2014 UAV Outback Challenge

Deliverable 2 – Technical Report

1   Table of Contents

2 Statement of Originality and Accuracy

We declare that this report is entirely the work of the team members listed below, and has not previously been submitted by us, or others for this challenge or any other similar event.

We have acknowledged external material with appropriate references, quotes or notes to indicate its source.

We declare that this report is an accurate record of activities carried out by us in preparing for this specific challenge. The events, data and other material contained within this report actually occurred and have been fully detailed.

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3 Compliance Statement

Team Name: CanberraUAV

We declare that this report and the entry that it describes complies with the rules of the 2014 UAV Challenge Outback Rescue, and that we enter with the intention of competing in the spirit of the challenge. Specifically we declare that our entry is compliant with the following topics and provide reference to within our Deliverable 2 document were our method of compliance is described:

Rules Reference	Topic	Compliance	Deliverable 2 Reference
Mandatory/Essential *(Note: Non-compliance in this section will result in a No-Go finding unless there are significant and/or extenuating circumstances. Please read the rules in detail with a view to safety and specific requirements.)*			
2.3	The aircraft and other Infrastructure	Compliant	Section 6.7
3.2	Aeronautics	Compliant - Airspeed Compliant – Stall Margin Details	
3.3	Altimetry	Compliant	
5.1	Aircraft Requirements and Limitations: All.	Compliant	Section 6.2
5.3.1, 5.3.2, 5.19, 8	Radio Equipment Frequencies: ACMA Compliance and Licensing.	Compliant	Section 7.1
5.4	UAV Controller Override: Compliance to override requirement or Safety Case provided.	Compliant – using controller override	Section 6.4
5.5	In Flight Failures and Emergencies: All. (Once activated it cannot be overridden – all modes.)	Compliant	Section 7.2
5.5.1	Criteria for Flight Termination: All (State Machine Diagrams and Transitions provided)	Compliant	Section 7.2
5.5.2	Loss of Data Link: All	Compliant	Section 7.3
5.5.3	Engine Failure: Procedure provided in Deliverable 2.	Compliant	Section 7.5
5.5.4	Loss of GPS: All and nomination of the implemented option for recovery.	Compliant – using *Dead Reckon*	Section 7.6
5.5.2, 5.5.4	Loss of Data Link **and** Loss of GPS: All.	Compliant	Section 7.3, 7.6
5.5.5	Mission Boundary Crossing – GeoFence: All.	Compliant	Section 7.7
5.5.2, 5.5.5	Loss of Data Link **and** Mission Boundary Crossing – GeoFence: All.	Compliant	Section 7.3, 7.7
5.5.6	"Lock Up" or Failure of	Compliant	Section 7.8

	Autopilot: All.		
5.5.7	"Lock Up" or Failure of GCS: All.	Compliant	Section 7.9
5.5.8	"Lock Up" or Failure of Stability Augmentation System (SAS): All.	Compliant (SAS available with manual disable)	Section 7.11
5.5.9	"Lock Up" or Failure of any processor and/or Hardware implementing the mission boundary crossing detection: All.	Compliant	Section 7.7
5.6	Flight Termination: All and nomination of the implemented option	Compliant – using *5.6 Implemented*	Section 7.2
5.6.1	Commercial off the shelf Flight Termination System used: manufacturer evidence provided	Not Applicable	Section 7.2
5.10	Team Sponsors: All.	Compliant	Section 5
5.16	Situational Awareness: Graphical display of waypoints and aircraft location.	Compliant	Section 6.7
5.16	Situational Awareness: NMEA 0183 Output.	Compliant	Section 6.7
5.23	Search Strategy	Compliant	Section 9
5.24	Cooperation between Teams	Compliant	N/A
6.2.1	Statement of Originality and Accuracy: All.	Compliant	Section 2
6.2.2	Compliance Statement: All.	Compliant	Section 3
6.3.1	Overview of Deliverable 3.	Not Applicable – Deliverable 2 Submission	N/A
6.3.1	Deliverable 3 Requirements.	Not Applicable – Deliverable 2 Submission	N/A
Highly Desirable			
5.15	Access to Video Stream from UAV	Compliant	Section 6.3
5.17	Li-Po Battery Management	Compliant – No Li-Po's used	Section 7.10
5.22	Offsite Data Processing	Not Applicable	Section 6.7
5.25	"Soft GeoFence"	Compliant	Section 7.7
6.2	Deliverable 2: Max 21 pages.	Compliant	N/A

Additional Information:

Date: 05/05/2014
Signed by a team representative, on behalf of all team members:
Printed Name: Stephen Dade

4   Executive Summary

CanberraUAV has been fortunate to attract team members from a wide variety of relevant disciplines, including aeromodelling, mechatronics, aerospace engineering, software engineering and communications engineering. Based on our experiences in the 2012 Outback Challenge, we have refined and improved our aircraft system and related infrastructure, particularly the airframe and bottle drop mechanism. Our team has taken an open source approach to this challenge believing this is the best way to advance the cause of amateur search and rescue aircraft for everyone.

Our design approach is to maximise autonomy while ensuring safety to people and property. Our redundant hierarchical architecture provides a high degree of on-board processing and decision making. The target tracking, automated take-off and landing, flight stabilisation, navigation, failsafe and communication to the ground station will be on-board. The ground station will perform the required overall monitoring and management functionality.

We are designing our system for completely automated "Joe finding", using a powerful on-board computer to control all aspects of the mission. The aim is for the aircraft to not just be able to fly itself, but to also perform automated take-off and landing, and to automatically find the target and perform the drop (after confirmation from OBC staff), while carefully monitoring all aspects of the mission to ensure that safety is maintained.

Our results from test flights have reliably demonstrated the above features. With ongoing testing, we are able to refine and debug our aircraft subsystems to provide a higher degree of accuracy, control and reliability.

Where it is still applicable, parts of this Deliverable are derived from CanberraUAV's Deliverable 2 in the 2012 Outback UAV Challenge.

As part of this Deliverable, we have submitted two airframes – one competition (primary) airframe and one backup airframe. Beyond the physical airframe (Section 6.2), the overall system will be identical – they will have identical payloads and electronics. Our intention is to use the competition airframe in the Outback Challenge, however if it is damaged beyond reasonable repair in the leadup to the Outback Challenge we will switch to our backup airframe.

Unless specifically mentioned in the relevant section, this report is applicable to both airframes.

Our videos accompanying this report (satisfying the video requirements in Section 6.2 of the rules) are at:

http://youtu.be/1XZK4Ztpb0U for our competition airframe

http://youtu.be/HzJL1mr-jTY for our backup airframe

5   Introduction

This report focuses on three major parts: Our design approach, risk management and flight test results.

Our design approach is based around satisfying the rules for the UAV Outback Challenge as our first priority. As part of this, safety is a key feature. This is reflected in the redundancy designed into our systems, including multiple independent radio links, a backup suite of sensors and a failsafe system which will terminate the flight if required. In the spirit of the competition, we are designing our aircraft to be as automated as possible, including automatic Joe-detection via on-board image processing and automatic take-off and landing.

Our risk management processes have evolved significantly. Importantly, for the flight phase we have proven procedures for various errors or failures that may be encountered whilst airborne, with an emphasis on safety to all people and property on the ground. Secondly, our pre-flight checks and procedures are designed to comprehensively check the aircraft's systems for errors before flight.

Our team has been flying a number of small and large test platforms over the last 30 months, including many flights with OBC-capable airframes. These development, test and evaluation flights have generated a significant data set that has enabled us to iteratively refine our command and control systems both in terms of flight accuracy and reliability. At the time of writing, all of the upgraded subsystems from our 2012 setup have been individually tested. Systems integration and testing of the upgraded systems has also been completed, with ongoing testing to determine reliability and refine some functions where necessary.

6   Design Approach and Rationale

6.1   Rationale

The major drivers of our design approach were fourfold: safety and reliability, automation, portability, and open source.

In order to satisfy the rules of the competition, in addition to maximising our chances of completing the challenge, our primary emphasis is on safety and reliability. This is reflected in our radio system setup and design and failsafe systems. An overall breakdown of this system is shown below.
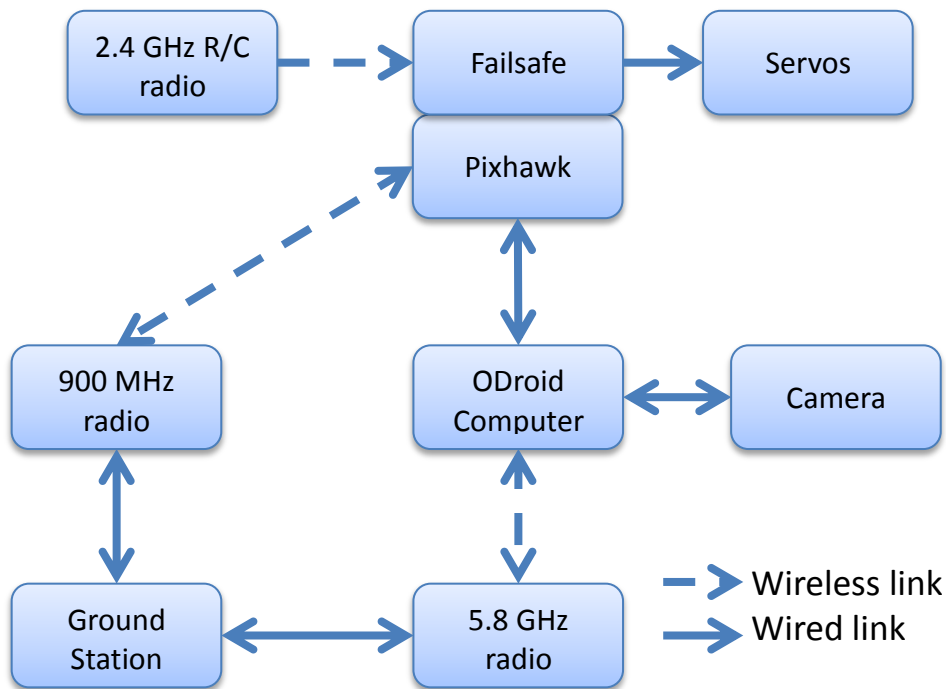
1 - Subsystem Layout of the UAV and Ground Station

To maintain the "spirit of the competition", we chose to automate as much of our aircraft as possible. This included automatic Joe detection and the development of an autopilot that will be capable of automatic take-offs and landings. Due to the choice of automatic Joe detection, our aircraft had to be big enough to carry the computing and image capture/analysis system – leading to the choice of a relatively large airframe. The aircraft airframe and engine is a custom designed and built remotely piloted aircraft. It has the range and load capacity to meet our requirements.

Our team made the choice to use (and contribute back to) open source hardware and software (where available) for our aircraft systems. We believe that our work should be available for all to use and further develop for the benefit of the whole amateur search and rescue aircraft community.

The specific set of hardware and software carried on-board the aircraft satisfies the UAV Outback Challenge requirements to Type 2 Autonomy.

6.2   Airframe

Our competition airframe is a conventional high wing tractor aircraft powered by a two-stroke petrol engine. It has a maximum takeoff weight of less than 18kg.

It is due to this large size we are able to fit in powerful computers and radio equipment (with associated batteries).

The stall speed of the competition airframe has been calculated to be below 13 m/s.

Our backup airframe is based on the "Pilatus Porter" large scale model aircraft. It is powered by a two-stroke petrol engine. It has a maximum takeoff weight of less than 16kg.

The stall speed of the backup airframe has been calculated to be below 13 m/s.

6.3 Imaging System

Our aircraft will be equipped with a high sensitivity machine vision camera for high resolution still colour images (PtGrey Chameleon). It will take photos at a rate of approximately 8 Hz as the aircraft flies a pattern over the search area. In order to negate the effects of vibration causing smearing to the images, the camera will be operated at a high shutter speed in addition to being actively stabilised by a roll servo to maintain a downward pointing direction.

These images will be streamed to the on-board computer and storage, where they will be processed in near real-time. The images will be automatically analysed for distinctive features that may indicate a human shaped and coloured target has been found.

Images from the machine vision camera will also be downloaded to the ground station for further evaluation to allow for the possibility of manual Joe detection should the automatic system fail to detect Joe.

6.4 Autopilot

The aircraft is using the Pixhawk autopilot platform running the APM:Plane software – an open source autopilot designed for small aircraft. The advantage of using the APM:Plane is that we can easily customise and debug the software to fit in with the requirements of the OBC, such as the geofencing requirement. The Pixhawk will feature dual GPS receivers and will be capable of carrying out the full mission in conjunction with the on-board mission control computer.

The Pixhawk features a double redundant power supply, with power coming from two separate sources on-board the aircraft.

The Pixhawk can be switched to a manual flight mode when in visual range. In this mode the values from the RC controller are directly passed to the aircraft's servos.

6.4.1 Airspeed Management

The Pixhawk will ensure that the aircraft's current airspeed is a sufficient margin above the stall speed in order to maintain adequate manoeuvrability through the flight. This will be achieved via the on-board sensors (including a pitot tube based airspeed sensor), combined with the Total Energy Control System (TECS) in the flight software. This ensures the aircraft is able to control its speed and manoeuvrability on an energy (kinetic and potential) basis.

We have measured the stall speed of our aircraft as under 13 m/s. The autopilot is programmed to maintain a minimum airspeed of 18 m/s with a target cruise airspeed of 28 m/s.

These parameters give enough of a margin to account for the worst-case environmental conditions present in Kingaroy.
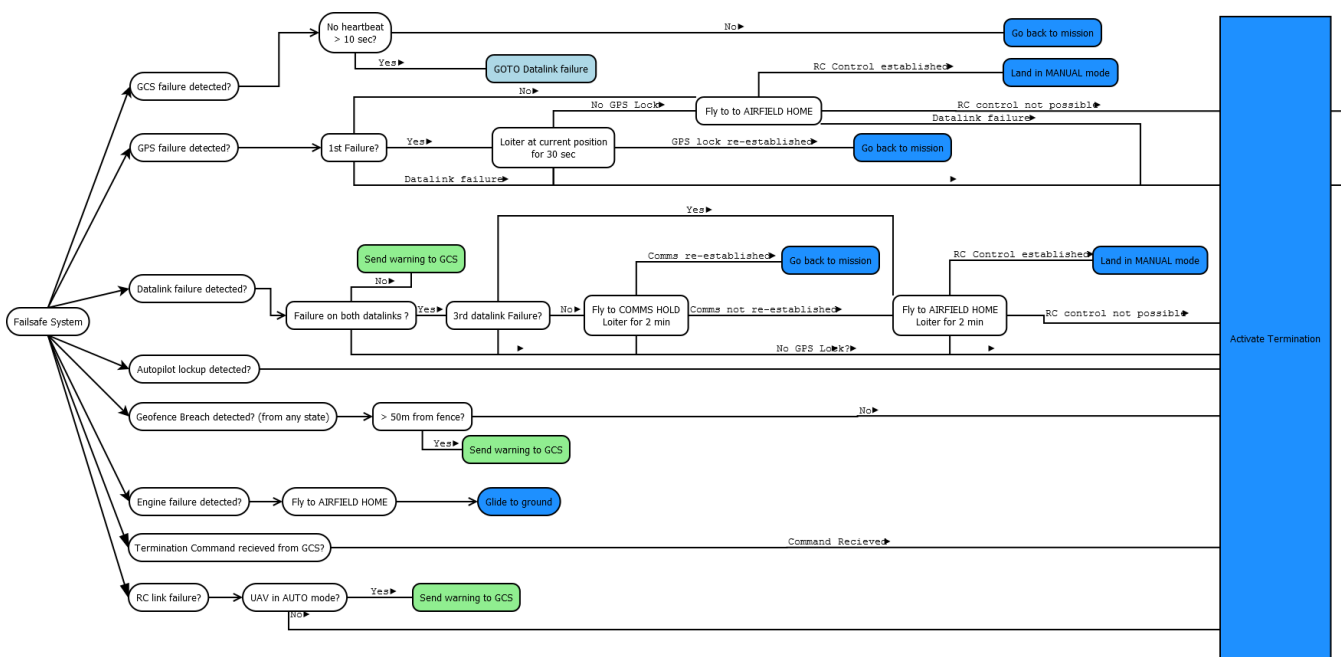
6.5 Radio Links

There will be three independent radio links to the aircraft. This includes a standard 2.4 GHz RC link for manual control, a 915-928 MHz low bandwidth link for telemetry and a 5.8 GHz high bandwidth link for telemetry and image transfer.

Both telemetry links have been confirmed to consistently work at 8km range at the desired data rate.

6.6 Control and Termination System

The Control and Termination System (C&TS) is contained within the Pixhawk platform, but running on a separate CPU with appropriate failsafe software. It will continuously monitor the autopilot. The state diagram for this system is shown below in Figure 2.

In combination with the main autopilot CPU, it will continually monitor the avionics systems and activate the fail-safe modes as per the OBC requirements outlined in Section 5.6 of the rules when a failsafe criterion is satisfied, or when commanded by the ground station.

2 - Failsafe State Diagram

6.7 Ground Control Station

The Ground Control Station (GCS) will comprise multiple hardwire networked laptops receiving data streams from both telemetry radio links. It will provide data on all aspects on the aircraft and current mission status. The GCS will also display a video stream from the on-board camera. A NMEA 0183 serial output will be available for the competition organisers.

A screen will display a graphical representation of the aircraft current location and mission waypoints.

The GCS will be operated from a single location on the airfield. No further infrastructure or personnel will be required outside of the airfield.

6.8 Package Deployment

The 500ml of water will be held within a package containing a small parachute and foam padding. The aim is for the package to reach the ground as soon as practical in order to reduce the effects of any crosswinds, whilst not being so fast as to break the bottle on impact.

The package will be carried externally under the belly of the aircraft. A simple servo-operated latch mechanism will hold it in place. A structure on the belly of the aircraft will fit over some of the package, to stop the effects of wind moving or changing the orientation of the package.

7 Risk Management Approach

Managing the safety of people, property and the aircraft is at the forefront of all of our design and testing activities. By ensuring we have redundancy in all mission critical systems, on-board failsafe systems, thorough ground testing and checklist procedures before flight, we can manage and reduce the overall risk.

In designing our system, we started by building a risk management matrix, identifying possible modes of failure and evaluated risk mitigation measures. This risk management matrix considered the consequence and likelihood of potential hardware and software failures.

The following section will outline our risk management approach for key items as outlined in the requirements for Deliverable 2.

7.1 Spectrum Management

All of our radios fall within the ACMA LIPD-2000 ISM class licenses. All radio communication is digital, including the video.

We are using the following frequency bands:

- 915-928 MHz band with 1Watt EIRP and 20 channel frequency hopping for low-bandwidth digital telemetry and control link. This falls under LIPD-2000 item 52 "frequency hopping transmitters"
- 2.4GHz band for visual range RC control (C-tick R/C full range transmitter)
- 5.8GHz band 4 Watt EIRP for high-bandwidth digital data link (LIPD-2000 item 55). The radios are C-tick compliant.

The team has done extensive range testing of the radio and antenna combinations over an 8 km range, including interference testing between radios.

7.2 Flight Termination (OBC 5.5.1)

We are using a control and termination system (C&TS) on board the Pixhawk's secondary processor. This module, although on the same physical board as the autopilot, is completely independent. The necessary software development has been completed, tested and incorporated into our baseline flight management system.

This system was confirmed as meeting the Outback Challenge failsafe requirements in an email from the UAV Outback Challenge Technical Committee on March 6th 2014.

The C&TS will implement the primary OBC S&R FTS option using fixed maximum servo positions. The C&TS will monitor the autopilot and will control flight surface and throttle servos, following the specific procedures outlined in the following sections. Flight termination can also be initiated by the GCS through controls to the autopilot via the dual telemetry links.

Once the flight termination mode is activated through one of the conditions below, it cannot be deactivated.

In case of flight termination activation, the servo positions will be forced by the C&TS system to be:

- Throttle closed

- Full up elevator

- Full right rudder

- Full down on right aileron

- Full up on left aileron

- Full down flaps

7.3 Loss of data link (OBC 5.5.2)

The on-board mission computer monitors data link integrity of both the high-bandwidth and low-bandwidth links via MAVLink heartbeat messages sent from the GCS at a rate of 2Hz. On loss of data link for 10 seconds, the aircraft will proceed to the comms hold waypoint. After 2 minutes at the comms hold waypoint the aircraft will navigate to airfield home and loiter. If data link is not re-established after 2 minutes at airfield home the safety pilot will attempt control via visual line of sight. If line of sight RC control is not possible flight termination will be initiated. If RC control is possible the safety pilot will land the plane. Loss of GPS at the same time as data link loss will cause flight termination. Flight outside the mission boundary at any time will cause flight termination including during a loss of data link. On the third data link failure, the aircraft will fly to the airfield home waypoint and loiter for 2 minutes whilst the pilot attempts to regain RC control and manually land the aircraft. Otherwise flight termination will be activated.

7.4 Loss of RC link (OBC 5.5.1)

The RC link status will be continuously monitored by the autopilot. If the link is lost for more than 1.5 seconds and the aircraft is not in automatic flight mode, flight termination will be activated.

7.5 Engine Failure (OBC 5.5.3)

The aircraft will have electronic engine monitoring. In case of engine or ignition failure, the aircraft will initiate a controlled glide (with the ignition off) towards airfield home. If the aircraft achieves visual range of the airfield the safety pilot will be able to control the glide via the standard RC transmitter link. If visual range of the safety pilot is not achieved the plane will land as best it can within the mission boundary. All other failsafe systems remain active during this procedure and will initiate a full flight termination if needed.

7.6 Loss of GPS (OBC 5.5.4)

In GPS failure mode the plane will slowly circle for 30 seconds, waiting for GPS signal. If there is no signal after 30 seconds then the autopilot will start dead-reckoning direct to airfield home waypoint. During dead reckoning the video link to the GCS and other on-board sensors will be used to monitor the planes status. If the planes position within the mission boundary becomes uncertain or the link to GCS is lost during a period of GPS failure then flight termination will be initiated.

On the second GPS failure, the aircraft will dead-reckon to the airfield home waypoint and loiter for 2 minutes to allow a manual landing by the pilot. If this is not possible then flight termination will be activated. If the planes position within the mission boundary becomes uncertain or the link to GCS is lost during a period of GPS failure then flight termination will be initiated.

Unless under manual control by the safety pilot, loss of data link while in GPS failure mode will cause an immediate flight termination.

7.7   Mission Boundary Crossing - GeoFence (OBC 5.5.5)

If the autopilot detects a mission boundary violation (either horizontal or vertical) it will raise a signal on the C&TS, which will initiate flight termination. Mission boundary edges and altitude limits will be programmed into the autopilot's non-volatile memory and checked during pre-flight prep.

This system has been verified to work through extensive simulation and real world testing with prototype airframes. The CanberraUAV geofencing system has been adopted as a standard feature in the APM:Plane software suite.

Any lockup or failure of this function on the CPU or associated sensors will be treated as an Autopilot lock-up (Section 7.8) and will result in the C&TS system being activated.

A "soft geofence" will be used to alert the ground station via audible signal when the aircraft's current course is predicted to take it within 50m of the actual geofence. For the vertical component, a dataset of terrain data for the local area will be available to the aircraft. Combined with the GPS altitude, the AGL altitude can be determined and used to ensure the aircraft remains in the 200 to 400 foot altitude (AGL) envelope as a "soft geofence".

7.7.1   Altitude Geofence

The barometer on board will be referenced via QNH before flight. This will be used to enforce the 3000 ft AMSL vertical component of the geofence.

On barometer failure, the autopilot will start to use GPS based altitude but with a safety margin of 500ft. If the GPS loses lock or detects an altitude of above 2500 ft AMSL the C&TS system will be activated.

7.8   Autopilot lock-up (OBC 5.5.6)

The autopilot will provide 10 Hz heartbeat signals to the C&TS system. If the autopilot fails to provide a heartbeat for a period of 1 second, the flight will be terminated.

The connection between the autopilot and the C&TS system is a dedicated high speed serial line. If messages stop arriving on the failsafe CPU on this line then termination will be automatically initiated

7.9   Failure of Ground Control Station (OBC 5.5.7)

If an autopilot detects no communications heartbeat signal from the GCS for a period of 10 seconds then the loss of data link procedure described above will be initiated. Note that in our design the ground station has multiple communication links (on different frequencies) to the aircraft and is able to automatically switch between the links to minimise the chance of link loss.

7.10 Li-Po Battery management (OBC 5.17)

The aircraft will not use any LiPo batteries.

7.11 Failure of Stability Augmentation System (OBC 5.5.8)

Whilst our aircraft does not require a stability augmentation system (SAS) for normal flight, we are able to take advantage of this system to increase controllability of the aircraft, and hence safety of the public.

The status of the SAS will be monitored by the ground station which will provide audible announcements.

In the case of SAS lockup, the SAS will be automatically isolated, allowing the safety pilot full manual control if within visual range. Beyond visual range, SAS lockup will trigger the flight termination system. The safety pilot can also disable the SAS system via a switch on the RC transmitter.

7.12 Ground Tests and Checklists

We have developed a pre-flight checklist which can be found at:
https://canberrauav.readthedocs.org/en/latest/in-progres/OBC2014/Checklists.html

This ensures that:

- The aircraft is airworthy

- All avionics are operating correctly

- All systems are correctly calibrated

- All systems are tested before flight

A run through of our checklist prior to engine start is shown in our Deliverable 2 video.

7.13 Testing

All aircraft software and hardware is thoroughly tested before being used in flight. The testing regime includes simulation where possible and small scale testing before being used in the final aircraft.

Our testing methodology is:

- Design and build new component or feature

- Software simulation testing where possible

- Hardware simulation testing where possible

- Short and long range test flights

- Acceptance

We make extensive use of additional test airframes for testing new features.

7.14 Personnel Safety Procedures

Short range tests are performed at Canberra Model Aircraft Club (CMAC), where we follow all MAAA and CMAC rules and procedures.

We have developed a range safety plan for use at our long distance testing facility. The focus of this plan is on physical safety ensuring that personnel have defined roles and responsibilities. This includes the position of "safety officer" who will oversee the day's flying activities ensuring that all procedures are followed.

Note that CanberraUAV has been granted an exception to the weight and engine size limitations of the MAAA MOP 067 (Self-guided Model Aircraft) by the MAAA. This allows us to perform full visual range test flights at our local MAAA flying club.

7.15 Overall Risk assessment

Using the risk assessment in our Deliverable 1 report as a basis, we expanded on and refined our risk assessment to ensure it remains up-to-date.

Failure	Mitigation
In general	• Preliminary work will be carried out at our local model aircraft field under MAAA procedures with MAAA insurance, and the regular critique of fellow modellers. Long range testing will be carried out over a private farm (with the landowner's permission) near Canberra after suitable insurance has been arranged.

Airframe Installation and Operation	• Operation to be in line with MAAA procedures. • Competition aircraft and pilots to obtain MAAA heavy model certificate before flight of competition aircraft.
Range Safety	• We will continue to refine and improve our range safety plan for each testing site. For the MAAA field we comply with the MAAA Manual of Procedures. For our long range test site, we have developed appropriate range procedures, with a designated range safety officer.
Motor	• Starting and operation to be in line with MAAA procedures • Take-off procedure to follow general aviation practice. • Stopping of engine to be by electronic ignition cut. Cut to be maintained when engine not operating.
Fuel	• Petrol will be contained in a strong container to resist bursting on impact, containing only enough fuel to carry out the mission with adequate reserve. • Safety procedures will include emptying the fuel tank when transporting the aircraft
Electrical power	• Separate battery packs for Primary control system and instrumentation. • Batteries to be NiMH or Lithium Iron Phosphate (LiFE). No LiPo. • Batteries to be of capacity adequate for mission with reserve.
Connections, wiring and soldering	• To be carried out by experienced electronics technician with years of experience in model aircraft and marine electronics in the field.
Air traffic	• Radio watch will be held by pilot in charge during trials at the test range by an experienced aviation pilot. At Kingaroy a listening watch will be held.
Take-off and landing	• Field testing and competition take-off and landing will follow standard General Aviation aircraft procedure, with a circuit height of 300 feet. Real-time flight and mission data will available. Flight logs and records will be kept for historical purposes.
Fly away of aircraft	• Extensive practice at test range to OBC rules (including geo-fencing), including automatic stopping of motor if below 200 feet, but with a soft termination to be carried out by the C&TS..
Rescue of lost aircraft	• Procedures to be put in place by our experienced bushwalker prior to field testing. Only Outback Joe will be left alone in the field.
New (not broken) vs. Old (proven) equipment reliability	• Upgrades to the autopilot software will be tested on a backup aircraft and in simulation before being used in the larger competition airframe.
Bugs in software	• Will use Hardware in the Loop (HITL) and Software in the Loop (SITL) simulation testing to verify software and autopilot hardware, and reduce risk of software bugs.
Configuration management	• We are using best software industry practice for configuration management and software version control.
Unintentional and intentional emergency package deployment	• Aircraft is only flown over areas well away from people and property. • Energy reduction of ground impact via drogue parachute and padding around the package. • A software-based arming switch will be used to stop any unintentional release of the package. The arming switch will only be activated shortly before the aircraft reaches the intended release point. • 2 micro switches on the deployment mechanism will provide positive confirmation of whether or not the rescue package has been released.
CASA regional check	• CASA regional representative has been contacted
Collision with buildings or other infrastructure	• Mission waypoints will be planned as so to avoid any buildings within the search area.

8 Flight Test Results and Discussion

8.1 Project Status

As of May 2014, CanberraUAV has achieved the following:

- Improved bottle drop mechanism

- Successfully trialled the Pixhawk flight controller

- Designed and built an antenna tracking system (hardware and software)

- Designed, built and flight tested a custom airframe

- Developed and tested incremental changes in the image recognition code for improved Joe detection

- Trialled the airframe for long duration flights

- Experimented with improved GPS methods for higher accuracy positioning information

8.2 Results

The CanberraUAV team has been working towards improving out flight and image recognition code continuously since the 2012 challenge. Key areas we have been working on are improved autopilot navigation, improved robustness to sensor failure and improved ground station interfaces for safe operation of the aircraft.

8.2.1 Sensor Redundancy

One of the main advances we have worked on is support for sensor redundancy. We have worked closely with the PX4 project which designs high performance autopilots to integrate multiple independent sensors at the hardware level for as many critical sensors as we can. For the 3.0 release of APM:Plane we worked with the Ardupilot development community to add support for dual gyroscopes, dual magnetometers, dual accelerometers and dual GPS. For each sensor type we developed algorithms to take best advantage of the additional sensor, not just using it as a failover, but using the inherent redundancy in IMU sensor suites to allow for sensor inputs to be combined in an intelligent fashion. For example, the two accelerometers are setup to sample at different frequencies which allows the AHRS code to detect when aliasing is occurring in high vibration environments and to automatically select and weight accelerometer inputs according to the consistency with the other sensors. The code we developed is already helping lots of aircraft that use Ardupilot to fly more accurately and reliably.

This is also ongoing work, with work being done towards redundant barometric pressure sensing and redundant airspeed sensors, as well as additional sensors such as a LiDAR for terrain altitude.

8.2.2 AHRS Redundancy

The redundancy effort is not just at the sensor level. We also have contributed to a large effort to create a complete redundant AHRS system within Ardupilot, allowing two completely different algorithms for attitude and position estimation to run in parallel based on the same sensor input. The two systems (one based on a DCM complementary filter and one based on a 21 state Extended Kalman Filter) provide redundant views on the current attitude and position of the aircraft. The ground station operator is able to see when these two views disagree and can change which algorithm is in command of the aircraft at any time during the flight.

8.2.3 Image Recognition System

On the image recognition front we have been working with several volunteer search and rescue organisations around the world to help them deploy the S&R image recognition code we developed for OBC'2012 in real S&R situations. That has resulted in valuable feedback on the system which we have used to improve the code for everyone. There is still a lot more to do, but we are pleased with the progress, and delighted with the way other groups have been able to use the technology we have developed.

We have also begun collaboration with research groups at the Australian National University, with one CanberraUAV team member supervising a PhD research project in UAV image recognition for S&R. It is hoped that this work will result in improvements in algorithms for S&R tasks at the academic level, and increased collaboration with other UAV research groups.

8.2.4 Test Flights

This has all been combined with lots of test flights! We have several workhorse test aircraft that we use to test out the new systems as we develop them. We have logged dozens of hours of test fights, and spent countless hours analysing logs to ensure that the systems we develop work as expected.

We hope all this will result in us putting in a good showing at the OBC this year, although of course we realise that things can go wrong on the day!

9 Search Strategy

The basic goal of our search strategy is to capture 10cm resolution imagery of the defined search area and to process this imagery in real-time on board the aircraft to find Joe. Many other aspects of hardware selection and flight testing are based on this objective.

The aircraft will fly a interleaved raster pattern over the search area. Each strip will capture a 60m wide strip of the search area below the aircraft.

In order to increase the radius of the turns at each end of the search area (and thus reduce stress on the airframe through tight-radius turns), the aircraft will fly over every second strip in the search area before reversing course and going over every other strip along the search area.

This is shown as:
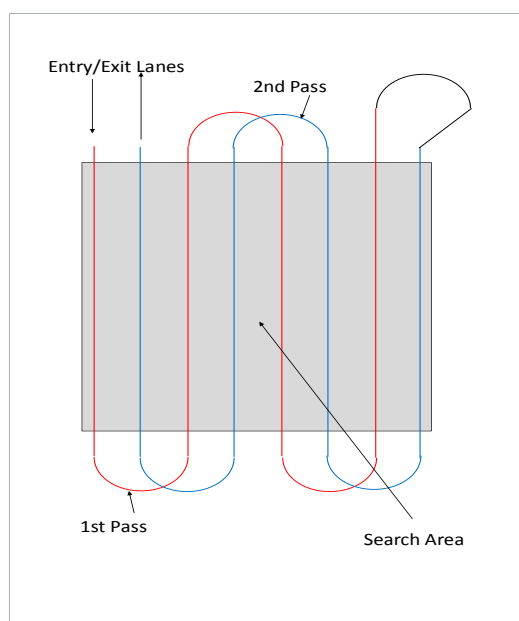
3 - Example search pattern

After being captured (and geotagged), each image is passed to the detection software. The detection software looks for unusual regions within the image using a RGB histogram threshold along with region size constraints.

This patch of colour is then checked that it is the correct size for being that of a person laying on the ground.

A final score is attached to each detection, referring to the image software's confidence that the particular detection is actually a person. The detection with the highest score is seen by the software as the most probable location of Joe. This has been tested and confirmed in a variety of situations to ensure the software reliably detects Joe.

This location of Joe in the image is passed to the Geolocation algorithm which takes into account the GPS position, altitude, heading, roll and pitch of the camera at the time the image was captured in order to come up with a final position of Joe to within 20m accuracy.

10 Conclusions

By using a design approach based upon safety and reliability and learning from our experiences at the 2012 Outback Challenge, we are well on our way to presenting a more mature, more effective and more reliable system for the 2014 Outback Challenge.

At this point in time, all of our subsystems have been tested, with developmental testing broadly complete. Our operational test and evaluation program is progressing smoothly and we plan to run as many flight tests as practical before September 2014.

We are very pleased with our results so far, which indicate that we are in a far better position to complete this Outback Challenge then we were for the 2012 Outback Challenge. Through the continued hard work of our team members we are on track to have a capable and reliable system well before the competition deadline.

The next challenge for us is to run more long-range tests of a similar nature to the Outback Challenge, which will enable us to further refine our system and procedures.

We are looking forward to meeting the other UAV Outback Challenge teams in September and competing in the challenge!