UAV Challenge: Medical Express 2018

Deliverable 1 Report

CanberraUAV – www.canberrauav.org.au

1 About us

CanberraUAV is a not-for-profit community group dedicated to developing and promoting the field of civilian UAVs. The group operates on a voluntary basis, and is open to all members of the community.

We have been fortunate to attract team members from a wide variety of relevant disciplines, including aeromodelling, mechatronics, aerospace engineering, software engineering, communications engineering, and photography. Building on our experiences in the 2012, 2014, and 2016 UAV Challenges, we have continued development of software and hardware for flight control, ground control, and mission systems. With the new requirements presented in the 2018 UAV Challenge, we have further extended our capabilities by developing additional functionality to operate with new and innovative airframes.

2 Summary

Development efforts so far are spread, with new air vehicle configurations, computer vision tools and communication systems all in various stages of test and evaluation. Our final system configuration will be determined closer to the UAV Challenge. We intend to participate in the Extension Autonomy Challenge component of the 2018 UAV Challenge.

A Thrust Vectored Belly Sitter (TVBS) air vehicle has been developed and test flown, in parallel with further refinement of the quad-plane configuration we used in 2016. Our computer vision tools remain under active development, both for the UAV Challenge and broader use cases. Work to overcome limitations with cheap sensors such as the Raspberry Pi Camera has resulted in promising results, as has experimentation with marker identification. We will again implement redundant and parallel communication links, and are currently working to improve capabilities with the RFD900X and 3G/4G modems.

3 Project Status

CanberraUAV is increasing our focus on developing a system that is accessible for hobbyists and organisations with limited resources. To achieve this we are working to achieve high end functionality using entry level hardware, such as small flying wings and the Raspberry Pi, as well as placing emphasis on documenting and recording our activities. Through the use of 3D printing and efficient design, we hope to employ a smaller air vehicle than previously used.

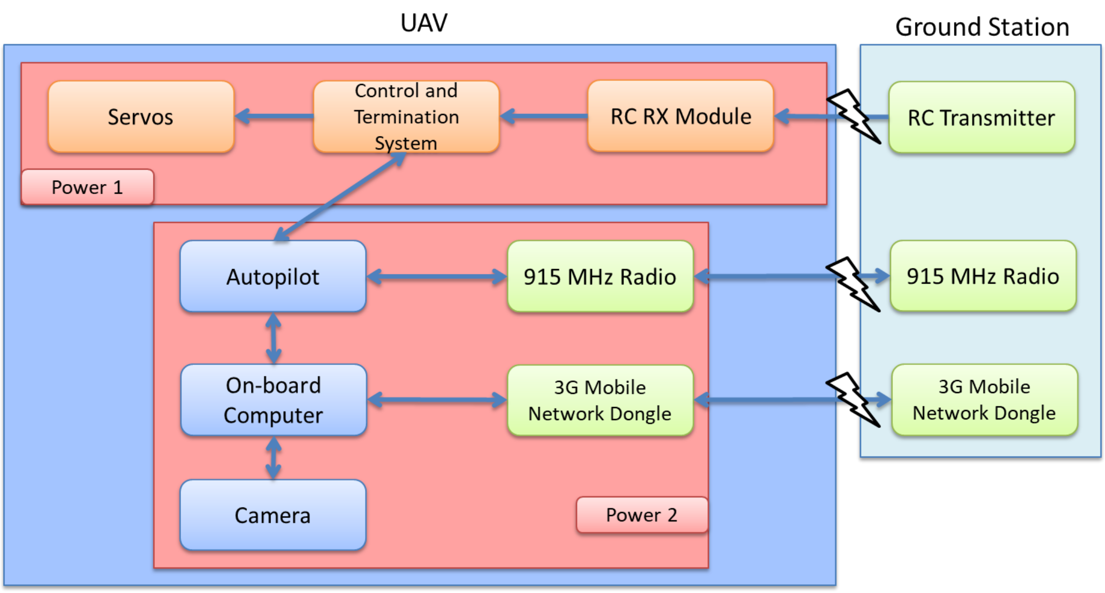
Our air vehicle development for the Retrieval UAV is currently focussed on a concept we call a Thrust Vectored Belly Sitter (TVBS). TVBS has evolved from dual motor tail sitting platforms, with the addition of tilt mechanisms to the motors. This concept achieves the compact footprint of Tail Sitter designs, yet overcomes instability due to cross wind and uneven terrain. TVBS control techniques have been proven in take-off, landing, and hover. We are continuing to optimise transition techniques and to refine thrust vectoring mechanisms. If the TVBS airframe does not progress to a level that we are confident is capable of completing the requirements of the UAV Challenge, a quad-plane platform (similar to that used in the 2016 UAV Challenge) will be used. If a Communications Relay UAV is needed we will most likely use a conventional fixed wing airframe.

We intend to implement the systems necessary to complete the extension autonomy component of the 2018 UAV Challenge by building on the existing ADSB avoidance code developed for ArduPilot by members of the CanberraUAV team. We aim to achieve the full-autonomy level of the 2018 UAV Challenge, including fully automatic target acquisition and landing.

4 Overall Design of the UAV systems

4.1 High level overview

A diagram of the overall system is shown in Figure 1. A description of each of the major systems is given in the subsequent text in this section. Both the Retrieval UAV and Relay UAV will carry the same flight controller systems and hardware required for avoidance.



4.2 Control and Termination System (C&TS)

The C&TS board is a standard part of the Pixhawk flight controller, which CanberraUAV has been heavily involved in the development of over the last six years. The board will have standard firmware to provide support for all UAV Challenge fail-safe requirements. The C&TS will be independently powered and will implement the primary flight termination system using fixed maximum servo positions.

The C&TS will monitor the autopilot, plus the radio control receiver, and will be the sole controller of flight surface actuators and motors. Flight termination can be initiated by the Ground Control System through command to the autopilots, or as a condition based autonomous action. If the C&TS system malfunctions, flight termination will be immediately initiated.

4.3 Geo-fence system

The autopilot will continually monitor mission boundary compliance via redundant GPS devices. If the autopilot detects a mission boundary violation it will signal the C&TS, which will initiate flight termination. Mission boundary detection will be via the standard even-odd ray-casting rule for polygons. Mission boundary edges will be programmed into the autopilots non-volatile memory and checked during pre-flight preparation, as well as displayed on the ground station for operator monitoring. Visual warnings (on the GCS) of approach to the geo-fence boundary will be used while under manual control during scrutineering.

Vertical boundary detection will be via barometric pressure. Compliance with AMSL pressure altitude limits will be performed by the autopilot and will trigger flight termination if breached.

4.4 E-stop

The UAVs will have a UAV Challenge compliant E-Stop device which will remove all power from propulsion systems and radios.

5 How will the UAV be employed to complete the mission?

The following description covers all options being considered in terms of airframe and communications links.

Both the Retrieval and Relay UAVs will take-off from the Base area and transition to fixed wing flight (as applicable) once at a safe altitude. The UAVs will fly via the Transit Waypoints to the Remote Landing Station. If either UAV detects a hazard (as part of the Extension Autonomy Challenge) it will automatically plot and fly a course around the obstacle.

Once at the Remote Landing Site, the Retrieval UAV will circle above the reported (approximate) location of Joe. An imaging system will provide input to computer vision software in order to pinpoint the location of the landing target. The Retrieval UAV will then perform a precision landing on the target (with opportunity for landing veto by organisers), using an on-board camera to refine the landing point as it descends. Once landed, the air vehicle will disarm and signal for Joe to load the blood sample.

Whilst the Retrieval UAV is at the landing site, the Relay UAV will relay the 900 MHz radio link to the GCS.

Once Joe has signalled that the sample is loaded and is a safe distance away (via the arming switch and 1-minute wait), both UAVs will return to the Base area, honouring the transit waypoints and avoidance requirements as needed.

6 Extension Autonomy Challenge

CanberraUAV intends to take part in the Extension Autonomy Challenge.

The ArduPilot flight controller software developed (in part) and used by CanberraUAV currently contains code to automatically avoid other aircraft based on ADSB signals, as documented in http://ardupilot.org/copter/docs/common-ads-b-receiver.html#enabling-manned-vehicle-avoidance.

CanberraUAV will further develop and test this code to meet the UAV Challenge requirements. This further development would include the capability to ingest non-ADSB data streams, plus intelligent planning of diversion paths taking into account the overall layout of mission waypoints and Joe's location.

7 Risk assessment

We seek to maximise autonomy while assuring safety to people and property. Our redundant hierarchical architecture provides a high degree of on-board processing and decision-making. Automated take-off and landing, flight stabilisation, navigation, failsafe, communication, sensors and computer vision systems will be situated on-board the aircraft, with the ground station providing the required overall monitoring and management functionality. A relay aircraft with the same level of autonomy may be employed to provide additional assurance for the communications link between the retrieval UAV and ground station.

Failure Mode	**Mitigation**
Insurance	Preliminary work will be carried out at our local model aircraft field under MAAA procedures with appropriate insurance, and the regular critique of fellow modellers. Testing may be carried out on private property near Canberra, with appropriate insurance.
Airframe Operation	Operation to be in line with CASA Part 101
Airframe Installation	Aircraft and pilots to obtain MAAA heavy model certification, if required.
Range Safety	We will develop a range safety plan appropriate for each site. For the MAAA field we will use the MAAA Manual of Procedures. For our long-range test site, we have developed appropriate range procedures, with a designated range safety officer.
Engine	- Starting and operation to be in line with MAAA procedures - Engine starting procedure in accordance with CanberraUAV Operations Manual. - Stopping of the engine to be by removing power to the ignition.
Fuel	If used, fuel will be stored in a AS/NZS 2906 compliant container, containing only enough fuel to carry out the mission with an adequate reserve. Appropriate safety procedures will be implemented for transport and storage.
Electrical power	- Where practicable, we will use separate battery packs for propulsion, Primary control system, instrumentation and C&TS. - Any LiPo batteries will be adequately protected. - Batteries to be of capacity adequate for mission with reserve.
Connections, wiring and soldering	To be carried out by experienced electronics technicians with years of experience in model aircraft and marine electronics in the field.
Autopilot	Loss of the heartbeat signal throughout software (written by a professional programmer) will notify failure to the C&TS.
Geofencing system failure	Failure of the system running the geo-fencing program will alert the control and termination system by loss of the heartbeat.
Air traffic	- Radio watch will be held by the pilot in charge during trials at the test range by an experienced aviation pilot. - Flight altitude will not exceed 1500 ft AGL.

	- Prior contact will be made with local gyrocopter pilots. - ADSB-In notifications to both the air vehicle and ground control software
Fly away of UAV	Extensive practice at test range to UAV Challenge rules (including geo-fencing), but with a soft termination to be carried out by the C&TS.
Rescue of lost UAV	Procedures to be put in place by our experienced bushwalker prior to field testing.
Bugs in software	Will use Software In The Loop (SITL) simulation testing to verify software and hardware (autopilot and peripherals), and reduce risk of software bugs.
Configuration management	We are using best software industry practice for configuration management and software version control.

8 Risk management protocols

8.1 'Safety first' culture

The team will comply with CASR-101, but will additionally stress safety first, and will not fly unless we are confident it is safe to do so.

8.2 Liability and insurance

Testing to this point has been at a MAAA insured site, staying within MAAA rules. We will obtain appropriate team insurance for both flight-testing and competition flights.

8.3 Pilot proficiency

Two team members hold MAAA[1] (Model Aircraft Association Australia) gold-wings and most others hold bronze-wings. Five members hold UAV Controller Certificates or Remote Pilot Licenses. The team has more than 50 years of aero-modelling experience between them. Four members also have experience in full-scale aviation as pilots or engineers.

8.4 Pre-flight checks

The team will use a combination of automated and manual checklists, physical inspection and testing to ensure all systems are operating correctly before flight. The GCS will display and report system status of all connected systems, and warn of any detected issues.

8.5 Management of radio frequencies

All radio communication will be digital, including the video link. We currently expect to use:

- 915-928 MHz band for low-bandwidth digital telemetry and control link
- 2.4 GHz band for visual range RC control (ACCST or similar)
- 700 MHz, 850 MHz, 900 MHz, 1800 MHz, 2100 MHz, 2600 MHz 3G/4G mobile network bands for high-bandwidth digital data link

8.6 Radio Control override

RC override by the safety pilot will only be undertaken within visual range. Any activation of the Flight Termination System will take priority over the safety pilot's RC input. Take-off and landing will be under autopilot control, with the option of manual take-off or landing at the discretion of the safety pilot. Radio control takeover and "stick mixing" will be used to allow instant override by the pilot without any intervention by the ground station operators.

[1] http://www.maaa.asn.au/

8.7 Loss of data link

The UAV will monitor data link integrity of both the high and low-bandwidth links via MAVLink heartbeat messages sent from the GCS at a rate of at least 2Hz. On loss of data link for 10 seconds, the UAV will return to the Base area (via the transit waypoints). If data link is not re-established after 2 minutes at the Base area and RC control is not possible by the pilot, a flight termination will be initiated. If RC control is possible the pilot will land the UAV. Loss of GPS at the same time as data link loss will cause flight termination.

8.8 Engine failure

The UAV will have electronic engine monitoring. In case of engine failure, the UAV will attempt to restart the motor. Should the problem persist, appropriate action will be taken by the GCS operators.

8.9 Loss of GPS positioning

Loss of GPS position will switch the autopilot into a dead-reckoning mode which fuses sensor information from the compass, airspeed sensor and IMU to estimate position. In GPS failure mode the UAV will circle, compensating for estimated wind, while maintaining current altitude for 30 seconds, and waiting for a GPS signal. If there is no signal after 30 seconds, a flight termination will be initiated.

8.10 Autopilot lock-up

The autopilot will provide a 10 Hz heartbeat signal to the C&TS system. Lack of heartbeat for 0.4 seconds will cause the C&TS to initiate flight termination.

8.11 Failure of Ground Control station

If the autopilot detects no communications heartbeat signal from the GCS for a period of 10 seconds then the loss of data link procedure will be initiated.

8.12 Additional systems

We do not currently propose to use any pyrotechnic devices.

8.13 Battery management

LiPo batteries will be used for the propulsion systems in all-electric airframes, or just the vertical propulsion system in the case of a hybrid electric/petrol airframe. Best practice techniques will be used for the safe usage and storage of the LiPo batteries.