U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

May 19, 2015

Exemption No. 11617
Regulatory Docket No. FAA–2015–0549

Mr. Clayton Barrows
Founder
Aerial Precision Survey
10662 West First Court
Star, ID 83669

Dear Mr. Barrows:

This letter is to inform you that we have granted your request for exemption. It transmits our decision, explains its basis, and gives you the conditions and limitations of the exemption, including the date it ends.

By letter dated February 16, 2015, you petitioned the Federal Aviation Administration (FAA) on behalf of Aerial Precision Survey (hereinafter petitioner or operator) for an exemption. The exemption would allow the petitioner to operate an unmanned aircraft system (UAS) to conduct precision photogrammetry and crop scouting.

See Appendix A for the petition submitted to the FAA describing the proposed operations and the regulations that the petitioner seeks an exemption.

The FAA has determined that good cause exists for not publishing a summary of the petition in the Federal Register because the requested exemption would not set a precedent, and any delay in acting on this petition would be detrimental to the petitioner.

Airworthiness Certification

The UAS proposed by the petitioner are the 3D Robotics Inc. Aero−M and 3D Robotics X8+.

The petitioner requested relief from 14 CFR part 21, *Certification procedures for products and parts, Subpart H—Airworthiness Certificates*. In accordance with the statutory criteria provided in Section 333 of Public Law 112−95 in reference to 49 U.S.C. § 44704, and in consideration of the size, weight, speed, and limited operating area associated with the aircraft and its operation, the Secretary of Transportation has determined that this aircraft meets the conditions of Section 333. Therefore, the FAA finds that the requested relief from 14 CFR part 21, *Certification procedures for products and parts, Subpart H—Airworthiness Certificates*, and any associated noise certification and testing requirements of part 36, is not necessary.

The Basis for Our Decision

You have requested to use a UAS for aerial data collection. The FAA has issued grants of exemption in circumstances similar in all material respects to those presented in your petition. In Grants of Exemption Nos. 11062 to Astraeus Aerial (*see* Docket No. FAA−2014−0352), 11109 to Clayco, Inc. (*see* Docket No. FAA−2014−0507), 11112 to VDOS Global, LLC (*see* Docket No. FAA−2014−0382), and 11213 to Aeryon Labs, Inc. (*see* Docket No. FAA−2014−0642), the FAA found that the enhanced safety achieved using an unmanned aircraft (UA) with the specifications described by the petitioner and carrying no passengers or crew, rather than a manned aircraft of significantly greater proportions, carrying crew in addition to flammable fuel, gives the FAA good cause to find that the UAS operation enabled by this exemption is in the public interest.

Having reviewed your reasons for requesting an exemption, I find that—

- They are similar in all material respects to relief previously requested in Grant of Exemption Nos. 11062, 11109, 11112, and 11213;
- The reasons stated by the FAA for granting Exemption Nos. 11062, 11109, 11112, and 11213 also apply to the situation you present; and
- A grant of exemption is in the public interest.

Our Decision

In consideration of the foregoing, I find that a grant of exemption is in the public interest. Therefore, pursuant to the authority contained in 49 U.S.C. 106(f), 40113, and 44701, delegated to me by the Administrator, Aerial Precision Survey is granted an exemption from 14 CFR §§ 61.23(a) and (c), 61.101(e)(4) and (5), 61.113(a), 61.315(a), 91.7(a), 91.119(c), 91.121, 91.151(a)(1), 91.405(a), 91.407(a)(1), 91.409(a)(1) and (2), and 91.417(a) and (b), to the extent necessary to allow the petitioner to operate a UAS to perform aerial data collection. This exemption is subject to the conditions and limitations listed below.

Conditions and Limitations

In this grant of exemption, Aerial Precision Survey is hereafter referred to as the operator.

Failure to comply with any of the conditions and limitations of this grant of exemption will be grounds for the immediate suspension or rescission of this exemption.

1. Operations authorized by this grant of exemption are limited to the 3D Robotics Inc. Aero−M and 3D Robotics X8+ when weighing less than 55 pounds including payload. Proposed operations of any other aircraft will require a new petition or a petition to amend this exemption.

2. Operations for the purpose of closed-set motion picture and television filming are not permitted.

3. The UA may not be operated at a speed exceeding 87 knots (100 miles per hour). The exemption holder may use either groundspeed or calibrated airspeed to determine compliance with the 87 knot speed restriction. In no case will the UA be operated at airspeeds greater than the maximum UA operating airspeed recommended by the aircraft manufacturer.

4. The UA must be operated at an altitude of no more than 400 feet above ground level (AGL). Altitude must be reported in feet AGL.

5. The UA must be operated within visual line of sight (VLOS) of the PIC at all times. This requires the PIC to be able to use human vision unaided by any device other than corrective lenses, as specified on the PIC's FAA-issued airman medical certificate or U.S. driver's license.

6. All operations must utilize a visual observer (VO). The UA must be operated within the visual line of sight (VLOS) of the PIC and VO at all times. The VO may be used to satisfy the VLOS requirement as long as the PIC always maintains VLOS capability. The VO and PIC must be able to communicate verbally at all times; electronic messaging or texting is not permitted during flight operations. The PIC must be designated before the flight and cannot transfer his or her designation for the duration of the flight. The PIC must ensure that the VO can perform the duties required of the VO.

7. This exemption and all documents needed to operate the UAS and conduct its operations in accordance with the conditions and limitations stated in this grant of exemption, are hereinafter referred to as the operating documents. The operating documents must be accessible during UAS operations and made available to the Administrator upon request. If a discrepancy exists between the conditions and limitations in this exemption and the procedures outlined in the operating documents, the conditions and limitations herein take precedence and must be followed. Otherwise, the operator must follow the procedures as outlined in its operating documents. The operator may update or revise its operating documents. It is the

operator's responsibility to track such revisions and present updated and revised documents to the Administrator or any law enforcement official upon request. The operator must also present updated and revised documents if it petitions for extension or amendment to this grant of exemption. If the operator determines that any update or revision would affect the basis upon which the FAA granted this exemption, then the operator must petition for an amendment to its grant of exemption. The FAA's UAS Integration Office (AFS−80) may be contacted if questions arise regarding updates or revisions to the operating documents.

8. Any UAS that has undergone maintenance or alterations that affect the UAS operation or flight characteristics, e.g., replacement of a flight critical component, must undergo a functional test flight prior to conducting further operations under this exemption. Functional test flights may only be conducted by a PIC with a VO and must remain at least 500 feet from other people. The functional test flight must be conducted in such a manner so as to not pose an undue hazard to persons and property.

9. The operator is responsible for maintaining and inspecting the UAS to ensure that it is in a condition for safe operation.

10. Prior to each flight, the PIC must conduct a pre-flight inspection and determine the UAS is in a condition for safe flight. The pre-flight inspection must account for all potential discrepancies, e.g., inoperable components, items, or equipment. If the inspection reveals a condition that affects the safe operation of the UAS, the aircraft is prohibited from operating until the necessary maintenance has been performed and the UAS is found to be in a condition for safe flight.

11. The operator must follow the UAS manufacturer's maintenance, overhaul, replacement, inspection, and life limit requirements for the aircraft and aircraft components.

12. Each UAS operated under this exemption must comply with all manufacturer safety bulletins.

13. Under this grant of exemption, a PIC must hold either an airline transport, commercial, private, recreational, or sport pilot certificate. The PIC must also hold a current FAA airman medical certificate or a valid U.S. driver's license issued by a state, the District of Columbia, Puerto Rico, a territory, a possession, or the Federal Government. The PIC must also meet the flight review requirements specified in 14 CFR § 61.56 in an aircraft in which the PIC is rated on his or her pilot certificate.

14. The operator may not permit any PIC to operate unless the PIC demonstrates the ability to safely operate the UAS in a manner consistent with how the UAS will be operated under this exemption, including evasive and emergency maneuvers and maintaining appropriate distances from persons, vessels, vehicles and structures. PIC

qualification flight hours and currency must be logged in a manner consistent with 14 CFR § 61.51(b). Flights for the purposes of training the operator's PICs and VOs (training, proficiency, and experience-building) and determining the PIC's ability to safely operate the UAS in a manner consistent with how the UAS will be operated under this exemption are permitted under the terms of this exemption. However, training operations may only be conducted during dedicated training sessions. During training, proficiency, and experience-building flights, all persons not essential for flight operations are considered nonparticipants, and the PIC must operate the UA with appropriate distance from nonparticipants in accordance with 14 CFR § 91.119.

15. UAS operations may not be conducted during night, as defined in 14 CFR § 1.1. All operations must be conducted under visual meteorological conditions (VMC). Flights under special visual flight rules (SVFR) are not authorized.

16. The UA may not operate within 5 nautical miles of an airport reference point (ARP) as denoted in the current FAA Airport/Facility Directory (AFD) or for airports not denoted with an ARP, the center of the airport symbol as denoted on the current FAA-published aeronautical chart, unless a letter of agreement with that airport's management is obtained or otherwise permitted by a COA issued to the exemption holder. The letter of agreement with the airport management must be made available to the Administrator or any law enforcement official upon request.

17. The UA may not be operated less than 500 feet below or less than 2,000 feet horizontally from a cloud or when visibility is less than 3 statute miles from the PIC.

18. If the UAS loses communications or loses its GPS signal, the UA must return to a pre-determined location within the private or controlled-access property.

19. The PIC must abort the flight in the event of unpredicted obstacles or emergencies.

20. The PIC is prohibited from beginning a flight unless (considering wind and forecast weather conditions) there is enough available power for the UA to conduct the intended operation and to operate after that for at least 5 minutes or with the reserve power recommended by the manufacturer if greater.

21. Air Traffic Organization (ATO) Certificate of Waiver or Authorization (COA). All operations shall be conducted in accordance with an ATO-issued COA. The exemption holder may apply for a new or amended COA if it intends to conduct operations that cannot be conducted under the terms of the attached COA.

22. All aircraft operated in accordance with this exemption must be identified by serial number, registered in accordance with 14 CFR part 47, and have identification (N−Number) markings in accordance with 14 CFR part 45, Subpart C. Markings must be as large as practicable.

23. Documents used by the operator to ensure the safe operation and flight of the UAS and any documents required under 14 CFR §§ 91.9 and 91.203 must be available to the PIC at the Ground Control Station of the UAS any time the aircraft is operating. These documents must be made available to the Administrator or any law enforcement official upon request.

24. The UA must remain clear and give way to all manned aviation operations and activities at all times.

25. The UAS may not be operated by the PIC from any moving device or vehicle.

26. All Flight operations must be conducted at least 500 feet from all nonparticipating persons, vessels, vehicles, and structures unless:
    a. Barriers or structures are present that sufficiently protect nonparticipating persons from the UA and/or debris in the event of an accident. The operator must ensure that nonparticipating persons remain under such protection. If a situation arises where nonparticipating persons leave such protection and are within 500 feet of the UA, flight operations must cease immediately in a manner ensuring the safety of nonparticipating persons; and
    b. The owner/controller of any vessels, vehicles or structures has granted permission for operating closer to those objects and the PIC has made a safety assessment of the risk of operating closer to those objects and determined that it does not present an undue hazard.

    The PIC, VO, operator trainees or essential persons are not considered nonparticipating persons under this exemption.

27. All operations shall be conducted over private or controlled-access property with permission from the property owner/controller or authorized representative. Permission from property owner/controller or authorized representative will be obtained for each flight to be conducted.

28. Any incident, accident, or flight operation that transgresses the lateral or vertical boundaries of the operational area as defined by the applicable COA must be reported to the FAA's UAS Integration Office (AFS−80) within 24 hours. Accidents must be reported to the National Transportation Safety Board (NTSB) per instructions contained on the NTSB Web site: www.ntsb.gov.

If this exemption permits operations for the purpose of closed-set motion picture and television filming and production, the following additional conditions and limitations apply.

29. The operator must have a motion picture and television operations manual (MPTOM) as documented in this grant of exemption.

30. At least 3 days before aerial filming, the operator of the UAS affected by this exemption must submit a written Plan of Activities to the local Flight Standards District Office (FSDO) with jurisdiction over the area of proposed filming. The 3-day notification may be waived with the concurrence of the FSDO. The plan of activities must include at least the following:
    a. Dates and times for all flights;
    b. Name and phone number of the operator for the UAS aerial filming conducted under this grant of exemption;
    c. Name and phone number of the person responsible for the on-scene operation of the UAS;
    d. Make, model, and serial or N−Number of UAS to be used;
    e. Name and certificate number of UAS PICs involved in the aerial filming;
    f. A statement that the operator has obtained permission from property owners and/or local officials to conduct the filming production event; the list of those who gave permission must be made available to the inspector upon request;
    g. Signature of exemption holder or representative; and
    h. A description of the flight activity, including maps or diagrams of any area, city, town, county, and/or state over which filming will be conducted and the altitudes essential to accomplish the operation.

31. Flight operations may be conducted closer than 500 feet from participating persons consenting to be involved and necessary for the filming production, as specified in the exemption holder's MPTOM.

Unless otherwise specified in this grant of exemption, the UAS, the UAS PIC, and the UAS operations must comply with all applicable parts of 14 CFR including, but not limited to, parts 45, 47, 61, and 91.

This exemption terminates on May 31, 2017, unless sooner superseded or rescinded.

Sincerely,

/s/
John S. Duncan
Director, Flight Standards Service

Aerial Precision Survey

February 16, 2015

US Department of Transportation
Docket Management System
1200 New Jersey Ave., SE
Washington, DC 20590

Re: Exemption Request under Section 333 of the FAA Reform Act and Part 11 of the Federal Aviation Regulations

Dear Sir or Madam:

Pursuant to Section 333 of the FAA Modernization and Reform Act of 2012 and the requirements contained within 14 C.F.R. Part 11, Aerial Precision Survey requests an exemption from Federal Aviation Regulations (FARs) detailed below for the 3D Robotics Inc. (3DR) Aero-M and X8+ unmanned aircraft system.

The requested exemption would support an application for a commercial Certificate of Authorization to support agriculture and land management. The 3DR Aero-M and X8+ systems consists of a lightweight battery operated aircraft both weighing less than 7 pounds each, ground based PC and handheld controller, and associated communications and imaging equipment. A geo-referenced still camera is carried by the aircraft that allows it to conduct precision photogrammetry and crop scouting at resolutions necessary for precision agriculture and land management. The high-resolution data will provide farmers with detailed information of their crops allowing them to determine which areas may need more seeding, fertilizer, and water at a faster rate than current conventional methods. Having the data at a faster rate will help farmers maximize crop yields which will directly benefit the agricultural industry.

The unmanned aircraft will be operated in the field with both a Pilot in Command (PIC) and a ground-based Visual Observer (VO) in accordance with the FAA Policy N 8900.227 Section 14 "Operational Requirements for UAS" with the following additional operating restrictions:

1. All operations will occur in Class G airspace at no more than 400ft AGL
2. Operations will be operated over private property with the permission of the land owner
3. All required permits will be obtained from state and local government prior to operation
4. The aircraft will not be operated over urban or populated areas
5. The aircraft will not be operated within 5 NM of an airport or heliport
6. The aircraft will not be operated at air shows or over an open-air assembly of people
7. The aircraft will not be operated over heavily trafficked roads
8. Operations will be limited to day and visual meteorological conditions

9. Aircraft will remain within visual line of sight at no greater than ½ NM of the PIC at all times
10. While the aircraft is airborne, the VO will be positioned within voice distance to the PIC
11. PIC will file a NOTAM providing radial/DME, radius, and a date/time group for each operation

The PIC and VO will meet the requirements outlined in the FAA Policy N 8900.227 Section 16 Personnel Qualifications. The PIC and VO will perform maintenance on the system along with completing an in-service on maintenance and safety procedures as part of their initial training. We do not anticipate the need for a supplemental pilot, due to the simplicity of the system.

We submit that the combination of strict operation under the guidelines established in 8900.227 and the aircraft's light weight, historically demonstrated flight performance, and a fully qualified flight crew, the FAA can have confidence that the operation will have an equivalent or greater level of safety of a manned aircraft performing the same mission.

The name and contact information of the applicant are:

Aerial Precision Survey
Attn: Clayton Barrows
Ph: 208-353-4402
Email: clayton.barrows@aerialprecisionsurvey.com

The regulations from which the exemption is requested are as follows:

14 CFR Part 21
14 CFR 91.203
14 CFR 45.23, 45.29
14 CFR 91.9
14 CFR 61.113(a) & (b), 61.133(a)
14 CFR 91.109, 91.119
14 CFR 91.121, 91.151
14 CFR Subpart E (91.401-91.417)
FAA Policy 8900.227 Paragraph 16(c)(4) and Paragraph 16(e)(1)

We are prepared to modify or amend any part of this request to satisfy the need for an equivalent level of safety. We look forward to hearing from your office. Please contact us at any time.

Sincerely,

Clayton Barrows
Founder, Aerial Precision Survey

Appendices:

A. Exemption Request and Equivalent Level of Safety
B. Safety Guidelines
C. Safety Log
D. Maintenance Procedures X8+
E. Maintenance Procedures Aero-M
F. Flight Log
G. User Manual

EXEMPTION REQUESTS AND EQUIVALENT LEVEL OF SAFETY

Aerial Precision Survey requests an exemption from the following regulations as well as any additional regulations that may technically apply to the operation of the 3D Robotics Inc. (3DR) Aero-M and X8+

14 CFR Part 21, Subpart H: Airworthiness Certificates

This part establishes the procedures for the issuance of an airworthiness certificate. While the FAA continues to work to develop airworthiness standards for UAS, we request an experimental certificate be issued for the 3DR Aero-M and X8+ under either or both of the following provisions:

> 21.191 Experimental certificates
> Experimental certificates are issued for the following purposes:
> **(a)** ***Research and development***. Testing new aircraft design concepts, new aircraft equipment, new aircraft installations, new aircraft operating techniques, or new uses for aircraft.
> **(b)** ***Showing compliance with regulations***. Conducting flight tests and other operations to show compliance with the airworthiness regulations including flights to show compliance for issuance of type and supplemental type certificates, flights to substantiate major design changes, and flights to show compliance with the function and reliability requirements of the regulations.

Since the experimental certificate can be used for commercial purposes such as market surveys, sales demonstrations, and customer crew training, we would expect that an experimental certificate would permit for our commercial purpose as well.

The aircraft will not carry persons or property, will not carry fuel, and will only fly under strict operation requirements. Combined with the fact that the Aero-M weighs only 6.8 pounds and is constructed primarily out of foam, and the X8+ weighs 5.6 pounds and is composed primarily of aluminum and carbon fiber, we propose that the 3DR Aero-M and X8+ will be at least as safe, if not safer, than a conventionally certificated aircraft performing the same mission.

If an experimental airworthiness certificate is not appropriate for this application, then we request an exemption of 14 CFR Part 21, Subpart H, and the requirement for an airworthiness certificate in general, citing the equivalent level of safety outlined in the previous paragraph.

14 CFR 91.203(a) & (b) Civil aircraft: Certifications required.

The regulation provides that an airworthiness certificate, with the registration number assigned to the aircraft and a registration certificate must be aboard the aircraft. Additionally, subparagraph (b) provides that the airworthiness certificate be "displayed at the cabin or cockpit entrance so that it is legible to passengers or crew." At 6.8 and 5.6 pounds the 3DR Aero-M and X8+ are too small to carry documentation, they do not have an entrance, and are not capable of carrying passengers or a crew.

To obtain an equivalent level of safety and meet the intent of 91.203, we propose that documents deemed appropriate for this aircraft by the FAA will be located with the crew at the ground control station and available for inspection upon request. In order to identify the aircraft, we propose that the following information be permanently affixed to the aircraft via placard:

Manufacturer: 3D Robotics Inc.
Model: Aero-M or X8+
Serial Number:

Registered to:
Aerial Precision Survey
10662 W First Court
Star, ID 83669

If found please contact: (208) 353-4402

14 CFR 45.23 Display of marks; general and 45.29 Size of marks.

These regulations provide that each aircraft must display "N" and the aircraft's registration number in letters at least 3 inches high. Additionally, the aircraft must display the word "EXPERIMENTAL" in letters at least 2 inches high near the entrance to the cabin, cockpit, or pilot station. The 6.8 and 5.6 pound 3DR Aero-M and X8+ do not have an entrance in which the word "EXPERIMENTAL" can be placed, and may not have a registration number assigned to it by the FAA.

We propose to achieve an equivalent level of safety by including the word "EXPERIMENTAL" on the top of the aircraft, where the PIC, VO and others in the vicinity of the aircraft while it is preparing for launch will be able to see the designation. We feel that the permanent placard discussed in the previous paragraph will provide the aircraft's registration information should it be found on the ground. We will also display at the ground station a high contrast flag or banner that contains the words "Unmanned Aircraft Ground Station" in letters 3 inches high or greater. Since the aircraft will operate within ½ NM of the ground station, the banner should be visible to anyone that observes the aircraft and chooses to investigate its point of origin.

14 CFR 91.9 Civil aircraft flight manual, marking, and placard requirements.

This regulation provides that no person may operate an aircraft unless a current, approved flight manual is in the aircraft. We assume that the intent of this requirement is to ensure that flight manual information is available to the aircrew while operating the aircraft. We request an exemption to this requirement since the aircraft is not only too small to carry documentation, the documentation would not be available to the crew.
To obtain an equivalent level of safety and meet the intent of 91.9, we propose that a current approved Airplane Flight User Manual (appendix G) must be available to the flight crew at the ground station anytime the aircraft in in or operating for flight.

14 CFR 61.113 Private pilot privileges and limitations: Pilot in Command and 61.133 Commercial pilot privileges and limitations.

Section 61.113(a) states that "no person who holds a private pilot certificate may act as a pilot in command of an aircraft that is carrying passengers or property for compensation or hire; nor may that person, for compensation or hire, act as pilot in command of an aircraft."

Section 61.113(b) states that "A private pilot may, for compensation or hire, act as pilot in command of an aircraft in connection with any business or employment if : (1) The flight is only incidental to that business or employment; and (2) The aircraft does not carry passengers or property for compensation or hire."

Section 61.133(a) states that "(1) General. A person who holds a commercial pilot certificate may act as pilot in command of an aircraft – (i) Carrying persons or property for compensation or hire, provided the person is qualified in accordance with this part and with the applicable parts of this chapter that apply to the operation; and (ii) For compensation or hire, provided the person is qualified in accordance with this part and with the applicable parts of this chapter that apply to the operation."

We request exemption from sections 61.113(a) and (b), and section 61.133(a) because our proposed operations include commercial operations. Considering the size, weight and operating characteristics of 3DR Aero-M and X8+ in question, and considering that the operation of the UAS is to be confined to an area over private property with controlled access, Aerial Precision Survey requests an exemption from section 61.113(a) and (b) with the following conditions:

1. The Pilot in Command (PIC) of the UAS must hold at least a private pilot airman certificate and a third-class airman medical certificate and:
2. UAS operation will additionally require a Visual Observer (VO) and the VO must have acceptable vision such that they can maintain visual line of sight (VLOS) with the UAS at all times

Additionally, both the 3DR Aero-M and X8+ are equipped with an onboard autopilot for autonomous flight, capable of being (and required by the operating manual to be) monitored by a Ground Control Station (GCS) at all times. The onboard autopilot will also ensure flight operation is kept within the controlled airspace, including prohibiting operation above a defined maximum altitude.

14 CFR 91.109 Flight instruction; Simulated instrument flight and certain flight tests

The regulation provides that "No person may operate a civil aircraft that is being used for flight instruction unless that aircraft has fully functioning dual controls." The 3DR Aero-M and X8+ ground control stations are based on a ground based PC and hand-held controller that offers a trainer plug for a second set of "controls", both the student and instructor can, and will, operate the controls simultaneously. With both student and instructor having "hands-on" the controls during flight, we feel that this meets the intent of 91.109 and provides an equivalent level of safety.

14 CFR 91.119 Minimum safe altitudes: General

The regulation provides that over sparsely populated areas the aircraft cannot be operated closer than 500 feet to any person, vessel, vehicle, or structure. Since the aircraft will be operating at a maximum of 400 feet AGL, we cannot comply with this requirement.

To provide an equivalent level of safety we will only fly over private property with the permission of the land owner. The land owner will be briefed of the expected route of flight and the associated risks to persons and property on the ground. We maintain that due to the small size of the 3DR Aero-M and X8+, the hazard to persons, vessels, vehicles, and structures is not comparable to manned aircraft and should be considered in granting the exemption.

The aircraft will not be operated over congested areas nor over any open air assembly of persons. The aircraft will be operated at an altitude allowing, if a power unit fails, an emergency landing without undue hazard to persons or property on the surface.

14 CFR 91.121 Altimeter settings

The regulation provides that aircraft shall maintain cruising altitudes by reference to an altimeter setting available within 100 nautical miles of the aircraft. The aircraft will fly below 400 feet AGL and will not need to maintain hemispherical cruising altitudes in order to de-conflict with other aircraft. An appropriate altimeter measurement presented to the pilot should be above ground level and should be based on the barometric pressure at the point of launch. To provide an equivalent level of safety, the UAS's AGL altimeter will be set to zero on the ground prior to every flight. Since neither aircraft will fly more than 40 minutes, even rapid changes in barometric pressure will have limited effect on the safety of the flight.

14 CFR 91.151 Fuel requirements for flight in VFR conditions

The regulation provides that no person may begin a flight in an airplane under day-VFR conditions unless there is enough fuel to fly to the first point of intended landing and to fly after that for at least 30 minutes. We feel that the intention of this paragraph is to provide a reserve of energy as a safety buffer for go-arounds and other delays to landing.

The 3DR Aero-M and X8+ are battery operated and the maximum duration of flight from a single battery charge is 40 minutes for the Aero-M and 15 minutes for the X8+. Since the aircraft will never fly more than ½ NM from the point of intended landing, a full battery charge at launch will ensure that we meet the reserve energy requirement of this paragraph. We request an exemption to the word "fuel" and ask for an equivalent interpretation with the word "energy".

14 CFR Subpart E (91.401-91.417) – Maintenance, Preventive Maintenance, and Alterations

The regulation provides that the operator is primarily responsible for maintaining the aircraft in an airworthy condition, including compliance with part 39 and 43. Paragraphs 91.407 and 91.409 require that the aircraft be "approved for return to service by a person authorized under 43.7"

after maintenance and inspection. It is our intention that the PIC perform maintenance and inspection of the aircrafts and "be authorized to approve the aircrafts for return to service."

As provided in the attached Maintenance Procedures (appendices D & E), the PIC will ensure that the aircraft is in an airworthy condition prior to flight and conduct detailed inspections after every 10 hours. Maintenance will performed and maintained by the PIC per the operating manual, which contains instructions and procedures for inspecting, maintaining, and repairing the UAS. The PIC will document work performed in accordance with 91.417. We feel that due to the size, construction, and simplicity of the aircrafts, the PIC can ensure an equivalent level of safety.

8900.227 Paragraph 16(c) (4) PIC Medical. And Paragraph 16(e) (1) Observer Medical.

This policy provides that both the PIC and VO must have a valid FAA second-class medical certificate issued under part 67 in order to perform as a pilot or observer. The aircrafts weigh 6.8 and 5.6 pounds. Requiring the crew to meet the same medical requirements as a commercial pilot carrying passengers in a large aircraft is an unnecessary burden.

We propose that the minimum medical requirements be vision corrected to 20/20 and a valid, state-issued driver's license. Due to the size and weight of the aircraft, the greatest hazard of our proposed operation will be driving to the launch site. A licensed driver is medically qualified to operate a much larger vehicle. The 20/20 vision requirement will ensure that the PIC and VO can see and avoid air traffic. Given the unlikely event that both the PIC and VO become medically incapacitated while the aircraft is in flight, the 3DR Aero-M and X8+ will recover autonomously to the landing location designated prior to launch without crew intervention.

Safety Check Procedure

Safety check of aircraft performed prior to very flight.

Visual Inspection of Aircraft:

- Check motor/engine and mounting attached to the airframe;
- Study propellers / mounting hardware (tight) / rotor blades for chips and deformation;
- Check the landing gear for damage and function
- Look at complete airframe for any cracks or abnormalities
- Wire connections tight and secure

Procedure for Failed Visual Inspection of Aircraft

PIC will log failure cause in detail and ground aircraft. Aircraft will not be put back into service until PIC has rectified problem per manufacturer guidelines and recommendations. If problem cannot be rectified, aircraft will be returned to manufacturer for direct replacement.

Pre-arm Safety Checks which will prevent the vehicle from arming if any of a fairly large number of issues are discovered before take-off including missed calibration, configuration or bad sensor data. These checks help prevent crashes and fly-aways. The pilot will notice a pre-arm check failure because he/she will be unable to arm the copter and the LED will be flashing yellow.

Procedure for Pre-Arm Check Fail

Recognizing which Pre-Arm Check has failed using the GCS

1. Connect the Flight Controller to the ground station using a USB cable or Telemetry.
2. Ensure the GCS is connected to the vehicle (i.e. on Mission Planner and push the "Connect" button on the upper right).
3. Turn on your radio transmitter and attempt to arm the vehicle (regular procedure using throttle down, yaw right)
4. The first cause of the Pre-Arm Check failure will be displayed in red on the HUD window

Log Failure cause in detail and ground vehicle until PIC has rectified cause per manufacturer recommendation and guidelines. If cause cannot be rectified, aircraft will be returned to manufacturer for direct replacement.

Failure messages

RC failures (i.e. transmitter/receiver failures):

RC not calibrated : the radio calibration has not been performed. RC3_MIN and RC3_MAX must have been changed from their default values (1100 and 1900) and for channels 1 to 4, the MIN must be less than 1300 and the MAX greater than 1700.

Barometer failures:

Baro not healthy : the barometer sensor is reporting that it is unhealthy which is normally a sign of a hardware failure.

Alt disparity : the barometer altitude disagrees with the inertial navigation (i.e. Baro + Accelerometer) altitude estimate by more than 2 meters. This message is normally short-lived and can occur when the flight controller is first plugged in or if it receives a hard jolt (i.e. dropped suddenly). If it does not clear the accelerometers may need to be calibrated or there may be a barometer hardware issue.

Compass failures:

Compass not healthy : the compass sensor is reporting that it is unhealthy which is a sign of a hardware failure.

Compass not calibrated : the compass(es) has not been calibrated. the COMPASS_OFS_X, Y, Z parameters are zero or the number or type of compasses connected has been changed since the last compass calibration was performed.

Compass offsets too high : the primary compass's offsets length (i.e. sqrt(x^2+y^2+z^2)) are larger than 500. This can be caused by metal objects being placed too close to the compass. If only an internal compass is being used (not recommended), it may simply be the metal in the board that is causing the large offsets and this may not actually be a problem in which case you may wish to disable the compass check.

Check mag field : the sensed magnetic field in the area is 35% higher or lower than the expected value. The expected length is 530 so it's > 874 or < 185. Magnetic field strength varies around the world but these wide limits mean it's more likely the compass calibration has not calculated good offsets and should be repeated.

Compasses inconsistent : the internal and external compasses are pointing in different directions (off by >45 degrees). This is normally caused by the external compasses orientation (i.e. COMPASS_ORIENT parameter) being set incorrectly.

GPS related failures:

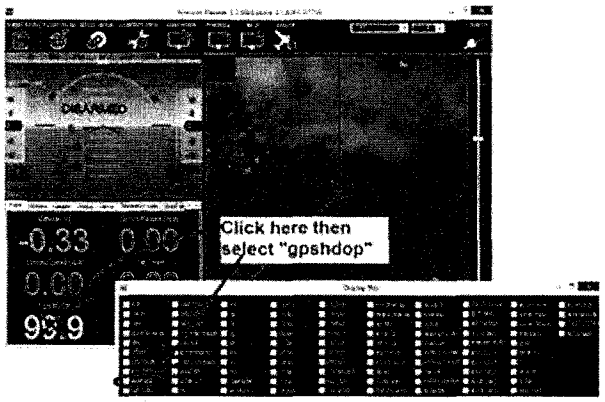
GPS Glitch : the GPS is glitching and the vehicle is in a flight mode that requires GPS (i.e. Loiter, PosHold, etc) and/or the circular fence is enabled.

Need 3D Fix : the GPS does not have a 3D fix and the vehicle is in a flight mode that requires the GPS and/or the circular fence is enabled.

Bad Velocity : the vehicle's velocity (according to inertial navigation system) is above 50cm/s. Issues that could lead to this include the vehicle actually moving or being dropped, bad accelerometer calibration, GPS updating at below the expected 5hz.

High GPS HDOP : the GPS's HDOP value (a measure of the position accuracy) is above 2.0 and the vehicle is in a flight mode that requires GPS and/or the circular fence is enabled. This may be resolved by simply waiting a few minutes, moving to a location with a better view of the sky or checking sources of GPS interference (i.e. FPV equipment) are moved further from the GPS. Alternatively the check can be relaxed by increasing the GPS_HDOP_GOOD parameter to 2.2 or 2.5. Worst case the pilot may disable the fence and take-off in a mode that does not require the GPS (i.e. Stabilize, AltHold) and switch into Loiter after arming but this is not recommended.

Note: the GPS HDOP can be readily viewed through the Mission Planner's Quick tab as shown below.



INS checks (i.e. Acclerometer and Gyro checks):

INS not calibrated : some or all of the accelerometer's offsets are zero. The accelerometers need to be calibrated.

Accels not healthy : one of the accelerometers is reporting it is not healthy which could be a hardware issue. This can also occur immediately after a firmware update before the board has been restarted.

Accels inconsistent : the accelerometers are reporting accelerations which are different by at least 1m/s/s. The accelerometers need to be re-calibrated or there is a hardware issue.

Gyros not healthy : one of the gyroscopes is reporting it is unhealthy which is likely a hardware issue. This can also occur immediately after a firmware update before the board has been restarted.

Gyro cal failed : the gyro calibration failed to capture offsets. This is most often caused by the vehicle being moved during the gyro calibration (when red and blue lights are flashing) in which case unplugging the battery and plugging it in again while being careful not to jostle the vehicle will likely resolve the issue. Sensors hardware failures (i.e. spikes) can also cause this failure.

Gyros inconsistent : two gyroscopes are reporting vehicle rotation rates that differ by more than 20deg/sec. This is likely a hardware failure or caused by a bad gyro calibration.

Board Voltage checks:

Check Board Voltage : the board's internal voltage is below 4.3 Volts or above 5.8 Volts.

If powered through a USB cable (i.e. while on the bench) this can be caused by the desktop computer being unable to provide sufficient current to the flight controller – try replacing the USB cable.

If powered from a battery this is a serious problem and the power system (i.e. Power Module, battery, etc) should be carefully checked before flying.

Parameter checks:

Ch7&Ch8 Opt cannot be same : Ch7 and Ch8 auxiliary switches are set to the same option which is not permitted because it could lead to confusion.

Check FS_THR_VALUE : the radio failsafe pwm value has been set too close to the throttle channels (i.e. ch3) minimum.

Check ANGLE_MAX : the ANGLE_MAX parameter which controls the vehicle's maximum lean angle has been set below 10 degrees (i.e. 1000) or above 80 degrees (i.e. 8000).

ACRO_BAL_ROLL/PITCH : the ACRO_BAL_ROLL parameter is higher than the Stabilize Roll P and/or ACRO_BAL_PITCH parameter is higher than the Stabilize Pitch P value. This could lead to the pilot being unable to control the lean angle in ACRO mode because the Acro Trainer stabilization would overpower the pilot's input.

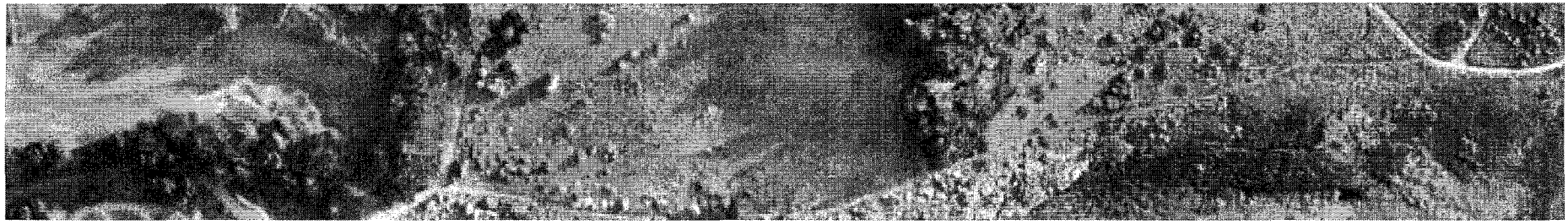
SAFETY TOG	PIC	DETAILS
NOTAM filed		
Verify transmitter battery charged to 12.0 – 12.6 v		Voltage reading:
Verify main battery charged to 16.5-16.8v		Voltage reading:
Check all surfaces for signs of damage, abnormalities, and overall condition; Inspect each boom to ensure they are in good structural condition and properly secured		
Check motor and mounting attached to the airframe		
Study propellers / mounting hardware (tight) / rotor blades for chips and deformation		
Check the landing gear for damage and function		
Test electrical connections, plugged in and secure		
Ensure photo / video equipment mounting system is secure and operational		
Check location of GPS equipment controlling the autopilot		
Check the IMU movements in the ground control software		
UAV / Drone is in a level location safe for takeoff		
All transmitter controls move freely in all directions		
All transmitter trims in neutral position		
All transmitter switches in correct position		
Transmitter throttle to zero		
Radio transmitter on		
Connect / power on battery to airframe		
Ensure led indicators and audible tones are correct		
Timer on (if applicable)		
Scan for nearby cars / people / animals		
Say "CLEAR!"		
Arm flight controller		
Increase throttle slightly listening for any abnormalities		
Short 20-30 second hover at 3-5 feet (listen for vibrations / loose items)		

- If any fails marked, PIC will perform and log maintenance in separate maintenance log sheet
- If any fails marked aircraft will be grounded until cleared by PIC

X8-M

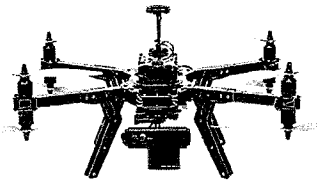
Operation Manual

Thank you for purchasing an X8-M! This manual contains important information about your aerial mapping platform. Please read these instructions before your first flight.



I Plan

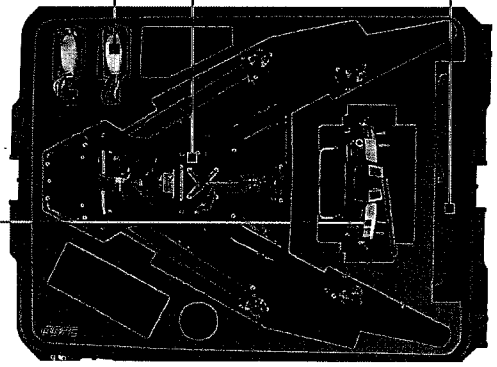
Parts



X8

batteries (2)

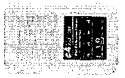
RC controller and accessories



registration card and Pix4D license key

ground station radio

micro-USB cable



charger and accessories

Android adapter cable

battery guard bag

Pixhawk micro-SD card adapter

propeller wrench

SF propellers

SFP propellers

spare UV filter

spare mounting nut

FPV/OSD System
If you selected to receive a FPV/OSD system, those components will be included with the X8's accessories. See page 27 for parts and instructions.

Flight Battery

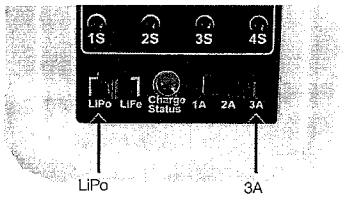
The X8 is powered by a rechargeable lithium polymer (LiPo) battery.
Charge the battery before your first flight.

Charging

1
Connect the charger to the power adapter cable and a wall outlet. Connect the red cable to the + port and the black cable to the - port.

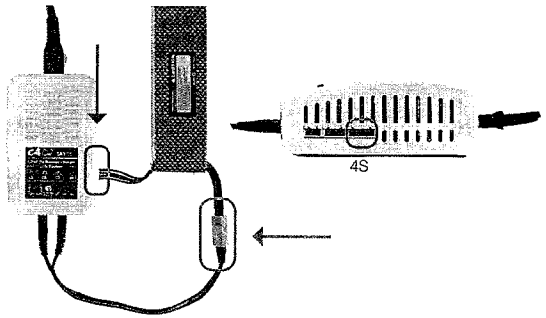
Charger with power cable and split-wire charging cable

2
Set the charger to LiPo and 3A.



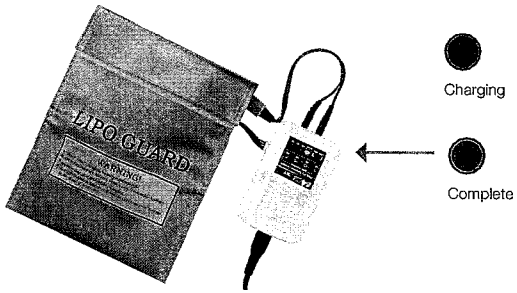
Charger settings

3
Connect the white connector to the 4S port, and join the two yellow connectors together.



Flight battery charging wiring

4
Secure the battery inside the guard bag, and charge until the status indicator displays green.



Charging in process

Safety

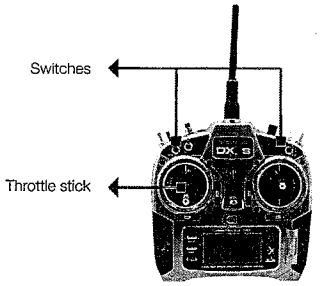
Flying with a low battery is a safety risk and can render the battery permanently unusable. Always fly with a fully charged battery.

Charge the battery using a designated LiPo balance charger only. Always monitor the battery while charging. Protect the battery from extreme heat, extreme cold, puncturing, and flammable surfaces. Always transport, charge, and store the battery in the guard bag.

Inspect the battery for damage before and after flying. If you observe any swelling of the package or the battery ceases to function, do not use the battery; locate your local battery recycling center, and dispose of the battery. In the US and Canada, visit call2recycle.org to find a location. Do not dispose of the battery in the trash.

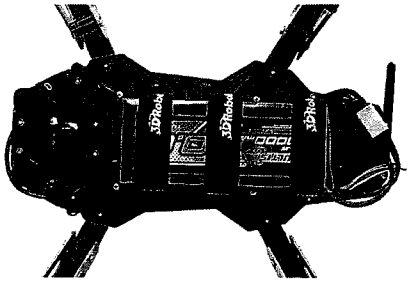
Powering the X8

1
Turn on the controller. To avoid triggering the controller's startup alarm, ensure that all switches are set back (away from you) and the throttle stick is set fully down.



RC controller

2
Attach the battery to the underside of the copter using the velcro straps, and join the yellow connectors.



It is important to establish communication before powering on the X8. Always turn on the controller before connecting the battery. When powering off the X8, disconnect the battery before turning off the controller.

Camera Setup

The X8 includes a Canon PowerShot S100 running the 3DR EAI script.

3DR EAI (Exposure-Aperture-ISO)

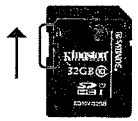
3DR EAI runs on the Canon Hacker Development Kit (CHDK), a powerful open-source tool that expands the functionality of Canon point-and-shoot cameras. 3DR EAI optimizes image exposure and integrates with the Pixhawk autopilot to enable distance-based imaging.

This software is designed to load off the camera's SD card, leaving the original Canon programming intact. The yellow switch on the side of the SD card allows you to lock or unlock the card. Lock the SD card to run 3DR EAI; unlock the SD card to save images to your ground station or to boot the camera with its original programming.

For more information about 3DR EAI, see page 36.

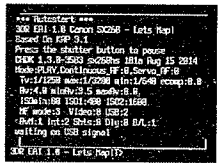
SD card locked
Load 3DR EAI

» Fly a mapping mission

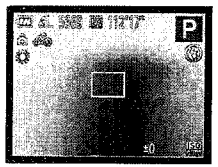


SD card unlocked
Load default Canon software

» View images on camera
» Save images to ground station
» Update script



Camera running 3DR EAI

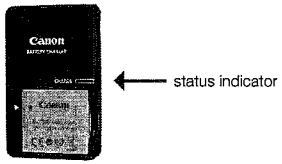


Camera running Canon software

⚠ Power off the camera before removing the SD card.

Charging

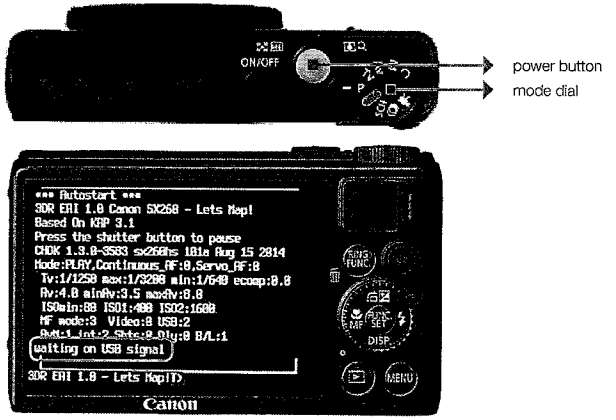
Charge the camera battery before your first flight. Once fully charged, insert the battery into the camera.



Canon battery charger

Starting a Mission

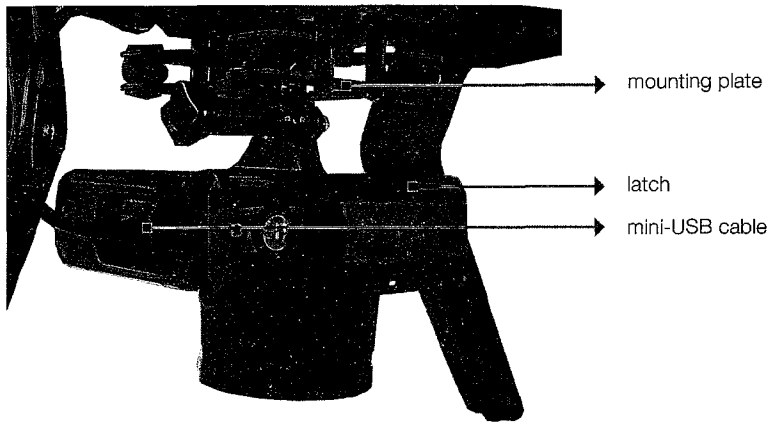
To prepare the camera to fly a mapping mission, ensure that the mode dial is set to *P (program)* mode. Power on the camera using the silver button on the top. 3DR EAI will start automatically, and you will see the script messages on the camera display. Check to see that the last line of the script reads *waiting on USB signal*. The camera is now ready to map!

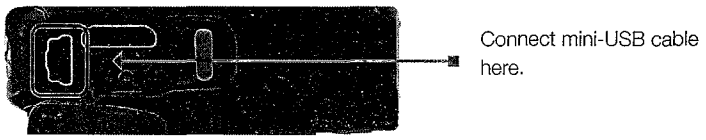


Camera ready to map: *waiting on USB signal*

Mounting

When the camera is ready to start the mission, open the latch, and insert the camera into the mount. Close the latch, and rotate the mount so the camera faces down. Connect the mini-USB cable to the camera.

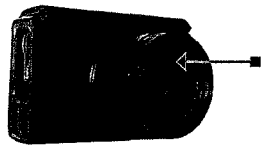




Camera (side)

The camera mount includes a cap to protect the UV filter during travel. Before you fly, remove the cap, and check that the filter contains no dirt particles or scratches that could affect image quality. If you notice any damage to the filter that could affect image quality, screw off the filter and replace with the extra filter provided with the X8.

Camera enclosure with cap



Camera enclosure with cap removed

Ground Station Setup

Mission Planner allows you to turn a Windows laptop into a full-featured ground station for configuring and monitoring autonomous missions. You will need to take this laptop into the field when you fly the mission. As part of the mission procedure, you will use the Pix4D Rapid Check to verify the quality of the image set before leaving the field.

Download Software

Mission Planner

Mission Planner is a full-featured ground station application for planning missions and monitoring the X8 in flight. Download Mission Planner from *3DR.com/download_software*.

If you already have Mission Planner installed, make sure you're running the most recent version: Select the *Help* tab and *Check for Updates*.

Mission Planner: *Help* tab

Pix4Dmapper LT 3DR Edition

Your license key for Pix4Dmapper can be found on the registration card inside the documents package.

Visit *mapper.pix4d.com/license-redeem* to create an account and redeem your license key; then visit *pix4d.com/download* to download Pix4Dmapper Discovery. Pix4D will automatically upgrade from the Discovery edition to the LT 3DR Edition (or Pro Edition if you selected to upgrade) when you log in to the program with your Pix4D account information.

Connect to Radio

To connect the X8 to Mission Planner, connect the ground station radio to the laptop, and power the X8.

1
Connect the ground station radio to your laptop using the micro-USB cable. Open Mission Planner.

Ground station laptop with radio connected

2
Select *57600* and *AUTO*, then select *CONNECT*. (When connecting directly to Pixhawk's micro-USB port, set the rate to 115200.)

Mission Planner *Connect* tool (top-right corner))

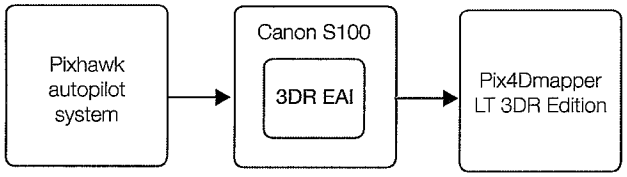
3
Select *Flight Data* to view live data from the X8.

Mission Planner *Flight Data* tab: connected to aircraft

Mission Planning

Operating Parameters

The X8 is a complete solution for creating high-resolution visual-spectrum aerial maps.



To create a map, the X8 flies an autonomous mission over the survey site, using the integration between the Pixhawk autopilot and custom-programmed camera to capture images at a consistent distance interval. Pix4Dmapper then stitches these images together into a georeferenced, orthorectified mosaic.

The accuracy of the map depends on the configuration of the mission. Planning a mission that captures high-quality images requires balancing the X8's operating parameters with the environmental factors at the survey site.

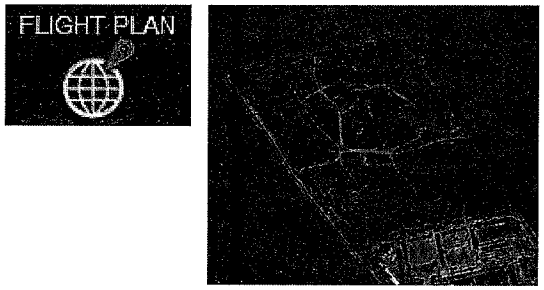
Operating Parameters

Camera	Canon S100
Camera Orientation	Landscape (top facing forward)
Operating Altitude	50-120 m
Default Altitude	60 m
Low-Wind Conditions	0-6 m/s
High-Wind Conditions	7-10 m/s
Maximum Wind Conditions	10 m/s
Operating Speed	1-17 m/s
Default Speed	5 m/s
Estimated Maximum Flight Time	14 min
Estimated Ground Resolution	2 cm/pixel
Estimated Maximum Survey Area	.1 km^2
Minimum Photo Interval	2 seconds

Load Maps

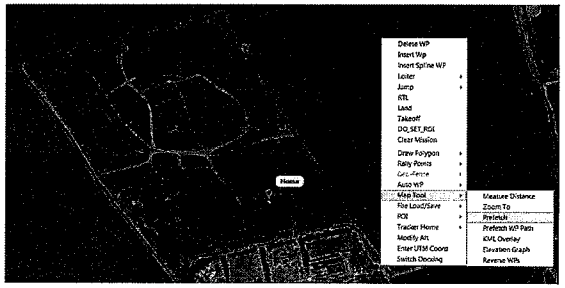
Mission Planner allows you to plan the mission away from the mapping location; however, it is important to assess the environmental conditions on site at the time of the mission and adjust the flight plan if necessary. Alternatively, you can plan the entire mission at the mapping location. To create or alter the mission, Mission Planner requires an Internet connection to access the maps. If you're unable to access the Internet on site, follow the instructions below to pre-fetch the maps within Mission Planner while you have Internet access.

1
Open Mission Planner, select ***Flight Plan***, and zoom to your flying location.



Mission Planner *Flight Plan* tab: zoom to mapping location

2
Right-click on the map, select ***Map Tool*** and ***Prefetch***, and accept the default prompts. Mission Planner will download the maps for the selected location to your computer.



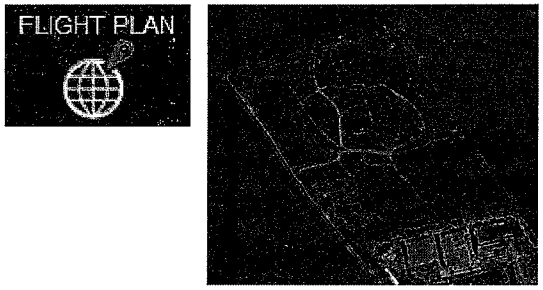
Mission Planner *Flight Plan* tab: Select *Prefetch*

3
Mission Planner will attempt to load the map data from the current level of zoom down to the closest level of zoom available. However, it can take hours to pre-fetch every level of zoom, and it is unlikely that the closer levels will be useful in planning the mission. To shortcut this process, check the slider on the right side of the map. The levels of zoom are represented by this slider from 0 (bottom) to 25 (top). Press the ESC key to skip levels of zoom at a greater detail than you need for mission planning.

Draw Polygon

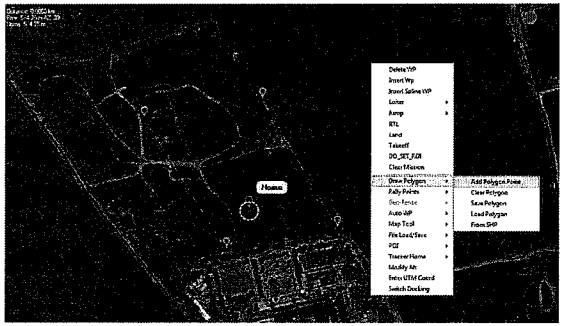
To begin planning the mapping mission, select the area you want to map using the *Polygon* tool. You'll be able to adjust the size and shape of the polygon later in the mission configuration process.

1
Select *Flight Plan*, and zoom to your mapping location.



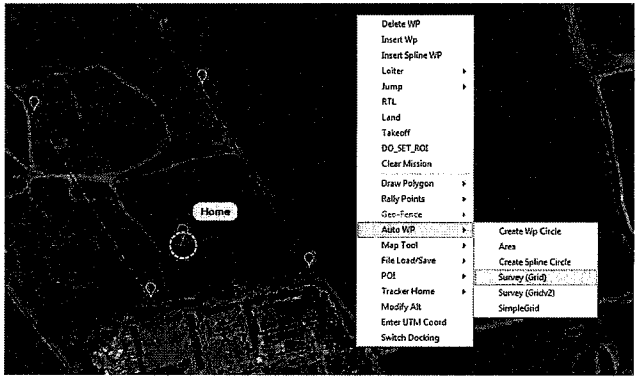
Mission Planner *Flight Plan* tab: zoom to mapping location

2
Right click on the map. Select *Draw Polygon* and *Add Polygon Point*. Click and drag to add points around the area you want to map.



Mission Planner *Flight Plan* tab: draw polygon

3
Right click on the polygon. Select *Auto WP* and *Survey (Grid)* to open the Survey Tool.



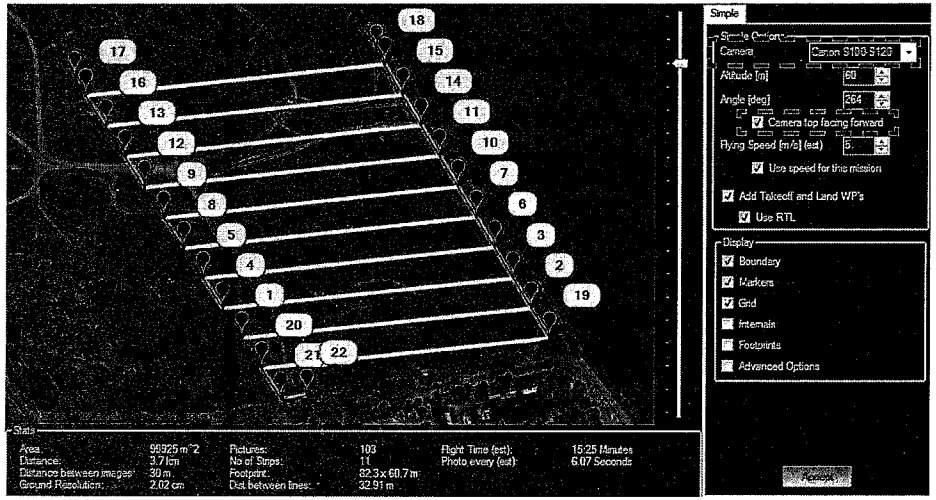
Mission Planner *Flight Plan* tab: open *Survey* tool

Units

The Survey Tool uses metric units. If your Mission Planner is set to imperial units, please change the settings to use metric to plan the mission. Support for imperial units in Mission Planner is coming soon; check *3DR.com/X8-M* for updates.

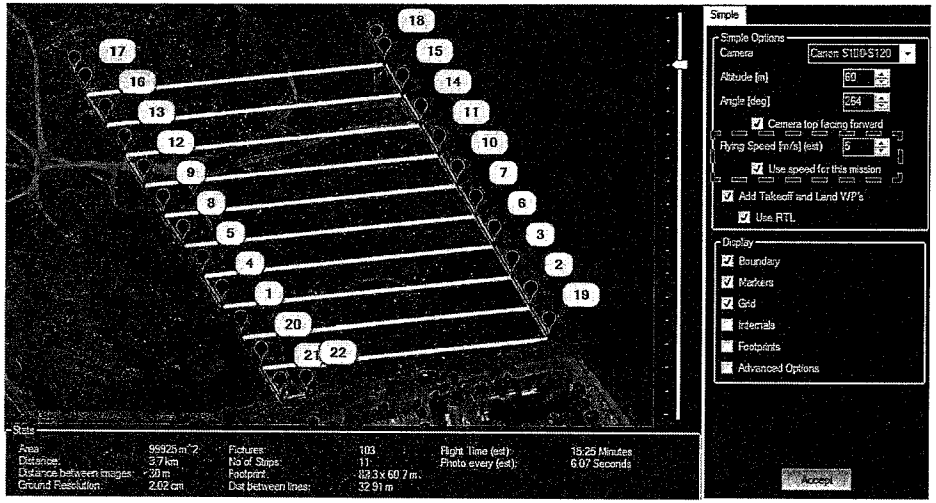
Configure Survey: Set Default Parameters

The Survey tool allows you to configure a mapping mission according to the X8's operating parameters and the current environmental conditions at the mapping location. First, set the default values for the X8.



Set Camera
Canon S100-S120

Set Camera Orientation
Check the option for ***Camera top facing forward.***



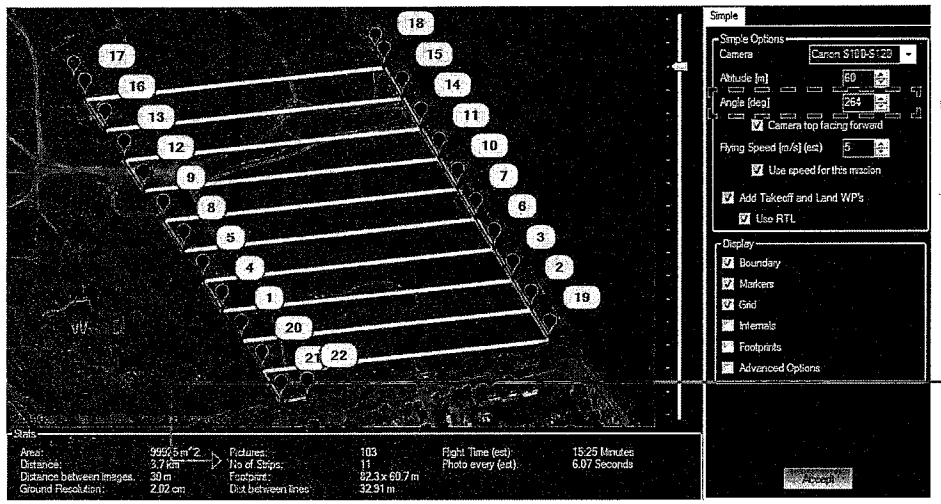
Set Default Speed
5 m/s

Apply Survey Speed
Check the option for ***Use speed for this mission.***
If unchecked, the mission will use the X8's default speed of 5 m/s regardless of the speed selected in the Survey Tool.

Mission Planner *Survey* tool

Configure Survey: Set Angle

Next configure the angle of the flight path for the current wind conditions.



Mission Planner *Survey* tool

Mission Planner Tip: Adjust Polygon
Click and drag the red polygon points to adjust the size and shape of the polygon from the Survey Tool.

Set Angle

Wind Direction

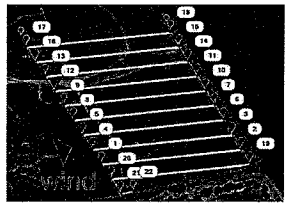
In environments with winds of less than 6 m/s, set the angle so that the X8 flies into the wind. In winds from 7-10 m/s, configure the flight path to travel perpendicular to the wind so the X8 flies cross-wind.

No. of Strips

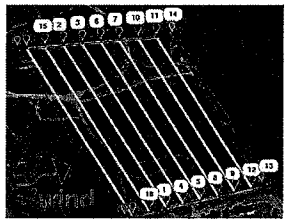
Adjust the angle so that the X8 makes as few turns as possible to complete its course. The ***No. of Strips*** parameter shows how many passes the X8 will make as you adjust the angle.

Review Wind Conditions On-Site

Always assess the wind conditions at your survey site at the time of the mission and adjust the mission accordingly.



Angle in low winds (1-6 m/s)

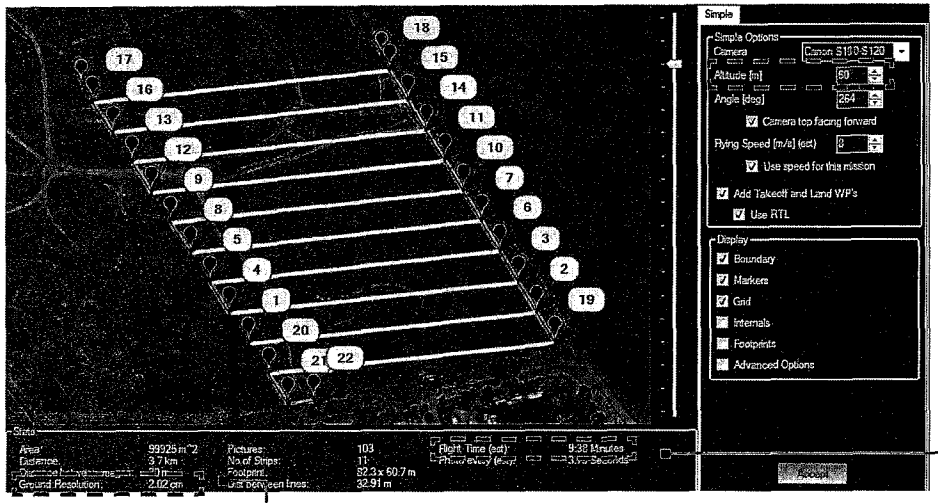


Angle in high winds (7-10 m/s)

Use caution when flying in winds over 10m/s. Mapping results may degrade as a result of inability to make headway or maintain appropriate groundspeed.

Configure Survey: Set Altitude

The survey altitude determines the duration of the mission and the ground resolution of the final map. Adjust altitude to balance flight time and power consumption with the current environmental conditions.



Mission Planner *Survey* tool

Set Altitude
Recommended altitude: 60 m
Operating altitude: 50-100 m

Increasing altitude decreases flight time, allowing you to cover more area per minute. Decreasing altitude improves ground resolution. Set the altitude to get the best ground resolution while keeping the flight time under 14 min and the altitude under 120 m.

Keep altitude below 120 m, and ensure that the altitude is appropriate for your flying area and local regulations.

Check Ground Resolution
Ground Resolution is the centimeters per pixel that you will have in the map and corresponds to the amount of detail that you will see.

To improve ground resolution by decreasing the number of centimeters per pixel, decrease altitude.

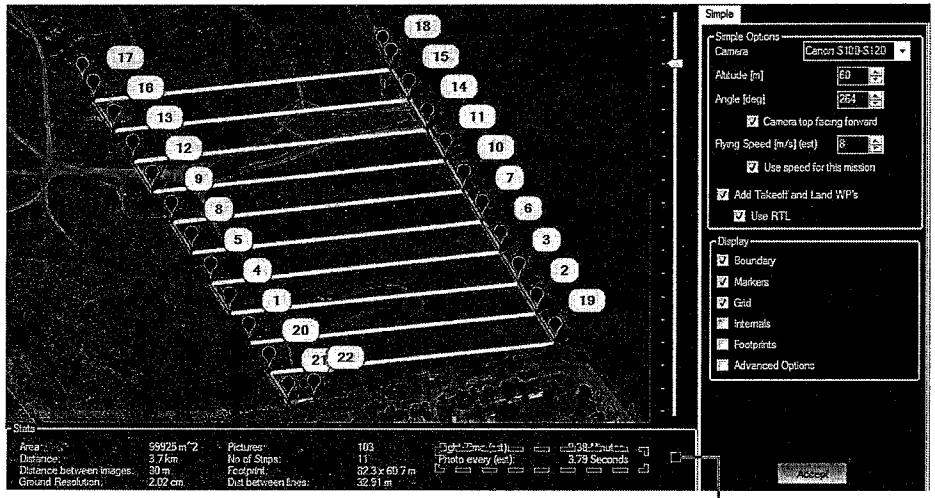
Check Flight Time
Flight Time estimates the duration of the mission. The total estimated flight time must be under 14 min for a fully charged X8 battery. To decrease flight time, increase altitude or speed.

High winds, humidity, high altitude, and extreme heat can affect power consumption and reduce flight time. Consider the environmental factors at your site when configuring flight time.

In this example, we increased speed to 8 m/s to keep flight time below 14 min while allowing for moderate wind conditions. When increasing speed, keep in mind that the increased power required to travel faster will impact flight time.

Configure Survey: Check Photo Interval

With the basic parameters in place, verify that the photo interval calculated from the altitude and speed complies with the operating parameters for the camera.



Mission Planner *Survey* tool

Check Photo Interval

Photo Every must be longer than 2 seconds for the S100 camera.

Altitude

Increasing altitude increases photo interval.

Keep altitude below 120 m, and ensure that the altitude is appropriate for your flying area and local regulations.

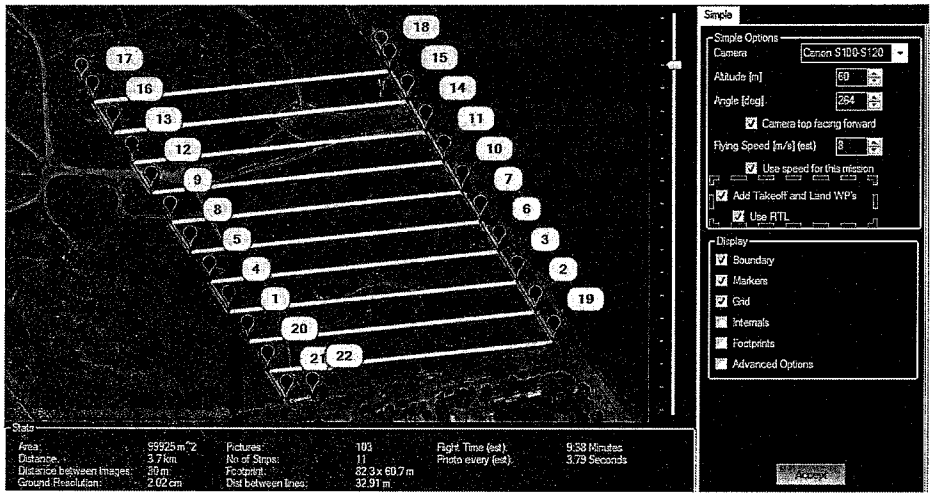
Speed

Decreasing speed increases photo interval.

Ensure that the ***Use speed for this mission*** option is checked.

Configure Survey: Set Takeoff and Landing

Now select a takeoff and landing pattern, either manual or automatic.



Mission Planner *Survey* tool

Takeoff and Land WP's

For automatic takeoff and landing (recommended)
Check the ***Add Takeoff and Land WP's*** option.
Check the ***Use RTL*** option.

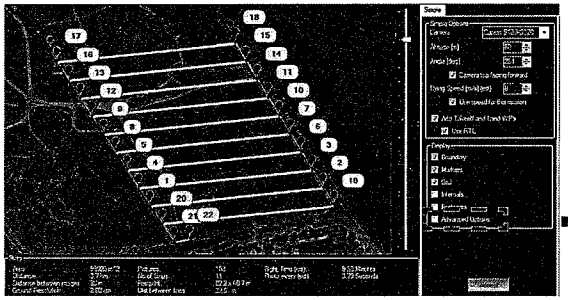
After initiating the mission, the X8 will automatically take off, climb to the survey altitude, and begin the mission. At the end of the mission, the X8 will automatically return to the launch point and land.

For manual takeoff and automatic landing
Uncheck the ***Add Takeoff and Land WP's*** option.
Check the ***Use RTL*** option.

Take off manually, and initiate the mission in flight. To end the mission, the X8 will land automatically at the launch point.

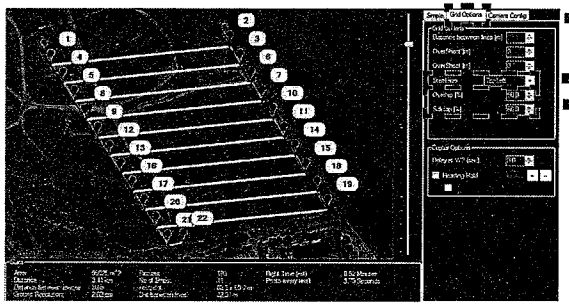
Configure Survey: Advanced Options

Mission Planner: Survey Tool



Check Advanced Options
to view the Survey Tool's advanced configuration options.

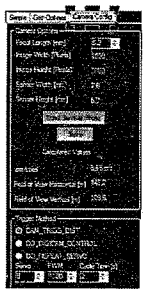
Survey Tool: Grid Options (Advanced)



Select Grid Options

Adjust StartFrom
During the mission, you will maintain contact with the X8 through the RC controller and ground station signals. If these signals are lost during flight, the X8 will respond with the assigned failsafe behaviors. See page 29. If your mission is likely to experience a loss of signal, it is best practice to start from the corner of the mission farthest from the launch point.

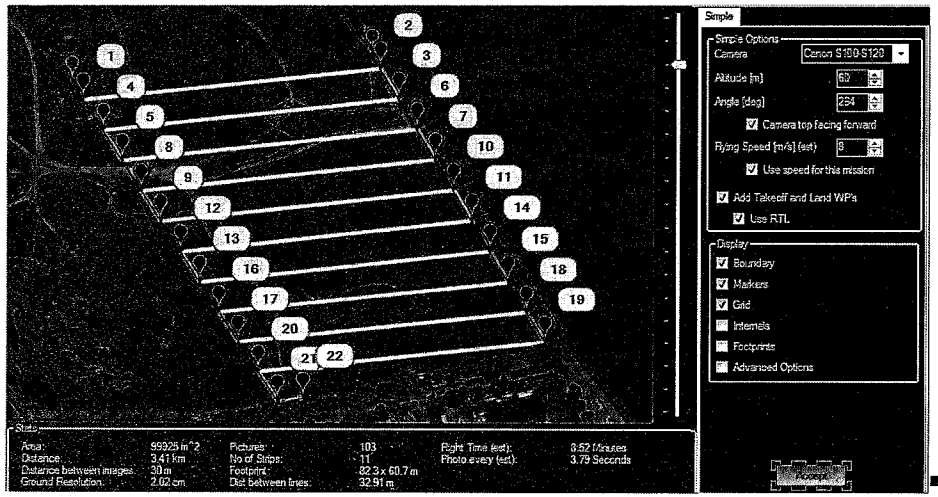
Adjust Overlap and Sidelap
Overlap and sidelap are set to 50% and 60%, respectively, by default. See page 35 for an in-depth discussion of these parameters.



Camera Config
The options under the Camera Config tab allow you to configure a camera other than the S100 and won't be used for operating the X8.

Configure Survey: Accept Survey

Before accepting the survey, check that the mission complies with the X8's operating parameters. Once you accept the survey, you will not be able to edit it directly by re-opening the Survey Tool. If you need to adjust the survey, clear the mission (right click, select Clear Mission), and repeat the survey configuration process.



Operating Parameters

Camera
Canon S100-S120

Altitude
50-100 m

Camera top facing forward
checked

Flying speed
1-17 m/s

Use speed for this mission
checked (optional if speed set to default speed of 5 m/s)

Photo Every
greater than 2 s

Flight time
under 14 min depending on environmental conditions

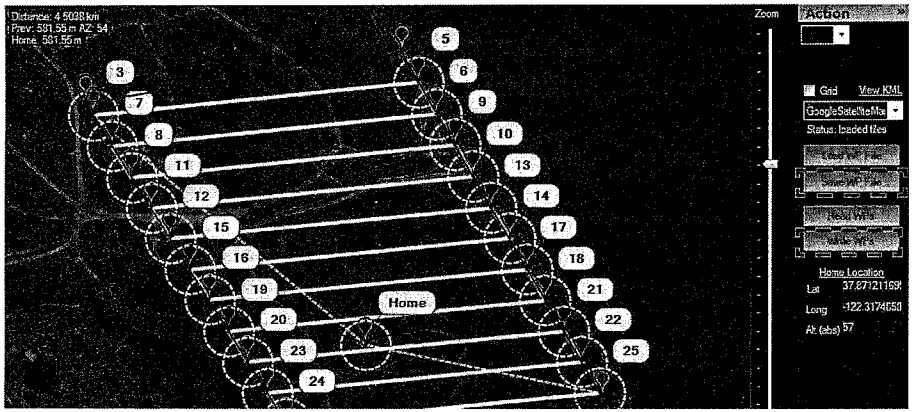
Accept
Select ***Accept*** to save the mission.

If Mission Planner prompts you for a home altitude, enter the altitude that you specified in the Survey Tool.

Do not accept the mission if any of the parameters exceed the X8's operating limits.

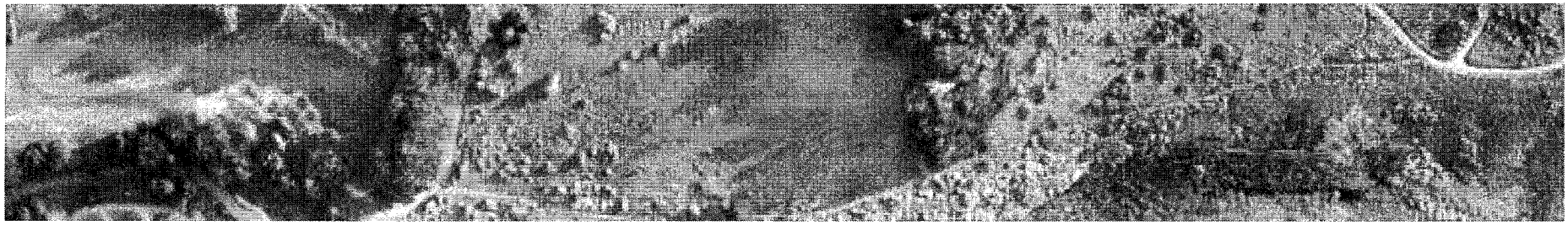
Save and Write Mission

On the Flight Plan screen, save the waypoint file to your computer and write the mission to the X8.



Select Save WP File
to save the mission file to your computer. To repeat this mapping mission, load the saved WP file from your computer.

Select Write WPs
to save the mission to the X8.



2 Fly

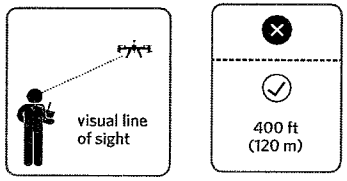
Safety

To ensure safe and successful flying, familiarize yourself with the safety information on this page. Always fly in accordance with your location regulations and these best operating practices.

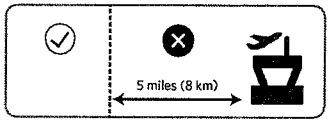
Before you fly, determine the boundaries of your safe flying area. If the X8 moves outside the designated area or exhibits instability in flight, switch to altitude hold mode and land the copter manually.

The X8 will not avoid obstacles on its own, including during missions. As the operator, it's your job to recognize and avoid obstructions while flying. Always be ready to regain manual control of the copter in the event of an unsafe situation.

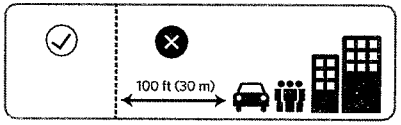
Location



Always fly below 400 ft (120 m) and within your visual line of sight. Don't let the X8 get too far away from you; make sure you can always see its orientation. Don't fly in low light, heavy wind, rain, or other conditions that might impede visibility.



Always fly at least 5 miles (8 km) away from airports and other areas where pilots operate manned aircraft.



Always fly at least 100 feet (30 m) away from people, vehicles, and buildings. Make the safety of people and property your first priority!

Propeller

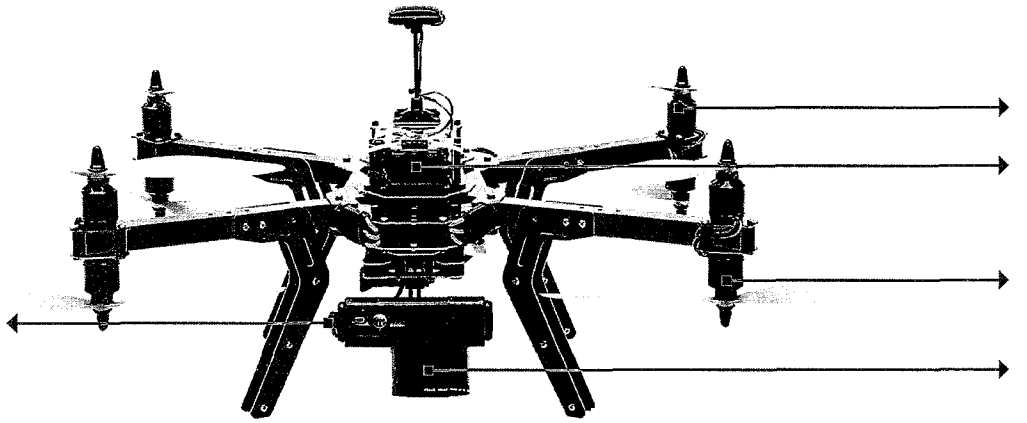
Spinning propellers can cause serious injury. The safety button indicates the status of the motors to help you prevent hazardous contact with the X8's high-speed propellers.

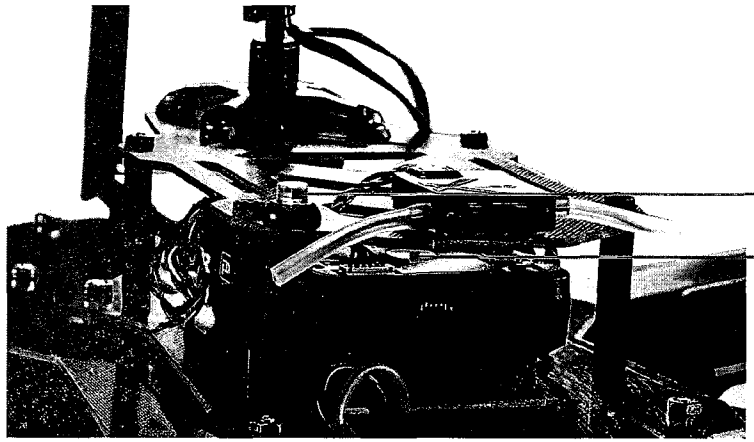
- When the X8 is powered on, the safety button will blink red, indicating that the motors are inactive and the propellers are safe to handle.
- When you're ready to fly, press and hold the safety button until it shows solid red. This indicates that the motors are active and the propellers can spin if armed. To make the propellers safe to handle again, press and hold the safety button until it blinks red.

You can find more safety tips throughout these instructions where you see this yellow box.

Aircraft Operation

Components



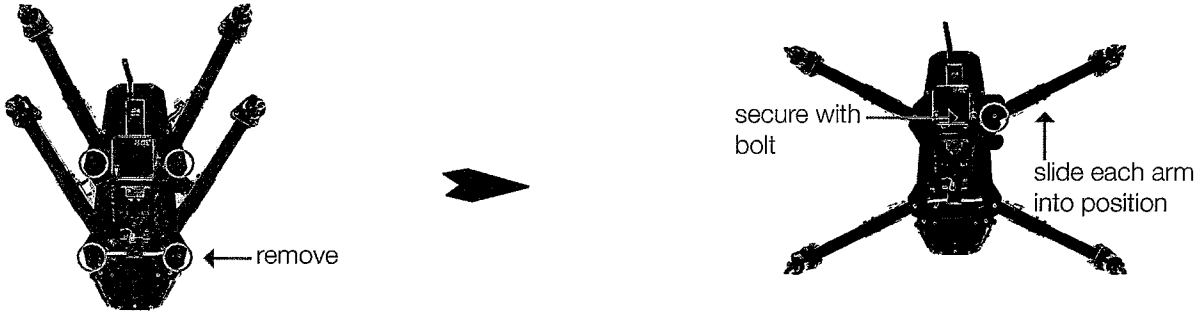


Assembly

The X8 arrives in travel configuration. Complete these steps to prepare the copter for flight.

Arms

Remove the bolt and nut outside each arm. Rotate the arm into position, insert the bolt through the plates and the arm, and secure the arm in place with the nut.

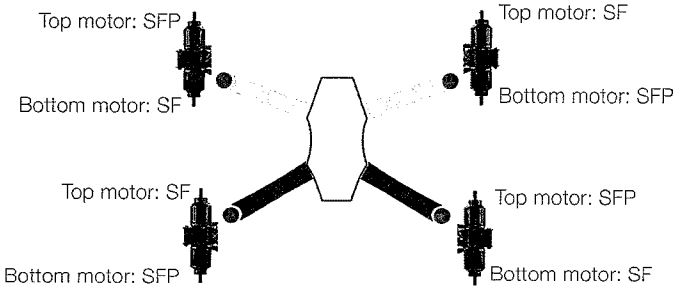


travel position

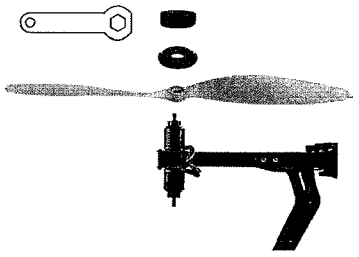
flight position

Propellers

Remove the nuts and washers from the motors. Add SFP propellers and SF propellers as marked below with the writing on the propellers facing towards the sky. This will be a tight fit; apply pressure and twist the propeller onto the shaft.



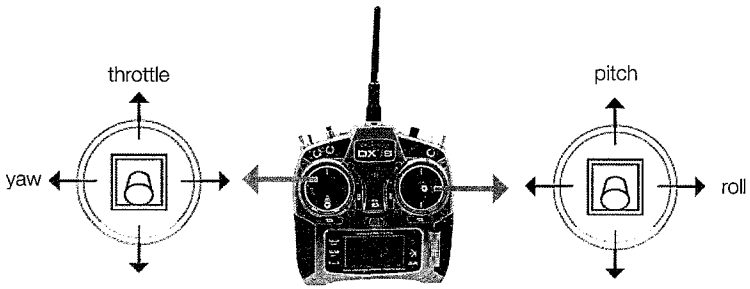
Place the washer over the propeller, and secure the nut tightly on top using the propeller wrench.



Ensure writing on all propellers faces the sky.

Controls

Fly the X8 manually using the RC controller.



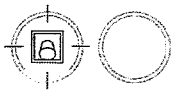
Throttle: Move the left stick forward and backward to control altitude and acceleration.

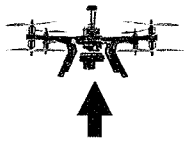
Yaw: Move the left stick horizontally to rotate and control orientation. Navigate by orienting the X8 with the blue arms facing forward.

Pitch: Move the right stick vertically to fly forward and backward.

Roll: Move the right stick horizontally to fly to the left and to the right.

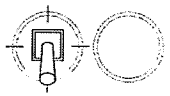
throttle up

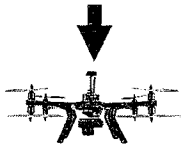




Increase speed and altitude.

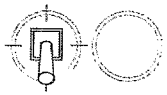
throttle down

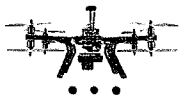




Decrease speed and altitude.

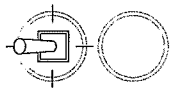
throttle fully down

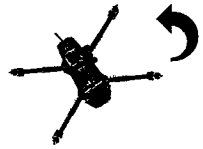




Land.

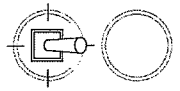
yaw left





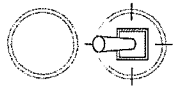
Rotate counterclockwise.

yaw right



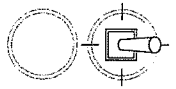
Rotate clockwise.

roll left



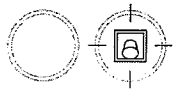
Fly to the left.

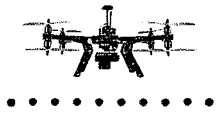
roll right



Fly to the right.

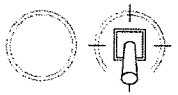
roll and pitch center

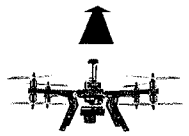




Automatically level.

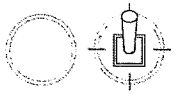
pitch up

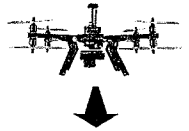




Fly forward.

pitch down





Fly backward.

Modes

Auto - *fly a mission*
Fly an autonomous mission. This is the mode that the X8 will use to create the map.

Altitude hold - *assisted manual control*
Altitude hold mode provides manual control of roll, pitch, and yaw, while allowing the autopilot to maintain the current altitude automatically. Set the left stick to center, and the copter will automatically maintain the current altitude. Raise the throttle stick above center to increase altitude (and to take off), and lower the throttle stick below center to decrease altitude. Adjust altitude and orientation with the left stick, and navigate with the right stick.

Loiter - *hover*
With automatic autopilot control of altitude, position, and orientation, loiter is the easiest way to fly. Just release the sticks and the copter will hover in place.

Return to launch (RTL) - *recall and land*
Activate RTL during the mission to end your flight automatically. RTL commands the X8 to achieve a minimum altitude of 15 meters, return to the launch point, hover for five seconds, and land. Use the right stick to adjust the position of the X8 during landing. After landing, the X8 will automatically disarm after a few seconds.

Stabilize - *full manual control*
Stabilize allows full manual control of altitude, position, and orientation without autopilot assistance.

To select a flight mode:

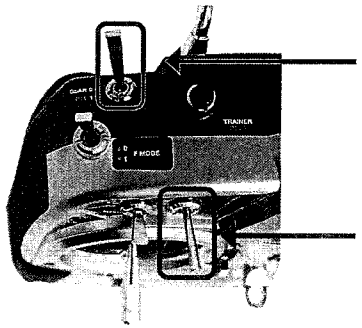
First, set the GEAR/MIX switch to select a set of modes. Then use the FLAP/GYRO switch to 0, 1, or 2 to select a specific mode.

With GEAR/MIX set to **GEAR**,

set FLAP/GYRO to: 0 for **Stabilize**
1 for **Loiter**
2 for **Auto**

With GEAR/MIX set to **MIX**,

set FLAP/GYRO to: 0 for **Stabilize**
1 for **Altitude hold**
2 for **RTL**



RC controller (top)

Pre-flight Checks

Visual Check

Before flying, examine the X8 to verify the following:

» All propellers are tightly attached in the correct order with the writing on each propeller facing the sky.

» All propellers can spin without obstruction.

» The antenna is oriented vertically.

Test Flight

Before flying the mission, fly a brief test flight to verify that the X8:

» Responds to controls correctly in stabilize mode.

» Holds position in loiter mode.

» Correctly executes a return-to-launch command.

LED Indicators


Initializing, please wait


Acquiring GPS, please wait


Autopilot ready, GPS locked


Armed


Loss of RC signal, automatic landing


Low battery, automatic landing


Loss of GPS signal, automatic landing


System error, see troubleshooting guide

GPS Lock

Auto, RTL, and loiter modes requires GPS lock. When powered, the autopilot will automatically search for GPS lock. If you plan to use auto, RTL, or loiter modes during your flight, ensure that the autopilot acquires GPS lock before takeoff, indicated by a blinking green status LED.

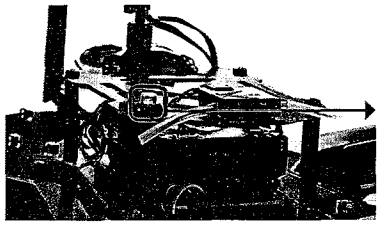
Tones

Visit 3DR.com/X8-M to listen to Pixhawk's status tones.

Arming and Disarming

Arming and disarming are important steps that must be completed before takeoff and after landing. There are two steps to arming the X8: the safety button and the throttle stick.

Before arming, check the status LED. Before you fly, wait for the autopilot to acquire GPS lock. The LED will flash blue while the X8 acquires GPS; this can take a few minutes. Once you see the flashing green LED, the autopilot has acquired GPS lock.



●●●● Initializing, please wait.

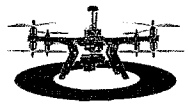
○●○● Autopilot ready, no GPS

○●○● Autopilot ready, GPS locked

Pre-arm check failure, see page 39.

Arming

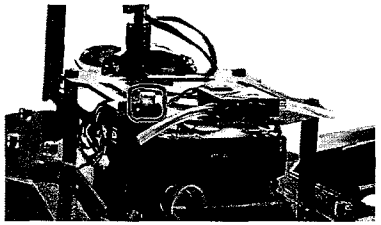
1
When you're ready to fly, place the copter at a clear launch point, with the blue arms facing away from you.



2
Press and hold the safety button until it displays solid red. This indicates that the X8 is now active. Stand back!

●○●○ Motors inactive, safe to handle

●●●● Motors active, deactivate before handling



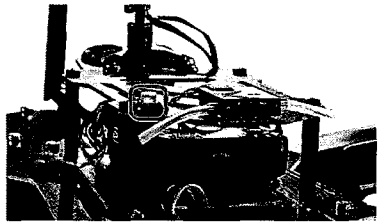
3
To arm the motors, hold the left stick down/right until the motors spin.

> The arming and disarming procedures ensure that you can safety start and stop motors without risk of injury.
>
> The X8's motors will spin when armed! Make sure the propellers are clear of any obstructions, including your hands, before arming.
>
> Do not handle the propellers or pick up the copter while the safety button is active (solid red).

Disarming

1
To disarm the motors, hold the left stick down/left until the motors stop.

2
Press and hold the safety button until it blinks red. The motors are now inactive, and the X8 is safe to handle.



FPV System Operation

If you selected to receive an optional FPV/OSD system, the components are pre-installed into the X8 to transmit on-board video.

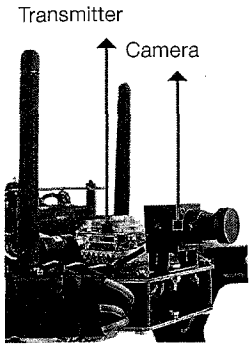
Parts

AV receiver

Antenna

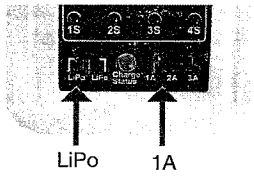
Receiver cables

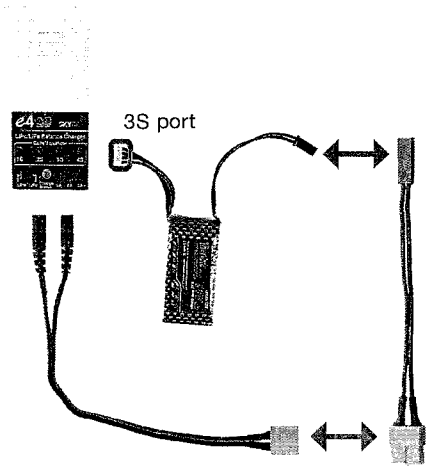
Batteries (1 plus 1 spare)



1 Charge battery

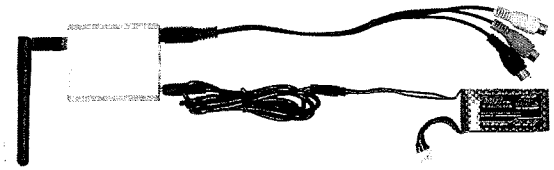
Charge both batteries before your first flight. Set the charger to LiPo and 1A. Connect the white battery connector to the 3S port, and connect the XT60-JST charger adapter to the red battery connector and yellow
charger connector.





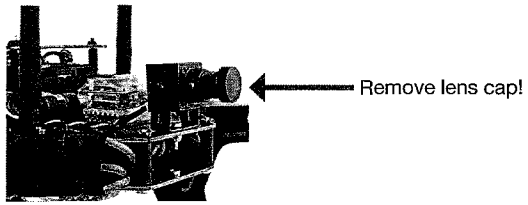
2 Wire and power receiver

Attach an antenna to the receiver. Connect the AV output cable to either receiver AV OUT port. Connect the RC power cable to the receiver DC IN port, and attach a battery to the red connector.



3 Remove lens cap

The video transmitter is powered by the main flight battery and will automatically turn on when the X8 is powered. To turn off the transmitter, disconnect the red JST connector. Remove the lens cap from the camera before takeoff.



4 Viewing video

When using a 3DR Black Pearl Monitor to view your video, set the mode to *DIV* (M button changes modes), the channel to *8* (+ and - buttons), and the band to *E* (press the power button to access the menu).

For more information about configuring the FPV/OSD system, visit *3DR.com/X8-M*.

Flying Mapping Missions

Takeoff Checklist

Before flying the mission, check the following:

» Camera is on with mission script ready and is secured into the mount with the mini-USB cable connected and the cap removed.

» X8 is powered and connected to the ground station with all pre-flight checks passed.

» The survey mission has been adjusted to account for present environmental conditions and saved to the X8.

Initiating

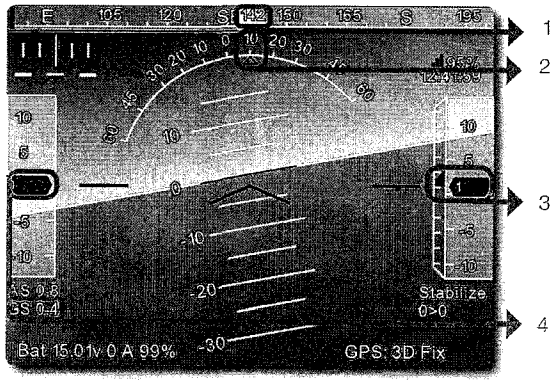
For automatic takeoff, arm the X8 in stabilize mode. Switch to auto mode, and raise the throttle to initiate the mission.

For manual takeoff, initiate the mission in flight by switching to auto mode.

Monitoring

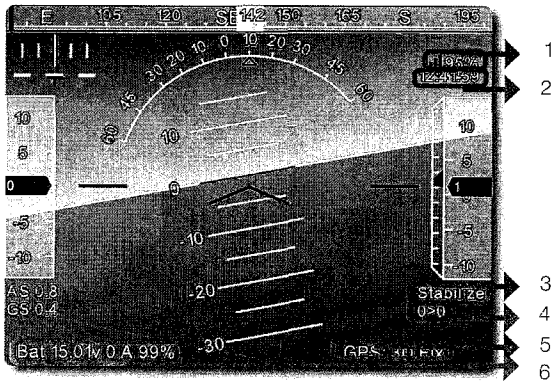
Monitor the X8 closely during the mission using your line of sight and the Mission Planner Flight Data screen.

Mission Planner Flight Data: Attitude



1 Heading direction
2 Bank angle
3 **Altitude*** (black) and rate of climb (blue bar)
4 Ground speed

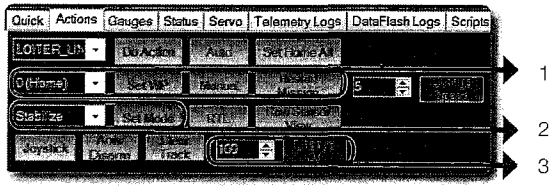
Status



1 **Ground station signal*** 4 Distance to current waypoint > current waypoint number
2 GPS time
3 Currently enabled mode
5 **GPS status***
6 **Battery status***
Full battery: 16.8 V
Low battery failsafe: 14 V

End your flight at 14.1 V!

Actions



1 Change waypoints or restart a mission
2 Change modes
3 Change altitude

Flight Map

1 Current heading
2 Direct path to current waypoint
3 GPS-reported direction of travel
4 Actual flight path
5 Latitude, longitude
6 Altitude

***Failsafe behavior enabled**

Failsafes

The X8 is programmed with a set of failsafe behaviors to prevent a crash in the event of a loss of one of the data or communication channels required for autonomous flight. Although certain failsafes have assigned LED indicators and tones, it is unlikely that you will be able to see these at a distance. Monitor the Flight Data screen for failsafe indications. If a failsafe is triggered, the assigned behavior will activate. To override the failsafe behavior (RTL in most cases), use the controller to regain manual control.

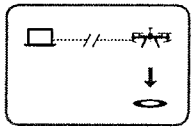
Regaining Manual Control

To regain manual control during the mission, switch to altitude hold mode using the controller. If you're a confident operator, switch to stabilize mode for full manual control. If you observe instability in the X8's flight behavior or it the aircraft moves outside your designated safe flying area, switch to RTL. Turning off the controller will automatically trigger an RTL and can be used in an emergency situation as a hard recall command.

Ground Station Signal Failsfe

Physical obstructions and interference from nearby wireless signals can affect the X8's connection with the ground station. Use the Mission Planner Flight Data display to monitor the ground station connection strength during flight.

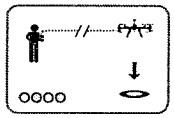
If the X8 loses contact with the ground station for over five seconds, it will automatically return to the launch point and land.



RC Controller Signal Failsafe

Physical obstructions and interference from nearby wireless signals can affect the X8's connection with the RC controller.

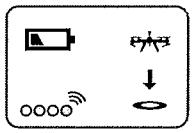
If the X8 loses contact with the RC controller, it will return to the launch point automatically and land, indicated by a blinking yellow status LED.



Low Battery Failsafe

Environmental conditions can affect power consumption. Use the Mission Planner Flight Data display to monitor the voltage of the battery during flight.

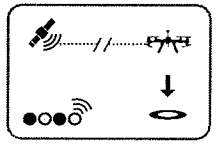
If the battery reaches 14 V, the X8 will land automatically at the current position, indicated by a blinking yellow status LED and a quick repeating tone.



GPS Failsafe

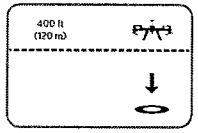
Enclosed areas, physical obstructions, and lack of available satellites can affect GPS strength. Use the Mission Planner Flight Data display to monitor the GPS during flight.

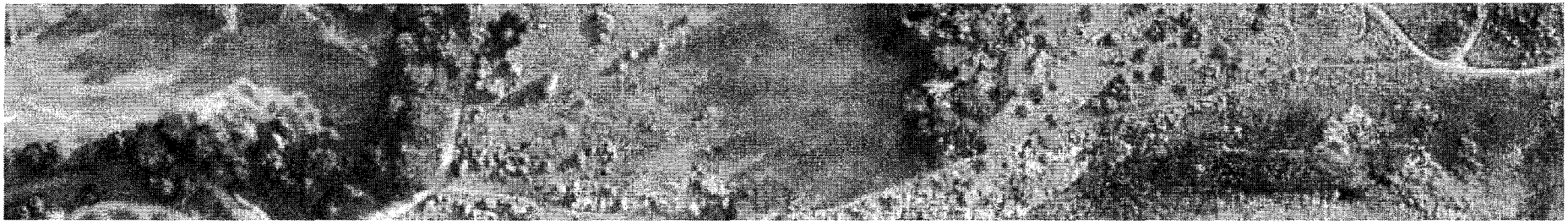
If the X8 loses GPS lock for over five seconds, it will land automatically at the current position.



Altitude Failsafe

The X8 has a 120 m altitude geofence enabled by default. If the geofence is breached, the X8 will automatically RTL.





3 Process

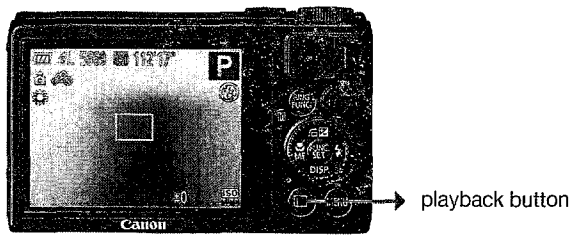
On-Site Quality Check

Before leaving the survey site, check the images using Pix4D to ensure sufficient quality for mapping by downloading the images from the SD card, downloading the log file from the X8, and completing Rapid Check Initial Processing in Pix4D.

If you observe poor image quality or the quality report returns errors, see the Image Quality Troubleshooting section on page 38 and repeat the mission.

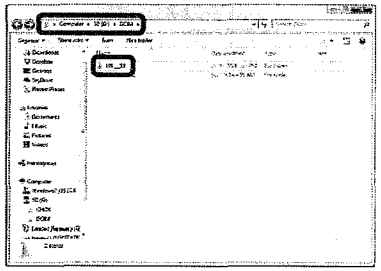
Spot Check (Optional)

The quickest way to see the images after a flight is to unlock the SD card and restart the camera. The camera will load the default Canon programming and you can select the playback button to review the images.



Download Images

Unlock the SD card and load into your ground station. Select the DCIM folder and locate the folder for your flight. Copy the files into a project folder on the ground station and delete them from the SD card.



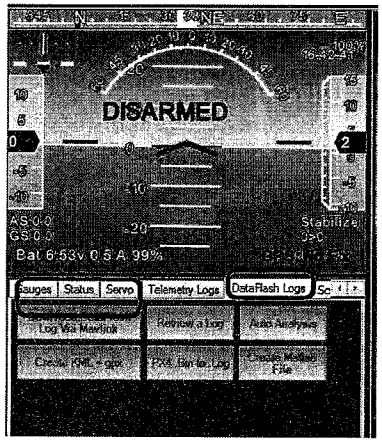
SD card file structure: Download images

Download Log File

Pix4D uses the GPS data from the X8's log file to georeference the images. To download the X8's dataflash log, power the X8 and connect to Mission Planner. The download process will be faster if you connect the micro-USB cable directly to Pixhawk's micro-USB port instead of connecting using the ground station radio. (When connecting directly to the X8, set the rate to 115200.)

On the Flight Plan screen, select the ***DataFlash Logs*** tab under the heads-up display, and select ***Download DataFlash Log over Mavlink.***

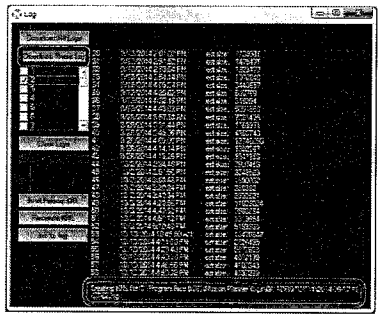
Mission Planner: Flight Data heads-up display



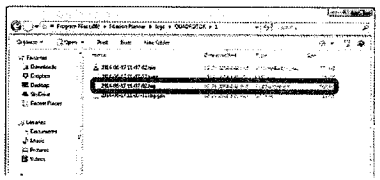
The Log window shows the X8's recent flights. Select the flight for your mission, and select ***Download These Logs.*** This will save the log file to your computer in the location displayed under the list of flights.

To retrieve the log file, access your computer's file structure under ***Program Files/ Mission Planner/logs/OCTOROTOR,*** and select the .log file for the date of your flight.

Mission Planner: Download Logs



Program Files: Retrieve log file

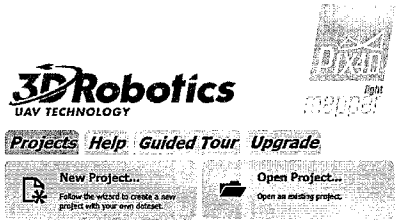


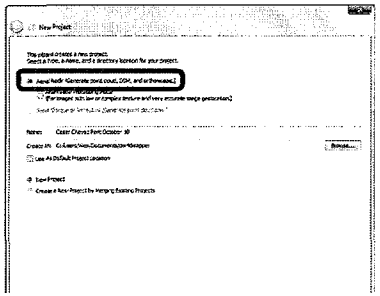
Pix4Dmapper Rapid Check: Create Project

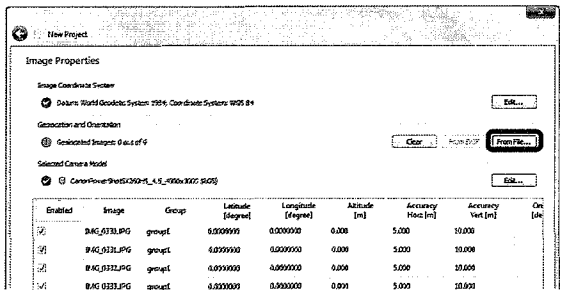
1
Open Pix4D Mapper, and create a new project.

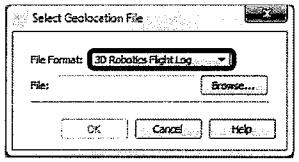
2
Select Aerial Nadir as the project type.

3
After adding the images, select *From File* to add the geolocation data from the X8's log file. In the pop-up window, select 3D Robotics Flight Log as the file format, and upload the dataflash log file downloaded from Mission Planner.



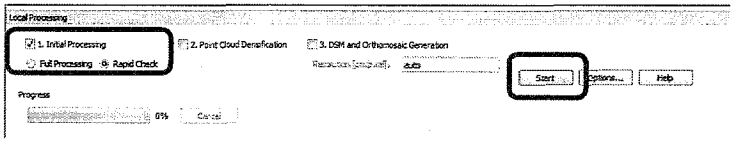




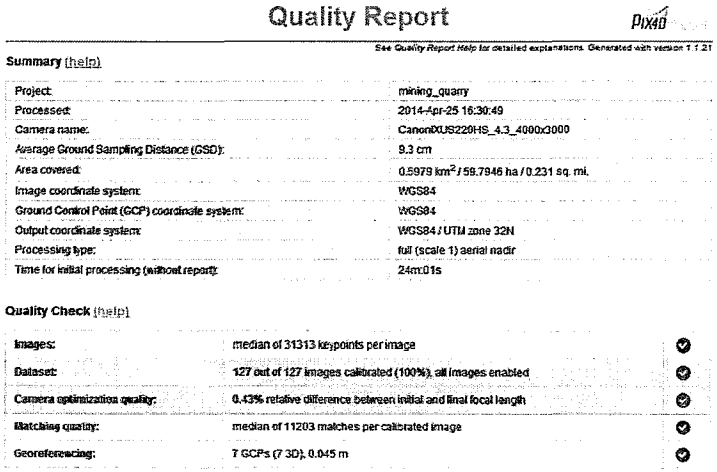


Pix4Dmapper Rapid Check: Initial Processing

After creating the project, select the Local Processing screen (Process menu). Check the option for Initial Processing and Rapid Check. Uncheck all other local processing options, and select Start.



Pix4D will generate a Quality Report that will indicate if the images are of sufficient quality to create a map.



Quality Report

Summary (help)

See Quality Report Help for detailed explanations. Generated with version 1.1.21

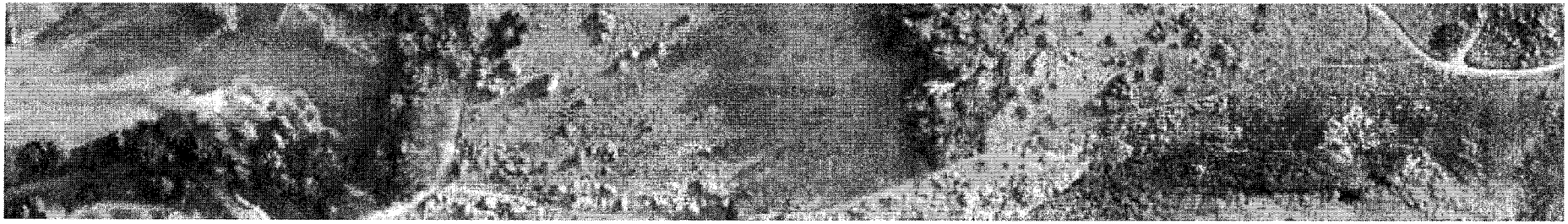
Project:	mining_quarry
Processed:	2014-Apr-25 16:30:49
Camera name:	CanonDUS220HS_4.3_4000x3000
Average Ground Sampling Distance (GSD):	9.3 cm
Area covered:	0.5979 km² / 59.7946 ha / 0.231 sq. mi.
Image coordinate system:	WGS84
Ground Control Point (GCP) coordinate system:	WGS84
Output coordinate system:	WGS84 / UTM zone 32N
Processing type:	full (scale 1) aerial nadir
Time for initial processing (without report):	24m:01s

Quality Check (help)

Images:	median of 31313 keypoints per image	✓
Dataset:	127 out of 127 images calibrated (100%), all images enabled	✓
Camera optimization:	0.43% relative difference between initial and final focal length	✓
Matching:	median of 11203 matches per calibrated image	✓
Georeferencing:	7 GCPs (7 3D), 0.045 m	✓

Full Processing

To complete full processing for the map, visit support.pix4d.com for instructions.



Appendix

Aerial Imaging Concepts

Understanding key concepts in aerial images can help you understand the mission planning process and create better maps.

Distance-Based Imaging

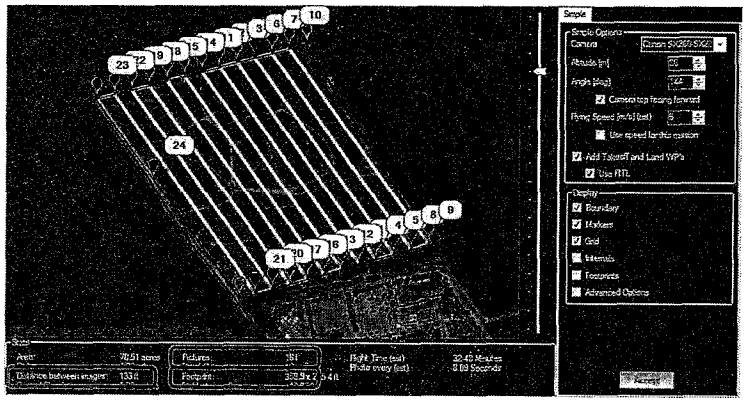
By default, the camera captures only the images required to create the map. The Pixhawk monitors the distance traveled by the aircraft and sends a command to the camera to capture an image at the distance interval specified by the camera trigger distance parameter (*CAM_TRIGG_DIST*). This parameter is set by the Mission Planner Survey tool during survey configuration by calculating the minimum distance between images based on the parameters specified for the survey (altitude, overlap, sidelap). This distance-based imaging allows for more precise data collection, resulting in less images and data storage cost. Once configured, the Survey tool creates an event at the start of the mission script (after takeoff) to set the camera trigger distance to the specified interval and an event at the end of the mission (before landing) to reset the camera trigger distance to 0.

Time-Based Imaging

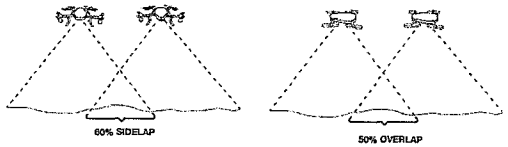
The camera is also equipped to capture images at a consistent time interval instead of using distance. This function can be useful if you want to capture images over an area without planning a mission. This time-based imaging results in more images per area, and therefore more processing time and storage cost. See the Trigger Type options on page xx to enable time-based imaging.

Overlap and Sidelap

To capture images for the map, the aircraft flies a lawnmower-like pattern in strips across the survey site. The front-to-back overlap between sequential images is called overlap; the side overlaps of adjacent pictures in different strips is called sidelap. The overlap and sidelap parameters in the Survey tool (see Advanced Options page xx) determine the distance between images and the number of images to be captured based on the projected ground area that each image will cover, called a footprint. Increasing overlap and sidelap improves the accuracy of the map while increasing flight time and processing time.



In the Survey tool, *Distance between Images* shows the specified camera trigger distance that will be assigned to the mission. You can also see the projected image footprint size and the total number of images to be captured.



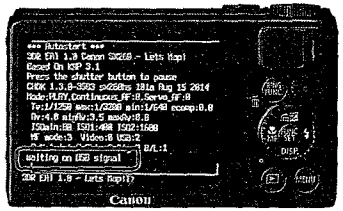
Default overlap: 50%
Default sidelap: 60%

3DR EAI

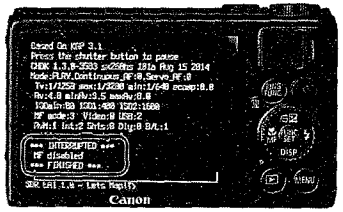
3DR EAI is based on KAP UAV Exposure Control Script v3.1: a great open-source project for kite and UAV aerial photography.

Start and Stop Script

Ensure the camera is set to P (program) mode before powering the camera. Upon startup, 3DR EAI starts automatically and listens for commands from the autopilot, indicated by *waiting for USB signal.* To stop (and re-start) the script, press the shutter button. The script will display INTERRUPTED when stopped.



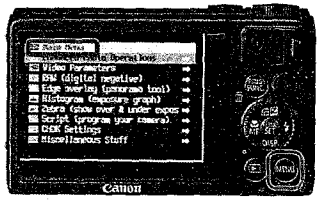
Script start: waiting on USB signal



Script stopped: INTERRUPTED FINISHED

CHDK Menu

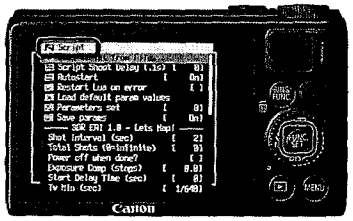
The CHDK menu contains all the standard options provided with CHDK. To access the CHDK menu, stop the script and select the *MENU* button.



CHDK menu

Script Menu

The script menu allows you to change the parameters associated with the script itself, including changing the trigger mode and adjusting exposure. To open the script menu, stop the script and select the *FUNC. SET* button. These parameters are configured for the S100 and do not require adjustment as part of standard operation.

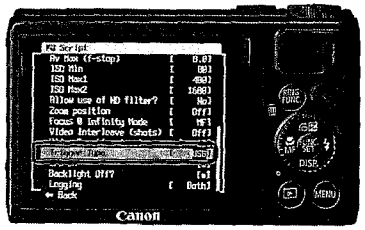


Script menu

Trigger Type

This parameter allows you to control how the camera captures images. Trigger type defaults to *USB* for distance-based imaging during mapping missions. For time-based imaging, select *Interval* and specify the length in the *Shot Interval* parameter.

Trigger Type default: *USB* (mapping)
Variable intervalometer: *Interval* (default to 2 seconds, specified by *Shot Interval*)



Script menu: Trigger Type

Memory Reset

If the battery is left out of the camera for too long, the camera will reset its memory. To re-configure the camera in this case, visit *3DR.com/X8-M* for instructions.

Online Resources and Information

Visit *3DR.com/X8-M* for links to updates, more information about KAP UAV, and full CHDK instructions.

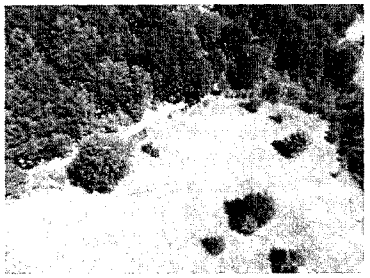
Image Quality Troubleshooting

If you observe poor image quality during the spot check or if you receive error messages during processing, use the settings below to troubleshoot the image quality.

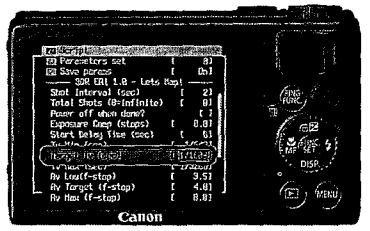
Blurry Images

To correct motion blur, adjust the shutter speed using the *Target Tv* parameter in the script menu.

Target Tv (shutter speed) default:	1/1250
To correct moderate motion blur:	Set to 1/1600.
To correct severe motion blur:	Set to 1/2000.



Example image: motion blur

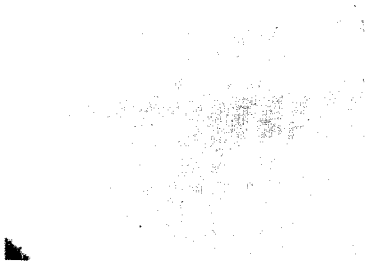


Script menu: Target Tv

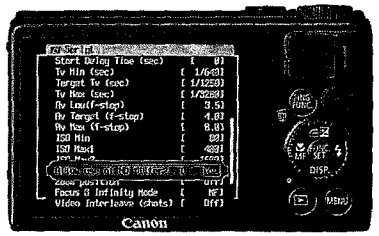
Overexposure

If the images are overexposed but do not show any motion blur, it can be due to flying in extremely bright conditions. To correct this, set the *Allow use of ND filter* parameter to YES in the script menu.

Allow use of ND filter default:	No
To correct overexposure:	Set to Yes.



Example image: overexposure

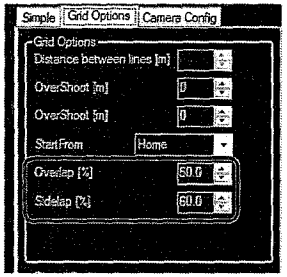


Script menu: ND Filter

Processing Errors

If you receive errors from Pix4Dmapper regarding the images, dataset, or matching points, increase the overlap and sidelap during survey configuration to improve the quality of the image set.

Overlap default:	50%
Sidelap default:	60%
To improve processing:	Set overlap to 60% and sidelap to 70%.



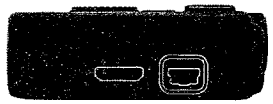
Mission Planner Survey tool Advanced Grid Options: Overlap and Sidelap

Operational Troubleshooting

No Images Captured

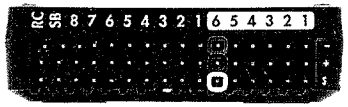
1 If the camera did not capture any images during the mission, first perform a physical inspection on the X8.

Is the mini-USB cable connected to the camera's USB port?



Camera (side)

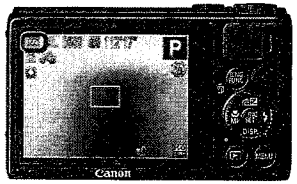
Are the AUX OUT 6 pins connected on Pixhawk?



AUX OUT 6: black (-), red (+), white (s)

Pixhawk (side)

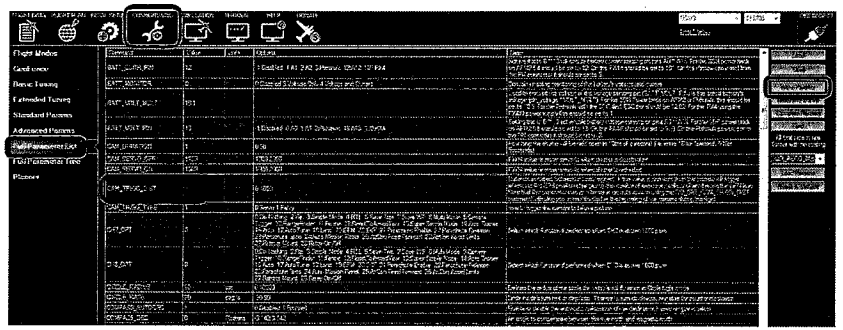
Is the camera battery charged? Unlock the SD card to view the Canon's battery level indicator.



Camera with SD card unlocked, running Canon software

2 Take a distance-triggered test image on the ground by manually setting the camera trigger distance parameter to 1 m.

Power the aircraft and connect to Mission Planner. Select ***Config/Tuning*** and ***Full Parameter List***. Change the ***CAM_TRIGG_DIST*** parameter to 1, and select ***Write Params***. Now carry the X8 for a few meters to see if the autopilot triggers the camera.



Mission Planner Full Parameter List: Set CAM_TRIGG_DIST to 1.

LED Error Indicator

If the status LED displays blinking yellow, the X8 is failing one the pre-arm safety checks. To determine the specific failure, check the heads-up display on the Mission Planner Flight Data screen. There will be an error message specifying the failed check.

Radio Calibration Failure:	Perform Radio Calibration in Mission Planner or RC controller re-binding
Accelerometer Calibration Failure:	Perform Accelerometer Calibration in Mission Planner
Compass Calibration Failure:	Perform Compass Calibration in Mission Planner
GPS Failure:	Wait for improved GPS signal or move to a more open area

! Safety - Read Before Flying !

Your first priority must absolutely be the safety of people!

Multicopters are essentially Flying Lawnmowers!

- **ArduCopter is an experimental aircraft running community-created code - Novel and unexpected results are NOT uncommon!**
- **Crashes can happen, because of pilot error or hardware or software malfunction.**
- **Especially while you are learning, it is recommended that you avoid, stiff, ultra-sharp carbon fiber props.**
  - Get cheaper more flexible and more breakable plastic ones.
  - Some carbon fiber props cut better than a Ginsu and while they are almost indestructible, you are not.
- **If you are flying anywhere near other people, you are putting them at risk!**
- **Be sure to maintain safe distances between yourself, and spectators and your copter.**
  - Circumstances will require that you will need to make your own determination of what is a "safe distance" from people and property.
  - At a minimum, consider: at least 10ft (3m) but not further than 30ft (10m) from you.
  - Keep all other people, property and obstacles considerably further away from your copter.
  - Ensure that no one gets between you and your copter.
  - Spectators should always be a safe distance behind the pilot.
  - If people intrude beyond what you have determined to be the "safe" area, land immediately and do not take off until they are clear.
  - At full power, an average sized multi-copter can exceed 20 mph (32 km/h), can ascend to hundreds of feet and easily travel more than a mile in distance before running out of battery.
- **Always ensure that the battery cable is (NOT) connected to the power distribution board or harness until you are ready to fly.**
  - After landing the first thing you should do is disconnect your battery cable.
  - Always remove your props while you are testing motors.
  - Your hands, arms and face and those of your friends will thank you.
  - When the battery is connected, always assume the motors are armed.
  - Check with a short throttle pulse.
  - Don't pick up the model and the radio at the same time, you may bump the throttle.
  - Do not attempt to fly longer than your batteries safe capacity.
    - At a minimum it is very hard on the battery and at worst you will crash destructively.
- **The APM and PX4 flight controllers we use incorporate a motor arming safety feature.**
  - Immediately prior to flight after the battery has been connected, the RC transmitters throttle stick needs to be held down and to the right for several seconds to arm the motors.
  - After landing your first response should be to hold the throttle down and to the left for several seconds to "Disarm" the motors.
  - Disarm condition can be tested by moving the throttle stick up, if the motors do not move it is dis armed.
  - Even when disarmed, the throttle stick should always be kept in the full down position except when flying.
- **Get used to switching back to Stabilize mode from other modes and reassuming full manual control.**
  - This is the single most important recovery technique (practice it).
  - Stabilize mode can have Simple mode added to it, but if you do, practice with it till you are proficient.
  - Do not use any modes other than Stabilize or Stabilize plus Simple until you are VERY comfortable flying.
- **Important primary response to a crash, inadequate landing or unknown flight controller state.**
  - The first thing to do is throw a towel over your copters propellers (Propellers may start spinning unexpectedly).
  - Then immediately disconnect the battery.
  - A large towel is your most important piece of safety equipment followed by a fire extinguisher and a first aid kit. - - Generally better to use the first one than the last one.
- **When testing or flying any of the navigation modes (using GPS):**
  - Ensure that your GPS has "Lock" before arming and takeoff.
  - Check that your home position on the Mission Planner is in fact correct.
  - Sometimes GPS's do not report the home position accurately, reboot if not accurate and wait for 8 or more satellites (not just 3D lock) and check again.

Keep a safe distance between your Copter and People!

These tips can also help protect your multicopter from damage.

- **Avoid sudden or extreme transmitter control stick deflections**
  - Move the control sticks in small measured increments and don't "yank" on them.
  - If the copter is properly calibrated and balanced it should require only small stick inputs to control altitude, direction and speed.
  - Your copter should be more or less stable on the horizontal plane without any control inputs.
  - If you are "fighting" the copter, land and fix it - something is not right - Hardware adjustment or software calibration may be required.
  - Be especially careful of large throttle inputs, as a copter can gain (or lose) altitude **very** rapidly.
- **Because MultiCopters are symmetrical it is especially easy to lose Visual Orientation.**
  - For manual flight modes, maintaining a clear vision of the Copters Orientation (direction it is facing) is the most critical part of successful flight.
  - Especially while learning it is very important to keep your copter appropriately close to you to aid in maintaining visual orientation.
  - Generally: more than 10ft (3m) but not further than 30ft (10m) from you.
  - If the copter gets further than about 100ft (30m) it starts getting difficult to be able to maintain **orientation** and can easily crash.
  - If you lose Yaw orientation while flying in Stabilize mode, try only flying forward and using yaw to steer like a car.
  - It is much better to simply descend and land rather than have an **orientation-induced** crash or **fly away**.
    - **Fly-Aways** often happen when the copter is commanded to tilt back towards the pilot but has rotated in the meantime and is so far away that orientation is lost.
    - Result: the copter flies further away and crashes or is lost.
- **Always have** Stabilize mode **as the (Go To) one of your 3 options.**
- **High or unexpected winds or gusts can make flight considerably more difficult.**
  - High winds can prevent forward progress or spin the copter around causing you to become disoriented.
  - The higher you are, the more likely high winds will be a problem.
  - Switching to Stabilize mode and landing before you reach your skill limits can help you save your copter.
- **Avoid flying at high speed or high altitude until you have gained considerable confidence in both manual and automatic modes.**
- **When flying around trees or buildings it is very easy to lose visual orientation or even to lose sight of the copter completely.**
  - Gusting winds around objects can also worsen the problem and radio signal loss can also occur.
  - If your copter is approaching a potentially interfering object, immediately switch to stabilize mode and land or retrieve the copter to your location.
- **ArduPilot specific safety modes: RTL, FailSafe and GeoFence.**
  - RTL can provide a safe Return to Launch if it starts to get away from you.
  - FailSafe and GeoFence can assist you with keeping the copter in a safe proximity.
  - Do not rely on the above safety modes, always be ready to take control in stabilize and land the copter.
  - Especially do not rely on the above safety modes to perform maneuvers or training that you would otherwise consider dangerous.
  - These modes are a supplement to, not a replacement for sound safety practices.
- **On your first takeoff after tuning or hardware setup**
  - In stabilize mode advance the throttle very slowly until the copter is almost hovering.
  - If the copter is trying to flip over turn it off and correct the problem, a motor could be turning the wrong direction, or a wrong direction prop could be installed.
  - If the copter tries to rotate on it's axis or fly off in some direction the transmitter or RC setup may be incorrect, a motor or ESC may not be performing properly or the props may be installed incorrectly.
  - When all problems are fixed it should be fairly easy to get the copter to hover a foot or 2 above the ground.
  - If a stable and stationary hover a foot or 2 above the ground cannot be achieved, land and fix the problem
- **When flying FPV "First Person View" (with a video camera), Set modes to: STABILIZE, SIMPLE, and RTL.**
  - Ensure RTL is working properly before using FPV,
  - Use Stabilize mode to fly FPV and If you lose FPV video switch to Simple or RTL to get back.
- **Make sure your battery can't fall out, use a Velcro Strap to hold it in place.**

Aero-M

Operation Manual

Thank you for purchasing an Aero-M! This manual contains important information about your aerial mapping platform. Please read these instructions before your first flight.

V3 2014

DCT0010

I Plan

Parts

Aero

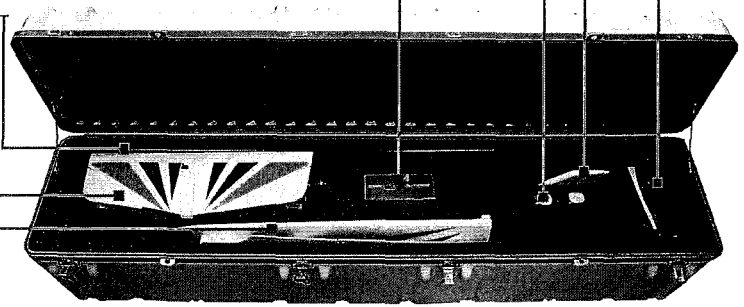
batteries (2)

camera

wing spar

horizontal stabilizer

wings



registration card and Pix4D license key

FPV/OSD System
If you selected to receive a FPV/OSD system, those components will be included with the Aero's accessories. See page 34 for parts and instructions.

RC controller and accessories

ground station radio

micro-USB cable

charger and accessories

battery guard bag

wing rubber bands (4 plus 2 spare)

propellers (1 plus 1 spare)

hex keys (?)

propeller wrench

spare control horns (2)

spare servo rods (2)

spare camera mount filters (2)

Pixhawk micro-SD card adapter

Flight Battery

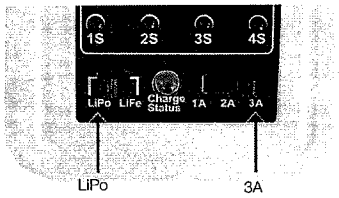
The Aero is powered by a rechargeable lithium polymer (LiPo) battery.
Charge the battery before your first flight.

Charging

1
Connect the charger to the power adapter cable and a wall outlet. Connect the red cable to the + port and the black cable to the - port.

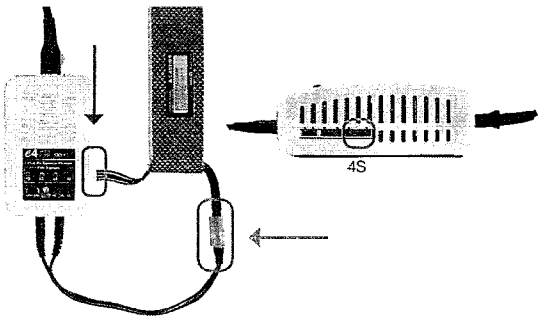
Charger with power cable and split-wire charging cable

2
Set the charger to LiPo and 3A.



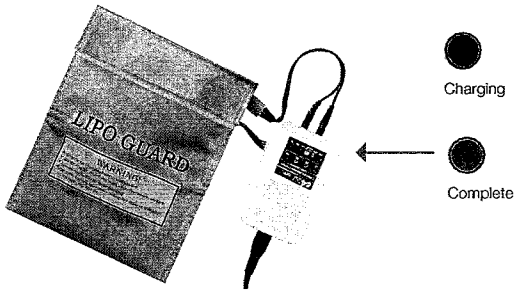
Charger settings

3
Connect the white connector to the 4S port, and join the two yellow connectors together.



Flight battery charging wiring

4
Secure the battery inside the guard bag, and charge until the status indicator displays green.



Charging in process

Safety

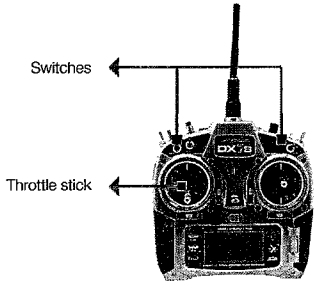
Flying with a low battery is a safety risk and can render the battery permanently unusable. Always fly with a fully charged battery.

Charge the battery using a designated LiPo balance charger only. Always monitor the battery while charging. Protect the battery from extreme heat, extreme cold, puncturing, and flammable surfaces. Always transport, charge, and store the battery in the guard bag.

Inspect the battery for damage before and after flying. If you observe any swelling of the package or the battery ceases to function, do not use the battery; locate your local battery recycling center, and dispose of the battery. In the US and Canada, visit call2recycle.org to find a location. Do not dispose of the battery in the trash.

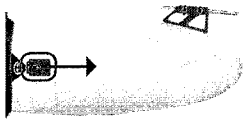
Powering the Aero

1
Turn on the controller. To avoid triggering the controller's startup alarm, ensure that all switches are set back (away from you) and the throttle stick is set fully down.



RC controller

2
Open the battery compartment by sliding the knob on the orange switch forward and lifting out the lid.

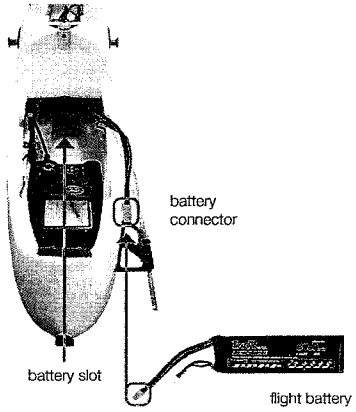


Aero: battery compartment lid

3
Insert a charged battery into the battery slot, and attach the yellow connectors. This will power on the Aero.

Hold the Aero still and level while it powers on.

Attach the velcro above the battery slot to the velcro on the battery. Close and secure the lid onto the battery compartment.



Aero: battery compartment interior

It is important to establish communication before powering on the Aero. Always turn on the controller before connecting the battery. When powering off the Aero, disconnect the battery before turning off the controller.

Camera Setup

The Aero includes a Canon PowerShot S100 running the 3DR EAI script.

3DR EAI (Exposure-Aperture-ISO)

3DR EAI runs on the Canon Hacker Development Kit (CHDK), a powerful open-source tool that expands the functionality of Canon point-and-shoot cameras. 3DR EAI optimizes image exposure and integrates with the Pixhawk autopilot to enable distance-based imaging.

This software is designed to load off the camera's SD card, leaving the original Canon programming intact. The yellow switch on the side of the SD card allows you to lock or unlock the card. Lock the SD card to run 3DR EAI; unlock the SD card to save images to your ground station or to boot the camera with its original programming.

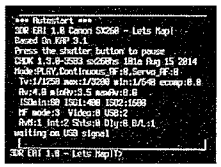
For more information about 3DR EAI, see page 43.

SD card locked
Load 3DR EAI

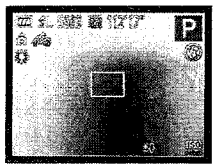
» Fly a mapping mission

SD card unlocked
Load default Canon software

» View images on camera
» Save images to ground station
» Update script



Camera running 3DR EAI

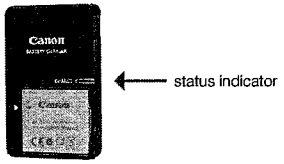


Camera running Canon software

⚠ Power off the camera before removing the SD card.

Charging

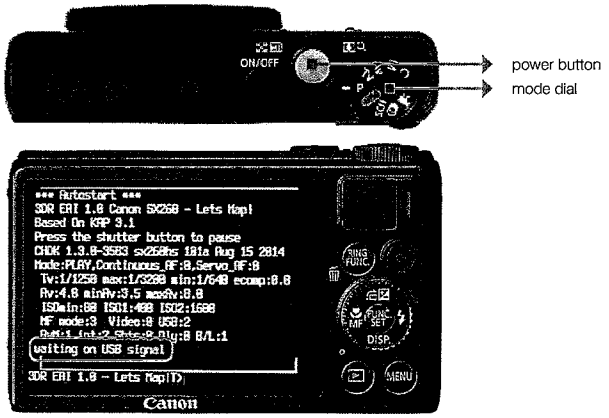
Charge the camera battery before your first flight. Once fully charged, insert the battery into the camera.



Canon battery charger

Starting a Mission

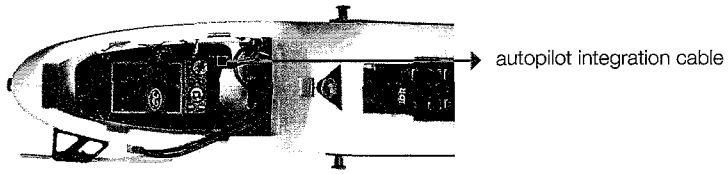
To prepare the camera to fly a mapping mission, ensure that the mode dial is set to *P (program)* mode. Power on the camera using the silver button on the top. 3DR EAI will start automatically, and you will see the script messages on the camera display. Check to see that the last line of the script reads *waiting on USB signal*. The camera is now ready to map!



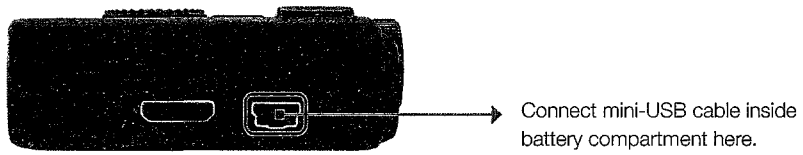
Camera ready to map: *waiting on USB signal*

Mounting

The camera mounts to the Aero inside the battery compartment and connects to the autopilot using the mini-USB cable. When the camera is ready to start the mission, insert the camera into the mount inside the battery compartment as shown below, connect the mini-USB cable to the camera, and secure the camera in place using the velcro strap.



Aero battery compartment: camera mount

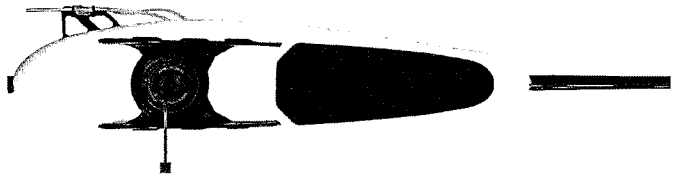


Camera (side)

The camera mount is fixed to the inside of the battery compartment and is not intended to be removed from the Aero.

The camera mount includes a lens cap that protects the filter during travel. Make sure to remove this lens cap before you fly, and check that the filter contains no foam particles, dirt, or scratches that could affect image quality.

It is expected that the filter will accumulate scratches after significant use. If you notice any damage to the filter that could affect image quality, unscrew the filter and replace with one of the extra filters provided with the Aero.



Camera mount (bottom): cap removed

Camera mount (bottom): cap attached

Ground Station Setup

Mission Planner allows you to turn a Windows laptop into a full-featured ground station for configuring and monitoring autonomous missions. You will need to take this laptop into the field when you fly the mission. As part of the mission procedure, you will use the Pix4D Rapid Check to verify the quality of the image set before leaving the field.

Download Software

Mission Planner

Mission Planner is a full-featured ground station application for planning missions and monitoring the Aero in flight. Download Mission Planner from *3DR.com/download_software.*

If you already have Mission Planner installed, make sure you're running the most recent version: Select the *Help* tab and *Check for Updates.*

Mission Planner: *Help* tab

Pix4Dmapper LT 3DR Edition

Your license key for Pix4Dmapper can be found on the registration card inside the documents package.

Visit *mapper.pix4d.com/license-redeem* to create an account and redeem your license key; then visit *pix4d.com/download* to download Pix4Dmapper Discovery. Pix4D will automatically upgrade from the Discovery edition to the LT 3DR Edition (or Pro Edition if you selected to upgrade) when you log in to the program with your Pix4D account information.

Connect to Radio

To connect the Aero to Mission Planner, connect the ground station radio to the laptop, and power the Aero.

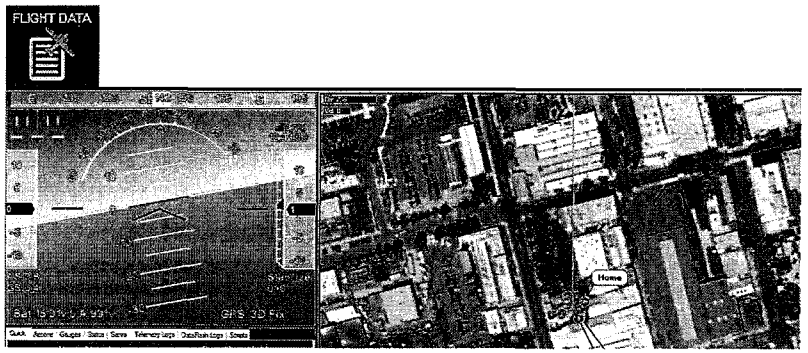
1
Connect the ground station radio to your laptop using the micro-USB cable. Open Mission Planner.

Ground station laptop with radio connected

2
Select *57600* and *AUTO*, then select *CONNECT.* (When connecting directly to Pixhawk's micro-USB port, set the rate to 115200.)

Mission Planner *Connect* tool (top-right corner))

3
Select *Flight Data* to view live data from the Aero.

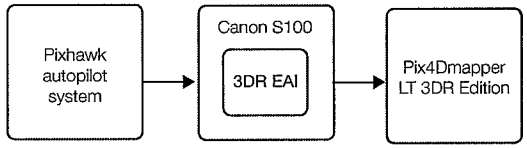


Mission Planner *Flight Data* tab: connected to aircraft

Mission Planning

Operating Parameters

The Aero is a complete solution for creating high-resolution visual-spectrum aerial maps.



Mapping system diagram

To create a map, the Aero flies an autonomous mission over the survey site, using the integration between the Pixhawk autopilot and custom-programmed camera to capture images at a consistent distance interval. Pix4Dmapper then stitches these images together into a georeferenced, orthorectified mosaic.

The accuracy of the map depends on the configuration of the mission. Planning a mission that captures high-quality images requires balancing the Aero's operating parameters with the environmental factors at the survey site.

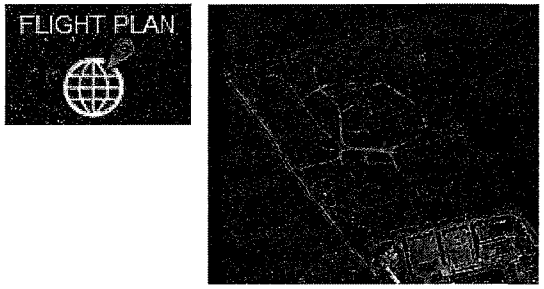
Operating Parameters

Camera	Canon S100
Camera Orientation	Portrait (side facing forward)
Operating Altitude	80-120 m
Standard Operating Altitude	100 m
Low-Wind Conditions	0-6 m/s
High-Wind Conditions	7-10 m/s
Maximum Wind Conditions	10 m/s
Operating Speed	8-20 m/s
Default Speed	15 m/s
Estimated Maximum Flight Time	40 min
Estimated Ground Resolution	5 cm/pixel
Estimated Maximum Survey Area	1 km^2
Minimum Photo Interval	2 seconds

Load Maps

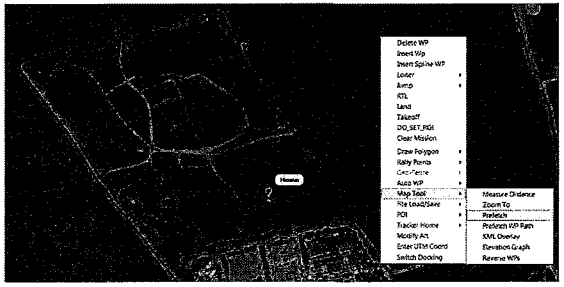
Mission Planner allows you to plan the mission away from the mapping location; however, it is important to assess the environmental conditions on site at the time of the mission and adjust the flight plan if necessary. Alternatively, you can plan the entire mission at the mapping location. To create or alter the mission, Mission Planner requires an Internet connection to access the maps. If you're unable to access the Internet on site, follow the instructions below to pre-fetch the maps within Mission Planner while you have Internet access.

1
Open Mission Planner, select ***Flight Plan***, and zoom to your flying location.



Mission Planner *Flight Plan* tab: zoom to mapping location

2
Right-click on the map, select ***Map Tool*** and ***Prefetch***, and accept the default prompts. Mission Planner will download the maps for the selected location to your computer.



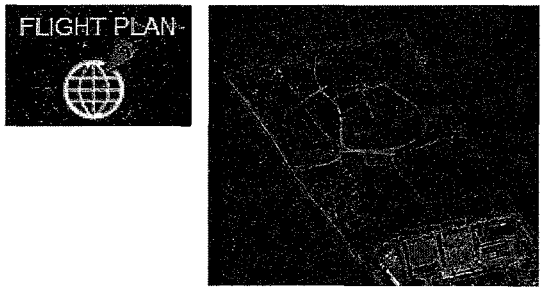
Mission Planner *Flight Plan* tab: Select *Prefetch*

3
Mission Planner will attempt to load the map data from the current level of zoom down to the closest level of zoom available. However, it can take hours to pre-fetch every level of zoom, and it is unlikely that the closer levels will be useful in planning the mission. To shortcut this process, check the slider on the right side of the map. The levels of zoom are represented by this slider from 0 (bottom) to 25 (top). Press the ESC key to skip levels of zoom at a greater detail than you need for mission planning.

Draw Polygon

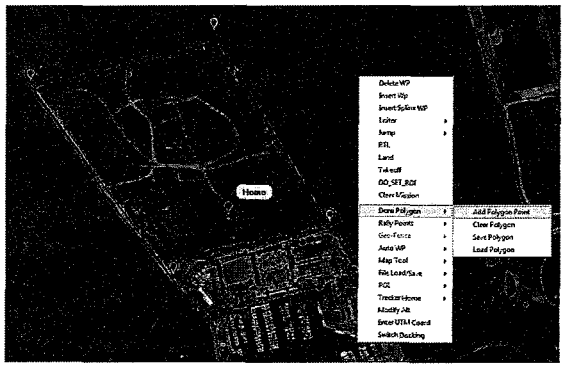
To begin planning the mapping mission, select the area you want to map using the ***Polygon*** tool. You'll be able to adjust the size and shape of the polygon later in the mission configuration process.

1
Select *Flight Plan*, and zoom to your mapping location.



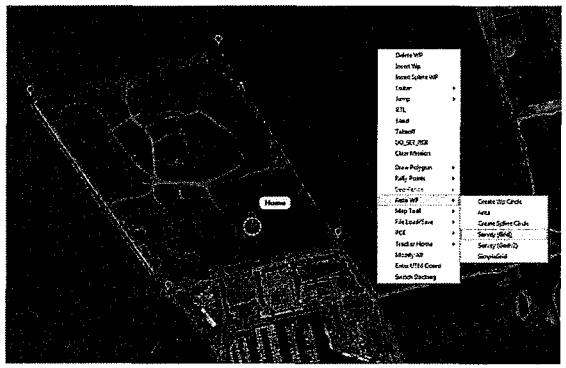
Mission Planner *Flight Plan* tab: zoom to mapping location

2
Right click on the map. Select ***Draw Polygon*** and ***Add Polygon Point.*** Click and drag to add points around the area you want to map.



Mission Planner *Flight Plan* tab: draw polygon

3
Right click on the polygon. Select ***Auto WP*** and ***Survey (Grid)*** to open the Survey Tool.



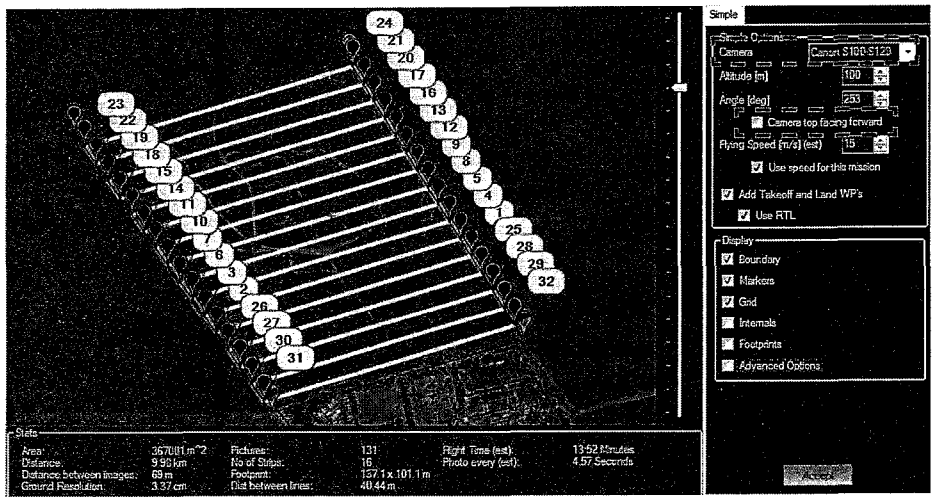
Mission Planner *Flight Plan* tab: open *Survey* tool

Units

The Survey Tool uses metric units. If your Mission Planner is set to imperial units, please change the settings to use metric to plan the mission. Support for imperial units in Mission Planner is coming soon; check ***3DR.com/Aero-M*** for updates.

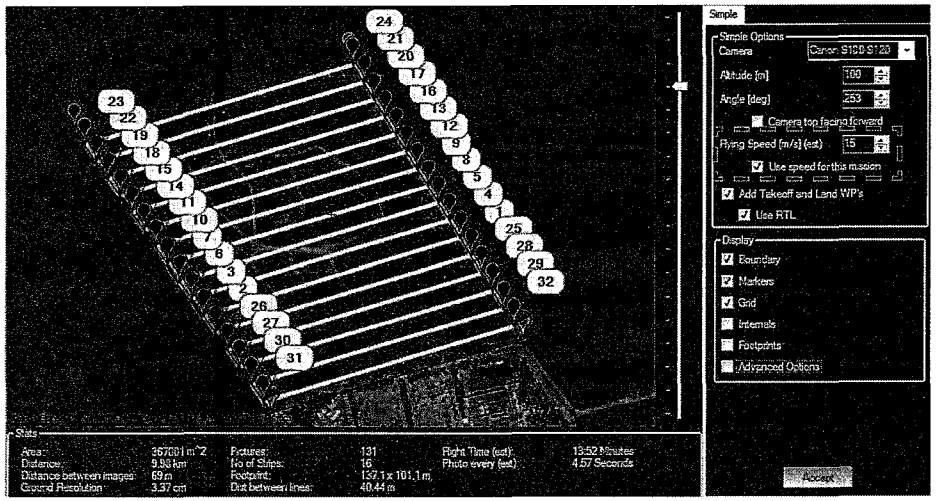
Configure Survey: Set Default Parameters

The Survey tool allows you to configure a mapping mission according to the Aero's operating parameters and the current environmental conditions at the mapping location. First, set the default values for the Aero.



Set Camera
Canon S100-S120

Set Camera Orientation
Uncheck the option for ***Camera top facing forward.***



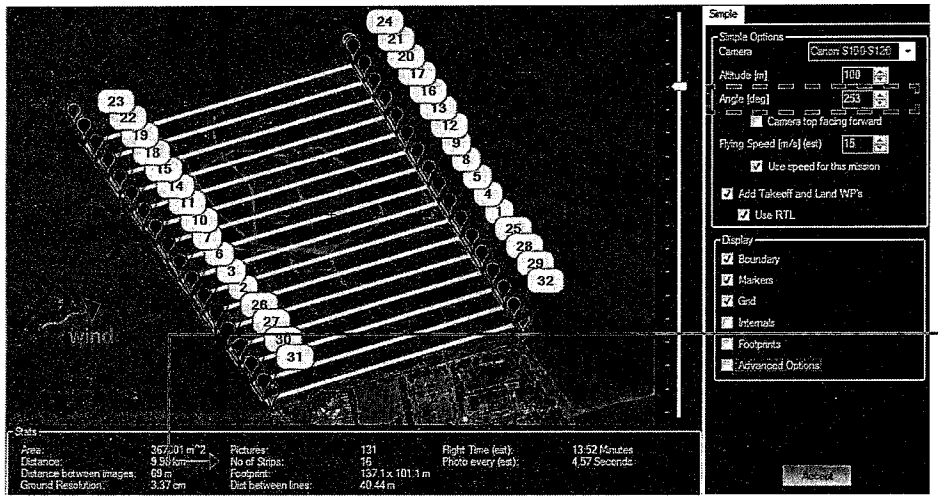
Set Default Speed
15 m/s

Apply Survey Speed
Check the option for ***Use speed for this mission.*** If unchecked, the mission will use the Aero's default speed of 15 m/s regardless of the speed selected in the Survey Tool.

Mission Planner *Survey* tool

Configure Survey: Set Angle

Next configure the angle of the flight path for the current wind conditions.



Mission Planner *Survey* tool

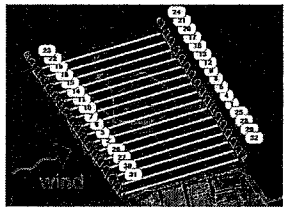
Mission Planner Tip: Adjust Polygon
Click and drag the red polygon points to adjust the size and shape of the polygon from the Survey Tool.

Set Angle

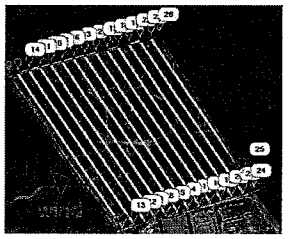
Wind Direction
In environments with winds of less than 6 m/s, set the angle so that the Aero flies into the wind. In winds from 7-10 m/s, configure the flight path to travel perpendicular to the wind so the Aero flies cross-wind.

No. of Strips
Adjust the angle so that the Aero makes as few turns as possible to complete its course. The ***No. of Strips*** parameter shows how many passes the plane will make as you adjust the angle.

Review Wind Conditions On-Site
Always assess the wind conditions at your survey site at the time of the mission and adjust the mission accordingly.



Configure the flight path parallel with the wind in low winds (1-6 m/s).

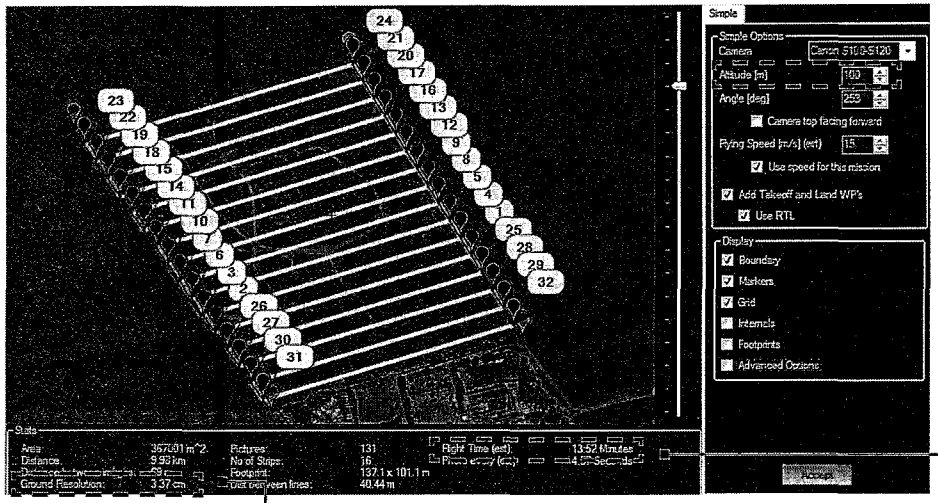


Configure the flight path perpendicular to the wind in high winds (7-10 m/s).

Use caution when flying in winds over 10m/s. Mapping results may degrade as a result of inability to make headway or maintain appropriate groundspeed.

Configure Survey: Set Altitude

The survey altitude determines the duration of the mission and the ground resolution of the final map. Adjust altitude to balance flight time and power consumption with the current environmental conditions.



Mission Planner *Survey* tool

Set Altitude
Standard operating altitude: 100 m
Operating altitude range: 80-120 m

Increasing altitude decreases flight time, allowing you to cover more area per minute. Decreasing altitude improves ground resolution. Set the altitude to get the best ground resolution while keeping the flight time under 40 min and the altitude under 120 m.

⚠

Keep altitude below 120 m, and ensure that the altitude is appropriate for your flying area and local regulations.

Check Ground Resolution
Ground Resolution is the centimeters per pixel that you will have in the map and corresponds to the amount of detail that you will see.

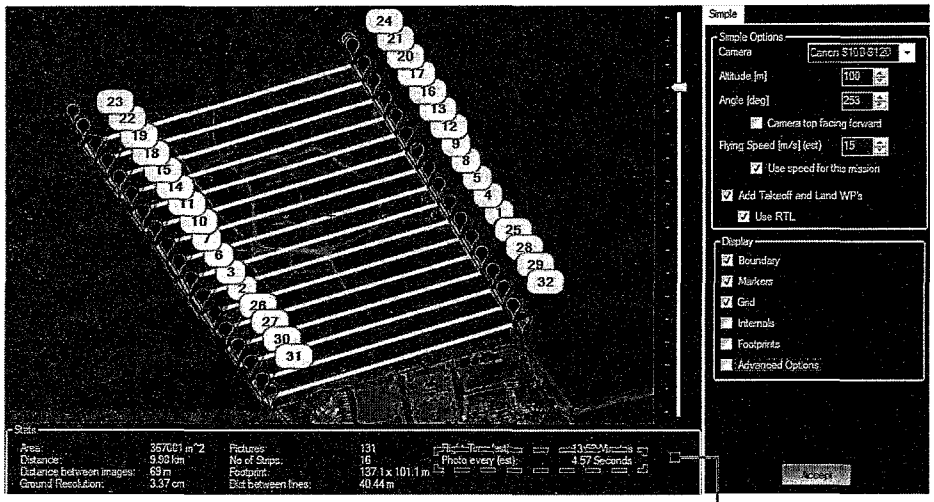
To improve ground resolution by decreasing the number of centimeters per pixel, decrease altitude.

Check Flight Time
Flight Time estimates the duration of the mission. The total estimated flight time must be under 40 min for a fully charged Aero battery. To decrease flight time, increase altitude or speed.

High winds, humidity, high altitude, and extreme heat can affect power consumption and reduce flight time. Consider the environmental factors at your site when configuring flight time.

Configure Survey: Check Photo Interval

With the basic parameters in place, verify that the photo interval calculated from the altitude and speed complies with the operating parameters for the camera.



Mission Planner *Survey* tool

Check Photo Interval
Photo Every must be longer than 2 seconds for the S100 camera.

Altitude
Increasing altitude increases photo interval.

⚠

Keep altitude below 120 m, and ensure that the altitude is appropriate for your flying area and local regulations.

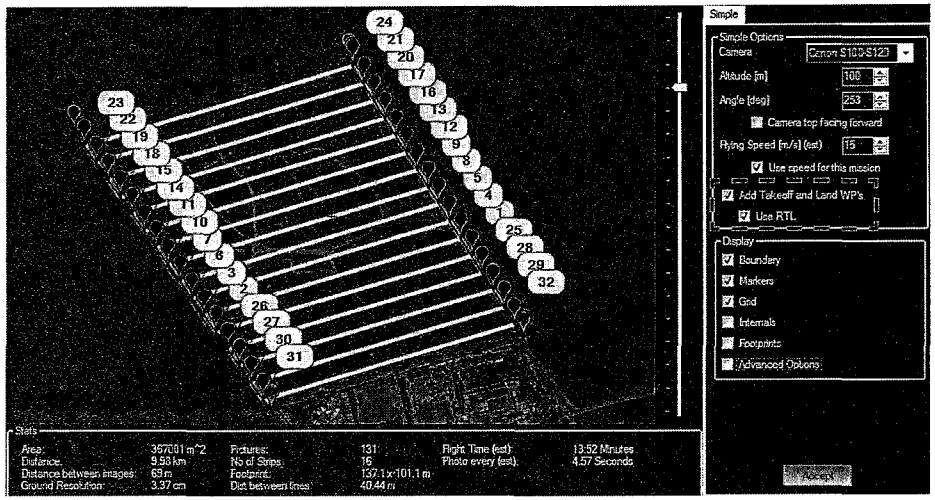
Speed
Decreasing speed increases photo interval.

⚠

Ensure that the ***Use speed for this mission*** option is checked.

Configure Survey: Set Takeoff and Landing

Now select a takeoff and landing pattern, either manual or automatic.



Mission Planner *Survey* tool

Takeoff and Land WP's

For automatic takeoff and landing
Check the ***Add Takeoff and Land WP's*** option.
Uncheck the ***Use RTL*** option.

This will create a takeoff waypoint and a placeholder waypoint for the landing pattern. After accepting the survey, configure the automatic landing pattern by following the instructions on page 20.

For automatic takeoff and manual landing
Check both the ***Add Takeoff and Land WP's*** option and the ***Use RTL*** options.

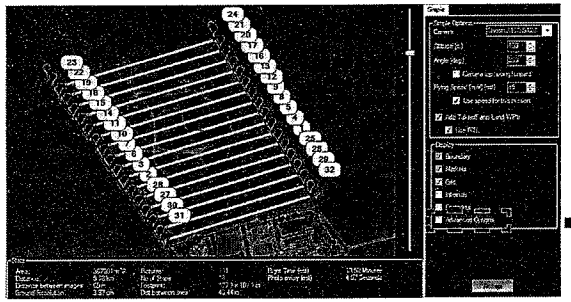
This will create a takeoff waypoint so the Aero will automatically climb to the survey altitude before heading to the first waypoint. The Aero will return to circle over the launch point after completing the mission.

For manual takeoff and landing
Uncheck the ***Add Takeoff and Land WP's*** option
Check the ***Use RTL*** option.

For this option, take off manually then initiate the mission in flight. The Aero will return to circle over the launch point after completing the mission.

Configure Survey: Advanced Options

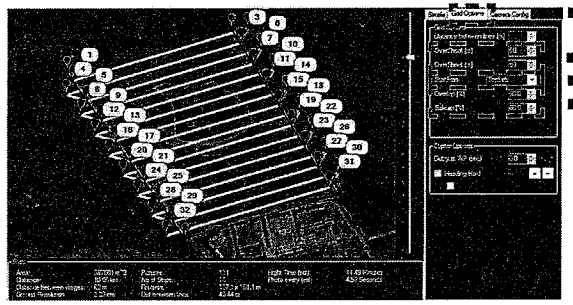
The Survey tool includes the following advanced configuration options. These options allow you to customize the mission to comply with best operating practices.



Check Advanced Options
to view the Survey Tool's advanced configuration options.

Select Grid Options

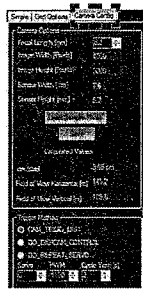
Set OverShoot
The Aero has a minimum turning radius of 90 degrees. To accommodate the sharp angles of the survey mission, set both ***OverShoot*** parameters to 50 to have the Aero overshoot the waypoints on either side of the polygon by 50% to ensure that the complete area of the polygon is covered by the images.



Mission Planner *Survey* tool: advanced options

⚠

OverShoot will affect flight time. Ensure that the total estimated flight time is less than the Aero's maximum flight time of 40 minutes.



Camera Config
The options under the Camera Config tab allow you to configure a camera other than the S100 and won't be used for operating the Aero.

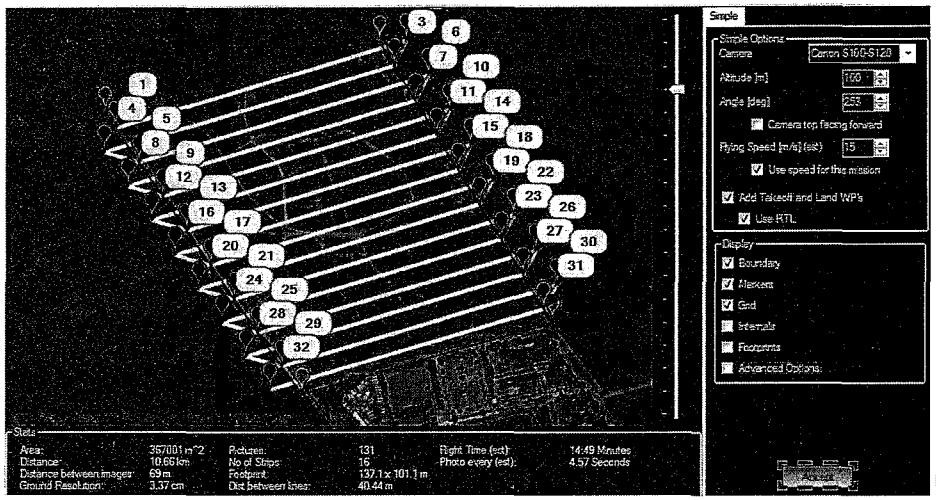
Adjust StartFrom
During the mission, you will maintain contact with the aircraft through the RC controller and ground station signals. If your mission is likely to experience a loss of signal, it is best practice to start from the corner of the mission farthest from the launch point. In this example, TopLeft is the corner of the mission farthest from the launch point.

Adjust Overlap and Sidelap
Overlap and sidelap are set to 50% and 60%, respectively, by default. See page 42 for an in-depth discussion of these parameters.

Mission Planner *Survey* tool: advanced options

Configure Survey: Accept Survey

Before accepting the survey, verify that the mission complies with the Aero's operating parameters.



Mission Planner *Survey* tool

Operating Parameters

Camera
Canon S100-S120

Altitude
80-120 m

Camera top facing forward
unchecked

Flying speed
9-15 m/s

Use speed for this mission
checked (optional if speed set to default speed of 15 m/s)

Photo Every
greater than 2 s

Flight time
under 40 min depending on environmental conditions

Accept
Select ***Accept*** to create this mission. After accepting, you will need to reconfigure the survey completely to make any adjustments.

If Mission Planner prompts you for a home altitude, enter the altitude that you specified in the ***Survey*** tool.

⚠ Do not accept the mission if any of the parameters exceed the Aero's operating limits.

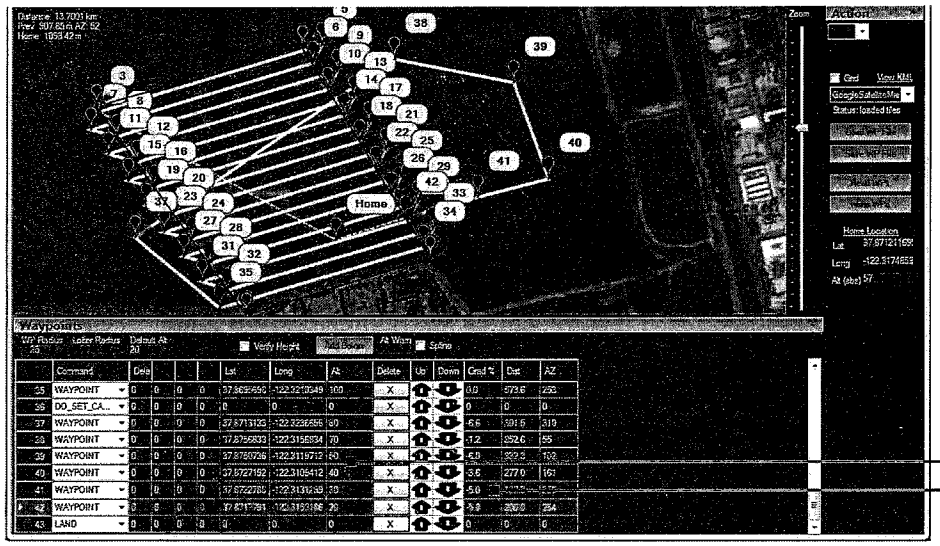
Configuring Automatic Takeoff and Landing

If you selected automatic landing in the Survey Tool by checking the ***Add Takeoff and Land WP's*** option and unchecking the ***Use RTL*** option, you will need to configure the landing waypoint pattern manually at this step in the mission planning process.

To begin, determine the direction of the wind and select an unobstructed area 200-500 m in length leading to the launch point, into the wind. On the main Flight Plan screen, create a series of waypoints along this path to decrease altitude gradually from the survey altitude to 0, ensuring that:

- Turns along the flight path are greater than 90 degrees.
- The altitude decreases by a maximum of 20 m between waypoints
- There is at least 20 m between each waypoint
- The *Grad %* does not exceed 20%

To add a waypoint, right click on the map in the location of the waypoint you would like to add, and select ***Insert WP***. For each waypoint you add to the mission, Mission Planner will prompt you for the new waypoint's place in the script: Add the series of landing waypoints immediately before the ***LAND*** waypoint in the script of events. For the first waypoint in the pattern, add it to the mission immediately following the ***DO_SET_CAM_TRIGG_DIST*** waypoint at the end of the mission. Specify the altitude of each waypoint and check the distance and gradient angle in the waypoints table.

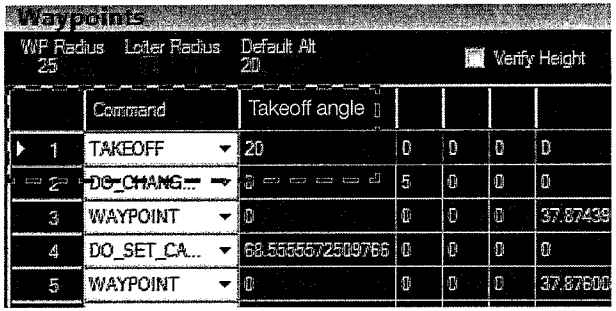


Mission Planner *Flight Plan* tab: Correctly configured automatic landing pattern

To add a waypoint, right click on the map in the location of the waypoint you would like to add, and select ***Insert WP***. For each waypoint you add to the mission, Mission Planner will prompt you for the new waypoint's place in the script: Add the series of landing waypoints immediately before the ***LAND*** waypoint in the script of events. For the first waypoint in the pattern, add it to the mission immediately following the ***DO_SET_CAM_TRIGG_DIST*** waypoint at the end of the mission. Specify the altitude of each waypoint and check the distance and gradient angle in the waypoints table.

Locate the Takeoff waypoint in the mission script and set the first option in the row to assign the takeoff angle.

Set the takeoff angle to 20-25 degrees depending on the length of your takeoff area.



Mission Planner Tip: Configure Waypoints
Measure the distance between waypoints by right-clicking at one end and selecting ***Measure Distance***; then right-click on the other end and select ***Measure Distance*** again. A dialog box will open with the distance between the two points.

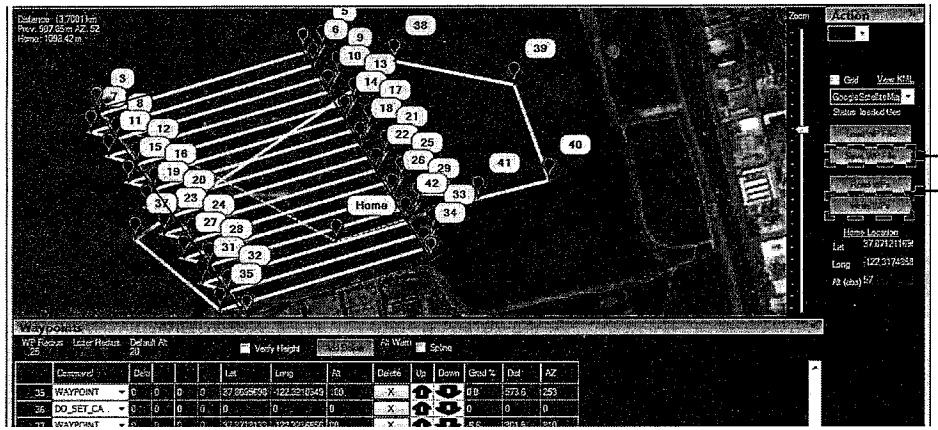
Double-click on a field in the waypoint table to edit the parameters for a waypoint.

Use the Up and Down arrow icons to re-order the waypoints.

Use the Delete option to remove a waypoint from the mission.

Save and Write Mission

For the Aero to run the mission, write the waypoint file to the autopilot.
Don't forget to save the waypoint file to your ground station for future use.



Select Save WP File
to save the mission file to your computer. To repeat this mapping mission, load the saved WP file from your computer.

Select Write WPs
to save the mission to the Aero.

Mission Planner *Flight Plan* tab: Save and write mission

2 Fly

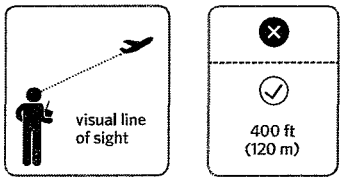
Safety

To ensure safe and successful flying, familiarize yourself with the safety information on this page. Always fly in accordance with your location regulations and these best operating practices.

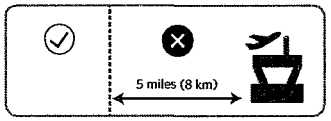
Before you fly, determine the boundaries of your safe flying area. If the Aero moves outside the designated area or exhibits instability in flight, switch to fly-by-wire mode and land the plane manually. Always be ready to regain manual control of the plane in the event of an unsafe situation.

The Aero will not avoid obstacles on its own, including during missions. As the operator, it's your job to recognize and avoid obstructions while flying. When planning missions, ensure that the selected altitude is appropriate for all geographical features of the area, including terrain.

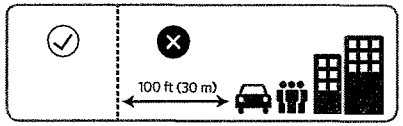
Location



Always fly below 400 ft (120 m) and within your visual line of sight. Don't let the Aero get too far away from you; make sure you can always see its orientation. Don't fly in low light, rain, or other conditions that might impede visibility.



Always fly at least 5 miles (8 km) away from airports and other areas where pilots operate manned aircraft.



Always fly at least 100 feet (30 m) away from people, vehicles, and buildings. Make the safety of people and property your first priority!

Propeller

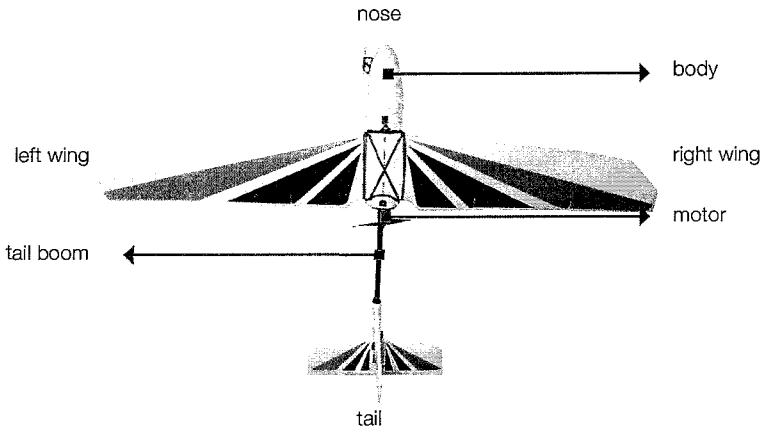
Spinning propellers can cause serious injury. The safety button indicates the status of the motor to help you prevent hazardous contact with the Aero's high-speed propeller.

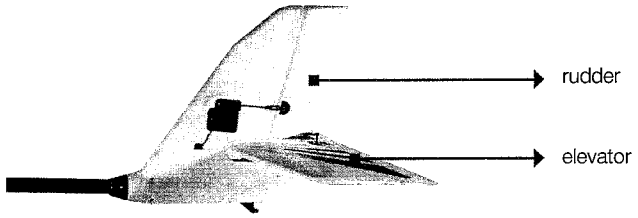
- When the Aero is powered on, the safety button will blink red, indicating that the motor is inactive and the propeller is safe to handle.
- When you're ready to fly, press and hold the safety button until it shows solid red. This indicates that the motor is armed and the propeller will spin if the throttle stick is raised. To make the propeller safe to handle again, press and hold the safety button until it blinks red.

You can find more safety tips throughout these instructions where you see this yellow box.

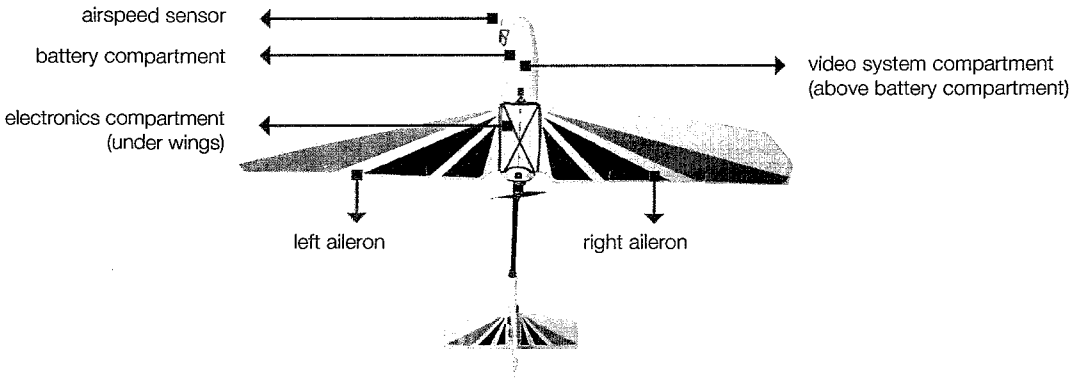
Aircraft Operation

Components



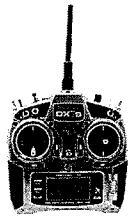


Aero tail



Aero (top)

ground station radio

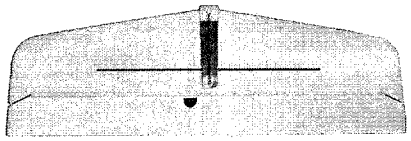


controller

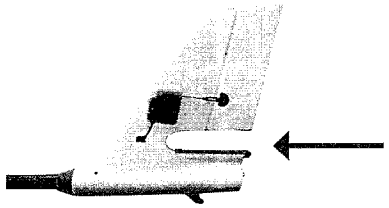
If the terms above are unfamiliar to you, visit *3DR.com/Aero-M*, and dive into the exciting world of planes with our Introduction to Flying Fixed-Wing Aircraft.

Assembly

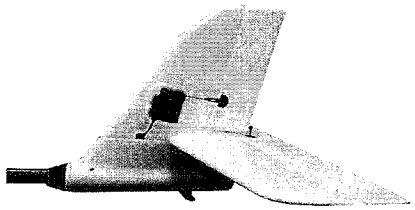
Tail
Slide the horizontal stabilizer into the vertical stabilizer along the orange groove. Make sure not to stress any of the components on the tail.



Horizontal stabilizer

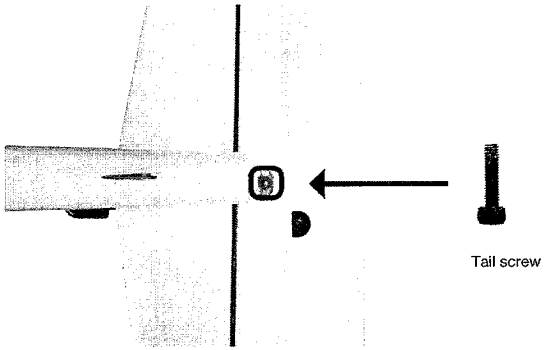


Vertical stabilizer



Complete tail assembly

Turn the plane over and insert the provided tail screw into the horizontal and vertical stabilizers.

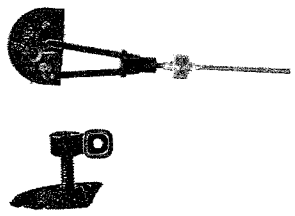


Tail screw

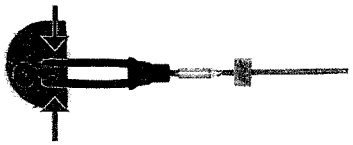
Tail assembly (underside)

On the top of the horizontal stabilizer, open the blue clasp at the end of the servo rod. Insert the pegs on the clasp into the open space in the servo horn, and close the clasp. Slide the blue rubber ring over the clasp to secure it in place.

clasp

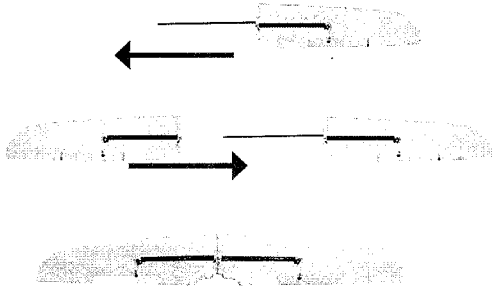


servo horn

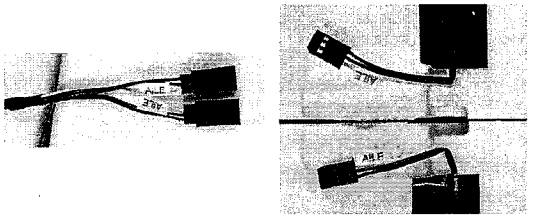


Wings

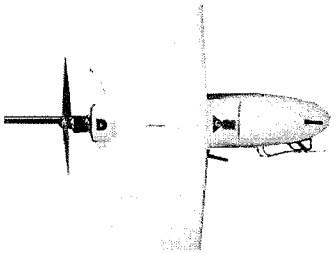
Attach a wing onto each side of the spar. Do not twist the wing or the spar so as not to stress the foam.



Locate the two cables inside the electronics compartment marked AILE. Connect these cables to the two cables on the wings marked AILE. (Either of the wing cables can connect to either of the plane cables; the order doesn't matter.)

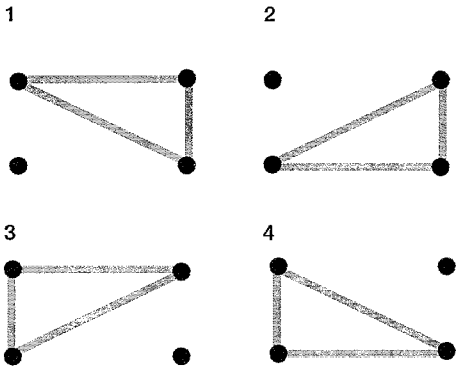


Place the wings over the body of the Aero with the foam squares fitted into the matching space in the electronics compartment. Make sure not to pinch the AILE cables.

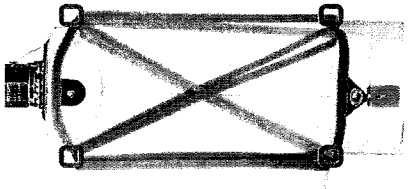


Locate the four large rubber bands. Use the bands to secure the wings to the body of the Aero by the four orange knobs on the body around the wings.

Attach two of the bands to the two knobs on one of the short sides and opposite knobs on the opposing side.

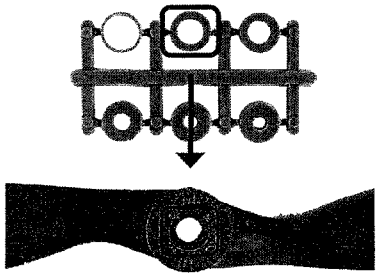


Repeat on the other short side with the remaining two rubber bands, resulting in two pairs of opposing right triangles.

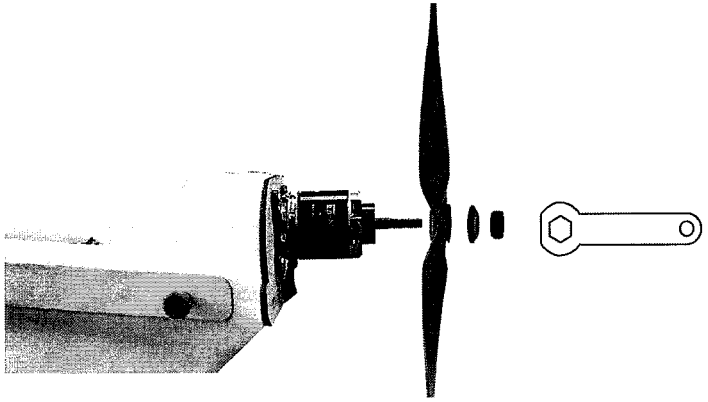


Propeller

Locate the rings inside the propeller package. Remove the ring with the second-largest internal diameter, and insert it into the back of the propeller hub.

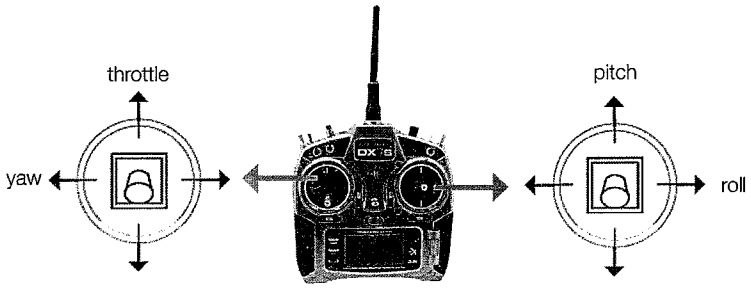


Remove the nut and the washer from the motor, add the propeller with the writing on the propeller facing towards the nose of the plane, add the washer and the nut over the propeller, and tighten the nut.



Controls

Fly the Aero manually using the RC controller.



Throttle: Move the left stick forward and backward to control the motor.

Yaw: Move the left stick horizontally to turn left and right using the rudder.

Pitch: Move the right stick up to pitch down and down to pitch up.

Roll: Move the right stick left and right to control the bank angle.

throttle up

Increase motor speed.

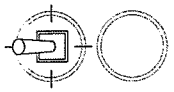
throttle down

Decrease motor speed.

throttle fully down

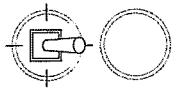
Stop motor.

yaw left



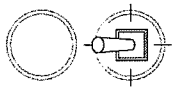
Turn left.

yaw right



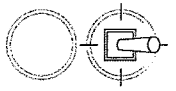
Turn right.

roll left



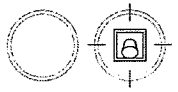
Roll left.

roll right



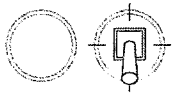
Roll right.

roll and pitch center



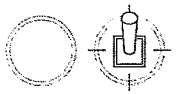
Automatically level.

pitch up



Pitch up.

pitch down



Pitch down.

Modes

Auto - *fly a mission*
Fly an autonomous mission. This is the mode that the Aero will use to create the map.

Fly by Wire - *assisted manual control*
Let the autopilot manage the control surfaces, and navigate based on where you want the Aero to fly. Fly-by-wire mode* (FBW) is the easiest way to fly and is the recommended mode for new operators.

*ArduPlane mode FBWA

Return to Launch (RTL) - *recall to launch point*
Command the plane to circle over the launch point. The Aero will return to the position where it acquired GPS lock and enter into a circle pattern at an altitude of 100 meters.

Loiter - *circle*
Activate GPS-positioned circling; the Aero will enter into a circle pattern with a radius of 60 meters at the current altitude. Move the right stick to adjust the position of the circle.

Stabilize - *stabilized manual control*
Stabilize mode provides manual control with an added autopilot safeguard: Release the right stick and the Aero will automatically return to a level flying orientation. Use stabilize mode for the freedom of manual control with return-to-level stabilization.

Manual - *full manual control*
Fly with fine-tuned manual control without autopilot assistance. Manual mode gives you the most direct input to the control surfaces, resulting in precise in-flight adjustment. Try manual mode if you're an experienced RC plane operator.

To select a flight mode:

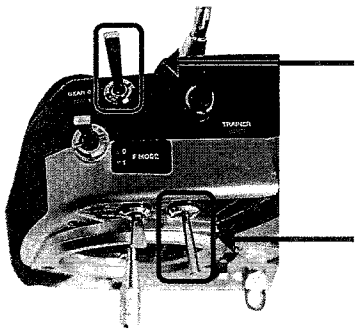
First, set the GEAR/MIX switch to select a set of modes. Then use the FLAP/GYRO switch to 0, 1, or 2 to select a specific mode.

With GEAR/MIX set to **GEAR**,

set FLAP/GYRO to:
0 for **Manual**
1 for **Stabilize**
2 for **Loiter**

With GEAR/MIX set to **MIX**,

set FLAP/GYRO to:
0 for **Auto**
1 for **Fly by wire**
2 for **RTL**



GEAR/MIX selects the set of modes.

FLAP/GYRO selects the specific mode, either 0, 1, or 2.

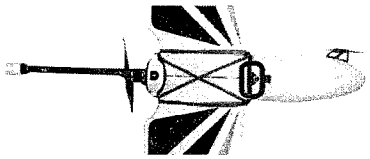
RC controller (top)

Arming & Disarming

Arming and disarming are important steps that must be completed before takeoff and after landing to activate and deactivate the motor, respectively.

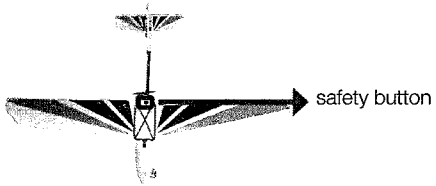
Before arming, check the status LED. The LED will flash blue while the Aero acquires GPS; this can take a few minutes. Once you see the green LED, the autopilot has acquired GPS lock.

Initializing, please wait.
Acquiring GPS lock, please wait.
Autopilot ready, GPS locked



To arm the motor, press and hold the safety button until it displays solid red.

To disarm, press and hold the safety button until it displays blinking red.



Inactive, motor disarmed
Active, motor armed

The arming and disarming procedures ensure that you can safety start and stop the motor without risk of injury.

The Aero's motor can spin when armed! Do not place your hands in the way of the propeller while the safety button is active (solid red).

LED Indicators

Initializing, please wait
Acquiring GPS, please wait
Armed, GPS locked
Loss of RC signal, automatic landing
Low battery, automatic landing
Loss of GPS signal, switch to fly-by-wre
System error, see troubleshooting guide

Tones

Visit 3DR.com/Aero-M to listen to Pixhawk's status tones.

GPS Lock

Auto, RTL, and loiter modes requires GPS lock. When powered, the autopilot will automatically search for GPS lock. The position of the Aero when the autopilot acquires GPS will be saved as the home position, and used as the coordinates for the launch point during RTL. If you plan to use auto, RTL, or loiter modes during your flight, ensure that the Aero is located at a suitable launch point when powered, and the autopilot acquires GPS lock before takeoff, indicated by a blinking green status LED.

Preflight Checks

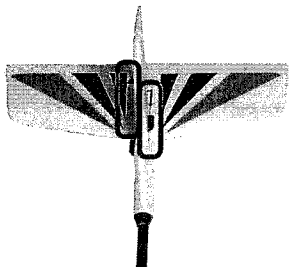
Before each flight, perform a physical component check, center of gravity check, and control checks in both manual and stabilize modes. If any of the components or assemblies in these checks are not secure, tighten the screws or use CA glue (super glue) to secure the components to the foam.

1
Examine the Aero to ensure that all components are secured in flight configuration.

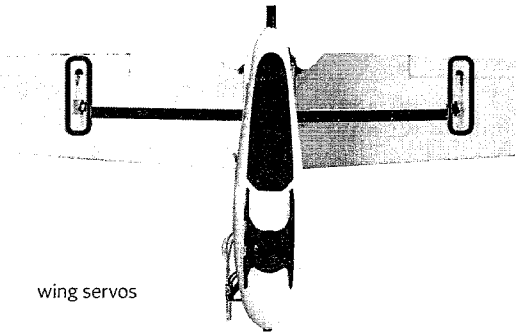
» Check that the wings, tail, and tail boom are fully assembled and securely attached.

» Check that the propeller is secured tightly to the motor.

» Check that the servo rods are secured to the servo horns with the blue clasps.

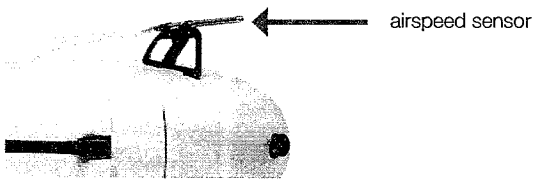


tail servos



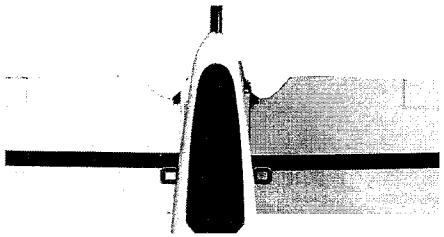
wing servos

2
Check that the airspeed sensor is secured to the side of the Aero and the tube is free from obstructions.

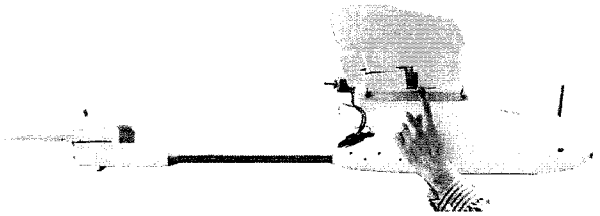


airspeed sensor

3
With the battery connected and the lid secured, check that the Aero is correctly balanced for flight. Hold the Aero with one finger on each of the clear, plastic balancing points shown below. These points indicate the Aero's center of gravity.



If the plane balances on your fingers, then the center of gravity is correct. If it won't balance, adjust the position of the battery until you can balance the plane on two fingers as shown below.

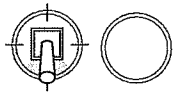


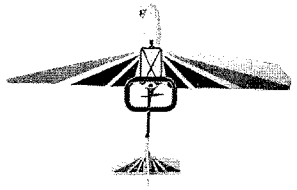
Flying the plane without the camera will affect the center of gravity. If you choose to fly without the camera, make sure to re-balance the center of gravity.

Preflight Checks: Manual Control Check

Before flying, power and arm the Aero on the ground and complete these checks to verify that the control surfaces respond correctly to the control inputs. Place the plane on the ground, and set the mode switches to select manual mode. Move each of the sticks as shown, and check for the corresponding movement of the motor or control surfaces.

1
Raise the throttle slightly until the motor spins, then immediately set the throttle back to fully down position.

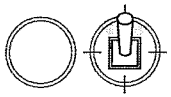


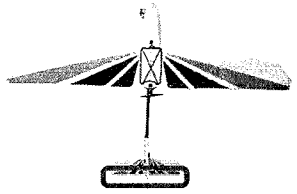


Motor spins.

⚠ Do not raise the throttle more than just enough to spin the motor while the plane is on the ground, and do not place your hands in the way of the propeller while the motor is armed.

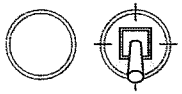
2
Pitch down

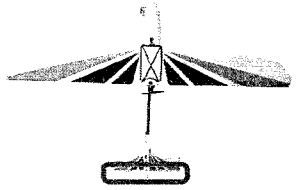




Elevator tilts down.

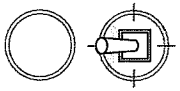
Pitch up

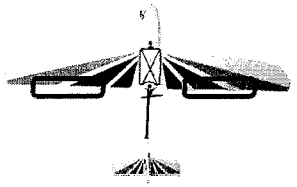




Elevator tilts up.

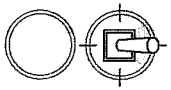
3
Roll left

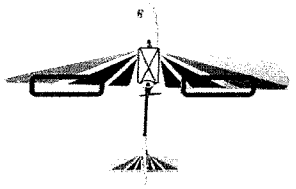




Left aileron tilts up, right aileron tilts down.

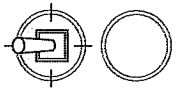
Roll right

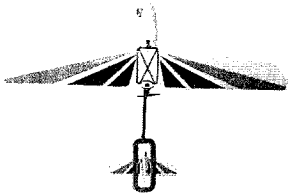




Left aileron tilts down, right aileron tilts up.

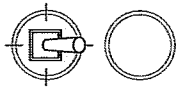
4
Yaw left

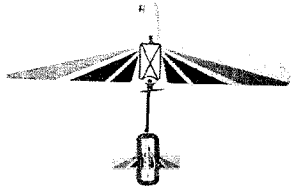




Rudder tilts left.

Yaw right





Rudder tilts right.

Preflight Checks: Stabilize Control Check

Set the mode switches to stabilize, and hold the plane in front of you. Move the plane as shown, and check for the stabilization response from the control surfaces.

1
Test: Tilt the plane left.

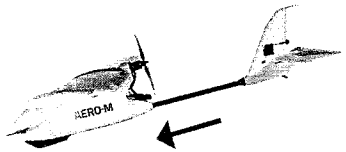
Result: Left aileron tilts down, right aileron tilts up.

Test: Tilt the plane right.

Result: Left aileron tilts up, right aileron tilts down.

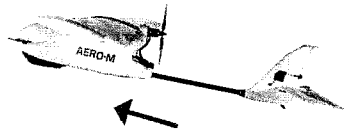
2
Test: Tilt the plane down.

Result: Elevator tilts up.



Test: Tilt the plane up.

Result: Elevator tilts down.



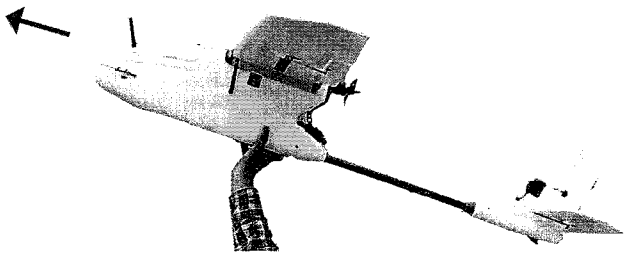
Automatic Takeoff

Auto-takeoff works by sensing the movement of the plane and launching it in that direction. Set the Aero to autonomous mode when you're ready to launch.

Find a launching area with at least 100 feet of clear space in front of you. Face into the wind, and hold the body of the Aero in one hand under the center of gravity. Be careful not to place your hand in the way of the propeller!

Hold the Aero above your head, run, and throw the plane at an upwards angle. The Aero will sense the throw, power the motor, and climb to the altitude specified by the takeoff waypoint before starting the survey mission.

⚠ DO NOT WIND UP YOUR THROW; if the Aero senses any backwards momentum it will attempt to launch in that direction. Use only forward momentum to throw to Aero!



Automatic takeoff requires you to configure the takeoff angle during mission planning. See page 18.

Manual Takeoff

If you're new to planes, we recommend having a friend help you launch the Aero. Have your friend throw the Aero while you control the controller.

We recommend setting the Aero to fly-by-wire mode for takeoff. Find a launching area with at least 100 feet of clear space in front of you. Face into the wind, and hold the Aero at the center of gravity. Raise the throttle to center position to start the motor. Be careful not to place your hand in the way of the propeller!

Hold the Aero above your head, run, and throw the plane at an upwards angle.

Once launched, the Aero will require immediate adjustment with the controller to navigate away from the ground and up to the desired altitude. Pitch up (right stick down) and add any other necessary controls based on wind, speed, and terrain.

Automatic Landing

To land automatically at the end of the mission, the Aero requires the mission to be configured with a specific pattern of landing waypoints that gradually decreases the altitude so that the Aero can land safely. For instructions on configuring automatic landing, see page 18.

Manual Landing

When you're ready to end your flight, follow these steps to land:

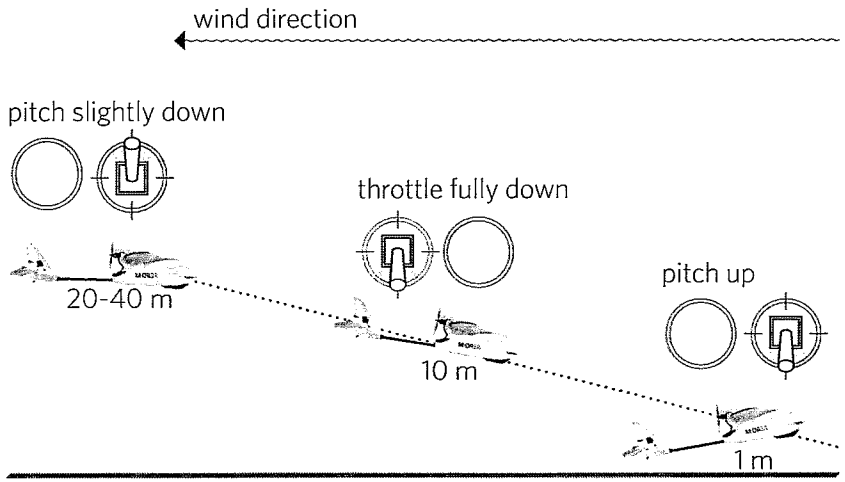
» Fly a circle pattern above your landing area.

» Come in on a final approach, flying into the wind at an altitude of 20 to 40 meters.

» When the plane reaches an altitude of 10 meters, set the throttle fully down to turn off the motor and glide down on a 15 to 20 degree down-pitch angle.

> ⚠ After stopping the motor at an altitude of 10 m, keep your thumb on the throttle stick in fully down position to ensure that the motor does not accidentally spin during landing.

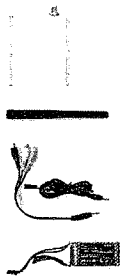
» When the plane is one meter above the ground, pitch up (flare) to land the Aero on the body of the plane instead of the nose.



FPV System Operation

If you selected to receive an optional FPV/OSD system, the components are pre-installed into the Aero to transmit on-board video.

Parts

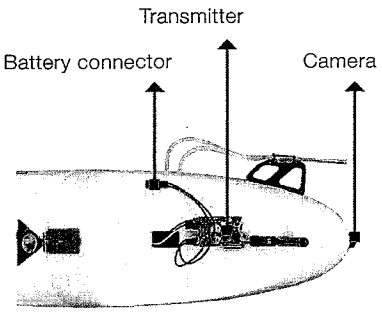


AV receiver

Antenna

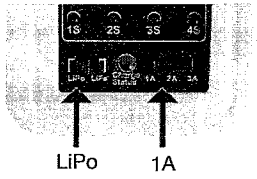
Receiver cables

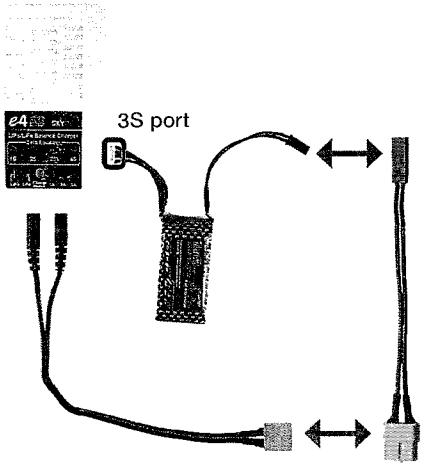
Batteries (2)



1 Charge battery

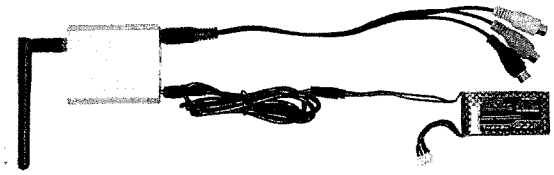
Charge both batteries before your first flight. Set the charger to LiPo and 1A. Connect the white battery connector to the 3S port, and connect the XT60-JST charger adapter to the red battery connector and yellow
charger connector.





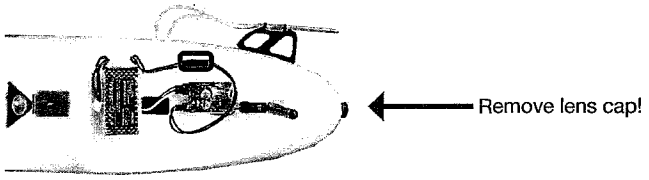
2 Wire and power receiver

Attach an antenna to the receiver. Connect the AV output cable to either receiver AV OUT port. Connect the RC power cable to the receiver DC IN port, and attach a battery to the red connector.



3 Prepare on-board components

Connect a fully charged battery to the transmitter inside the compartment in the nose of the plane. Remove the lens cap from the camera.



4 Viewing video

When using a 3DR Black Pearl Monitor to view your video, set the mode to *DIV* (M button changes modes), the channel to *8* (+ and - buttons), and the band to *E* (press the power button to access the menu).

For more information about configuring the FPV/OSD system, visit *3DR.com/Aero-M*.

Flying Mapping Missions

Takeoff Checklist

Before flying the mission, check the following:

» Camera is on with mission script ready and is secured into the mount with the mini-USB cable connected and the cap removed.

» Aero is powered and connected to the ground station with all pre-flight checks passed.

» The survey mission has been adjusted to account for present environmental conditions and saved to the Aero.

Initiating

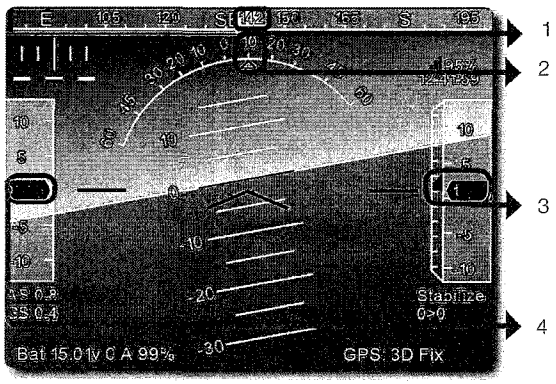
For automatic takeoff, set the Aero to auto mode and launch according to the instructions in the Automatic Takeoff section of these instructions (page 33).

For manual takeoff, set the Aero to auto mode after takeoff to initiate the mission in flight.

Monitoring

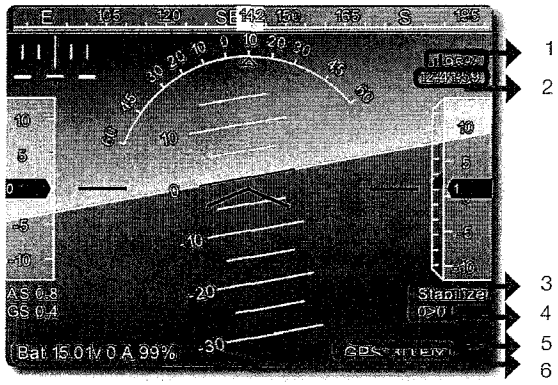
Monitor the Aero closely during the mission using your line of sight and the Mission Planner Flight Data screen.

Mission Planner Flight Data: Attitude



1 Heading direction
2 Bank angle
3 Altitude (black) and rate of climb (blue bar)
4 Ground speed

Status

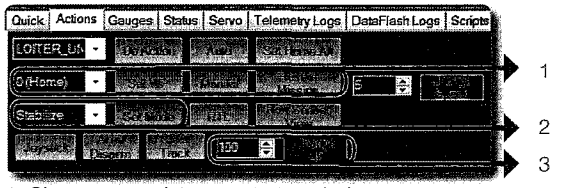


1 Ground station signal
2 GPS time
3 Currently enabled mode
4 Distance to current waypoint > current waypoint number
5 GPS status
6 **Battery status***
Full battery: 16.8 V
Low battery failsafe: 13.8 V

End your flight at 14 V!

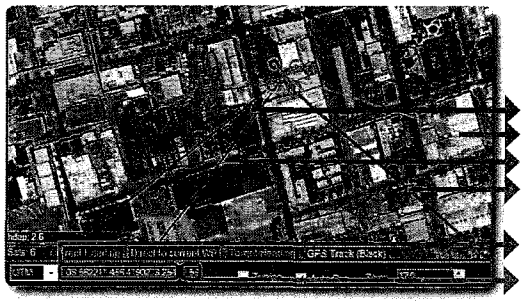
***Failsafe behavior enabled**

Actions



1 Change waypoints or restart a mission
2 Change modes
3 Change altitude

Flight Map



1 Current heading
2 Direct path to current waypoint
3 GPS-reported direction of travel
4 Actual flight path
5 Latitude, longitude
6 Altitude

Failsafes

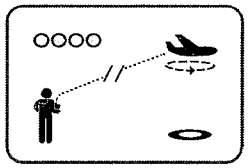
The Aero is programmed with a set of failsafe behaviors to prevent a crash in the event of a loss of one of the data or communication channels required for autonomous flight. Although certain failsafe have assigned LED indicators and tones, it is unlikely that you will be able to see these at a distance. Monitor the Flight Data screen for failsafe indications. If a failsafe is triggered, the assigned behavior will activate. To override the failsafe behavior (RTL in most cases), use the controller to regain manual control.

Regaining Manual Control
To regain manual control during the mission, switch to fly-by-wire mode using the controller. If you're a confident operator, switch to stabilize mode. If you observe instability in the Aero's flight behavior or it the aircraft moves outside your designated safe flying area, switch to RTL. Turning off the controller will automatically trigger an RTL and can be used in an emergency situation as a hard recall command.

RC Controller Signal Failsafe
Physical obstructions and interference from nearby wireless signals can affect the Aero's connection with the RC controller.

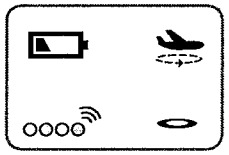
If the Aero loses contact with the controller, it will return to the launch point automatically and enter into a circle pattern above the launch point, indicated by a blinking yellow status LED.

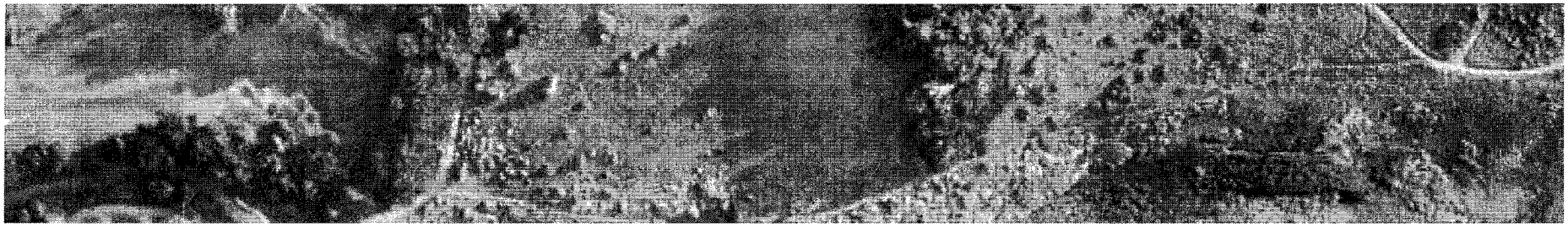
If the controller failsafe is triggered, wait for the Aero to return to the launch point, then regain manual control and either land or restart the mission.



Low Battery Failsafe
Environmental conditions can affect power consumption. Use the Mission Planner Flight Data display to monitor the voltage of the battery during flight.

If the battery reaches 13.8 V, the Aero will return automatically to circle above the launch point, indicated by a blinking yellow status LED and a quick repeating tone.





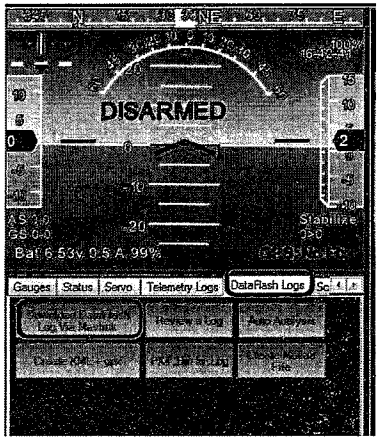
3 Process

Download Log File

Pix4D uses the GPS data from the Aero's log file to georeference the images. To download the Aero's dataflash log, power the Aero and connect to Mission Planner. The download process will be faster if you connect the micro-USB cable directly to Pixhawk's micro-USB port instead of connecting using the ground station radio. (When connecting directly to the Aero, set the rate to 115200.)

On the Flight Plan screen, select the *DataFlash Logs* tab under the heads-up display, and select *Download DataFlash Log over Mavlink.*

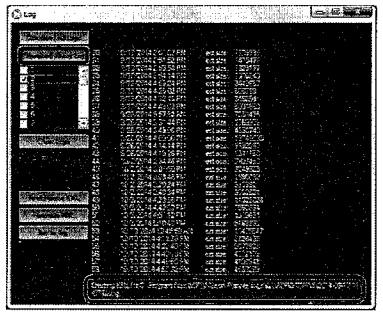
Mission Planner: Flight Data heads-up display



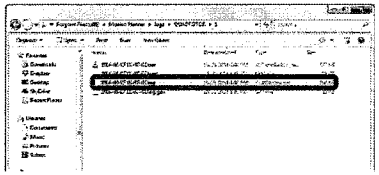
The Log window shows the Aero's recent flights. Select the flight for your mission, and select *Download These Logs.* This will save the log file to your computer in the location displayed under the list of flights.

To retrieve the log file, access your computer's file structure under *Program Files/Mission Planner/logs/PLANE,* and select the .log file for the date of your flight.

Mission Planner: Download Logs



Program Files: Retrieve log file

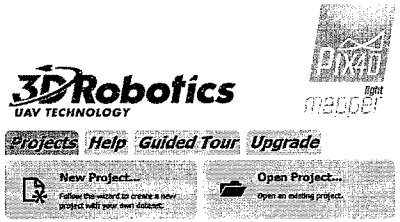


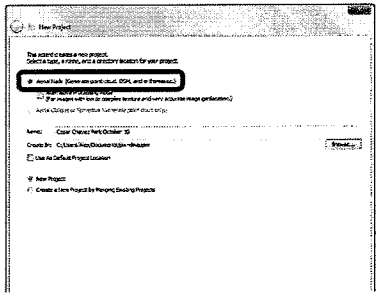
Pix4Dmapper Rapid Check: Create Project

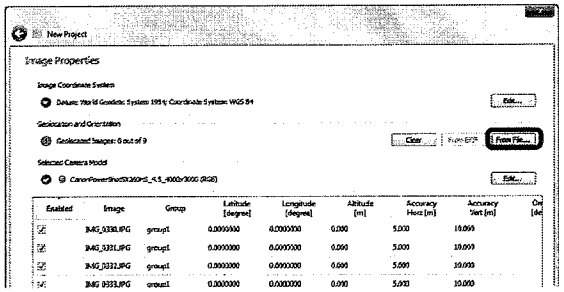
1
Open Pix4D Mapper, and create a new project.

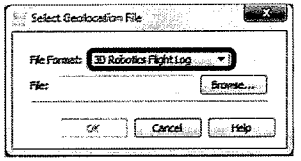
2
Select Aerial Nadir as the project type.

3
After adding the images, select *From File* to add the geolocation data from the Aero's log file. In the pop-up window, select 3D Robotics Flight Log as the file format, and upload the dataflash log file downloaded from Mission Planner.



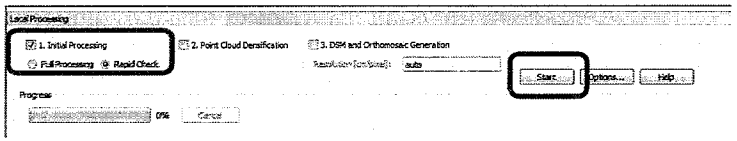




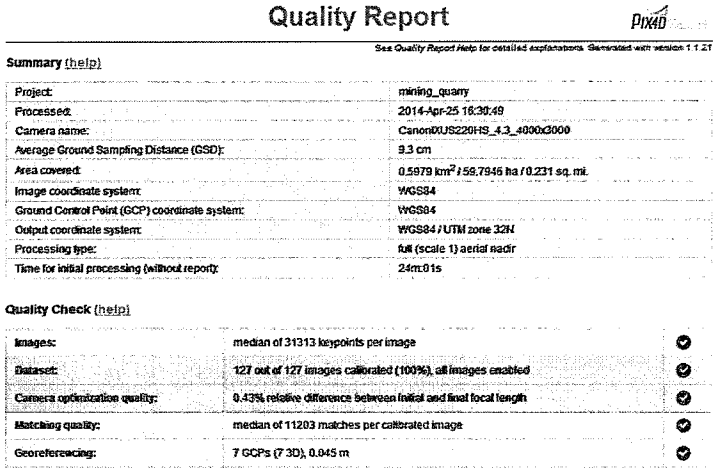


Pix4Dmapper Rapid Check: Initial Processing

After creating the project, select the Local Processing screen (Process menu). Check the option for Initial Processing and Rapid Check. Uncheck all other local processing options, and select Start.



Pix4D will generate a Quality Report that will indicate if the images are of sufficient quality to create a map.



Quality Report

Pix4D

See Quality Report Help for detailed explanations. Generated with version 1.1.21

Summary (help)

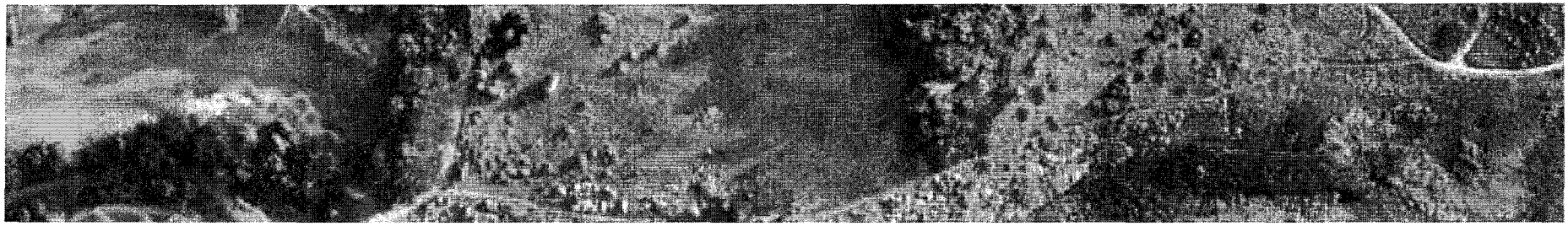
Project:	mining_quarry
Processed:	2014-Apr-25 16:30:49
Camera name:	Canon0US220HS_4.3_4000x3000
Average Ground Sampling Distance (GSD):	9.3 cm
Area covered:	0.5979 km² / 59.7946 ha / 0.231 sq. mi.
Image coordinate system:	WGS84
Ground Control Point (GCP) coordinate system:	WGS84
Output coordinate system:	WGS84 / UTM zone 32N
Processing type:	full (scale 1) aerial nadir
Time for initial processing (without report):	24m:01s

Quality Check (help)

Images:	median of 31313 keypoints per image	✓
Dataset:	127 out of 127 images calibrated (100%), all images enabled	✓
Camera optimization quality:	0.43% relative difference between initial and final focal length	✓
Matching quality:	median of 11203 matches per calibrated image	✓
Georeferencing:	7 GCPs (7 3D), 0.045 m	✓

Full Processing

To complete full processing for the map, visit support.pix4d.com for instructions.



Appendix

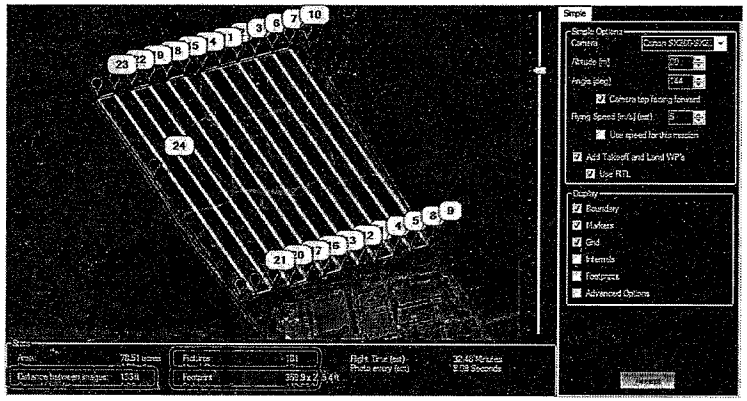
Aerial Imaging Concepts

Understanding key concepts in aerial images can help you understand the mission planning process and create better maps.

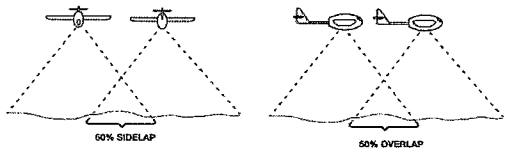
Distance-Based Imaging
By default, the camera captures only the images required to create the map. The Pixhawk monitors the distance traveled by the aircraft and sends a command to the camera to capture an image at the distance interval specified by the camera trigger distance parameter (*CAM_TRIGG_DIST*). This parameter is set by the Mission Planner Survey tool during survey configuration by calculating the minimum distance between images based on the parameters specified for the survey (altitude, overlap, sidelap). This distance-based imaging allows for more precise data collection, resulting in less images and data storage cost. Once configured, the Survey tool creates an event at the start of the mission script (after takeoff) to set the camera trigger distance to the specified interval and an event at the end of the mission (before landing) to reset the camera trigger distance to 0.

Time-Based Imaging
The camera is also equipped to capture images at a consistent time interval instead of using distance. This function can be useful if you want to capture images over an area without planning a mission. This time-based imaging results in more images per area, and therefore more processing time and storage cost. See the Trigger Type options on page xx to enable time-based imaging.

Overlap and Sidelap
To capture images for the map, the aircraft flies a lawnmower-like pattern in strips across the survey site. The front-to-back overlap between sequential images is called overlap; the side overlaps of adjacent pictures in different strips is called sidelap. The overlap and sidelap parameters in the Survey tool (see Advanced Options page xx) determine the distance between images and the number of images to be captured based on the projected ground area that each image will cover, called a footprint. Increasing overlap and sidelap improves the accuracy of the map while increasing flight time and processing time.



In the Survey tool, *Distance between Images* shows the specified camera trigger distance that will be assigned to the mission. You can also see the projected image footprint size and the total number of images to be captured.



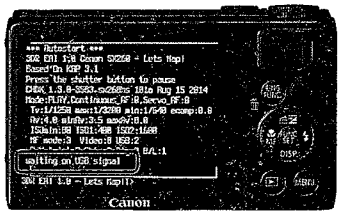
Default overlap: 50%
Default sidelap: 60%

3DR EAI

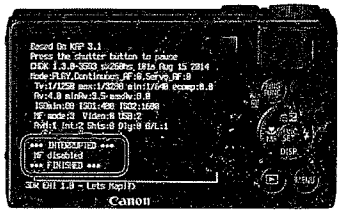
3DR EAI is based on KAP UAV Exposure Control Script v3.1: a great open-source project for kite and UAV aerial photography.

Start and Stop Script

Ensure the camera is set to P (program) mode before powering the camera. Upon startup, 3DR EAI starts automatically and listens for commands from the autopilot, indicated by *waiting for USB signal*. To stop (and re-start) the script, press the shutter button. The script will display INTERRUPTED when stopped.



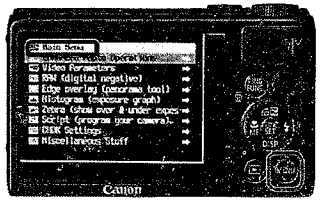
Script start: waiting on USB signal



Script stopped: INTERRUPTED FINISHED

CHDK Menu

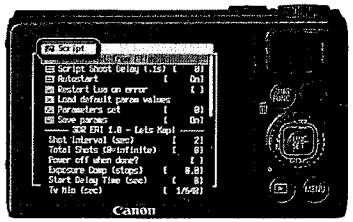
The CHDK menu contains all the standard options provided with CHDK. To access the CHDK menu, stop the script and select the *MENU* button.



CHDK menu

Script Menu

The script menu allows you to change the parameters associated with the script itself, including changing the trigger mode and adjusting exposure. To open the script menu, stop the script and select the *FUNC. SET* button. These parameters are configured for the S100 and do not require adjustment as part of standard operation.



Script menu

Trigger Type

This parameter allows you to control how the camera captures images. Trigger type defaults to *USB* for distance-based imaging during mapping missions. For time-based imaging, select *Interval* and specify the length in the *Shot Interval* parameter.

Trigger Type default: *USB* (mapping)
Variable intervalometer: *Interval* (default to 2 seconds, specified by *Shot Interval*)

Script menu: Trigger Type

Memory Reset

If the battery is left out of the camera for too long, the camera will reset its memory. To re-configure the camera in this case, visit *3DR.com/Aero-M* for instructions.

Online Resources and Information

Visit *3DR.com/Aero-M* for links to updates, more information about KAP UAV, and full CHDK instructions.

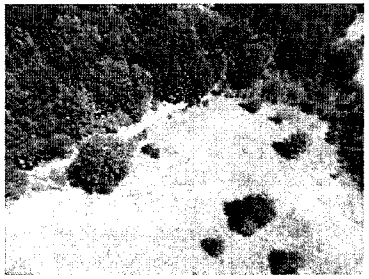
Image Quality Troubleshooting

If you observe poor image quality during the spot check or if you receive error messages during processing, use the settings below to troubleshoot the image quality.

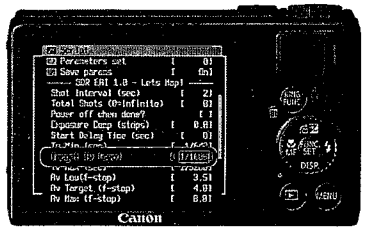
Blurry Images

To correct motion blur, adjust the shutter speed using the *Target Tv* parameter in the script menu.

Target Tv (shutter speed) default:	1/1250
To correct moderate motion blur:	Set to 1/1600.
To correct severe motion blur:	Set to 1/2000.



Example image: motion blur

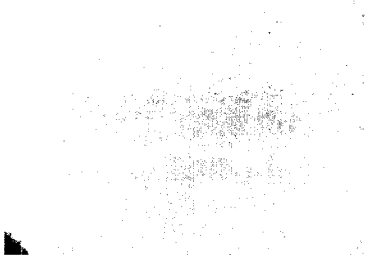


Script menu: Target Tv

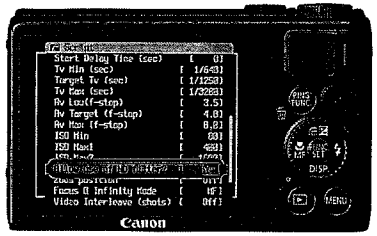
Overexposure

If the images are overexposed but do not show any motion blur, it can be due to flying in extremely bright conditions. To correct this, set the *Allow use of ND filter* parameter to YES in the script menu.

Allow use of ND filter default:	No
To correct overexposure:	Set to Yes.



Example image: overexposure

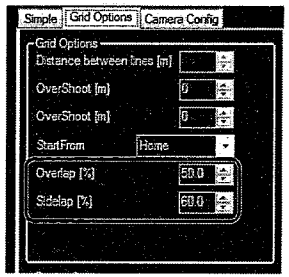


Script menu: ND Filter

Processing Errors

If you receive errors from Pix4Dmapper regarding the images, dataset, or matching points, increase the overlap and sidelap during survey configuration to improve the quality of the image set.

Overlap default:	50%
Sidelap default:	60%
To improve processing:	Set overlap to 60% and sidelap to 70%.



Mission Planner Survey tool Advanced Grid Options: Overlap and Sidelap

Operational Troubleshooting

No Images Captured

1 If the camera did not capture any images during the mission, first perform a physical inspection on the Aero.

Is the mini-USB cable connected to the camera's USB port?

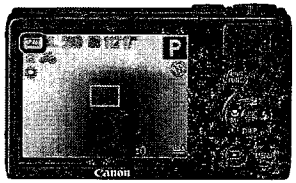
Camera (side)

Are the AUX OUT 6 pins connected on Pixhawk?

AUX OUT 6: black (-), red (+), white (s)

Pixhawk (side)

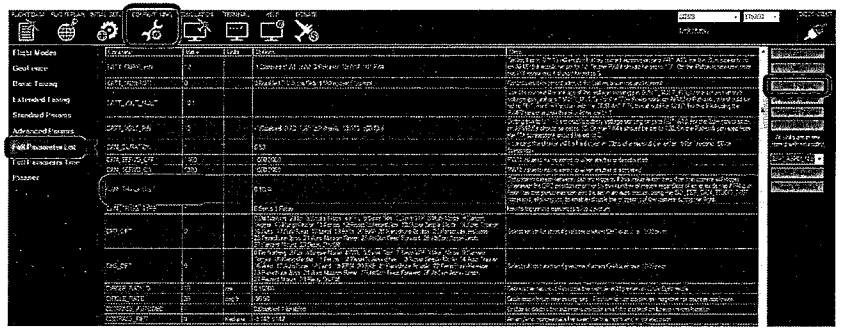
Is the camera battery charged? Unlock the SD card to view the Canon's battery level indicator.



Camera with SD card unlocked, running Canon software

2 Take a distance-triggered test image on the ground by manually setting the camera trigger distance parameter to 1 m.

Power the aircraft and connect to Mission Planner. Select ***Config/Tuning*** and ***Full Parameter List***. Change the ***CAM_TRIGG_DIST*** parameter to 1, and select ***Write Params***. Now carry the Aero for a few meters to see if the autopilot triggers the camera.



Mission Planner Full Parameter List: Set CAM_TRIGG_DIST to 1.

Aerial Precision Survey

Appendix D

X8+ Maintenance

In order to maintain the continued safe operation of the X8+ platform and to maintain it running at its optimal performance, we will maintain the X8+ aircraft at the following intervals:

If any part of the X8+ or its support equipment show signs of fatigue or damage, it will be immediately grounded until the component has been properly replaced by PIC per manufacturer recommendations.

Every flight

-Inspect the batteries for any signs of damage or abnormality as well as operating voltage.

-Inspect motors for any signs of abnormal wear, rough movement, or contact.

-Inspect propellers for any cracks, debris, or abnormalities.

-Inspect main body and arms for any cracks or abnormalities.

-Clean dusty components with compressed air or a soft cloth.

-Perform Safety Check

Every 30 days or 10 hours of flight (whichever comes first)

-Cycle flight batteries

-Perform Safety Check

-Run motors and observe for any wobble, abnormal sound or roughness.

-Inspect motor mounts and fasteners to ensure tight and secure.

-Inspect main body and arms for any cracks or abnormalities.

-Inspect all wires and connectors

-Inspect landing gear for cracks or wear

-Inspect condition and voltage of PIC controller and controller battery

Annually or every 300 hours of flight (whichever comes first)

-Inspect motor mounts

-Replace motors

-Replace propellers

-Replace all flight battery sets

-Replace PIC controller battery

-Inspect and clean all electrical connections

-Check for firmware update

-Recalibrate magnetometer

-Inspect all wires and connectors

-Perform Safety Check

-Inspect landing gear for cracks or wear

Appendix D

X8+ Flight Maintenance Procedures

Aircraft Name:		Serial Number:	
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Inspect batteries for any signs of damage/abnormality and operating voltage			
Inspect Motors for any signs of abnormal wear, rough movement or contact			
Inspect Propellers for any cracks, debris, or abnormalities			
Inspect main body and arms for any cracks or abnormalities			
Clean dusty components with compressed air or soft cloth			
Perform Safety Check			

X8+ 10 hour/30 Day Maintenance Procedures

Aircraft Name:	Serial Number:		
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Cycle Flight Batteries			
Run motors and observe for any wobble, abnormal sound or roughness			
Inspect motor mounts and fastners to ensure tight and secure			
Inspect main body/arms for any cracks or abnormalities			
Inspect all wires and connectors			
Inspect landing gear for cracks or wear			
Inspect condition and voltage of PIC controller and controller battery			
Perform Safety Check			

Appendix D

X8+ Annual/300 HOUR Maintenance Procedures

Aircraft Name:	Serial Number:		
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Inspect Motor Mounts			
Replace Motors			
Replace Propellars			
Replace all flight battery sets			
Replace PIC controller battery			
Inspect and clean all electrical connections			
Check for firmware update			
Recalibrate magnetometer			
Inspect all wires and connectors			
Inspect landing gear for cracks or wear			
Peform Safety Check			

Aerial Precision Survey

Appendix E

Aero-M Maintenance

In order to maintain the continued safe operation of the Aero-M platform and to maintain it running at its optimal performance, we will maintain the Aero-M aircraft at the following intervals:

If any part of the Aero-M or its support equipment show signs of fatigue or damage, it will be immediately grounded until the component has been properly replaced by PIC per manufacturer recommendations.

Every flight

-Inspect the batteries for any signs of damage or abnormality as well as operating voltage.

-Inspect motor for any signs of abnormal wear, rough movement, or contact.

-Inspect propeller for any cracks, debris, or abnormalities.

-Inspect fuselage for any cracks or abnormalities.

-Clean dusty components with compressed air or a soft cloth.

-Perform Safety Check

Every 30 days or 10 hours of flight (whichever comes first)

-Cycle flight batteries

-Perform Safety Check

-Run motor and observe for any wobble, abnormal sound or roughness.

-Inspect motor mount and fasteners to ensure tight and secure.

-Inspect fuselage for any cracks or abnormalities.

-Inspect main wing, vertical and horizontal stabilizers for cracks or warps

-Inspect all control linkages and connectors.

-Inspect all surface hinges for cracks or tears

-Replace main wing rubber bands.

-Inspect condition and voltage of PIC controller and controller battery

Annually or every 300 hours of flight (whichever comes first)

-Inspect motor mount

-Replace motor

-Replace propeller

-Replace all flight battery sets

-Replace PIC controller battery

-Inspect and clean all electrical connections

-Check for firmware update

-Recalibrate magnetometer

-Inspect all control linkages and connectors

-Replace main wing rubber bands

-Perform Safety Check

-Inspect main wing, vertical, and horizontal stabilizers for cracks or warps

-Inspect all surface hinges for cracks or tears

-Inspect all movable surfaces for wear

Aero-M Flight Maintenance Procedures

Aircraft Name:		Serial Number:	
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Inspect batteries for any signs of damage/abnormality and operating voltage			
Inspect Motors for any signs of abnormal wear, rough movement or contact			
Inspect Propeller for any cracks, debris, or abnormalities			
Inspect fuselage for any cracks or abnormalities			
Clean dusty components with compressed air or soft cloth			
Perform Safety Check			

Aero-M 10 hour/30 Day Maintenance Procedures

Aircraft Name:	Serial Number:		
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Cycle Flight Batteries			
Run motors and observe for any wobble, abnormal sound or roughness			
Inspect motor mount and fastners to ensure tight and secure			
Inspect fuselage for any cracks or abnormalities			
Inspect main wing, vertical and horizontal stabilizers for cracks or warps			
Inspect all control linkages and connectors			
Inspect all surface hinges for cracks or tears			
Replace main wing rubber bands			
Inspect condition and voltage of PIC controller and controller battery			
Perform Safety Check			

Aero-M Annual/300 HOUR Maintenance Procedures

Aircraft Name:	Serial Number:		
Maintenance Procedure	**Date**	**Completed By**	**Comments**
Inspect Motor Mount			
Replace Motor			
Replace Propellar			
Replace all flight battery sets			
Replace PIC controller battery			
Inspect and clean all electrical connections			
Check for firmware update			
Recalibrate magnetometer			
Inspect all control linkages and connectors			
Replace main wing rubber bands			
Inspect main wing, vertical , and horizontal stabilizers for cracks or warps			
Inspect all surface hinges for cracks or tears			
Inspect all movable surfaces for wear			
Perform safety check			

FLIGHT LOG

Appendix F

Date of Flight	Platform ID #	Location	Take off time	Land time	Total flight time in minutes	Date of last maintenance	Hours between maintenance before flight	Hours to next maintenance after flight	Post flight comment