McGill University

UNMANNED SYSTEMS CANADA
2019 Design Paper

McGill Aerospace Design Society
AERO McGill Drones

January 13, 2019

Contents

1 Analysis of Alternate Solutions

An effective design process prior to this competition must extensively address requirements listed throughout the Concept of Operations (CONOPS) with the goal of creating a unique and optimal solution to the tasks outlined within. In the context of UAV operations, the solution is composed of fleet organization, airframe selection, subsystem con- figuration and mission planning. Each aspect, tangible or intangible, merits research into the best option available concerning the missions. This yields specificity when writing parameters such as choosing optimal cruising speed or generality when planning the division of roles during flight. Below is a re-enactment of the decision process for selecting UAV types to employ from a technical and operational point of view.

1.1 Criteria for evaluating alternatives

1. **Flight Time**: In multi-step missions with distance to cover this is an important factor. It commands a weight of 15 (normally it would be 20 but the missions are not as time-intensive compared to previous years).

2. **Payload Capacity**: This is viewed as critical to both missions because it allows for delivery of the markers and surveying with a camera; mission success is impossible otherwise. It commands a weight of 30.

3. **Multirole**: When an extensive range of tasks will be performed by a given fleet structure, a versatile platform is necessary for flexibility in mission planning. Platforms exclusively adequate for a single task drain resources, remain underutilized and are to be avoided. It commands a weight of 35.

4. **Human Factors**: This accounts for the ease of interaction between UAS and crew during flight operations. It commands a weight of 20 (Normally 15 but one of AERO's priorities is that systems be as streamlined as possible for this year′s competition).

Vehicle	Flight Time	Payload	Multirole	Human Factors	Weighted Total
Weighting	**15**	**30**	**30**	**30**	**100**
Fixed-Wing	1	0.2	0.2	0.4	31
Large Multicopter	0.6	0.8	0.8	0.8	74
Small Multicopter	0.3	0.5	0.6	1.0	60

Table 1: Analysis of Options Regarding UAV Type

1.2 Discussion of evaluation

- **Fixed wing**: Fixed wing platforms similar to the Wing Wing Z-84 845mm have been studied. These fixed wing frames' most compelling advantage is extended flight time (exceeding two hours), although payload capacity is unimpressive [1]. While excellent for survey missions, the tasks on the second day feature an onerous amount of hovering above targets as well as precise payload delivery which render this platform useless for a whole day. The ease of use is relatively low as it entails a vast knowledge regarding fixed wings that is currently inexistent in our team.

- **Large Multicopter**: A hexacopter based on the Tarot X6 frame with a custom Lithium Ion battery provides an hour of flight time, more than enough for the missions although not nearly as much as a fixed wing. The lift power allows for a significant payload including a DSLR camera on a 3-axis gimbal, something unachievable by the other two options. This platform has been adopted as a heavy "Carrier".

• **Small Multicopter**: A versatile quadcopter based on the DAYA 550 frame was appraised. While incapable of fulfilling any mission objective on its own, it is well-suited as a "Recce" platform to support operations led by the more capable Carrier in accordance with the adopted BVLOS doctrine.

2 UAS Features and Capabilities

2.1 Heavy Lift and Endurance

The Carrier's powertrain makes use of T-Motor MN5212 motors and 1855 carbon fiber propellers to minimize the Sisyphean compromise between lifting power and propulsive efficiency. According to calculations and simulations, the Carrier is capable of carrying up to 8 kg of mission payload. A novel feature is the use of a state of the art 22.2V Lithium-Ion battery pack consisting of an array of NCR18650 Li-Ion cells, boasting a total capacity of 31500 mAh. This compelling setup provides a flight time of over 1 hour.

2.2 Robust Guidance, Navigation and Control

An autopilot is the central component in a UAV's avionics suite. The Pixhawk 2.1 multifunctional Pixhawk Cube Carrier Board has been selected after considering factors such as electrical specifications, interfaces with peripherals, and documented use cases. This autopilot runs the Ardupilot flight control software, which demonstrates excellent flight performance and robustness.

Navigation and control is aided by a dual-precision GPS system. A standard-precision GPS configured to be highly fault-tolerant safeguards navigation capability in all weather conditions, while a novel Real Time Kinematic (RTK) GPS enables high-precision position control when necessary.

2.3 Modular and Mission Capable

The Carrier's airframe has been designed to accommodate various avionics, submodules, and payloads. The new design introduced strategic structural reinforcement and weight reduction. The airframe is compatible with off-the- shelf foldable carbon-fiber frame arms to ease transportation. Furthermore, the Carrier is designed as a modular platform capable of carrying two sets of payload.

2.3.1 High-definition Imagery Acquisition Capability

A core competency is the ability to survey an area with a high definition Sony A5000 DSLR camera on a 3-axis auto- stabilization system. The gimbal can be locked to point in the nadir direction or be remotely controlled in three axes.

Integrated with a remote control and video transmitting system, it is capable of taking a 20-megapixel picture under command of a

Ground Control Station (GCS) and stream 540p live video. The DSLRs high resolution greatly reduces the time required to complete an automatic field survey by allowing for high altitude flight and less passes in a grid pattern. Additionally, a remotely-controlled optical zoom capability greatly improves the quality of images taken in the context of a detailed inspection.

2.3.2 Precise Marker Placement System (PMPS)

The PMPS consists of three sections, as shown below in Figure 1.

1. Marker dispenser
2. Payload delivery turret (PDT)
3. Motorized winch

The marker dispenser makes use of storage and feeding mechanisms inspired by firearm magazines [2]. A pair of servo-driven pawls ejects the marker, while a spring feeds new markers to be dispensed. As the system is retracted, the pawls ensure the marker remains on the target.

The PDT is a disk 20 centimeters in diameter containing a shaft dri gearing to which the marker dispenser is connected. Once the PD large radius allows for the rotational degree of freedom to deliver t face of the PDT's base is covered in velcro to securely anchor the P

The motorized winch enables precise control of the vertical po components in accordance with the operational BVLOS doctrine. D

to minimize dynamic disturbances. For delivery, it extends to allow the Carrier t altitude.

(a) Marker dispenser

(b) PDT and motorized winch

Figure 1: CAD renderings of PMPS

2.4 Reconnaissance Platform

In addition to the Carrier, the light Recce quadcopter is fielded on both days. By providing 30 minutes of flight time with more agility and less payload capacity, it supplements the Carrier for each task. While its avionics are similar to those of the Carrier, the Recce's most notable mission system is its Forward Looking Infrared (FLIR) camera. Operating with a nadir infrared (IR) camera restricts the field of view to a small area directly beneath the UAV. However, by point- ing the IR acquisition device in the horizontal direction, visibility is greatly increased and IR contacts are identified rapidly.

2.5 Ground Control Station

Images are post-processed at the GCS using OpenDroneMap and OpenCV software libraries which allow for the dis- play of a landscape in one ultra-high definition stitched image [3]. Efficient mapping software reduces the number of pictures required for stitching. Consequently, post-processing times for the generation of the orthomosaic and sur- veying flight time to take pictures are both reduced. Furthermore, post-processing software is customized to allow for the orthomosaic to be quickly appended with points of interest loaded from a KML file and manual overlay of additional features.

3 Communication and Control

A radio telemetry link acts as the primary communication and control (C^2) link. A RFD900X radio modem [8] is used for its exceptional range and reliability. To maximize link quality, the radio modem is equipped with high-gain dipole antennae and supplied with filtered 5 Volts power.

Radio telemetry devices are robust but remain limited by data rate. Therefore, a novel 2.4 GHz point-to-point WiFi link provides a secondary, high-bandwidth communication link. Since the expected BVLOS conditions entail terrain features that obstruct transmission, the WiFi modem and antennae will be mounted on a mast.

The transmission of WiFi and telemetry data are configured such that sufficient separation of frequency prevents any mutual interference. Furthermore, the WiFi link is expected to fail before the radio telemetry link due to its shorter range. This ensures control of the vehicle is maintained to the last possible moment with failure of the WiFi link forewarning impending loss of signal.

Mission critical live video feeds from the DSLR and FLIR cameras use high power analog transmission on the proven 5.8 GHz band on different sub channels to avert interference.

3.1 Ground Command

3.1.1 Aircraft Control

A computer running MAVProxy unifies the two C^2 links. This provides a graceful failover in case either a computer or a modem unit fails. The Mission Planner GCS connects to this data stream to provide flight data visualization and direct vehicle guidance.

MAVProxy, a utility for routing MAVLink data, also features rudimentary vehicle control and command functions to guide the vehicle in case the primary C^2 link is interrupted [4]. In fact, any smart device, like tablets or smartphones, can be used to communicate with the vehicles as long as one of the two communication computers is available. This capability gives ready access to vehicle diagnostics and hardware status to crew members.

3.1.2 Mission Control

The proprietary VR-GCS virtual reality control system is used as a central mission control dashboard, providing the di- rector of flight operations with a streamlined environment where all mission-critical data is presented in a distraction- free immersive simulated environment using the HTC Vive virtual reality system. Similar solutions have been used in military aircraft, such as the F-35 [5], as they greatly improve situational awareness. Flight information and sensor readouts are provided by virtual holographic displays, which can be rearranged in 3D space.

A TeamSpeak 3 voice communication server is used for team communications in place of radio handsets. This offers improved audio clarity and advanced features like speaker priority and background noise canceling. TeamSpeak 3 will be hosted on a independent server isolated from C^2 data traffic to avoid network congestion.

Ethernet switch technology used for networking ground station subsystems is reliable and can handle massive work- loads.
Nevertheless, if the Ethernet switch fails, the C^2 link can be maintained by each computer.

3.2 Summary of frequencies

A list of frequencies for all RF devices is given here

- 900 MHz - Radio control and telemetry
  - Ground and Air: 1000 mW transmit- ting power, 121 dBm receiving sensi- tivity
- 2.4 GHz - WiFi telemetry & VR video stream- ing_

Ground: 800 mW transmitting power,
up to 25 dbi gain

- Air: 800 mW transmitting power, 5 dbi gain

- 5.8 Ghz Analog Video FPV: DSLR & FLIR Live Feed
  - Air: 800 mW transmitting power, 5 dbi gain

Figure 2: Ground Station Network

4 BVLOS Strategy

A competent and well-coordinated flight crew is mission critical as human error is the leading cause of aviation inci- dents [6]. A crew resource management centered approach is used to improve human performance in the presence of factors such as fatigue and emergencies during flight. When the aircraft is airborne, the responsibility for safe op- erations is shared between the director of flight operations (DFO) and the pilot who are experienced in the Standard Operating Procedures (SOPs) for the most common emergencies.

4.1 Flight Crew

DFO Focuses on mission success by ensuring all flight objectives are met within a safe flying environment, coordi- nating crew activities and acting as mission commander. Using a virtual reality headset, the DFO assumes a quasi-omniscient presence via a bird's eye view which shows aircraft position information, live video feeds and telemetry data overlays (battery, mission progress).

Carrier Pilot Wields a powerful 16 channel remote control; Operates the Carrier in a level of involvement ranging from a micromanaging owner (position assist mode) or anxious bystander (fully autonomous mode) during the mission. During payload delivery, the pilot operates the PMPS.

Recce pilot Operates the Recce in position assist mode. They receive instructions from respectively the Carrier Pilot (to assist in spatial awareness) or the DFO (to investigate targets of interests).

Imagery Specialist Conducts image recovery, processing and runs the necessary algorithms to complete tasks. Dur- ing the survey and detailed inspection, they perform the time critical task of imagery analysis using computer vision algorithms supplemented by visual confirmation of features.

Systems Specialist Transports, assembles and configures the UAVs and GCS. This person masters the onboard and the ground systems, assists with miscellaneous tasks on the flight line and monitors the aircraft and ground station during flight operations. In case of an unforeseen emergency, their input helps the DFO and Pilots make decisions.

4.2 Operations Doctrine

During both flight windows, multiplatform operations are conducted. To mitigate the complexity of this type of flight environment, guiding principles are implemented.

The Carrier is the most valuable strategic asset available to the DFO. Experience proves that field repairs on the flight line or between competition events are impractical on this platform. Furthermore, it is financially prohibitive to main- tain an identical copy of the UAV in reserve. Therefore, the Carrier is primarily used for pre-planned, automated mis- sions (Survey) to known GPS coordinates at altitudes never below 2.5 meters to avoid ground effect and wireless data link line-of sight issues. Missions with in-flight rerouting and manual low level flying (Infrared Search) are assigned to the cheaper, expendable and more easily repaired Recce. When low flight in position assist mode is required of the Carrier (to use the imagery system and PMPS for detailed inspection and payload delivery), the agile Recce is flown manually to be used as a chase aircraft to maintain spatial awareness.

Deconfliction of both platforms is achieved first by assigning different launching times to ensure lateral separation when en-route to the area of operations. During the survey, within the farm, separation is maintained by altitude with the Carrier assigned higher flight levels. To avoid the Recce from being accidentally photographed during the survey, the DFO maintains situational awareness and gives direct evasive vectoring to the Recce Pilot if needed. On the second day, during inspection and placement both aircraft fly in the same formation with the chase Recce maintaining visual (first-person view) separation with the Carrier.

4.3 Aircraft Mission Configuration Table

Day 1 Day 2

Carrier

Gimbal Config. Locked to nadir direction Remotely controlled DSLR Config. FPV output enabled FPV output and Optical Zoom enabled Autopilot Config. Standard Parameters Flight Parameters to assist precise maneuvering Extra Payload N/A PMPS, 2 Parallel Lasers Recce FPV Extra Config. Payload FLIR with visible light filter Standard FPV

Digital Video Recorder Digital Video Recorder

Table 2: Aircraft Mission Configuration Table

4.4 Mission Flowchart

Figure 3: Order of Operations for Day 1

Figure 4: Order of Operations for Day 2

5 Survey Methodology

5.1 Carrier Area Survey

The Carrier, equipped with an image acquisition system featuring the DSLR and a gimbal locked in the nadir direction, will independently carry out an autonomous survey of the field for all information other than damaged solar panels. The DSLR camera shutter controlled by a relay will automatically take pictures with a relatively low value of 20% sidelap and overlap during the grid survey. Post-flight, the images are recovered for processing, as shown in Figure 5. Utilizing geotagging technology, which appends a corresponding GPS coordinates onto each picture, the Imagery Specialist generates an orthomosaic with relatively few pictures (a typical sidelap value is 40%). The geotagged picture (EXIF file) is processed efficiently with the field mapping software OpenDroneMap. The output is an orthomosaic image with a ground resolution of 1 centimeter per pixel, which is sufficient.

Figure 5: Order of Operations for Image Processing

The lower sidelap value allows for fewer passes and a quicker grid survey. A typical flight plan for a rectangular area is shown in Figure 6. The survey is performed at an altitude of 40 meters and speed of 8 meters per second. The survey time is under 10 minutes, covering 90000 sq. meters of area to yield the desired target ground resolution.

By flying along the largest dimension of the survey area, the total number of turns is minimized. Additionally, entrance and exit of the pattern are on the side nearest to the launch and recovery point. Furthermore, a turning radius of 2 meters is sufficient to avert aggressive turning generating excessive airframe loading while following the pattern. These best practices will be implemented if possible on the actual area of the farm.

Figure 6: Example of a grid survey covering 90000 m^2

5.2 Recce Infrared Search

Simultaneously, the FLIR camera-equipped Recce flies at lower altitudes (not exceeding 30 meters). A "move-look- move" methodology is followed with the goal of focusing only on locating IR signals. Interpreting the FLIR FPV data, the DFO will declare IR contacts and provide an estimated distance and bearing from the UAV. Using the current GPS coordinates of the Recce, the Imagery Specialist attempts to locate the IR contact, which is then logged and overlaid onto the DFOs virtual reality view. The DFO calls for closest targets to be overflown (and hovered on) at low altitude for precise coordinates to be recorded. In Figure 7, the rerouting of the mission for the purpose of further investigation can be seen by the Point of Interest markers 3 through 7. The damaged panels coordinates are compiled and read from a KML file and appended onto the orthomosaic as markers. The video replay of the IR camera and time stamping of the GPS locations will allow identification of the three most damaged panels. Finally, changes of major features will be indicated by numbered shaded areas on the orthomosaic after a visual comparison by the crew.

Figure 7: Example of inflight rerouting to investigate IR Contacts

6 Detailed Inspection Methodology

Cooperation between two UAVs assists in the completion of Task 2. The Carrier performs detailed inspection while the Recce provides overwatch. The Carrier is flown autonomously to the GPS Coordinates of a panel at a cruising altitude of 10 meters before position assist mode is engaged followed by a descent to 3 meters directly above the panel. Parallel beams of visible laser light are activated to provide a scale for the damaged region and numerous pictures are taken by remotely triggering the camera shutter and varying levels of optical zoom. The remotely-controlled three-axis gimbal reorients the camera without maneuvering the UAV to obtain sharp, centered and focused pictures. After the flight, these images are retrieved from the DSLR to analyze the type of damage, a task performed visually by the Imagery Specialist (reading the text in zoomed-in pictures). OpenCV-based software is then used to automatically compute the dimensions of the damaged area. The area is recreated to scale as a vector image using LibreOffice Draw as a graphics editor from the OpenCV data.

7 Marker Placement Methodology

At each panel, following the inspection, the Pilot will remain in position assist mode. Precise re-positioning of the Carrier is possible under guidance of the RTK GPS. To avoid the hazards of ground effect, the Carrier hovers at an altitude of 3 meters while the PMPS is lowered on to the target. As the operator will be focused on payload delivery, the Recce will provide an overwatch view angle and ensure that the Carrier is clear of conflict with the panel or any obstructions. Both the Recce and the DSLR camera provide the necessary view for payload delivery. Once the PDT adheres to the target, it can reorient the dispenser and align it with the release point. The PDT is effective on angled surfaces due to its ability to adhere to velcro securely. Upon successful placement, the Carrier will hoist up the PDT and hold position until the Recce is at a safe distance as explained in Figure 4. At each damaged panel, the detailed inspection followed by the marker placement is repeated. Both UAVs will return to base autonomously.

8 System Level Testing

A rigorous testing process has been developed upon review of the team's performance last year. The following systems were tested by simulation, experimentally on the ground or in-flight with the following resulting analysis:

Performance Reproducibility More than ten test flights were carried out, all showing promising and consistent re- sults for each UAS with regards to endurance, survey time, and payload delivery. Little variation or undesirable behavior was observed in conditions of light rain, heavy wind and even snow.

Avionics (Hardware, Software, Electrical) The avionics suite, comprised of the Pixhawk Cube 2.1 autopilot, M8N standard GPS and RTK GPS, has proven itself to be versatile and reliable during flight. The power supply and distribution has no electrical points of failure that is unguarded by protective circuits; similarly, all airframes are evaluated to be structurally resilient. The Mission Planner software, with the ability to create extensive flight plans and quickly rewrite vehicle settings, performed satisfactorily.

Mission systems The DSLR, with its numerous features and optical zoom was extensively reconfigured. Settings such

as aperture, exposure and scene selection were studied under different conditions to determine optimal config- uration for each mission. The gimbal's range of motion was tested to derive the maximum travel it should have without stressing wires or destabilizing the system. The PMPS was stress tested to failure to find its maximum carrying weight and accuracy of motion. The IR camera image quality and effective range under different light- ing conditions were evaluated with the competition IR emitters. Each of the aforementioned subsystems was independently tested on a benchmark UAV prior to being incorporated on the Carrier or Recce

Communications Special attention was paid to communication links based on outcomes seen in previous years when attempting to incorporate experimental systems such as antenna trackers or a new telemetry protocol. Each radio link (video, remote control and telemetry) was independently tested by varying transmitter power, line-of-sight obstruction and distance to evaluate effective range and data rates. These systems were tested simultaneously to verify that interference would not cripple our operations.

Pilot Competence Airmanship was tested with mission simulations, unexpected triggering of failsafes and control in the unassisted Stabilize mode. The pilots' extensive experience has been defined by many years of RC flying and the tests included elements of effective communication with other members and prioritization of specific mission objectives when facing unanticipated events.

9 Innovation and Novelty

It is important to reiterate the innovative and novel components of the presented systems and mission approach. Due to varying levels of maturity of new technology and the complexity of implementing new procedures, such choices must be justified.

Remotely Controlled DSLR with Optical Zoom Although the setup of the entire gimbal-DSLR-remote zoom is exper- imental, it has been deemed highly beneficial and a core competency compared with traditional imagery setups for survey time and image quality during detailed inspection.

Proprietary Payload delivery The risk of the Carrier crashing due to ground effect has been deemed too high. Con- sequently the combination of a lengthy winch with visible light laser avoids this problem. The entire system is designed and 3D printed in-house.

FLIR A horizon facing camera offers a more expansive field of view, contributing to a faster mission completion time as opposed to that of a grid survey and stitching.

Folding Arms Whether it is being transported to the theater of operations or between the flight line and the launch location, portability of the considerably heavy Carrier streamlines logistics.

Multirole platforms The diverse requirements of each mission mandate that UAVs feature modular subsystems that can be effortlessly swapped. The Carrier supports a gimbal, DSLR camera and payload delivery system all at once; it is more capable than most UAVs.

Dual UAVs Having both the Carrier and Recce UAVs operating at the same time ensures constant enhanced situa- tional awareness and the ability to carry out multiple tasks simultaneously. Its proven success during flights has only reinforced the legitimacy of this configuration.

Mission-dependent Dynamic Software On day 2 different parameters are uploaded onto the Carrier's flight con- troller to smoothen throttle, yaw, pitch and roll inputs. While controls are more sluggish, this facilitates payload delivery.

Crew Resource Management Within the context of flight operations, the human factor is taken into account and meticulous attention is given to crew communication to minimize human error. The introduction of an aviation concept to the UAS ground station is novel.

10 Safety and Risk Management

10.1 System Level Safety Issues

UAS Operation poses inherent risks to people on the ground and other airspace users [7]. The table below covers failure scenarios and mitigation strategies.

Failure scenario Response Mitigation Strategy Flyaway Manual kill switch by pilot IMU and GPS testing / re-calibration Total loss of communication link Automatic kill switch Communication system metering;

Range assessment and testing Component detachment Operational pause. Decision by DFO for course of action (continue mission or attempt return to base).

Checklist for fasteners, crew resource management training

Catastrophic structural failure Manual / automatic kill switch Flight testing, checklist for fasteners

Table 3: Table of safety issues and mitigation

10.2 Potential Single Point Failure Modes

Component Failure Mode Impact on Safety Impact on Mission Motor Loss of thrust Minor: Hexacopter platform re-

tains limited airworthiness

ESC Burnout Minor: Hexacopter platform re-

tains limited airworthiness

Voltage sag

Minor: Battery failsafe triggers, ve- hicle returns to base, or failing that, lands immediately

Battery Battery dam-
age

BMS Measurement

error

Minor: Mis-estimation of remain- ing battery capacity, possibility of battery drain leading to vehicle crash

Major: Operator must decide to abort mission or reduce mission scope

Autopilot BEC Burnout

Avionics BEC Burnout

Radio Telemetry
Range Dropout
Minor: Telemetry system activates failover to use WiFi telemetry
Minor: Mission scope reduced due to shorter range of WiFi link
WiFi Teleme- try
Range Dropout
Minor: Video feed lost, telemetry system activates failover to use ra- dio telemetry

Loss of 3D lock
Minor: Hexacopter retains con- Minor: trollability

Autopilot exits auto flight modes, operator continue mission in manual flight modes GPS GPS glitch Major: Erroneous position estima- tion may lead to flyaway
Minor: Operator force switch to manual flight mode and continue mission Gimbal sys- tems
Stabilization malfunction
Minor: Hexacopter retains full air- worthiness and controllability
Major: Operator continues mission with increased difficulty in visual surveying

Table 4: Potential Single Point Failure Modes

11 Project Management

11.1 Project Risk Management Plan

Project management presents inherently significant risks [8]. Unexpected budgetary, logistical and technical issues can lead to unforeseen project delays and setbacks. Therefore, it is critical to identify and mitigate potential risks.

Category Fault Desc. Consequence Mitigation Plan
Management Team communica- tion issues
Team progress slows

A central communication system (SLACK) and regular meetings ensure good communication and continuous organization in team.
Development
Economy shipping will only be used if time al- Shipping Delays
lows. When courier shipping is used, customs Development delays
brokering is sought in advance. Vehicle component incompatibility
An abundant supply of connectors allow for on- site customization if required
Software develop- ment issues
Programming standards are strictly adhered to. Preparations to fall back to previous stable ver- sions are made during development
Testing
When installing and testing components, a list of best practices are enforced, such as:

- Always plug in smoke stoppers if the main battery is connected during testing
- Always use multimeter to check for short circuits when powering freshly installed components

• Always follow a full set of pre-flight checks
• Always enforce a geofence, with minimum dimensions 80m in altitude, 60m in radius
Depletion of Sup- plies
Testing delay and Damage to vehicle
potential setbacks components
in competition preparation
An inventory of consumables including elec- tronics supplies, hardware, and fasteners are kept. The inventory list is updated as supplies are consumed during work sessions
Travel
Time wasted in waiting for resupply; Progress delays
Flight crew members are required to check their schedules for traveling far ahead of the competi- tion. Multiple crew members may take over driv- ing duties, extra vehicles are prepared, and re- sources are allotted for using air transport at the last minute
Damage to vehicle components
Team supply and Travel issues
travel safety are affected
Unable to complete mission task Appoint crew member to plan repairs Crew issues Crew member un-
available
In prior months, crew training is emphasized and expansive; team will have stand-ins ready

Table 5: Project Risk Management

11.2 Milestones, Scheduling and System Level Testing

• Team formed and tasks assigned (9th September)
• Aerial platforms airworthy with avionics (15th October)
• Ground station layout, communication frequencies determined (15th October)
• Pickup mechanism design selected (15th November)
• Final onboard mission systems selected (15th November)
• Flight Validation of Imagery Systems (15th December)
• Image stitching software validated (15th December)
• Customized Manufacturing completed

– Airframe customization completed and installed (31st December)

11.3 Milestones ahead

• Payload delivery and recovery mechanism manufactured (31st January)

• Testing completed

– System level

* Flight testing

· Three successful test flights with all avionics and mission systems (16th February)

· Mock competition flight in mission scenario (23rd February) * Crew training

· Pit Stop certification: Crew capable of changing propeller and battery or conduct repairs (31st January)

– Component level tests in preparation for flight testing (28th January)

* Avionics: Software validation and electromagnetic compatibility (EMC) tests (19th January) * Data transmission: Range testing and RF environment compatibility tests (19th January) * Payload (including

pickup mechanism, gimbal): Functional tests (26th January)

- Flight team trained (31st March)
- Competition SFOC obtained (7th March)

Figure 8: Project Gantt Chart

11.4 Project Budget

McGill Drones is a project team within the AERO McGill Student Society which handles costs associated with outreach, logistical support, and branding.

Expenses	Budget ($)	Actual ($)	Specifications
Registration Fees	500	500	
Travel	1500	TBD	Gas, rental, food
Airframes	1500	830	Tarot X6, DAYA 550, extra sets of frame arms and landing gears
Propulsion elements	2000	1930	New T-Motor MN5212, 40A, ESCs, 3 sets of 18x5.5 CF Propellers
Avionics	1500	660	SpektreWorks Kore carrier board, Pixhawk 2.1 Cube, GPS, RTK GPS,
Video and imagery acquisition	1000	720	5.8GHz Video transmitter and receiver, HDMI decoder, monitor
C2 Link Hardware	800	520	Radio and WiFi modems
Custom manufacturing	600	TBD	Machining and 3D printing services
Supplies	600	450	Batteries, wires and cables, tools
Total	10000	5110	

Table 6: AERO Project Budget

Figure 9: Budget Allocation for AERO McGill 2018-2019

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