Deliverable 2 – Technical Report and Video

H2Joe – West Coast UAV Team

http://h2joe.wordpress.com

Due: 7 May 5pm AEST

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1 Table of Contents

Video

A video of the team's preflight set up and check, footage of take-off and landing, and footage of the aircraft dropping the package with stability post drop can be found on Youtube by searching for H2Joe Deliverable 2, or by following this URL: http://youtu.be/-oks2O9FgYQ

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.

Michael Thomas 22.4.14.

Zachary Oliver 24.4.14

Geoff Chambon 30/04/2014

3 Compliance Statement

Team Name: **H2Joe**

We declare that this report and the entry that it describes complies with the rules of the 2014 UAV Challenge, 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 ☐ Compliant – Off Airfield Names and Equipment ☐ Non-Compliant	Section 9.1 Section 6.1
3.2	Aeronautics	☑ Compliant – Airspeed ☐ Compliant – Stall Margin Details ☐ Non-Compliant	Section 6.3
3.3	Altimetry	☑ Compliant ☐ Non-Compliant	Section 6.3
5.1	Aircraft Requirements and Limitations: All.	☑ Compliant ☐ Non-Compliant	Section 6
5.3.1, 5.3.2, 5.19, 8	Radio Equipment Frequencies: ACMA Compliance and Licensing.	☑ Compliant ☐ Non-Compliant	Section 6.5 Section 7.11
5.4	UAV Controller Override: Compliance to override requirement or Safety Case provided.	☑ Compliant – *Override* ☐ Compliant - *Safety Case* ☐ Non-Compliant	Section 6.3
5.5	In Flight Failures and Emergencies: All. (Once activated it cannot be overridden – all modes.)	☑ Compliant ☐ Non-Compliant	Section 7.12
5.5.1	Criteria for Flight Termination: All (State Machine Diagrams and Transitions Provided)	☑ Compliant ☐ Non-Compliant	Section 7.12 Section 6.3
5.5.2	Loss of Data Link: All	☑ Compliant ☐ Non-Compliant	Section 7.12 Section 6.3
5.5.3	Engine Failure: Procedure provided in Deliverable 2.	☑ Compliant ☐ Non-Compliant	Section 7.12
5.5.4	Loss of GPS: All and nomination of the implemented option for recovery.	☐ Compliant – *Flight Termination* ☑ Compliant – *Dead Reckon* ☐ Compliant - *Video* ☐ Non-Compliant	Section 7.12 Section 6.3
5.5.2, 5.5.4	Loss of Data Link **and** Loss of GPS: All.	☑ Compliant ☐ Non-Compliant	Section 6.3
5.5.5	Mission Boundary Crossing – GeoFence: All. (Horizontal and Vertical)	☑ Compliant ☐ Non-Compliant	Section 6.3 Section 7.12

Rules Reference	**Topic**	**Compliance**	**Deliverable 2 Reference**
5.5.2, 5.5.5	Loss of Data Link **and** Mission Boundary Crossing – GeoFence: All.	☑ Compliant ☐ Non-Compliant	Section 6.3
5.5.6	"Lock Up" or Failure of Autopilot: All.	☑ Compliant ☐ Non-Compliant	Section 7.12
5.5.7	"Lock Up" or Failure of GCS: All.	☑ Compliant ☐ Non-Compliant	Section 7.12
5.5.8	"Lock Up" or Failure of Stability Augmentation System (SAS): All.	☑ Compliant ☐ Non-Compliant ☐ Not Applicable	Section 7.12
5.5.9	"Lock Up" or Failure of Mission Boundary Crossing detection: All	☑ Compliant ☐ Non-Compliant	Section 7.12 Section 6.3
5.6	Flight Termination: All and nomination of the implemented option	☑ Compliant - *5.6 Implemented* ☐ Compliant - *5.6.1 Implemented* ☐ Compliant - *5.6.2 Pyrotechnics* ☐ Non-Compliant	Section 7.12 Section 6.3 Section 6.4
5.6.1	Commercial off the shelf Flight Termination System used: manufacturer evidence provided	☐ Compliant ☐ Non-Compliant ☑ Not Applicable	n/a
5.10	Team Sponsors: All.	☑ Compliant ☐ Non-Compliant	Section 4
5.16	Situational Awareness: Graphical display of waypoints and aircraft location.	☑ Compliant ☐ Non-Compliant	Section 6.3
5.16	Situational Awareness: NMEA 0183 Output.	☑ Compliant ☐ Non-Compliant	Section 6.3
5.23	Search Strategy	☑ Compliant ☐ Non-Compliant	Section 9
5.24	Cooperation between Teams	☑ Compliant ☐ Non-Compliant	Section 4
6.2.1	Statement of Originality and Accuracy: All.	☑ Compliant ☐ Non-Compliant	Section 2
6.2.2	Compliance Statement: All.	☑ Compliant ☐ Non-Compliant	Section 3
6.3.1	Overview of Deliverable 3.	☐ Compliant – Deliverable 3 Submission ☐ Non-Compliant ☑ Not Applicable – Deliverable 2 Submission	n/a
6.3.1	Deliverable 3 Requirements.	☐ Compliant – Deliverable 3 Submission ☐ Non-Compliant ☑ Not Applicable – Deliverable 2 Submission	n/a
Highly Desirable			
5.15	Access to Video Stream from UAV	☐ Compliant ☑ Non-Compliant	Section 6.6
5.17	Li-Po Battery Management	☑ Compliant ☐ Non-Compliant	Section 7.8
5.22	Offsite Data Processing	☐ Compliant ☐ Non-Compliant ☑ Not Applicable	n/a

Rules Reference	Topic	Compliance	Deliverable 2 Reference
5.25	“Soft GeoFence”	☑ Compliant ☐ Non-Compliant ☐ Not Applicable	Section 7.12
6.2	Deliverable 2: Max 21 pages.	☑ Compliant ☐ Non-Compliant	n/a

Additional Information:

- No video stream from UAV available, however we will make images from search site available as they are received if wanted.
- It is noted that the elevation of the search area is around 1620 feet AMSL, and the elevation of the airfield home is around 1480 feet AMSL. It is requested that the upper geofence altitude limit be set to 400 feet above the higher point in the mission area (2020 feet AMSL), and the lower geofence altitude limit will be set to the lowest point in the mission area (1620 feet AMSL). Whilst waypoint altitudes will be set the fly comfortably below the 400 ft AGL limit reflective of the elevation of the terrain, it is noted that the geofence upper limit will be effectively 540 feet AGL around the airfield home area. We believe allowing an extra margin on the geofence altitude limits and taking appropriate precautions around this will be simpler and safer than the alternative of adjusting the altitude offset of the autopilot throughout the mission to compensate for the varying terrain.

Date: 22.4.14.

Signed by a team representative, on behalf of all team members:

Printed Name: Michael Thomas.

4 Executive Summary

Our team, H2Joe, consists of 3 focused individuals with an avid interest in UAV technology. The goals of our team are:

- Develop robust and safe UAV technology
- Pass all criteria, enter in, and win the 2014 UAV Outback Challenge (OBC)
- Develop strong relationships with other OBC Teams and the wider UAV industry

Our UAV platform is designed to be simple, cheap and easy to operate whilst meeting all the capabilities required for the OBC.

Safe operations are fundamental to our team. We have developed a rigorous risk management approach to address all the risks surrounding the operation of UAVs.

Since our team formed in March 2012, we have been busy developing and testing the various systems that make up our UAV. Our key progress to date is:

- Autonomous flights with Development Airframe
- UAV platform fully specified
- Bottle release mechanism designed, built and tested
- Understanding of ArduPilot autopilot system, and changes necessary for required OBC functionality
- Continued testing and development of Competition Airframe
- Testing of Comms System
- Testing of Camera and search algorithm for detection of lost hiker

We seek to maintain a positive image of our team and UAV technology within the community. To do this we maintain an active community involvement (including presenting at a local Robofair, and articles in the local paper), and frequently write about our experiences on our team website (http://h2joe.wordpress.com). We believe this media presence adds to and builds on the positive image of UAVs in the community that the UAV Outback Challenge is trying to promote.

Our team is funded by its members, and received support from our sponsorship partners RF Design, and 3xtrusions. Our team members are not members of other Outback Challenge teams.

We are a motivated and committed team. We are well prepared to meet the challenges and safety requirements of this competition. We are looking forward to meeting all the teams at Kingaroy in September!

5 Introduction

The document provides a detailed review of the system design, risk management approach, flight test results and search strategy which demonstrate our capability to comply with all regulations and safely operate a robust platform for the 2014 UAV Outback Challenge.

Our design approach is to keep things as simple as possible whilst meeting all the requirements of the competition. Where possible we have used existing systems and software, to avoid 're-inventing the wheel', which allows us to focus on gaining operational experience. Our system is comprised of an airframe, autopilot system, failsafe device, comms system, joe locating system and bottle drop system. Each system has been chosen to perform its required functions in a safe and reliable manner.

A culture of safety and a thorough risk management approach has been adopted by our team to ensure that all risks are identified and mitigated. Our fundamental attitude is that safety is the number one priority, and this means that operations cannot proceed no matter how urgent unless we are satisfied that we can control all the risks. We seek to stay abreast of industry best practice to identify, and understand all the risks including failure of our system, environmental hazards, lithium batteries, propellers, etc. We then develop controls and mitigation strategies to ensure that these risks can be reduced to an acceptable level. We will only proceed to operate the UAV when we are all convinced that all risks are addressed.

Rigorous and constant flight testing is an essential component of the development of our UAV system. Each component of our UAV is tested thoroughly to see how it operates in as many different situations as possible. After each component and subsystem has been tested in isolation we gradually integrate more of the systems together and continue the testing process. This approach ensures that we identify and fix any issues that may exist in our design, and a thorough degree of operational experience is gained in the process

In order to perform the specific mission of finding Joe in Kingaroy, a search strategy has been developed which our UAV will perform. Mapping out the distinct flight phases, entry and exit procedures and scanning path helps us to understand the exact requirements of our systems and gives us more focus for where to direct our development and testing.

We are confident that we have a robust system to carry out the mission, procedures and processes to mitigate risk, and through operational experience gained through rigorous testing that we can safely compete and win the 2014 UAV Outback Challenge.

6 Design Approach and Rationale

6.1 Overview & System Architecture

The goals of our UAV design are:

- Safety and reliability
- Meeting all requirements of the competition
- Simple, and avoid reinventing the wheel where possible
- Be as small, and lightweight as possible – to reduce difficulty of testing
- Be cheap, easily fixable and easily replaceable

The overall system architecture is described in the below diagram.

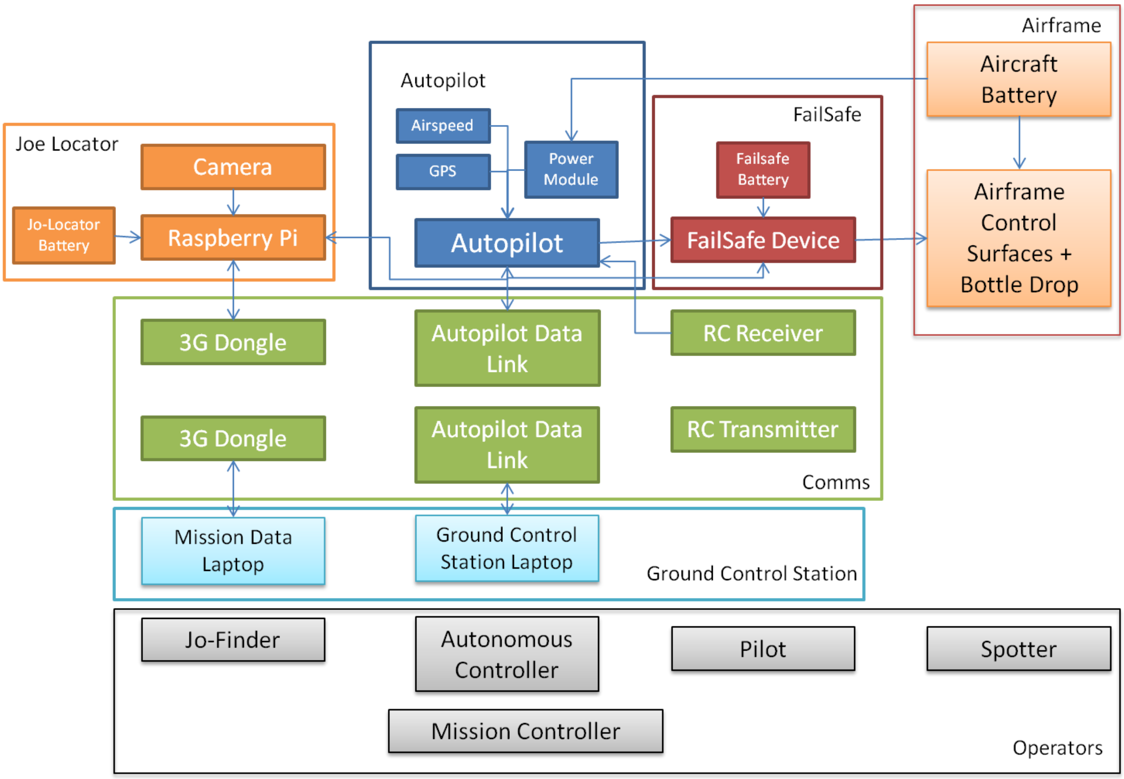


Figure – System Architecture

6.2 Airframe

We are using the Skyhunter which is a cheap, electric, light-weight, foam aircraft for our airframe. This means it is easily repairable and replaceable in the event of a crash, and also the risk of potential damage and injuries from crashing are minimised due to its low weight.

The Skyhunter is quite stable in manual and autonomous flight, whilst travelling at fast enough speeds (approx. 60 km/h) to cover the distances required in the competition, and deal with expected winds.

The weight of the airframe, with the required batteries and payload falls within the maximum recommended MTOW for the aircraft at 3.5kg.

Modelling of the propulsion systems theoretical thrust, power and rotational speed has been conducted to select the optimal configuration for the propulsion system. The propeller has been balanced to minimise vibration.

The aircraft can be safely hand-launched.

6.3 Autopilot and Ground Control Station

Our Autopilot system and Ground Control Station was chosen to meet the requirements outlined in the OBC Rules. This includes capabilities to detect and act upon: manual override, geofencing, loss of comms, loss of GPS, command flight termination, command the bottle release, and provide output of the GPS coordinates.

We chose the ArduPilot with the Mission Planner Ground Control Station software as this was identified to meet these requirements, with the inclusion of the OBC module developed by the CanberraUAV team. Autonomous take-off and landing is possible and this capability will be investigated by the team.

The team has gained an understanding of the ArduPilot code in order to fully understand its functionality and ensure we are using it correctly. The relevant configuration parameters, waypoint files and geofence files are all carefully documented and understood.

The mission planner provides a graphical display of the location of the UAV, the waypoints, and a NMEA-0183 serial output. A script has been written for the Mission Planner to easily control the bottle drop and command flight termination.

Aeronautical & Altimetry Requirements

The ground control station is set to report units of measure that comply with the AIP guidelines, and the geodetic reference datum used will be the World Geodetic System – 1984 (WGS-84)

An airspeed sensor is used on the autopilot, which is essential to ensure that the speed is maintained at a suitable margin above the stall speed to avoid to risk of stall.

The autopilot is set to use and report barometric pressure altitudes. The QNH reference pressure will be set into to autopilot at the start of the mission to ensure a consistent reference is used with other airspace users and UAS operators. Altitudes will be stated as AMSL or AGL to avoid confusion.

State Machine Diagram and Transition

The Flight Termination functionality can be described by the following State Machine Diagram.

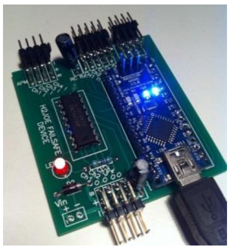
Machine State	Action(s)	Condition to transition	State to transition to
All modes		Geofence breached	FLIGHT TERMINATE
		Autopilot lock-up	FLIGHT TERMINATE
		Flight Terminate requested	FLIGHT TERMINATE
Manual	Pass through manual controls	Loss of control link > 1.5s	RTL
		Change to Auto mode	AUTO
Auto	Follow mission	Datalink loss > 10s	DATALINK LOSS

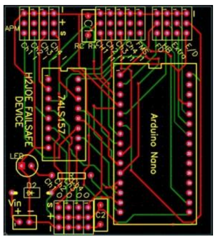
	waypoints	GPS Loss > 3s	GPS LOSS
		Change to Manual mode	MANUAL
		Loss of control link > 1.5s	Stay in AUTO
Datalink Loss	Count loss Go to Comms Hold, loiter 2 min, go to airfield home, loiter 2 min, autonomous landing)	GPS Loss > 3s	FLIGHT TERMINATE
		Datalink recovered before leaving Comms Hold Loiter, and loss count < 3	AUTO (resume WP)
GPS Loss	Count loss Go to GPS Loss WP, loiter 30s, dead-reckon to airfield home, land aircraft	Datalink loss > 10s	FLIGH TERMIANTE
		GPS recovered, and GPS loss count < 2	AUTO (resume WP)
Flight Termination	Set controls to flight termination positions	-	-
RTL	Go back to airfield home	Control link regained	Manual

6.4 Failsafe Device

A custom, stand-alone Failsafe Device was developed by the team. This consists of a microprocessor which monitors a 10 Hz heartbeat signal from the autopilot, and controls the signals from the autopilot to the control surface servos. When the heartbeat signal fails, the failsafe commands the control surfaces to the required position. A four channel multiplexer is used to avoid latency between the autopilot and the control surfaces in normal operation.

We would like to acknowledge Jack Pittar, from Canberra UAV team, for his help in the circuit design process.





6.5 Comms

Our Comms system consists of three components:

- Reliable long-range telemetry link
- Reliable short-range control link
- Imaging system data link

We are using the RFD900 900MHz telemetry module for our telemetry link as this has been demonstrated to be a reliable product based on other teams experience using it in previous competitions. The maximum power output will be reduced to ensure the gain of the antennas does not exceed the EIRP limitations as per the ACMA regulations. The channel ID and number of frequency hopping channels will be optimised for maximum reliability and to avoid interference. (Spectrum Management – OBC 5.19).

A 2.4 GHz digital RC controller is used to control the plane. The manual control has a failsafe setting where the throttle PWM signal is cut when the link is lost to ensure that this is detected by the autopilot.

Our Joe Locator system has been designed to require low-bandwidth, so a 3G modem will be used to transmit this data to a cloud server which can be accessed from the ground station. It is understood that the 3G reception in Kingaroy can be reduced at times; however given the low bandwidth required we do not see this as in issue.

6.6 Joe Locator

Our Joe Locator consists of a Raspberry Pi computer, small visual spectrum camera, image scanning algorithm, telemetry downlink tap, and image uploading protocol.

Images are taken throughout the search area, whist the telemetry downlink tap listens to the autopilot to get the current GPS coordinates and roll, pitch and yaw where the image is taken. The image is then scanned using the image scanning algorithm to detect likely signatures of the lost hiker. If a possible detection is made, this is geo-referenced using the GPS coordinates, roll, pitch, and yaw angles, and then uploaded to a cloud drive to be verified on the ground. This images will be made available to the competition organisers if wanted.

The camera must be of sufficient quality to take images with an acceptable level of distortion from the vibrations and forward speed experienced in the aircraft. The Raspberry Pi camera, which is cheap and light-weight, was found to be sufficient.

We would like to acknowledge CanberraUAV for sharing their image scanning algorithm which we will be using.

6.7 Bottle Release Mechanism

The requirements of our Bottle Release Mechanism are to: securely hold bottle during take-off and flight, reliably release bottle when commanded, and for the bottle survive impact. It is desirable for the bottle to reach the ground in a minimal amount of time to reduce drift.

We have designed and built a simple and reliable latch mechanism for our bottle release mechanism. The bottle will be secured to the underside of the fuselage with a strap. The servo on the mechanism will open the latch, releasing the strap, which will allow the bottle to fall free.

A combination of a strong burst resistant water bottle, impact absorbing cushioning, and velocity limiting parachute will be used to ensure the bottle hits the ground without bursting, with minimal drift and minimal risk of entanglement. Infusion bags have been found to be a sturdy water vessel with good burst resistance, additionally they have no hard corners which reduces risk of injury to people on the ground if the bottle in inadvertently released.

7 Risk Management Approach

7.1 Safety Strategy

As there is a high element of risk in what we do, our team has a robust safety strategy and culture in place to ensure that we understand all the risks, and have effective mitigation strategies to ensure we can do what we want to do safely.

Our team has set a hierarchy of objectives so that we are aware that even though we might be really keen to perform a certain test flights, this will not be at the cost of personal safety. These are:

1. Avoid personal injury
2. Operate within all rules and regulations
3. Preserve aircraft
4. Perform UAV operations and compete in competition

It is through a thorough understanding of the system that we can develop a comprehensive risk assessments and mitigation strategies. Our team has gained a thorough understanding of the rules and regulations associated with our intended operations, and we maintain a high degree of visibility with the relevant regulatory bodies by keeping communication lines open.

Common sense is an approach that we take onboard to all of our operations, this extends to taking time to assess the risks of new activities, wearing appropriate PPE, sharing safety tips. Having a qualified senior first aid team member, and designated safety officer are additional measures our team has undertaken to ensure our safe operations.

In addition we adopt an approach of continuous learning and improvement to our safety strategy as we continue to further our knowledge of this technology, and stay abreast of industry best practice and changing legislature by discussing these issues with fellow enthusiasts and industry professionals.

7.2 Risk Assessment

Risks have been identified relating to every aspect of our team's operation. We then score these risks in terms of their likelihood and severity, look at the mitigations that are in place and look at the risk after the mitigations.

Risk	Worst Case Outcome	Mitigation
Comms		
Loss of autopilot data link	Loss of control	Flight termination procedure [D2 – 7.14]
Interference	Loss of data link	Pre-flight check [D2 – 7.3] Spectrum Compliance [D2 – 7.11]
Aircraft out of range	Loss of data link	Testing Strategy [D2 – 7.9]
Run out of batteries	Loss of data link	Battery management [D2 – 7.8] Testing Strategy [D1 – 7.9]
Autopilot		
Loss of GPS	Loss of control, crash	Flight termination procedure [D2 – 7.14]
Sensors fail	Loss of control, crash	Testing Strategy [D2 – 7.9] Proven history – Flight Log [D1 – 7.4]
Autopilot Lockup	Loss of control, crash	Flight termination procedure [D2 – 7.14]
Ground Control Station Lock-up	Loss of control, crash	Flight termination procedure [D2 – 7.14] Good power supply

Cross Mission Boundary	Flying out of controlled airspace, increased risk to people and property	Flight termination procedure [D2 – 7.14]
Run out of batteries	Loss of control, crash	Battery management [D2 – 7.8] Flight termination procedure [D2 – 7.14]
<u>Operational</u>		
Weather	Reduced control of aircraft, crash	Understanding limitations of aircraft [D2 – 7.6] Testing Strategy [D2 – 7.9] Piloting proficiency [D2 – 7.5]
Fly out of line of sight	Loss of control, crash	Flight termination procedure [D2 – 7.14]
Mid-air collision	Crash, damage, injury	Operations Manuals [D2 – 7.3] CASA [D2 – 7.7]
Wild-life	Mid-air collision	Be aware of local wildlife
Stall	Loss of control, crash	Understanding limitations of aircraft [D2 – 7.6]
Fire	Damage to people and property	Operations Manual [D2 – 7.3] Be aware of potential bush fire risk [D2 – 7.10]
Inexperienced operators	Loss of control, crash	Pilot proficiency and airmanship [D2 7.5]
Heavy lifting	Personal injury risk	Correct lifting procedure
Hand-launch	Personal injury risk	Operations Manual [D2 – 7.3]
Damaged equipment	Loss of control, crash	Care in transportation, Build Quality & maintenance log [D2 – 7.4]
Propellers	Personal injury risk	Operations Manuals [D2 – 7.4] Safety switch for ESC [D2 – 6.2]
Inadvertent bottle drop	Personal injury risk	Build Quality & Maintenance Log [D2 – 7.4] Pre-Flight Checks [D2 – 7.3] Package drop [D2 – 7.13]
<u>Airframe</u>		
Breaks apart	Crash	Build Quality & Maintenance Log [D2 – 7.4] Pre-Flight Checks [D2 – 7.3]
Loose electrical connections	Crash	Build Quality & Maintenance Log [D2 – 7.4] Pre-Flight Checks [D2 – 7.3]
Control responses incorrect	Crash	Pre-Flight Checks [D2 – 7.3] Pilot proficiency and airmanship [D2 – 7.5]
Run out of battery	Crash	Battery management [D2 – 7.8] Testing [D1 – 7.9]
Loss of engine power	Crash	Build Quality & Maintenance Log [D2 – 7.4] Pre-Flight Checks [D2 – 7.3]
<u>Emergency</u>		
Bushfire		Emergency response plan [D2 – 7.10]
Personal injury		Senior First Aid [D2 – 7.1]
Damage to property		Insurance [D2 – 7.14]
<u>Environment and Community</u>		
Adverse reaction from public	Negatively impact UAV operations in Australia	Be mindful of public concerns, and open about operations

7.3 Operations Manual & Pre-Flight Check Procedure

An Operations Manual will be used to detail the correct and safe way to set-up, use and maintain all equipment related to our operations.

A pre-flight check procedure was developed to ensure the integrity of the aircraft and on-board systems, as well as environmental risks are acknowledged and addressed. (Safety Inspections – OBC 5.3). Aircraft that fail any part of the pre-flight check will need to be fixed and rechecked before they will be allowed to fly to ensure the safety of all present and prevent damage to the aircraft. All pre-flight checks will be stored for future reference and to ensure previous failed sections are rectified before future flights.

7.4 Flight Logs & Maintenance Logs

Flight logs shall be filled out every flight day for each aircraft, their purpose will be to record the performance of aircraft and to highlight any important findings from the flight. Build quality of airframes shall be kept to the highest standard to ensure failure of components due to human error is reduced. To do this we constantly look to other teams to understand how they build and maintain their airframes and adopt the best practice. All maintenance that is carried out shall be logged and must be verified to be complete before launches.

7.5 Pilot Proficiency & Airmanship (OBC 5.2, OBC 9)

Regular flying practice and an association with a local model-aircraft club help to ensure skill levels are kept at a high level. We shall endeavour to have the lead pilot advance their piloting skills by achieving the MAAA Bronze wings or Gold wings to ensure they are a proficient pilot.

7.6 Aircraft Limitations & Stall Margin (Avoiding stalls OBC 3.2)

Extensive testing of our airframe to understand its characteristics, flight performance and limitations will be carried out. This includes identifying safe launching methods, as well understanding the maximum environmental conditions (ie wind speeds, and rain) in which it is safe to operate. The airspeed and flight data will be closely monitored during flight to ensure we are operating inside these conditions and are not inducing a potential stall.

7.7 Regulations

The following steps have been taken to ensure we comply with local regulations:

- Extracted the relevant sections from CASR101 to better understand the requirements for the various testing phases;
- Contacted the local CASA branch to communicate the Team's intentions and further confirm compliance; and,
- Sought out local MAAA (Model Aeronautical Association of Australia) clubs to locate and utilise nearby flying fields as well as benefit from the vast experience of MAAA members with unmanned aircraft.

As per the regulations for recreational use of UAVs, we will: fly below 400 ft, away from built up areas, within visual line of sight, and away from airfields and designated airspace.

For the purposes of long-range testing, we will ensure that we have a spotter maintaining constant visual line-of-sight with our UAV who is in constant communication with the UAV controller.

To ensure continued compliance in a rapidly evolving industry, frequent communication will be maintained with the local CASA branch and MAAA representatives, and we will keep them informed of our activities.

7.8 LiPo Battery Management (OBC 5.17)

Using LiPo battery technology present additional risks as such our team has developed a battery management strategy designed to mitigate these risks.

A reliable battery charger is used to ensure cells are balanced and batteries are not overcharged. Batteries will be charged under supervision. Batteries will be stored and charged a LiPo sack, and in an area where fire can be contained.

Each battery is labelled and its usage is logged so that we can detect when the batteries will be nearing the end of their life. Batteries will be housed in protective foam to reduce the risk of damage to the battery in the event of a crash. Batteries will be disposed in designated battery recycling bins.

Additionally as the team will be travelling to Kingaroy from Perth via commercial aircraft, we will ensure our LiPo batteries are transported in accordance with the IATA Packing Instructions 965, such that: each battery less than 100 W.h, with capacity clearly displayed, total of 10kg of batteries per person, they are packed in strong outer packaging, and the battery terminal are covered to protect to prevent against short circuits.

7.9 Development and Testing

As many of the systems we are developing are new and unproven we are conscious of the need to effectively test each development and ensure a robust testing strategy is in place. To mitigate the risks of testing unproven technology our team has developed a development and testing strategy which includes: strict version control of software, logging all maintenance and changes to the aircraft configuration, HIL and SIL simulation testing for the Autopilot development, and extensive range testing for our radio equipment.

7.10 Emergency Response Plan

The team will be equipped to handle emergencies such as bushfires, personal injury and damage to property by full evaluating the potential risks and ensuring clear response plans are thought through. This includes having a senior first aid trained members, a first aid kit on hand, and considering the bush fire risk of the area we are operating in.

7.11 Spectrum Management

All of our radios are compliant with the ACMA LIPD-2000 ISM class licenses. We are using the following frequency bands:

- 915-928 MHz band with 1 Watt EIRP and 50 channel frequency hopping for the low-bandwidth digital telemetry link
- 2.4GHz band for control link (standard R/C transmitter)
- Telstra 3G modem (2100 Mhz)

We will ensure the power is dialled down to account for gain in the antennas, so this does not exceed the 1Watt EIRP. We will be aware of interference caused to others, and others interference to us, and the effects that this may have.

7.12 Flight Termination & Condition Monitoring

Flight termination will be handled by the on-board Failsafe Device. This will monitor the heartbeat from the Autopilot, if the Autopilot locks up, or detects any condition requiring Flight Termination, the heartbeat will cease, and Flight Termination mode will be entered. Once Flight Termination mode is entered it cannot be overridden. The following conditions are constantly monitored by the autopilot: Loss of Data Link, Loss of GPS, Lock-up/ failure of autopilot, and Crossing of the geofence. Additional details are provided on the following flight termination and condition monitoring events.

Loss of control link in manual mode : The control link receiver is programmed to cut the throttle signal when it loses control link, which is then detected by the Autopilot. The autopilot will then enter the 'RTL' mode which will autonomously return the aircraft back to the home location. At this point the aircraft can either be regained into manual flight, or flight termination can be commanded.

Soft-Geofence : The crossing of the Geofence will be monitored by the Autopilot system, and then command flight termination. A soft-geofence strategy is implemented and monitored from the Ground Control Station. A script will monitor the distance of the plane to the geofence. If the plane strays too close to the geofence boundary (ie due to wrong waypoints, when under manual control, or control strategy is inadequate), then the plane will be commanded to fly to a safe waypoint, and with increased control authority gains.

Loss of engine power : Loss of engine power will be detected by monitoring the airspeed and altitude of the aircraft, and the current drawn from the batteries. If the aircraft is losing airspeed, dropping altitude and/or has an abnormal current draw this may indicate engine issues. In this case the mission will be aborted and the plane will be brought to land as quickly as safely possible from the mission planner or in manual control.

Failure of Stability Augmentation System : Our autopilot has a stability augmentation mode, failure of this system will be detected by the same means as detecting the autopilot lock-up.

Failure of the Ground Control Station : If the Ground Control Station locks up, the radio modem will be disconnected thereby causing the loss of datalink mode to be entered by the autopilot.

7.13 Package drop

The 500ml bottle of water has significant energy when dropped from a height of 100m, and could cause significant injury or damage to property.

To reduced to risk of inadvertent drop a reliable payload release mechanism has been developed and pre-flight checks to ensure the bottle is securely attached and will release on command.

To reduce the risk of injury in the event of an inadvertent drop a bottle with no sharp edges is used, with foam cushioning and a small parachute to limit the speed of the fall, and ensure correct orientation.

7.14 Insurance

Insurance is taken out with the local model aircraft club for test flights, and with the Outback Challenge organisers for the competition.

8 Flight test results and discussion

A summary of the major tests is as follows:

- Airframe trials
  - Airframe selection
  - Endurance and environmental conditions tests
- Autopilot functionality test
  - Basic autopilot functionality
  - OBC failsafe function, and failsafe device
- Imaging system
  - Camera testing
  - On-board scanning
- Bottle drop test
- Comms testing

8.1 Airframe Trials

Several airframes have been flown to gain experience and ensure the selected airframe will meet our needs. These include: Bixler, Skywalker, X-8, and Skyhunter.

The Bixler and Skywalker are useful light-weight airframes to test different systems on, but do not have the payload capacity or endurance required by the competition.

The X-8 was trialled and looked to meet our requirements, however issues with wing-stalls, the folding propeller, and unsafe launching procedures led us to not use this airframe.

The Skyhunter meets our needs in payload and endurance, and has good flight characteristics. During the initial phases of testing the aircraft was found to be difficult to control, however upon finding the ideal weight balance these were resolved. The Skyhunter has been safety flown in winds up to 15 knots.

Initial tests indicate that the airframe can comfortably fly at an airspeed of 35 knots, which is well above the noted stall speed of 20 knots. Further airframe tests on the Skyhunter will be conducted to ensure its reliability, test its endurance, and gain a further understand the flight envelope, stall margin, and maximum environmental conditions in which it is safe to fly.

8.2 Autopilot functionality tests

A number of flights have been carried out to test the basic Autopilot functionality, using the ArduPilot 2.5 on a variety of different airframes. These tests have proven that the Ardupilot is capable of manual control, auto control, waypoint tracking, display of current position, updating waypoints, and air-speed measurement.

The ArduPilot, or any autopilot system for that matter, is an extremely complex piece of software, and the team considers it very important to gain as much experience using the autopilot system as possible and gaining familiarity with all the settings and configurations.

The team has an understanding of the code architecture and has implemented the specific OBC Failsafe and Flight Termination requirements into the Autopilot. This has been integrated with our Failsafe Device and tested on the ground.

Problems have been encountered with the autopilot and subsequently analysed, identified, fixed, and controls put in place to prevent their further occurrence. These include a brownout of the autopilot when the power system was incorrectly set-up, and the autopilot pitching down uncontrollably in auto mode which was due to incorrect set-up.

8.3 Aerial photography & Camera testing

Various cameras have been trialled to determine if they are resistant to vibration and the forward speed of the aircraft.

A GoPro was used initially to capture aerial photos. This produced high quality images and photos. We found that in the fully enclosed housing the GoPro was susceptible to a build-up of fog which reduced the image quality. This was solved by using an open housing.

The Raspberry Pi camera was tested in flight, and from a moving car, to ensure that the progressive scan shutter would not be affected by vibration and the forward speed of the aircraft. Minor distortion can be seen, however we found this to be within acceptable limits for our purposes.

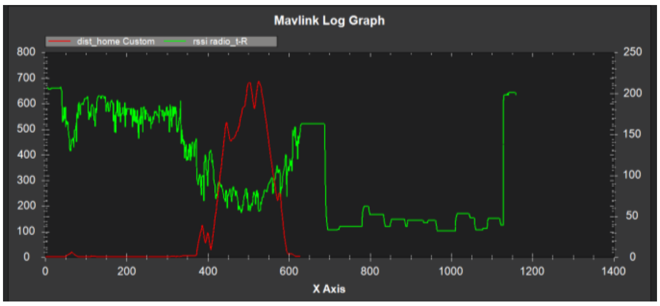
Further testing will be done running the Joe detector on the airframe, scanning the images onboard, georeference, and upload via 3G link. Additionally the image detection algorithm will be tested with different targets.

8.4 Bottle Drop Test

The bottle drop mechanism has been tested in flight, successfully releasing a 500ml bottle of water. The aircraft was noted to be stable after the drop. Further testing will be done to work out the best method of reducing the bottle’s velocity, cushioning the impact of the fall, and finding a burst resistant bottle. Initial testing with an infusion bag is showing promising results.

8.5 Comms Testing

Testing of the comms system has been carried out with 100 mW 900 Mhz transmitters. Analysing the flight logs we can compare the RSSI to distance from the home location. The RSSI drops from 200 to about 50 when the UAV is 700m away, this indicates that the expected range is achieved.

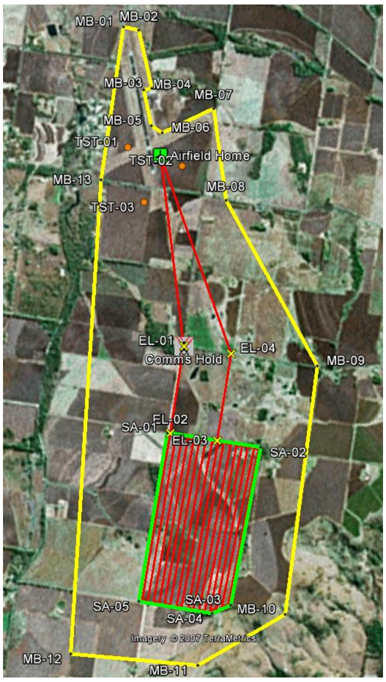


The RFD900 radio has been tested in flight, further testing will be carried out to ensure it meets our range requirements.

Our RC link and 3G link have proved to be reliable over expected ranges.

9 Search strategy

9.1 Flight Phases



Set up (15 min) The plane will be assembled and pre-flight checks carried out. There will be no equipment or personnel off the airfield.

Launch (2 min) The UAV will be hand launched into the wind in manual mode. The UAV will then be switched into autonomous mode, climb to 330 feet AGL, and the UAV will track to the search area.

Fly to search area (5 min) The UAV will fly 2 nm through the search corridor, entering the search area through the correct waypoint. (Air Traffic Management Requirements 2.12).

Search (30 min) The search area will be covered by flying 75m transacts. The total distance covered will be 17 nm. Throughout this the images will be taken from the plane, and analysed with the on-board computer. When Joe is identified, a thumbnail of him will be sent to the ground station for confirmation. Once his location is confirmed with the OBC organisers we will proceed to the bottle drop.

Bottle drop (5 min) A suitable approach for the plane to deliver the water bottle will be calculated and the plane directed there, the plane will then drop the bottle at the appropriate time and continue back to home.

Return to home (5 min) The search area will be exited through the correct waypoint, and the plane will fly 2 nm back through the corridor to the airfield home and loiter there ready for manual recovery.

Landing (2 min) The plane will be switched back into manual mode and landed.

Pack up (15 min) All equipment will be packed up and we will exit the airfield.

9.2 Roles

Pilot / Spotter – fly plane manually for take-off and landing. Communicate mission status to OBC organisers. Direct other team members based on OBC organisers instructions.

UAV Controller – operate and monitor UAV when in autonomous mode. Update waypoints for bottle drop. Monitor number of Data Link Loss and GPS Loss events, proximity to geofence, comms strength.

Imaging System Controller – review images sent to ground, calculate georeferencing, confirm location with OBC organisers, calculate ideal ballistic trajectory for bottle drop

9.3 Other notes

A strong wind will have the effect of slowing our mission, and this will be noted.

10 Conclusions

We believe that H2Joe has a robust system design and risk management strategy to ensure the safe and successful completion of the 2014 UAV Outback Challenge.

We have completed significant development of our various subsystems, and are happy with our progress and results thus far.

The remaining challenges will be:

- Testing the flight termination functionality
- Integration of the imaging system
- Further airframe testings
- Gaining increased experience with the autopilot

We aim to uphold the spirit of the competition by having fun, and we look forward to meeting these challenges with hard work and a focus on safety.