Deliverable 1 Report

UAV Outback Challenge 2012 (Search and Rescue Challenge)

Summary

The Canberra UAV[1] team's design approach is to maximise platform 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 platform based. 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 UAV 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.

Imaging System

The CanberraUAV platform will include 3 cameras. Two of the cameras will be high sensitivity machine vision cameras for high resolution still images. One of these cameras will be grey-scale with an IR pass filter; the other will be colour with an IR blocking filter. These two still cameras will be locked together to provide a high discrimination of IR sources while eliminating false positives from natural IR sources. The colour camera will serve a secondary purpose of target validation by looking for the distinctive colouring of Joes clothing relative to the surrounding terrain. The 3rd camera will provide a real-time digital video feed to the ground crew and OBC Staff for mission monitoring.

Project Status

The CanberraUAV team has been working hard towards our goal of a safe and reliable platform for rescuing Joe. Key achievements to date include:

- Built an autopilot based on the ArduPilotMega[2]
- Successful autonomous flights, with search missions modelled on the OBC mission
- Successfully tested a reliable bottle-drop mechanism
- Successfully tested aerial photography with a high resolution infrared camera (we have captured more than ten thousand high resolution images from the air)

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[1] http://www.canberrauav.com

[2] http://code.google.com/p/ardupilot-mega/

- Integrated camera with a powerful on-board computer system for automated camera control, integration with autopilot telemetry, machine vision and ground communications
- Built and tested a custom ground control station, including sunlight readable display
- Written and successfully tested machine vision software for detecting a IR50WFL11 IR lamp
- Demonstrated target acquisition from the air with an accuracy of better than 25m

Overall Design of the UAV System
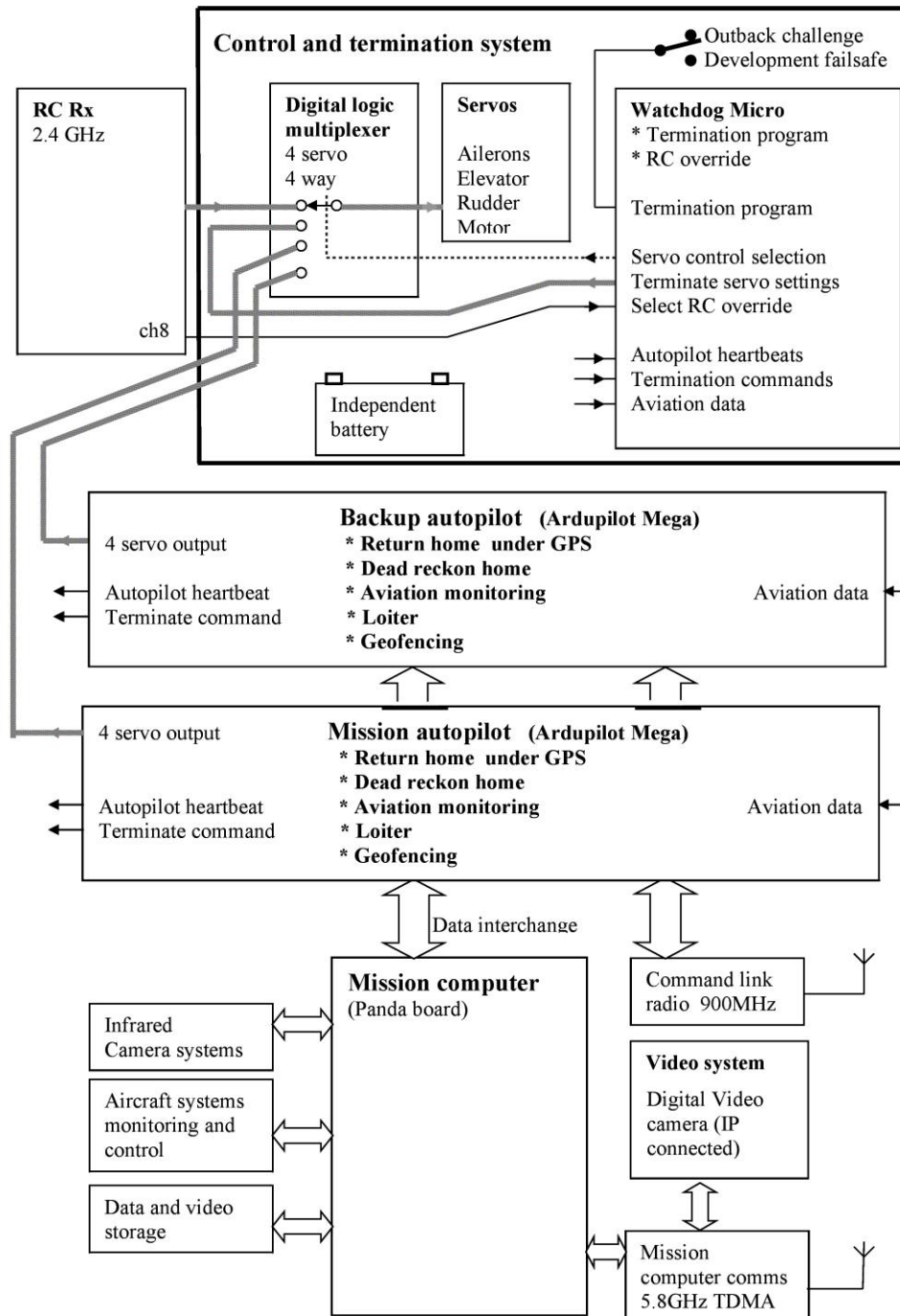
Autopilots – Primary and backup autopilots. The Control and Termination System (C&TS) selects between them based on heartbeat signals. Either autopilot is capable of full mission and geo-fencing. Independent GPS receivers will be on each autopilot. Connected to Ground Control Station (GCS) will be via low-bandwidth telemetry and control link.

Mission control computer – Dual-core ARM Pandaboard[3] for image processing, automated Joe-finding, drop control and overall on-board mission control. Feeds waypoints to autopilots. Connected to GCS via high bandwidth TDMA radio link. Connected to autopilots via serial link.

Search cameras – Two Ptgrey chameleon machine vision cameras (one IR greyscale, one colour). Roll and pitch stabilised for direct downward view. Connected to on-board mission control computer.

Digital Video Camera – IP connected camera linked to ground via TDMA radio link

Control and Termination System - When a failsafe criterion is satisfied, or when commanded, this will initiate the termination program with fixed servo settings as per OBC rules 5.6. Also accepts input from RC controller pilot when in range. Flight termination takes priority over RC control. It is separately powered from other systems.

Low-bandwidth link – Telemetry and control link will use the MAVLink[4] (Micro-Aerial-Vehicle link) protocol. Using 900MHz class license with omni antenna on plane and tracking antenna on ground.

High-bandwidth link – TDMA Ubiquity digital radio with antenna tracking, using the 5.8GHz class license. Running IP link carrying digital video, MAVLink telemetry and control and mission control computer control from GCS.

Ground Control Station – Custom GCS linked via both low-bandwidth and high-bandwidth links to plane. Provides NMEA GPS and video feeds to OBC organisers. Control and monitoring of all aspects of mission. The GCS will report all waypoint crossings.

RC control – Standard 2.4GHz RC transmitter and receiver for visual range control. Also able to be used for long range control via video feed and MAVLink RC control feed to plane.

Aircraft specifications (OBC 5.1)

NOTE: In this section references to S&R rules sections will be indicated via "OBC x.y.z"

The aircraft will be a fixed-wing airframe with a 3m wingspan. The total flight weight will be less than 25 kg. The aircraft itself will be based on the Mugin[5] airframe, but will use avionics and control systems custom built by the CanberraUAV team. The aircraft is capable of autonomous flight via on-board autopilot and mission control computers. The aircraft will have continuous communication with the UAV controller on the ground via multiple radio links, on separate frequencies from the RC transmitter. One radio link will be to the autopilots and the other to the mission control computer. Either link will be sufficient for full control, monitoring of the aircraft and completion of the mission.

We expect the mission will be conducted at an altitude of approximately 400 feet, except for take-off and landing. If testing shows that flying between 400 and 1500 feet improves mission performance, we will apply for permission and will adjust the mission accordingly.

Safety First (OBC 3)

The team will comply with CASR-101, but will additionally stress safety first, and will not fly unless we are sure it is safe to do so. We have made contact with our local CASA office to inform them of our activities and ensure compliance.

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[3] http://pandaboard.org/

[4] http://www.qgroundcontrol.org/mavlink/start

[5] http://www.fpvflying.com/products/Mugin-UAV-Platform.html

Pilot Proficiency (OBC 5.2)

Two team members will hold MAAA[6] (Model Aircraft Association Australia) gold-wings. The team has more than 50 years of aeromodelling experience between them. The primary pilot also holds a pilots certificate with cross-country endorsement.

Pre-flight tests (OBC 5.3)

The team will use a combination of automated (where possible) and manual checklists, visual 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 issues. These procedures will be developed and extensively tested throughout the development process.

Radio Frequencies (OBC 5.3.1/5.3.2)

While the team has two Australian licensed HAM radio operators available for consulting during development, we do not at this stage anticipate needing special licensing beyond ACMA class licenses. All radio communication will be digital, including the video link. We currently expect to use:

- 900 MHz band for low-bandwidth digital telemetry and control link
- 2.4GHz band for visual range RC control (ACCST or similar)
- 5.8GHz band for high-bandwidth digital data link (Ubiquity TDMA or similar)

The team is actively testing radio setups and will adjust antenna and radio links based on test results and EIRP requirements.

RC Override (OBC 5.4)

RC override by team pilot will be possible both within visual range, and when outside visual range via the high-bandwidth video/control link. Flight termination activation will take priority over RC override. Assuming successful testing during the development phase, we will use automated take-off and landing. RC takeover and "stick mixing" will be used to allow instant override by RC pilot in case automated take-off or landing is not considered safe by pilot.

Flight Termination (OBC 5.5.1)

We are developing a custom C&TS system based on a custom microprocessor board containing a TTL logic multiplexer to route the appropriate control signals. The C&TS will be independently powered and will implement the primary OBC S&R FTS option using fixed maximum servo positions. The C&TS will monitor the two autopilots, plus the RC receiver, and will control flight surface servos. Flight termination activation will proceed as per the following sections. Flight termination can be initiated by the GCS through controls to the autopilots. If the C&TS system fails, flight termination will be immediately initiated.

Loss of data link (OBC 5.5.2)

The UAV will monitor 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, or airfield home (whichever is closer). 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 and RC control is not possible by RC pilot, flight termination will be initiated. If RC control is possible the RC pilot will land the plane. Loss of GPS at the same time as data link loss will cause flight termination.

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

Engine Failure (OBC 5.5.3)

The UAV will have electronic engine monitoring. In case of engine failure, the UAV will initiate a controlled glide towards airfield home. The RC pilot will be able to control the glide via MAVLink connected RC transmitter using the high-bandwidth radio link and digital video display on GCS, or directly if in visual range.

Loss of GPS position (OBC 5.5.4)

Loss of GPS position in the primary autopilot will cause takeover by the secondary autopilot. Loss of GPS on both autopilots will cause the UAV to enter GPS failure mode. In GPS failure mode the plane will 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. The pilot will be able to adjust dead reckoning progress via "stick mixing" using RC transmitter connected via MAVLink on the high-bandwidth link, using the digital video feed displayed on GCS as a guide. If the link to GCS is lost during a period of GPS failure then flight termination will be initiated.

Geo-fencing (OBC 5.5.5)

Both autopilots will continually monitor mission boundary compliance via separate GPS devices. If the active autopilot detects a mission boundary violation it will raise a signal on the FTS, 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 prep.

Autopilot lock-up (OBC 5.5.6)

Both autopilots will provide 10 Hz heartbeat signals to the FTS system. Lack of heartbeat for 0.4 seconds will cause the FTS to hand control to the other autopilot. If both heartbeat signals fail during autonomous flight then the FTS will initiate flight termination

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 will be initiated.

Additional systems (OBC 5.5.8/5.6.2)

- A stability augmentation system will not be required for safe manual flight control and will not be used during the pilot proficiency assessment.
- The aircraft will not use any pyrotechnic devices.

Liability and Insurance (OBC 5.10)

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.

Video Stream from UAV (OBC 5.14)

A digital video stream from the aircraft will be available on the GCS, and will be available to judges. Additionally, a NMEA 0183 GPS serial stream will be provided.

Battery Management (OBC 5.16)

The aircraft will not use any LiPo batteries. We will be using safer A123 or NiMH cells for all on-board electronics.

Risk Assessment

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. Extensive testing will be carried out over Lake George (which is mostly dry and not populated) near Canberra, within the one year span of appropriate insurance.
Airframe Installation and Operation	• Installation and build will be up to Federation Aeronautique Internationale (FAI) competition standards. • Operation to be in line with MAAA procedures. • Competition aircraft and pilots to obtain MAAA heavy model certificate before flight of competition aircraft. • Airframe build will be checked by local CASA officials
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 will develop 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 short circuiting of ignition. Short circuit 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. Appropriate safety procedures will be implemented for transport and storage.
Electrical power	• Separate battery packs for Primary control system and instrumentation. • Batteries to be NiMH or Lithium Iron Phosphate (A123). 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.
Autopilot	• Loss of the heartbeat throughout software (written by a professional programmer) will signal failure to the C&TS. • There are two autopilots. The C&TS will automatically choose the correct option from either autopilot, the RC receiver, or self-controlled termination.
Geofencing system failure	• Failure of the system running the geofencing program will alert the control and termination system by loss of the heartbeat.
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.
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 program will be made to only one of the two autopilots at a time. The control and termination system will select the alternate autopilot on failure of the heartbeat, or on command from the GCS
Bugs in software	• Will use Hardware in Loop (HIL) 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.