Best Practices for Drone Imagery Survey

Conducting drone imagery surveys in Canada requires strict compliance to safety and legal guidelines. This guide provides essential information on flight regulations for different remotely piloted aircraft system (RPAS) categories, including microdrones (less than 250 gr), small drones (between 250 gr and 25 kg) and RPAS operations requiring Special Flight Operations Certificates (SFOC). This resource also covers flight planning strategies, ground control point management, and practical tips for conducting surveys using drones safely and legally.

List of Abbreviations and Definitions

Aerodrome..... Any area designed, prepared, equipped or set apart for the arrival, departure, movement or servicing of aircraft.
Airport (APRT)..... An aerodrome for which an airport certificate is in force.
Airspace ..... A part of the atmosphere over a country that falls under its jurisdiction.
ATC Service ..... Air Traffic Control Service – A service provided for the purposes of preventing collisions between aircrafts, obstacles and vehicles on the manoeuvring area and expediting and maintaining an orderly flow of air traffic.
Bystander ..... An unofficial term used to denote a person who is not considered part of the crew.
BVLOS ..... Beyond visual line-of-sight – RPAS operation in which no crew member maintains unaided visual contact with the aircraft sufficient to be able to maintain control of the aircraft and know its location.
Drone..... Colloquial term commonly used to refer to any type of RPAS.
NAV CANADA..... A private corporation that owns and operates Canada's civil air navigation system (ANS). Their products/services include Flight Authorization, Airspace Permission, Local Area Weather Manuals and Aviation Weather Service Guide.
RPAS..... Remotely Piloted Aircraft System
SFOC ..... Special Flight Operation Certificate
TC..... Transport Canada
VLOS..... Visual line-of-sight – RPAS operation in which unaided visual contact is maintained at all times with the aircraft sufficient to be able to maintain control of the aircraft.

Flight Regulations in Canada

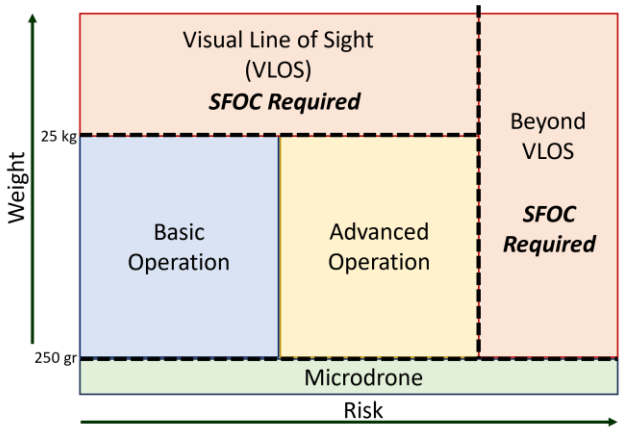


Figure 1 Category of Drone Operation in Canada. Modified from: Transport Canada

Flying drones under 250 grams (microdrones)

While flying drones under 250 grams in Canada does not require drone registration or a drone pilot certificate, it's crucial to operate your drone responsibly and adhere to all relevant laws, including the Criminal Code offences against Air or Maritime Safety, Breaking and Entering, Mischief, your province's trespass act, laws related to voyeurism and privacy. You also should maintain your drone below 122 m (400 ft), maintain visual line of sight, avoid advertised events, and avoid airports (Transport Canada).

Flying drones/RPAS between 250 grams and 25 kg

In Canada, drones weighing between 250 grams and 25 kg are subject to specific rules and regulations to ensure safety in the airspace. These regulations include:

- **Registration**: Drones weighing over 250 grams must be registered with Transport Canada (TC). This registration provides a unique identification number that must be affixed to the drone.
- **Pilot Certification**: Operators of drones weighing over 250 grams must obtain a Pilot Certificate. This involves passing a written exam that covers knowledge of Canadian aviation regulations, safe flying practices, and airspace rules.
- **Fly Safe and Respect Rules**: Drone operators must adhere to strict safety guidelines. These include flying within visual line of sight, avoiding people, animals, and buildings, and staying away from restricted airspace, airports, and emergency scenes.
- **Fly Below 400 Feet**: Drones should not exceed an altitude of 122 metres (approximately 400 feet) above ground level. This regulation helps prevent potential conflicts with manned aircraft.
- **No-Fly Zones**: There are specific areas, such as airports, military bases, and other sensitive locations, where drone flying is prohibited. Drones must not be flown in these no-fly zones. Please refer to the drone site selection tool to obtain this information.

- **Privacy and Consent**: Drone operators must respect individuals' privacy and obtain consent before capturing images or videos of people in private spaces.
- **Insurance**: While not mandated, having liability insurance for drone operations is strongly recommended to cover any potential damages or accidents.

Operation Categories for Drones between 250 grams and 25 kg

Table 1 Rules for basic and advanced drone operations

Condition	Basic Operation	Advanced Operation
Type of drone	• Any drone between 250 gr and 25 kg	• Any drone between 250 gr and 25 kg that is on the Transport Canada approved list
Airspace	• 5.6 km (3 nautical miles) away from airports • 1.9 km (1 nautical mile) away from heliports • NOT in controlled or restricted airspace	• Within 5.6 km (3 nautical miles) of an airport • Within 1.9 km (1 nautical mile) of a heliport • In controlled/restricted airspace with approval (from ATC, NAV CANADA)
Proximity to people (bystanders)	• Must fly more than 30 m (100 ft away) from bystanders • Must NOT fly over bystanders	• May fly up to 5 m (15 ft) away from bystanders when flying a drone approved for flying "**near people**" • May fly over bystanders when flying a drone approved for flying "**over people**"
Advertised events	• Must NOT fly at an "advertised event"	• Must NOT fly at an "advertised event"
Required documents	• Basic Operations Pilot Certificate	• Advanced Operations Pilot Certificate • Pass a personal Flight Review • Fly an approved drone

Table source: Don Joyce, 2019; Drone Information

Special Flight Operations Certificate for RPAS

Operating drones with a weight exceeding 25 kg, conducting flights beyond visual line of sight (BVLOS), or involving foreign pilots or any other conditions than those previously mentioned requires obtaining a Special Flight Operations Certificate (SFOC) for RPAS. To assess and manage associated risks, it is advisable to refer to the Specific Operations Risk Assessment Advisory Circular (AC) No. 903-001. This guidance is applicable for operations conducted in Canada and is adapted from the standards set by the Joint Authorities for Rulemaking of Unmanned Systems (JARUS), which are recognized in many other countries.

It is important to note that these regulations aim to ensure the safety of both airspace users and the general public. Failing to comply with these rules can result in fines or penalties. By following these

guidelines and practicing responsible drone operation, enthusiasts and professionals alike can enjoy the opportunities that flying drones offer while contributing to a secure and well-regulated airspace.

Flight Regulations Resources

- Canadian Aviation Regulations (CAR) Part IX
  https://laws-lois.justice.gc.ca/eng/regulations/sor-96-433/page-112.html?wbdisable=true
- Drone site selection tool
  https://nrc.canada.ca/en/drone-tool/
- RPAS 101 – A general knowledge guide for Canadian drone (RPAS) pilots
  http://www.aerialevolution.ca/rpas101/ or https://www.aerialevolution.ca/wp-content/uploads/2022/02/Nov-27-RPAS-101_EN-Final.pdf
- Getting a drone pilot certificate
  https://tc.canada.ca/en/aviation/drone-safety/drone-pilot-licensing/getting-drone-pilot-certificate
- Register your drone
  https://tc.canada.ca/en/aviation/drone-safety/registering-your-drone-overview
- Pilot certificate advanced
  https://tc.canada.ca/en/aviation/drone-safety/learn-rules-you-fly-your-drone/find-your-category-drone-operation#advanced
- Transport Canada Aeronautical Information Manual (TC AIM)
  https://tc.canada.ca/en/aviation/publications/transport-canada-aeronautical-information-manual-tc-aim-tp-14371
- General information for RPAS (drone) pilots
  https://tc.canada.ca/en/aviation/publications/knowledge-requirements-pilots-remotely-piloted-aircraft-systems-250-g-including-25-kg-operating-within-visual-line-sight-vlos-tp-15263
- Fly your drone safely and legally
  https://tc.canada.ca/en/aviation/drone-safety/learn-rules-you-fly-your-drone/flying-your-drone-safely-legally

Tips for Drone Imagery Surveys

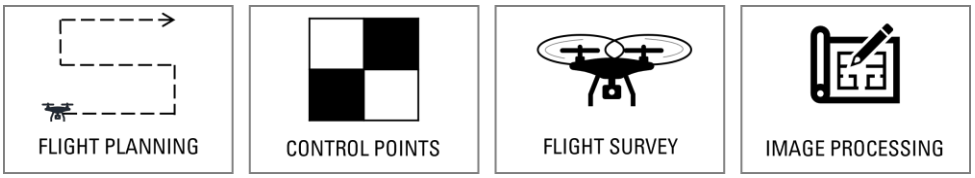


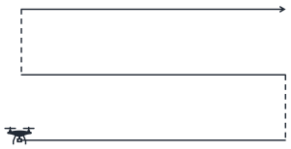
Figure 2 Drone Imagery Workflow

Flight Planning

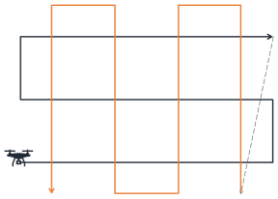
A drone flight plan consists of a predetermined set of instructions, which may include coordinates (flight path/waypoints), speed, altitude, direction, heading, gimbal actions, camera actions, and more. These instructions guide the drone to complete a flight and carry out a specific mission (AgEagle, 2020). Conducting flight planning also helps enable drones to be flown automatically.

Common Flight Paths

- **Area Survey**: The flight pattern for this survey follows a "boustrophedonic" or lawnmower pattern, where the flight path consists of parallel lines. This survey type is often combined with nadir imagery and is suitable for mapping large areas with minimal elevation changes.

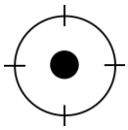


- **Crosshatch Survey**: This survey employs two perpendicular lawnmower flight patterns. It is often used in combination with oblique gimbal angles, making it ideal for sites with numerous vertical features or elevation changes.



- **Perimeter Scan**: This survey pattern involves circling the area or object, altering flight altitude vertically, and repeating the circling process. It is optimized when paired with gimbal angles set to a minimum of 35° at lower altitudes and 65° at higher altitudes. This method is especially effective for generating high-resolution 3D models of tall structures.

- **Inspection**: This type of survey does not follow a specific pattern or altitude; it is typically flown manually, often utilizing the FPV (first-person view) mode. It is ideal for inspecting structures and job sites. See drone inspections for some example applications.



- **Vertical Scan**: This flight pattern is akin to an area survey, but the drone's direction is vertical or at an angle, often with a slope. It is commonly employed for mapping vertical structures such as walls, facades, geological outcrops, and mining excavations.

- **Corridor Scan**: The flight path usually runs parallel to the corridor to capture data along linear features like highways, railways, utility lines, or pipelines.

Gimbal Angle

- **Nadir imagery** involves pointing the camera directly towards the ground, creating a 90° angle with the surface.
- **Oblique imagery** captures data at an angle other than 90°, typically recommended at 25-35°. This angle allows for the collection of side details, enhancing the quality of 3D models.

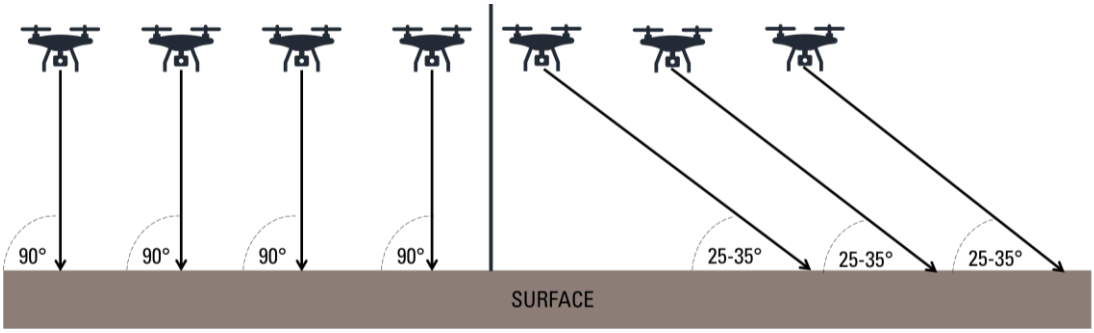


Figure 3 Nadir Imagery vs Oblique Imagery

Terrain Considerations

If your survey area has significant terrain variations, consider setting your mission to **terrain follow** (illustrated in the picture below). The drone will maintain its cruising altitude, for example keeping it 100 m above the ground level.

Figure 4 Example of drone altitude when using terrain follow setting.

Image Quality Check

Once the mission is completed, inspect the images that you have collected, check the quality and, if you use ground control point markers, check if you can see it clearly from your images. You can always redo the mission if there is an issue with the images that you have collected. Transfer the images to your personal cloud storage or to your computer to process it further.

Flight Planning Resources

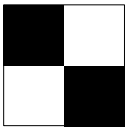
- Drone Flight Plans: How to Choose the Right Path
  https://ageagle.com/blog/drone-flight-plans-how-to-choose-the-right-path/
- Site Scan for ArcGIS
  https://support.esri.com/en-us/knowledge-base/faq-what-are-the-flight-modes-available-in-site-scan-fl-000022893
- Designing the Image Acquisition Plan
  https://support.pix4d.com/hc/en-us/articles/202557459-Step-1-Before-Starting-a-Project-1-Designing-the-Image-Acquisition-Plan-a-Selecting-the-Image-Acquisition-Plan-Type-PIX4Dmapper#label2
- Site Scan Flight Planning v4.0 Release
  https://www.esri.com/arcgis-blog/products/site-scan/imagery/site-scan-flight-planning-v4-0-release/

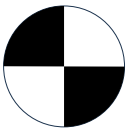
Ground Control Points

Ground Control Points (GCPs) are optional but advised in drone imagery and remote sensing applications. These points are positioned on the Earth's surface, their geographic coordinates accurately measured using high-precision GNSS (Global Navigation Satellite System) or surveying equipment. During data processing, GCPs serve as reference markers, facilitating the georeferencing of captured drone imagery, aligning it with real-world locations. This process enhances accuracy and precision, particularly in orthorectification, where terrain distortions are corrected.

GCP workflow

1. Position marker boards (as shown in the following images) or DIY markers crafted from materials like bucket lids, plywood, or vinyl, and painted black and white or a contrasting color relative to the surrounding survey area. Alternatively, you can mark points directly on the ground using spray paint. Typically, marker boards have dimensions of approximately 0.5 m x 0.5 m (2 ft x 2 ft), though this can vary depending on the ground sampling distance (GSD), which is the spacing between two consecutive pixel centers.





2. Utilize GNSS/GPS receiver devices to mark the points. Make sure you know the coordinate system used for your measurements. Then transfer the collected data to your desktop computer, saving it in a *.csv file. This file can be used as an input for Control Points in applications like ArcGIS Drone2Map.

Number of Points

Depends on the size and range of terrain of the survey area. If it is relatively flat and narrow area, at least 4-5 GCPs are recommended. If there are large terrain elevation variations, try to place markers near the highest and lowest areas of the site.

Spacing and Distribution of Control Points

GCPs should be evenly distributed across the survey area. To prevent a “doming” effect – distorted elevation data, it is better to place one or more GCPs inside the mapping area or in the center. It is advisable not to position GCPs precisely at the edges of the area to ensure adequate image coverage for subsequent processing.

Ground Control Resources

- Ground Control
  https://doc.arcgis.com/en/drone2map/latest/help/ground-control.htm
- Ground Control Points (GCPs)
  https://help.dronedeploy.com/hc/en-us/articles/1500004965282-Ground-Control-Points-GCPs-
- All about GCP
  https://civiltracker.xyz/all-about-ground-control-points/
- Optimize Ground Control Points placement
  https://www.propelleraero.com/blog/how-to-optimize-your-ground-control-point-placement-for-drone-surveying/; https://support.pix4d.com/hc/en-us/articles/202557489-Step-1-Before-Starting-a-Project-4-Getting-GCPs-on-the-field-or-through-other-sources-optional-but-recommended-PIX4Dmapper
- GCP in corridor mapping
  https://support.pix4d.com/hc/en-us/articles/202559299-Number-and-distribution-of-ground-control-points-GCPs-in-corridor-mapping
- Minimum Ground Control Points
  https://www.propelleraero.com/blog/real-reason-propeller-sells-aeropoints-sets-10/
- Importance of Ground Control Points
  https://www.pix4d.com/blog/why-ground-control-points-important/
- Improve your drone surveying accuracy
  https://enterprise-insights.dji.com/blog/ground-control-points
- Ground Sampling Distance (GSD) and how it affects your drone data
  https://www.propelleraero.com/ground-sample-distance-gsd-calculate-drone-data/
- A Guide to Using Ground Control Points for Surveying
  https://www.heliguy.com/blogs/posts/guide-to-using-ground-control-points

Flight Survey

Flight Preparation

1. **Check the weather**: Please consult your drone's operating manual for manufacturer recommendations. Different platforms may have varying capabilities in different weather

conditions. Another important weather consideration is cloud cover, as it can affect the image stitching process from shadows.

2. **Carry the appropriate documentation**: You must always have your proof of drone registration, your pilot certificate, your proof of recency of your pilot certificate (every 24 months), and your drone's operating manual available in print or digital format (for basic, advanced or operations that require SFOC). Obtain any necessary permissions from the landowner, site operator, or any required regulatory authorities.
3. **Know your airspace**: You can use the drone site selection tool website to locate controlled or restricted airspace.
4. **Know your surroundings**: Make sure to follow the proximity rules outlined in the preceding section and maintaining visual line of sight at all times unless you have SFOC for BVLOS.
5. **Have an emergency plan**: Most drones have the features to safely handle an emergency situation including loss of control, return to home, emergency stop and automatic stop.

Records

Procedural requirements based on the Canadian Aviation Regulations (CARs) include records containing a Journey Logbook (pilot and aircraft information, flight logs) and Technical Logbook (mandatory action, maintenance action, and modification or repair performed on the drone system). In the case of transferring ownership of the system to another person, these records should be transferred as well.

- **Pilot and aircraft information**: Name, address, contact information, pilot certificate information, and the aircraft/drone information (registration number, purchase date, approval for advanced operation if apply, operating manual).
- **Flight log**: Date, time, type of aircraft, location, flight crew information, flight time, flight note. It is also mandatory to record and report any incident occurred during the flight (e.g, including hitting a tree).
- **Maintenance activity for each aircraft**: Date, type of maintenance performed, supplier name/part numbers, and instructions followed (if maintenance is conducted by the operator).

Pre-Flight Checklist

- **Airspace**
  - □ Aviation restrictions and hazards: Refer to Table 1 Rules for basic and advanced drone operations, above.
  - □ Cleared Airspace for Your Flight: Ensure that your drone will not be in a Controlled Airspace or Restricted Airspace. Check the Drone site Selection tool, Designated Airspace Handbook, or NAV CANADA's Flight Supplement (if necessary).
- **System Check**
  - □ Functioning Drone: Inspect drone for damage, cracks, or other signs of potential failure, and ensure that the drone is fully charged.
  - □ Charged Remote Controller: Ensure no damage and that it is fully charged.

- □ Charged Mobile Device with preferred software to fly: If using devices (mobile or tablet) to perform the flight (e.g., DJI Fly, Site Scan for ArcGIS, Pix4DCapture, DroneDeploy Mapping), ensure the device is fully charged.
- □ Up to Date Firmware: Ensure that the firmware for drones, controllers, batteries, and flight computers are up to date.
- □ Batteries: Ensure there are adequate batteries for the flight, and they are all charged.
- □ Card with Adequate Space for your Images: Ensure there are adequate cards for your mission.
- □ Cable for Your Mobile Phone or Tablet: Ensure you have functioning USB cable, lightning or charging cord packed.
- □ Enough Propellers for Your Drone: Ensure you have enough propellers, and they are in working order.
- □ Connectivity: Check the connection between the controller and drone, ensure no obstacles that potentially disrupt the signal (such as big buildings, hills, tree) and electromagnetic interference (such as power lines, concrete, or metal objects).

Operation Procedures

- **Take-off and Launch Procedure**: Ensure all bystanders are clear, check on your monitor if everything is in order (GPS control, datalink strength, battery levels) while taking off (initial hover), and initiate the flight mission.
- **Landing Procedure**: Ensure the landing zone is clear, return the aircraft to the landing zone, turn the drone off and the ground control unit (remote, flight control app), and complete the flight log and post-flight maintenance check.
- **Emergency Procedure**: Provide information for medical issues or injury, standard procedure for aircraft fly-away, aircraft failure/crash/flight termination, control station failure, loss of command-and-control link.

Flight Survey Resources:

- Canadian Logbook Requirements for Drone Pilots
  https://coastaldrone.co/drone-logbook-requirements/
- Canadian Drone Pilot Logbook: Instructions
  https://www.youtube.com/watch?v=pNzBMjdKe2I
- Altitude University Pre, During, & Post Drone Flight Checklist
  https://www.altitude-university.com/blog/pre-flight-checklists.
- Flight Checklist
  https://www.dartdrones.com/wp-content/uploads/2017/10/flight_checklist_2017.pdf
- Set Up for Flying – Start Here!
  https://help.dronedeploy.com/hc/en-us/articles/1500004964262-Set-Up-for-Flying-Start-Here-
- How to do a drone survey: a step-by-step guide
  https://dronesurveyservices.com/how-to-do-a-drone-survey/
- Pre-Flight Checklist
  https://help.dronedeploy.com/hc/en-us/articles/1500004964802-Pre-Flight-Checklist;
  https://support.pix4d.com/hc/en-us/articles/10445879222557-Mission-checklist-PIX4Dcapture-Pro

Upload and Process your Images

You now have gained some information about how to conduct drone imagery survey safely and legally, the next step is diving into the ArcGIS Drone2Map tutorial (”Discover ArcGIS Drone2Map” document in this series). This tutorial will focus on the process of image processing, where you can transform the acquired drone images into 2D mapping products.

Production Date

The Education and Research Group at Esri Canada makes every effort to present accurate and reliable information. The Web sites and URLs used in this tutorial are from sources that were current at the time of production but are subject to change without notice to Esri Canada.

- Production Date: September 2023.