

Exercise 9:

1. Take off from the landing zone and weave laterally around the cones (figure 8).

2. Keep the front of the drone *facing the operator* at all times.

3. Continue until you have passed around all of the cones.

4. Weave your drone back to the landing pad and land in the middle of the landing zone.

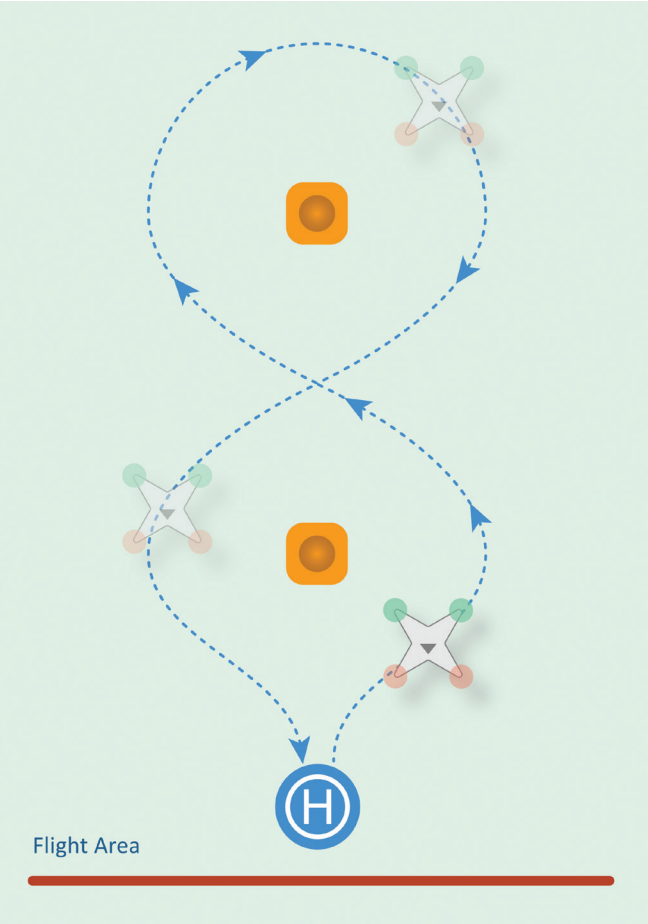


Figure 8: The beginner drone weave.

The Intermediate Drone Weave

The Intermediate Drone Weave is similar to the Drone Weave, but the front of the drone *will always face the direction of travel* (not the operator). This exercise builds on previous exercises and requires advanced orientation and flight operation skills.

Skills: Take off, control orientation while drone operating a drone laterally (facing the direction of travel), track visual depth perception, land.

Exercise 10:

1. Take off from the landing zone, and weave laterally around the cones (figure 9).
2. Keep the front of the drone *facing the direction of travel* at all times.
3. Continue the weave flight pattern until you have passed around all of the cones.
4. Weave your drone back to the landing pad and land in the middle of the landing zone.

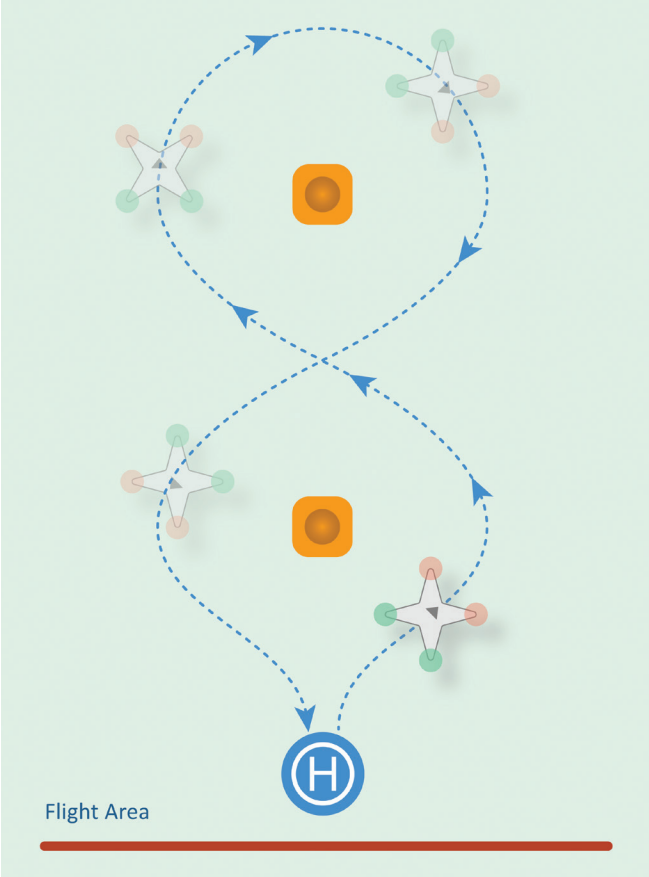


Figure 9: The intermediate drone weave.

Putting it all together: The Advanced Drone Weave

The Advanced Drone Weave is similar to the previous two exercises, but the scale of the proposed flight operation is larger, containing more cones and a longer distance. This exercise builds on previous exercises and requires advanced orientation and flight operation skills.

Because of the large flight path and increased complexity of these exercises, it may be beneficial to position an observer in a safe location at the back of the flight area. Take safety precautions such as providing the observer with a safety vest, hard hart, safety glasses, etc., and positioning the observer way off to the side. Provide the observer with a radio, cell phone, or other device that can be used to communicate with the RPIC to provide additional confirmation of flight performance, a different perspective, and/or flight suggestions as guidance.

Skills: Take off, control orientation while drone operating a drone laterally (facing the direction of travel), assess visual depth perception, radio communication skills, land

Exercise 11:

1. (Optional) Place an observer in a safe location in the field with a radio.
2. Take off from the launch zone and weave laterally around the cones (figure 10).
3. Keep the front of the drone *facing the direction of travel* at all times.
4. Continue the weave flight pattern until you have passed around all the cones.
5. Weave your drone back to the landing pad and land in the middle of the landing zone.

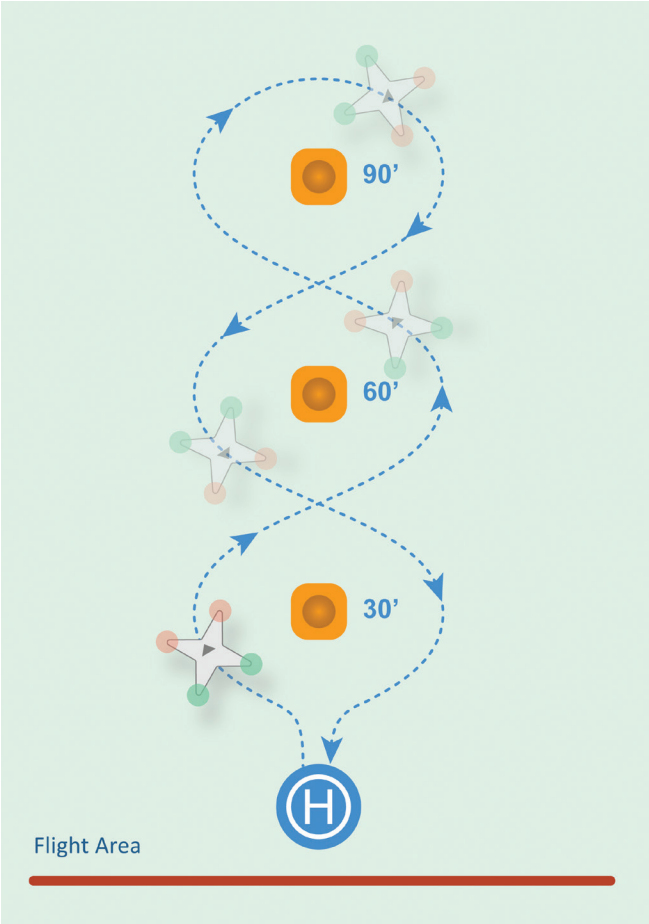


Figure 10: The advanced drone weave.

The Vertical Box

Learning to manually operate an sUAS in a vertical pattern is also critical. When returning to the landing base, for example, you may need to avoid trees or other tall structures. These exercises will help you gain familiarity with manual piloting using the vertical controls (left joystick). Cones can be placed on the ground to delineate the width of the quadrilateral. Keep the drone below 50 feet AGL.

Skills: Take off, control orientation while drone operating a drone vertically (facing the operator), track visual depth of field, understanding depth perception at different altitudes, land.

Exercise 12:

1. Take off from the landing zone and navigate horizontally about 25 feet (to provide a safe distance away from the RPIC), then climb to about 50 feet AGL before directing the sUAS to move laterally in a square or rectangular pattern.

2. Keep the front of the drone *facing the operator* at all times. The floor of the rectangle should be approximately 15 feet AGL.

3. Continue making a vertical box several times before coming back down to 15 feet AGL and returning to a spot above the landing pad. (figure 11).

4. Land in the middle of the landing zone.

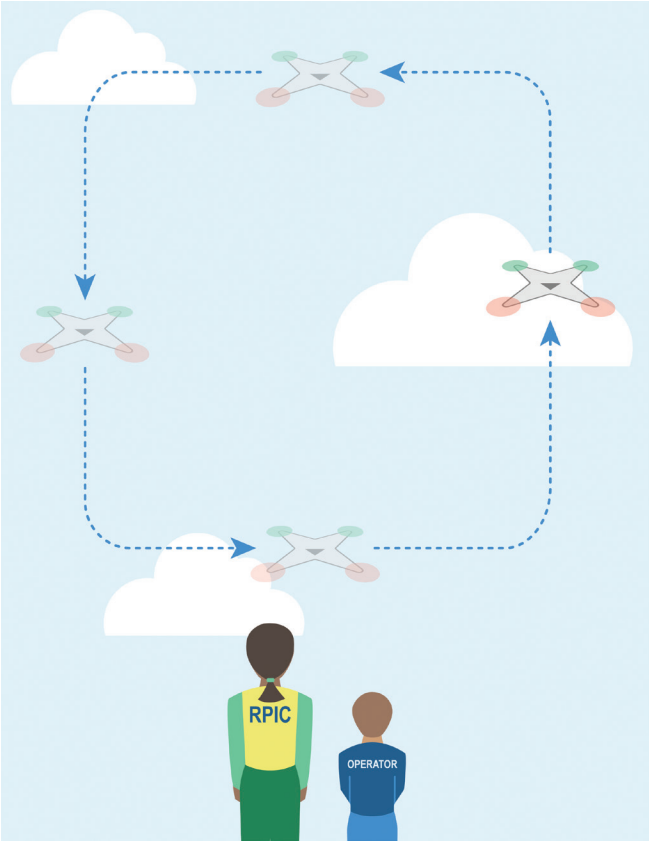


Figure 11: The vertical box.

Exercise 13:

Skills: Take off, control orientation while drone operating a drone vertically (facing the direction of travel), track visual depth of field, understanding depth perception at different altitudes, land.

1. Take off from the landing zone and navigate horizontally about 25 feet (to provide a safe distance away from the RPIC), then climb to about 50 feet AGL before directing the sUAS to move laterally in a square or rectangular pattern.

2. Keep the front of the drone *facing the direction of horizontal travel* at all times.

3. The maximum height of the ceiling should be approximately 50 feet AGL

4. The floor of the rectangle should be approximately 15 feet AGL.

5. Continue making a vertical box several times before coming back down to 15 feet AGL and returning to a spot above the landing pad. Land in the middle of the landing zone.

The Vertical Figure Eight

This advanced exercise continues to build on your flight experience by incorporating both horizontal and vertical flight skills. Take it slowly at first and increase your speed with experience. Cones can be placed on the ground to delineate the width of the quadrilateral. Keep the drone below 50 feet AGL.

Skills: Take off, control orientation while drone operating a drone both vertically and horizontally (facing the operator), understand depth perception at different altitudes, land.

Exercise 14:

1. Take off from the landing zone and navigate (horizontally and then vertically) in a figure-eight pattern. Try to make the turns of the figure eight as curvy as possible (as opposed to a boxy figure eight). The ground width of the figure eight should be approximately 30 feet (figure 12).

2. Keep the front of the drone facing the operator at all times.

3. Land in the middle of the landing zone.

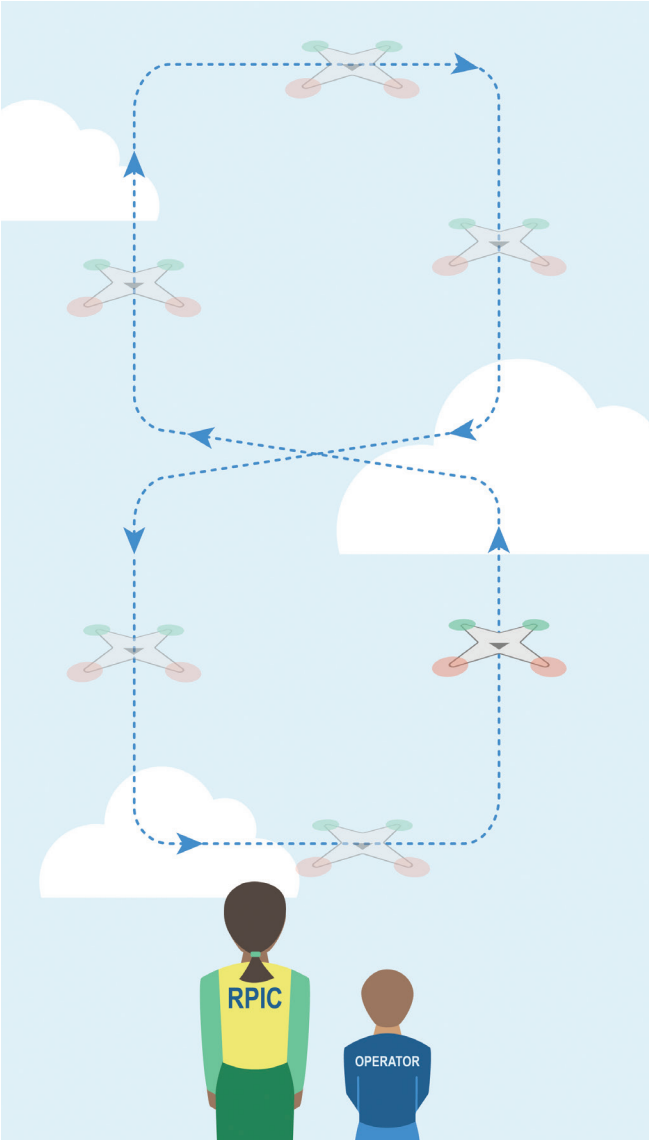


Figure 12: The figure eight.

Exercise 15:

Skills: Take off, control orientation while drone operating a drone both vertically and horizontally (facing the direction of travel while moving horizontally), understand depth perception at different altitudes, land

1. Take off from the landing zone and navigate (horizontally and then vertically) in a figure-eight pattern. Try to make the turns of the figure eight as "curvy" as possible (as opposed to a boxy figure eight). The ground width of the figure eight should be approximately 30 feet.

2. When traveling horizontally, keep the front of the drone *facing the direction of travel*.

3. Land in the middle of the landing zone.

Disrupting Visual Line of Sight (VLOS)

Maintaining visual line of sight (VLOS) with a drone is central to FAA regulations. However, these regulations also stipulate that the RPIC can lose VLOS for very brief periods of time. Pilots, for example, may lose sight of the sUAS briefly while inspecting structures such as roofs or wind turbines. Natural resource managers may lose VLOS when the sUAS goes behind a tree. In this exercise, the remote pilot will maneuver the sUAS behind a small structure (this can be a large cardboard box, a small shed, a dugout, or other small screen) where visual line of sight is briefly lost.

Skills: Take off, control orientation while drone operating a drone, operation beyond VLOS, land. Additional (optional) skills can include managing a camera or other sensor while in flight, and/or established radio communication protocols.

Exercise 16:

1. Take off from the landing zone and navigate horizontally toward the structure.

2. The remote pilot will briefly lose sight of the sUAS as it disappears behind the structure.

3. Return to the landing pad and land and in the middle of the landing zone (figure 13).

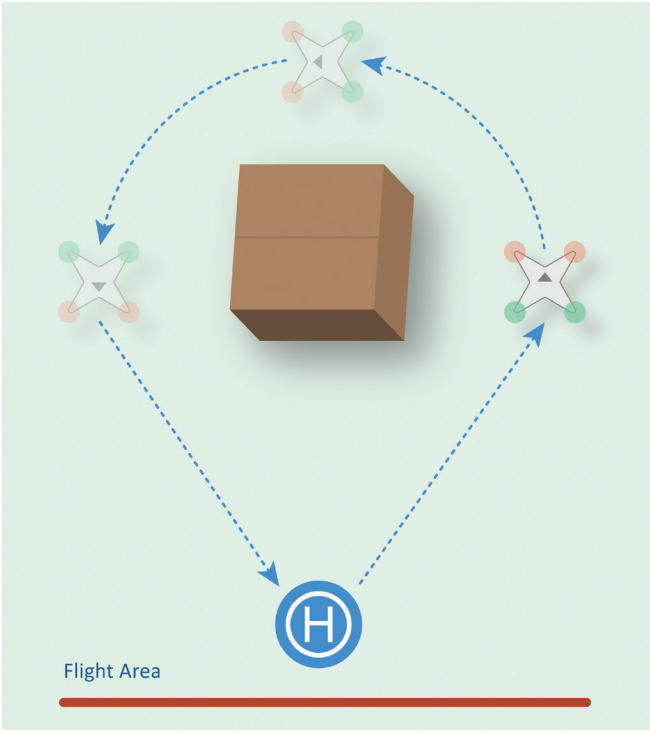


Figure 13: Disrupting visual line of sight (VLOS).

Exercise 17:

1. Take off from the landing zone and navigate horizontally toward the structure.

2. In this more advanced exercise, the remote pilot will inspect the structure (box, dugout, etc.). This will require the pilot to operate around and over the structure.

For an even more advanced exercise, capture imagery (either photos or video) of the structure. In a classroom environment, the student can download the images/video to a local device and assess the images for structural anomalies such as cracks, peeling paint, rusty nails or bolts, leaks, or peeling tape from a cardboard box. A visual observer can be placed a safe distance from the flight operations and can provide the RPIC with the status of the flight while the drone is beyond VLOS via a radio or cellphones.

Drone Obstacle Course

Now that you have mastered the art of manual flight, you may be ready to maneuver through more complicated terrain and between (and through) structures. This is an excellent opportunity to establish a drone obstacle course.

Suggestions for an obstacle course:

- Fly through a hula hoop.
- Fly through a field goal, or through, above, and back around a soccer goal (without the net).
- Use bamboo or other poles to establish a slalom course.
- Set up poles in a teepee or lean-to style and fly in and out of the open structure. Pool noodles can provide an excellent buffer around poles.
- Get a large box and fly through it.
- Land on top of a dugout or other elevated flat surface.

An obstacle course can be conducted inside in open areas such as gymnasiums using fairly small and affordable drones (about 6 ounces or lighter; examples include a DJI Tello or a Hubsan). These smaller drones can also be used outside in confined areas when there is no wind. Otherwise, it is suggested that you use more stable drones for outside use (such as a Mavic or Phantom).

Wrap-Up

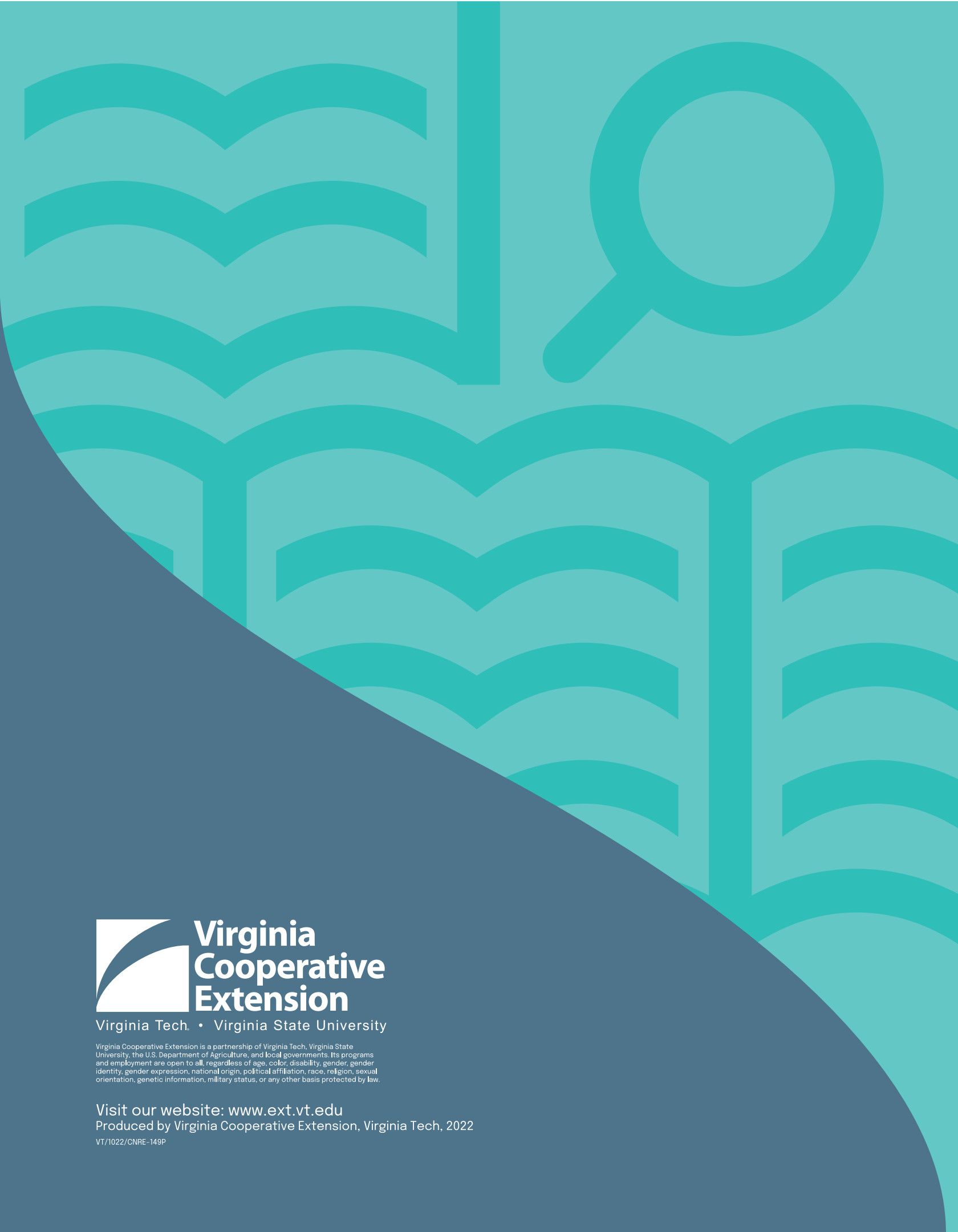
sUAS are transformative tools that are becoming essential to support many of the jobs of the future that require timely Earth observation. sUAS workflows are typically associated with three steps that include: (1.) flight planning, (2.) flight operation, and (3.) data processing. This document provides support for the 'flight operation' component of this workflow, by providing new drone operators with practice exercises (and other suggestions) to become safe and successful drone pilots. Some of the skills introduced in this manual include:

- Understanding basic safety precautions
- Record keeping through check sheets
- Understanding a typical controller
- Taking off
- Understanding a drone's orientation and how this impacts flight operations
- Basic flight operations including: hovering, horizontal flight and vertical flight operations
- Communication
- Depth perception
- Flight operations at higher altitudes
- Landing

As you become more experienced and confident in your skills, keep in mind that that every flight is different due to varying terrain, atmospheric conditions, and an array of safety considerations.

Reference

Ikopta. (2018). *How to do DJI drone compass calibration dance*. YouTube. Retrieved June 22, 2022, from https://www.youtube.com/watch?v=5s9dhGUs4iY



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