THE UNIVERSITY OF
MELBOURNE

Capstone Project

Final Report

2015

Project Title: Hybrid UAV Development for Emergency Response

Date: 12/09/2015

Project Team Information

Identifier:	**CP-CBU-155**	
Student workers:	Matthew De Bono	390758
	Alexander Daraio	389844
	Wesley Lim	391053
	Shanon Loveridge	218041
Academic supervisor:	Colin Burvill	
Academic examiner:	Saman Halgamuge	
Industry Mentor:	Jonathon Manton, DEEE	
Version:	1.0	

Acknowledgements

Team CP-CBU-155 would like to acknowledge several contributions to the project:

Melbourne School of Engineering for providing the workspace to complete the project, Colin Burvill and Saman Halgamuge for their guidance and supervision, Andrew Nolan and Jeff Hollingworth for their expertise and equipment, and the Phoenix Multicoptor teams for the laughs, advice and co-operation throughout the year.

Make sure to uncomment line here to generate Table of Contents, then comment out again

Contents

1 Executive Summary

COMPLETE THIS SECTION LAST

The Executive Summary offers a succinct statement of your findings and contributions.

It will summarise the project description and your contributions to the associated discipline.

This section can be based on key sentences and paragraphs from your Scope of Works and Progress Report documents, and your Conclusions and Recommendations section.

No more than five pages of text and images.

2 Introduction

This project is titled "Hybrid UAV Development for Emergency Response", it is a sub-division project of Melbourne Autonomous Search and Rescue (MASR). MASR is a official entrant into the UAV Challenge - Medical Express 2016.

The UAV project entails the design and development of a fully custom UAV which is able to autonomously survey an area and perform search and rescue actions. Specifically, Team CP-CBU-155 was responsible for the development of mechanical design, flight controls, autonomous decision making software, novel sensing method, integration as well as operational roles of developed UAVs.

The primary objectives of the project were the following:

1. Develop a UAV system to meet challenge requirements
2. Achieve a functional UAV (that is to be continued on by next years team)
3. Introduce design novelty

A successful UAV capable of search and rescue applications will incorporate the following features:

- Payload receipt and transportation back to base
- Automated target identification of an uncommon (non high-visibility) target
- Capacity to switch between Vertical Take Off and Landing (VTOL) and traditional fixed-wing flight modes
- Capacity to switch between automated and manual flight modes through user commands
- A total flight travel distance of at least 60km
- A total flight duration of at least 60 minutes

This years team was tasked to provide a solid starting point for which next years team can build upon to realise the challenge requirements and goals. Specific deliverables were selected by the team to develop throughout the year in order to realise UAV Challenge objectives.

- **Transition System:** The development of a novel transistion system which allows the aircraft to switch between VTOL and fixed-wing flight modes
- **Flight Autonomy:** The development, documentation and implementation of automated flight controls
- **Object Detection and Avoidance:** The development of a low-cost medium range sensor system to enable object detection and path routing

WHAT DOES OUR AIRCRAFT BRING TO THE RESEARCH COMMUNITY

- Low cost autonomous aircraft
- Hybrid flight modes
- Long range AND long flight time in a single unit
- Intelligent drone flight (not just "follow me" behaviour)
- Uncountable applications beyond medical transport

3 Literature Review

This section will summarise and analyse the literature sourced and reviewed for your project.

This task should have been mostly completed when you completed your Progress Report #2 presentation.

This section and the associated Bibliography should be directly transferred from your Progress Report submissions.

Include the Samsung aircraft to the lit review list

Since PR1:

Firmware: https://github.com/diydrones/ardupilot (used as a base for our opensource firmware) http://dev.ardupilot.com/ https://pixhawk.org/dev/start

SetUp: http://copter.ardupilot.com/

Transition: https://www.youtube.com/watch?v=SZFagyigkPI (like the firefly 6)

4 Summary of UAV Challenge

The UAV Challenge is a competition held every 2 years where teams enter their UAV for the purpose of completing a autonomously search and rescuse type task. This iteration of the challenge is titled "Medical Express 2016", whereby teams are tasked with using an unmanned aircraft to fly out to a known area through specific transit corridors, search and correctly identify "Outback Joe", land close to him, have Joe place his simulated blood sample within the aircraft and then have the aircraft fly back to base such that his blood sample can be analysed.

The time period of the competition extends from registration (before 2nd September, 2015) to final competition (week starting 19th of September, 2016), spanning over 1 year. The following table highlights the key dates and corresponding events of the 2016 UAV Challenge.

Add completed to D1 once we get the response

Events	Date
Registration and Deliverable 1: Short Technical Report	2nd September 2015
Deliverable 2: Technical Report and Video	13th April 2016
Deliverable 3: Autonomous Flight Record	3 August 2016
Final "Go/No-Go" decision for teams	10 August 2016
Medical Express Challenge	Week starting 19th September 2016

5 Picking Up From 2014

-briefly What they did last year (wes) -Disproof (need to find that one we made matt)

Matt: I still don't think we need this section, at least not in the main body. It was necessary for Project 1, but has had no influence on the project since then. Appendix A seems like a good spot.

6 Formulation of Design Requirements and Constraints

The design requirements and constraints of the project are determined by following the performance, deadline and safety requirements of the 2016 UAV Challenge, and also self-imposed constraints and requirements. For this task the required flight time, distance and maximum weight for a classification were selected as the starting parameters for the calculations.

Secondary objectives included the prioritization of low cost development, as well as use of readily available components and materials. The ranking of the priority of objectives is define as follows:

- **High Priority:** Primary objective of the project.
- **Medium Priority:** Objectives that result in performance specifications (treated negotiable).
- **Low Priority:** Not of primary concern, but to be addressed where feasible.

Table 1: Project Objectives for CP-CBU-155

Objective	Criteria	Priority
Compete in UAV Challenge 2016		
Register in UAV Outback Competition	Pass/Fail	High
Submit and Pass UAV Challenge Deliverable 1	Pass/Fail	High
Achieve a functional UAV		
Achieve maiden flight	Pass/Fail	High
Achieve autonomous flight	Pass/Fail	High
Adhere to UAV Challenge 2016 rules		
Be able to take off and land in obstacle rich environment	Pass/Fail	High
Introduce design novelty		
Introduce transition system between VTOL and fixed-wing modes	Pass/Fail	High
Utilize 3D printed components	Pass/Fail	High
Adhere to UAV Challenge 2016 rules		
Ability to take off and land in an obstacle rich environment	Pass/Fail	High
Ability to travel at least 60 kilometers	Pass/Fail	High
Ability to complete competition in at most 60 minutes	Pass/Fail	Competition
Other		
Manufacturable with available resources	Pass/Fail	Low
Manufacturable with readily available components	Pass/Fail	Low
Low cost project	Total Expediture (AUD)	Low
UAV transportable via car	Pass/Fail	Low

- **Competition Priority:** Important objectives to compete in competition, but out of this years scope.

The formulation of objectives, requirements and constraints provide the performance specificiations that are used as a foundation for the selection of motor, propellor and battery components. Everything required, and what we have covered this year (wes,matt,shanon,alex)

7 Aircraft Design and Implementation

- Basically PR1(prototype/printing/etc) (WES)
- Extra stuff (Alex))

8 Autonomous Flight

- Can possibly merge this with another section
- Introduce the various flight modes (VTOL [Take-off and landing], Fixed wing [Main flight mode], Search [Identify Joe] for later sections

9 Sensing

Figure 1 outlines the on-board sensing capabilities that will be available to the aircraft. The sections below detail the use of each sensor during a mission, and are separated according to the different flight modes introduced in Section **??**.

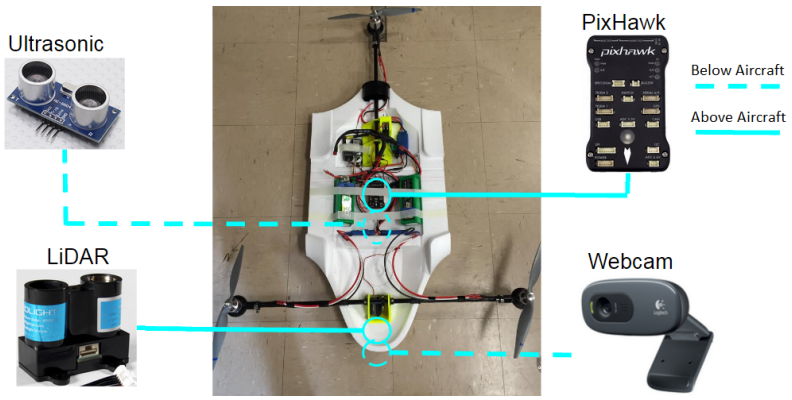

Figure 1: Onboard sensing capabilities for Prototype #1

9.1 All Flight Modes

Raspberry Pi

The Raspberry Pi will act as the aircraft's on-board computing platform, providing autonomy by giving flight commands to the flight controller, as well as the processing and intelligence for path planning, and object detection. It will also pull flight data from the PixHawk and other sensors, and generate detailed flight logs for later review.

PixHawk Flight Controller

The PixHawk will control the aircraft's flight functionality, such as controlling motors and ailerons, and executing flight paths and commands from the Raspberry Pi.

9.2 Vertical Take-Off and Landing

Ultrasonic Module

The ultrasonic module will be mounted underneath the aircraft. The GPS and altimeter will provide altitude measurements during fixed-wing flight; the ultrasonic will augment these by providing a more reliable and controllable height measurement during rotor-based flight, assisting with search and landing.

9.3 Long Range Flight

PixHawk Sensors

It also has several in-built or plug-and-play sensors, including a 3-axis accelerometer, altimeter, compass, and GPS. The PixHawk will provide the aircraft's telemetry to the Raspberry Pi and the base station, which will be augmented by the additional sensors below.

9.4 Finding Joe

Webcam

The webcam will be mounted beneath the nose of the aircraft. It will provide vision for the aircraft's obstacle avoidance manoeuvers, and will form the basis for identifying Joe using his hat and blue jeans.

LiDAR

The LiDAR will be mounted in the nose of the aircraft. The LiDAR can only measure the range of objects directly in front of it, so it will be mounted on a dual servo system that allows it to sweep a hemisphere in front of the aircraft (see Figure 2). It will provide a 3D map of the environment in front of the aircraft, and will assist in path planning and obstacle avoidance.

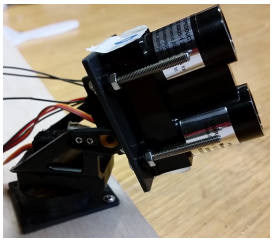

Figure 2: LiDAR mounting

10 Planning

-fill this part out with all the stuff that is and isnt tangible that youve been doing (shanon)

11 Transition

(alex)

- all the stuff done
- tests to prove it worked
- Anything that broke as a result of not testing something, or anything that resulted in modification to Dragonfly, write it as if we performed a test, then made the change, rather than "oh that broke, what happened?"

12 Tests and Failures

- when we started flying really low (wes)
- machines and mechanisms we tested on to make sure it wouldnt break (wes)
- flight tests and tweaks in courtyard (wes)
- major flight tests that worked well (july 3 and September 6)
- Tuning
- Data LOGS!!!
- Major crashes and broken parts (Either don't include this, or frame it in a positive note. We can't have a section on failures.)
- final transition

13 Remaining Sections

You are welcome to choose appropriate names for section headings.

The main argument will begin with a section describing your team's major activities, leading to the fulfillment of the objectives of your project. A flow chart will provide a useful visual aid.

Introduce the tasks that you were required to complete to satisfy the agreed project scope. Itemise tasks whenever possible to assist cross-referencing with following sections (i.e. your contributions).

Describe the development your ideas and strategies, the conceptual design and research methods used (as applicable), and why they were chosen (your literature review will be of value here).

Discuss any original contributions including, for example, modifications or extensions of published methods or associated knowledge. Your team may have made a more humble, but still valuable, contribution, where you

customised an existing method for your specific application. Describe the benefits and, if applicable, deficiencies associated with your contributions.

The criteria against which preferred concepts are identified should be discussed. This aspect of your report, appropriately sectioned, will make extensive use of pictorial information (figures) and organised information (lists and tables).

Given Final Report submissions are normally not paper-based, all supporting material (figures, tables) in the main body should be easily read on a standard computer screen, for example: Text/font size should be consistent, Do not change from portrait to landscape orientation Maintain A4 size (i.e. no fold outs to accommodate A3 size) Appendices can include different page sizes to accommodate, for example, large-format Gantt charts.

The details of completed analyses and supporting calculations can be included in an Appendix, referred to, as required, from the main body of the report. Summaries, flow charts identifying methodologies, and sample calculations should be included in the main body of the report.

The process that you developed and then used to facilitate specific contributions may, itself, be one of your contributions (i.e. providing a framework for ongoing work by other practitioners or researchers). This is worthy of inclusion as a section of the main body of the report.

14 Conclusions and Recommendations

14.1 Achievements

14.2 Further Work

14.3 Recommendations

Confirm that the objectives stated in the Introduction have been met. If the objectives in the Scope of Works document have not been fully met, an argument is required as to why the outcomes do not correspond with those envisaged.

Opportunities for further work, identified through the activities of the current project but outside its scope, should be identified.

This section will summarise your teams final response to the initial question, problem or issue. A summary of the arguments associated with your outcomes will be provided so that the reader is aware of your reasoning.

Do not include any personal responses to the project (eg. ...we enjoyed working with Joe and learnt a lot from Jen...). Write this report as if you are a professional practitioner, representing a research organization or consulting design bureau.

You are encouraged offer details of successful task completion. Success can be interpreted in many ways, for example: Team CP-xxxx contributed X to the overall Y research program led by Professor Z The client mentor was satisfied with the alternative conceptual designs offered by team CP-xxxx The leader of the research division of the collaborating organisation was impressed with the alternative experimental method proposed by team CP-xxxx An extensive review of the scientific literature has been completed by team CP-xxxx Commercially available solutions were identified and ranked against criteria developed in conjunction with the client

You can report on the status of your contributions. For example, within the collaborating research laboratory, research group, research initiative, or client company, the final proposals of team CP-xxxx: have been implemented, are under review for later implementation, are awaiting detailed costing, or have provided a range of novel alternative strategies for later consideration.

Do not apologise. Focus only on the positive outcomes of your work. As an example, it is likely that tasks identified in your Scope of Works but not completed would have required more resources than were available. Identify important tasks not completed as opportunities for further work within the associated DME laboratory or client organization, and discuss why they are important. Given the many tasks that you have likely completed, your team now have an excellent knowledge of the requirements of the tasks not completed briefly outline your expectation of the resources (i.e. personnel expertise, equipment, facilities, finance) needed to complete important tasks.

Appendix A

Detailed work completed by the project team not included in the main body (calculations, sketches, details of activities not suited to the main body, e.g. raw data from experiments).

Appendix B

Management and administration information: Gantt chart (schedule) Include important issues associated with task duration prediction presented in your Progress Reports. Cumulative hours spent on project individual and/or team based, project diaries, meeting minutes or summaries (i.e. useful outcomes from each meeting). Each meeting will require a numeric identifier if you are to reference expert opinion in the main body of your report (eg. Section A.2.3). Individual or team based project diary. Copy of your final Scope of Works.

-Shanon can you do gant stuff? -[Lets get a list of all trello jobs submitted here (when they were completed etc). This can be out diary]

Appendix C

Existing Aircraft

Figure 3: Arcturus Jump, taken from `http://www.arcturus-uav.com/aircraft_jump.html`

Figure 4: X PlusOne, taken from
`https://www.kickstarter.com/projects/137596013/x-plusone-your-ultimate-hover-speed-aerial-camera`

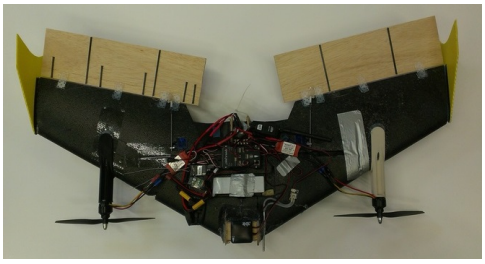

Figure 5: TBS Caipirinha, taken from `https://pixhawk.org/platforms/vtol/tbs_caipirinha_vtol`

Add Samsung aircraft

Figure 6: FireFly6, taken from `http://www.robotshop.com/ca/en/firefly6-vtol-y6-multirotor-drone-frame.html`