QUT Airborne Systems Lab

UAV for Urban Search and Rescue
UAVUSR - 2019

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This document presents a specification for an autonomous UAV with the capability for urban search and rescue sought by QUT ASL Lab. The capability is required by November 2019 to allow QUT ASL to fulfil its obligations to its international clients.

This document has been prepared for scoping purposes for QUT ASL sub-contractors

Background

The QUT Airborne Systems Lab (ASL) is a world-leading research centre based in Brisbane, Australia. QUT ASL conducts research into on autonomous technologies which support the development of autonomous aircraft with on-board sensor systems for a wide range of commercial applications. QUT Airborne Sensing Systems is known for its high-quality research and its ability to take leading edge research concepts from paper to flight-tested reality.

Project Overview

The students of EGB349 have been commissioned by QUT ASL to design and build a UAV for urban search and rescue.

The UAV^{U}SR is required to conduct constant search around a simulated urban environment after a natural disaster event. During monitoring, it must have the capability of identifying and locating two human targets and deploy the correct emergency medication. Additionally, QUT ASL requires that the UAVUSR is designed and developed using Systems Engineering (a rigorous and disciplined engineering methodology for complex projects) to ensure QUT ASL requirements are met.

High Level Objectives

Teams of students are required to design, build, test, and demonstrate a multirotor-based UAV that can use an on-board camera to autonomously navigate around a simulation of a cluttered urban environment, locate two injured persons, and assist them with medication. The platform is to be operated via a remote ground control station, where platforms telemetry and imagery data is displayed and logged. The designed system must meet the objectives listed below.

HLO-M-1 – Autonomous Operation

The UAV^{U}SR is shall be capable of autonomous flight while remaining below a maximum take-off weight of 1.8 kg. The QUT ASL ROS UAV software should be used as the base control system for the navigation software to be interfaced with. Fully autonomous operation is required, such that the UAV^{U}SR can be commanded to begin the mission, and without any further user input, the mission shall be performed and completed.

All interactions with the UAV^{U}SR are via a ground control station, which will display and log real time flight telemetry and imagery from the UAV^{U}SR.

The system shall demonstrate the ability to complete two basic navigation tests (1: take-off, hover for 10 seconds, land; 2: 4 waypoints in a square pattern) autonomously before final demonstration to the client. Flight logs of the navigation tests will be accepted if they are successful, with no in-flight incidents, failures, and demonstrate stable flight (norm tracking error <0.1m).

HLO-M-2 – Indoor Zone Coverage

The UAV^{U}SR must autonomously navigate around a given area without colliding with the net, walls, floor, ceiling, or obstacles, and must successfully find both persons and deploy the medications in a single flight.

The required search area will be 4x4m, and the UAV will be deployed at the coordinates of [-1,-1] from the area centre during the final demonstration .

The obstacle that is expected to be found in the flight area are pillars that extend from floor to ceiling, however the position will not be known prior to arriving at the search area. Information on the obstacle, as well as other information about the flight area, will be provided as an Occupancy Grid (Appendix C) and will be made available through ROS.

HLO-M-3 – Sensor Data

The UAV^{U}SR must transmit live telemetry and imagery to the ground control station for display and logging. The displayed telemetry must contain the information described in the Further Details section. All sensor information should be displayed graphically to the customer in real time.

On the detection of a person, the ground control station shall alert the operator by vocalising the persons location and injury type. This information must also be shown in a 3D visualization of the search area.

This data must then be made available in real time through the ROS system and shall use standardised ROS messages in favour of other methods whenever possible.

HLO-M-4 – Marker Identification

Using the imagery data collected, an on-board Socket on Chip (SoC) computer (e.g. Raspberry Pi, Odroid) must be utilized to identify the injury type, then must localize the person to an accuracy of 50cm.

The marker identification shall be performed on-board the UAV^{U}SR

The injured persons in the simulated search area will be represented with markers on the ground (Appendix A) representing their specific injury. The combination of marker colour and shape shall be unique in the environment, however there should be no tolerance to false positives.

HLO-M-5 Medication Delivery

When each marker is identified and located, the UAV^{U}SR must immediately deploy the correct simulated medication.

The UAV^{U}SR must autonomously hover above the person for five seconds (to ensure an accurate deployment) and shall require no user input during the manoeuvre. The UAV^{U}SR must then drop the correct simulated medication (Appendix D) to the person. The impact location of the simulated medication must be within 20 cm of the intended marker.

HLO-M-6 – Basic Hardware Demonstration

A demonstration of the flight capabilities of the UAVUSR shall be completed by Semester 1 Week 11. The flight shall consist of an operator manually guiding the base UAV (basic airframe and flight controller only) to hover in the netted area in O-Block.

HLO-M-7 – Systems Engineering Method

The developed solution shall conform to the Systems Engineering approach taught throughout the rest of this unit. All preliminary designs shall be completed by weeks 11.

HLO-M8- Equipment

QUT ASL has a recommended list of suppliers for their equipment. The developed solution shall conform to the proffered equipment options supplied by the customer.

Further Details

The simulated inspection area is located at QUT ASL (22-24 Boronia Rd, Eagle Farm, Queensland, Appendix B). A second area will be available for testing in O134 QUT-GP. Your system should be design to meet the objectives set in the simulated inspection area. Measuring the features of the simulated inspection area and incorporating these measurements into your design is allowed if required, however it is a good idea to try and keep any designed systems robust enough that you can change such measurements with ease.

To assist with the issue of room measurements and autonomous navigation, the Occupancy Grid that will be provided (Appendix C) with will contain the following information:

- Flight area size and boundary location
- Obstacle size and location

The markers to be detected are the two figures that are included in Appendix A. The designed system should be able to detect both two markers in an arbitrary order and should be smart enough to not alert the operator about a marker that has already been found. The markers will be placed randomly around the room for the final demonstration, thus the positions will be unknown prior to take-off. Each marker will be exactly 200x200mm in size (exact size print-outs will be made available via Blackboard). Please note the following constraint on group size:

- **<=6 members:** Only the two markers will be placed in the search environment (marker size less relevant during detection)
- **7 members:** False positives (±50% size) will be placed in the search environment (marker size may need to be checked during detection)

Due to the specifics of the simulated search area, the optimum vertical flight envelope is between 1.3m and 1.7m from the ground.

For networking, two wireless routers will be made available, one for development S901 and one at QUT ASL and will more than sufficient for networking involved to complete the task at hand.

The Robotic operating system (ROS), at its most basic, is a framework that allows simple and reliable communication between software. More details on ROS will be explained throughout the semester, but for the time being, all that you need to know is that it allows programs to send and receive messages in a standardized method.

The ground control station (GCS) is essentially a computer with communication equipment that allows an operator to receive information from the platform and send commands to the platform. A GCS will be set up for use at QUT ASL. Often, students will bring additional equipment (e.g. laptops) for additional screen space, although this is not necessary.

The telemetry required for this platform will be collected by sensors or information to form state of the system, which will then be communicated to the ground control station. For this project the minimum telemetry that needs to be transmitted and displayed includes:

- The mode that each flight-reliant subsystem is in (e.g. test, calibration, initialisation, search, standby, deployment, landing, armed, disarmed, etc.)
    - The current navigation state of the system (position and attitude)
- The current navigation goal of the system (position and attitude)
- Live imagery from the camera, with some form of overlay present when a target has been detected

Budget

A selection of appropriate hardware and software will be made available for you to perform a trade study on during the first few weeks. Although detailed examples of subsystem's possible solution will be further discussed in later weeks, it is suggested that all students perform some preliminary research to gain an understanding of the potential solutions to the task.

There is a fixed budget for the project $500 per team to go towards the components you select for your platform. A risk assessment should be performed to determine how much you budget you will need to put aside to pay for repairs or additional costs. Additional budget can be organized in the event of damaged or broken equipment if required to ensure you can complete the unit.

Acceptance Tests – Flight Demonstration in Week 11 Semester 1

As per customer requirement, the system should be able to complete an initial acceptance test in accordance with the Acceptance Test Prototype CRA (will be made available on Blackboard), with video evidence, by Semester 1 Week 11.

Acceptance Tests – Flight Demonstration in Semester 2

As per customer requirement, the system should be able to complete the acceptance test in accordance with the Acceptance Test CRA (will be made available on Blackboard), with video evidence, by Semester 2 Week 12. It is acceptable to attempt, and have marked, the final acceptance tests before the final test day.

Semester 2 (EGH450) Overview

EGH450 is dedicated to the second part of the project which includes:

- Building and integrating the various sub-systems
- Testing the system to show that requirements have been met
- Revising and retesting designs that fail requirement tests (very common)
- Demonstrating the final system to the customer
- Presenting your final work to the panel from industry and academia.

Team Structure

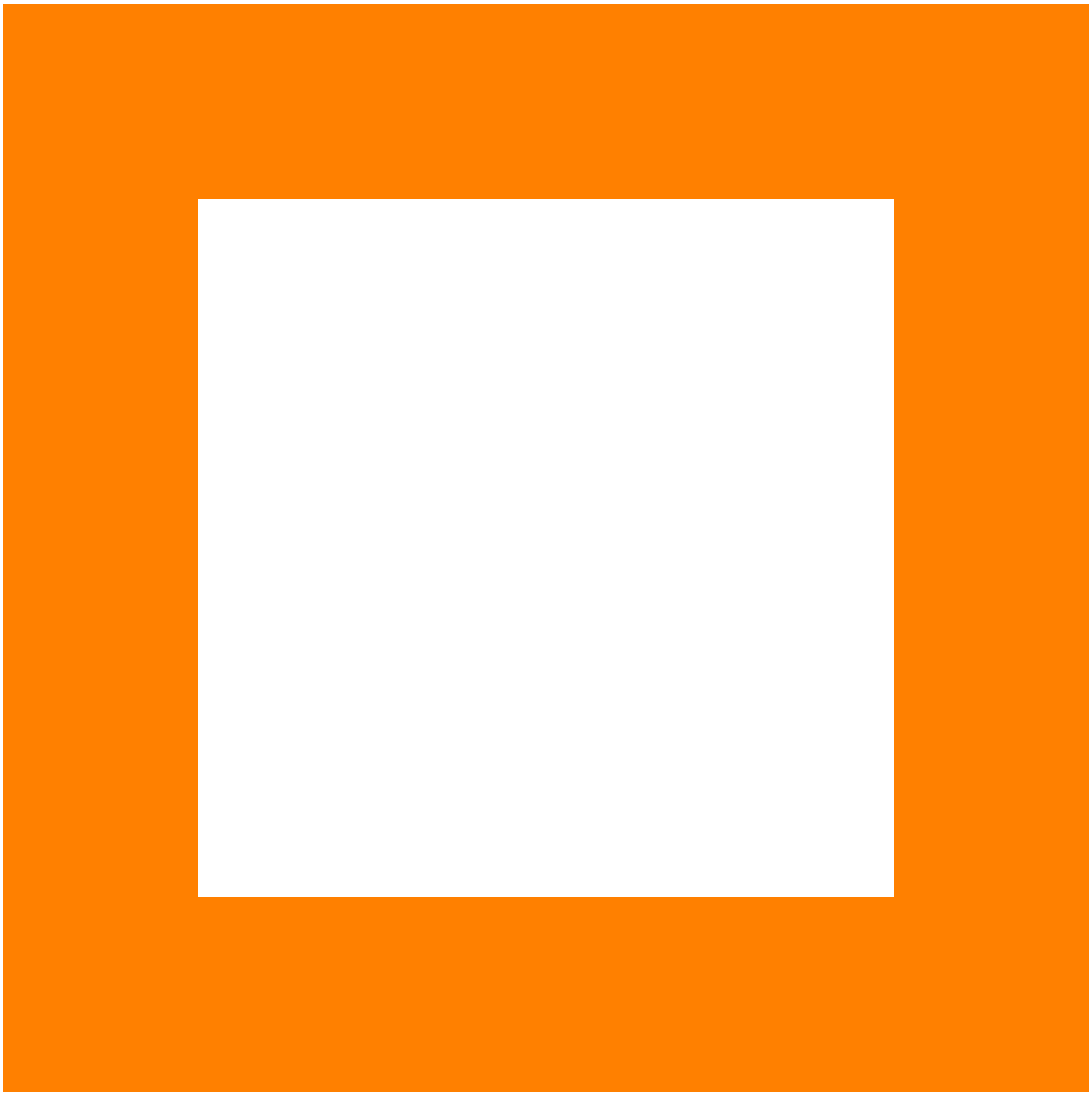
The recommended subsystem allocation can be seen below. Due to class make-up, this layout may be variable, but it is required that there are no more than 7 students per team.

The Learning Outcomes are aimed at the specific tasks that this subsystem will be undergoing in Semester 2. It is recommended that if you have experience or high interest in specific outcomes, you should heavily consider them when choosing your subsystem.

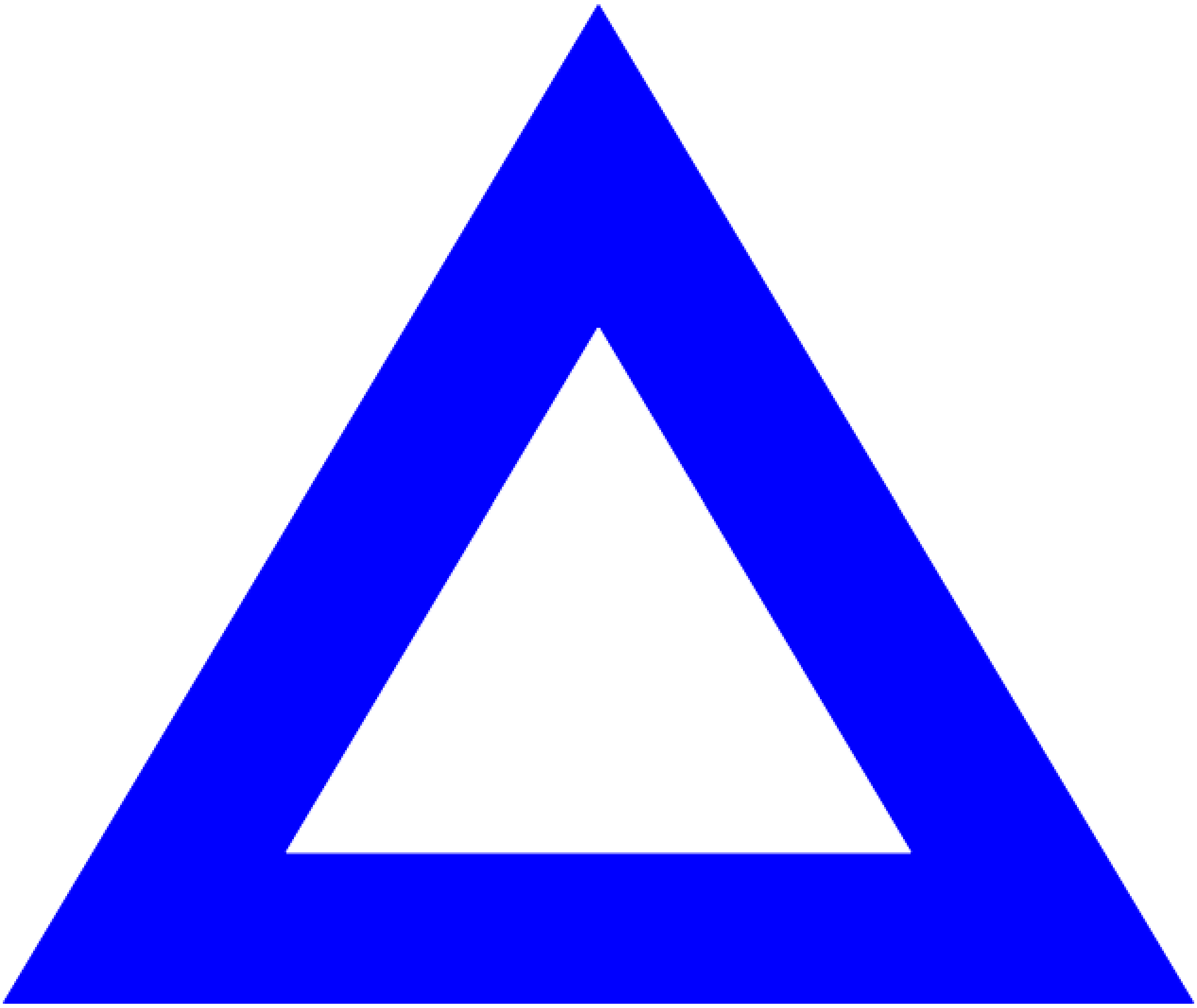
In addition to the Learning Outcomes, there will be enough content covered in Semester 1 Labs that everyone will have enough knowledge to take on any subsystem. Every subsystem will also heavily include learning the ROS framework.

Position	Suggested Background	Learning Outcomes
Project Manager	Aerospace / Other	Project management
Airframe, Power & Propulsion	Aerospace / Mech./ Other	Hardware, CAD, Circuitry
Payload Deployment	Mech./ Software / Other	CAD, Microcontrollers
Autopilot Navigation & Localization	Aerospace / Elec / Software	Microcontrollers, PID Tuning
Operator Interfaces	Software / Elec / Other	Graphical User Interfaces
Target Acquisition & Image Processing	Software / Aerospace	Image Processing, Cameras

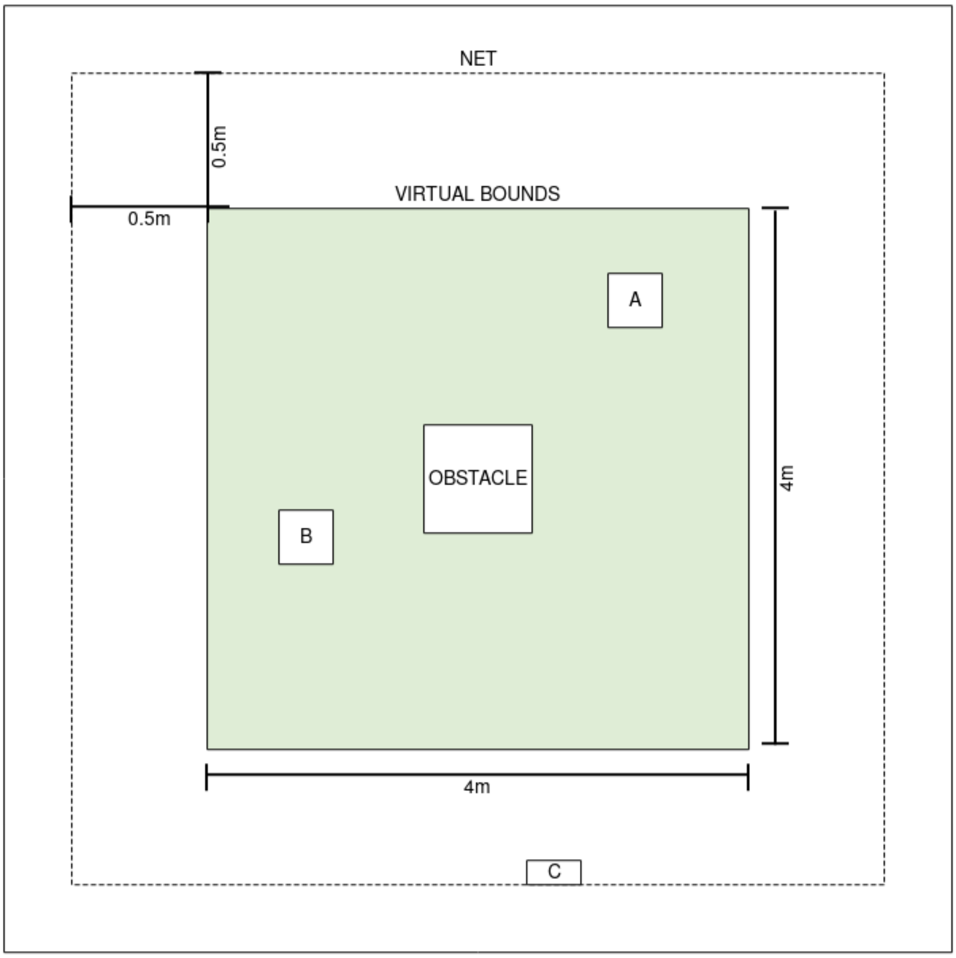
Appendix A1 – Marker for Person with Anaphylaxis



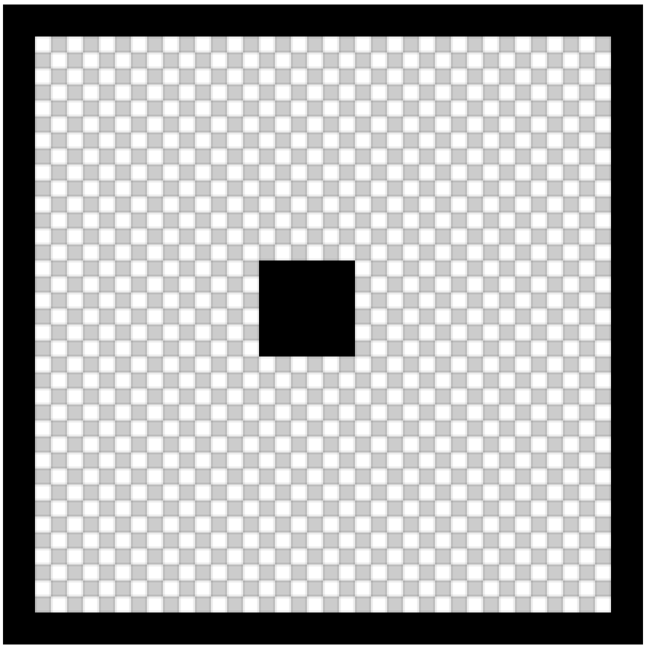
Appendix A2 – Marker for Person with a Haemorrhage



Appendix B – Simulated Flight Area (with Example Obstacle)



Appendix C – Example Obstacle Occupancy Map



Appendix D – Medical deployments

Real Life medical application

Epipen to treat Anaphylaxis

Emergency Bandage (Israeli Bandage) to treat Haemorrhaging

Demonstration Deployment Object

Dimensions:

- Length: 0.15m
- Diameter: 0.025m

Mass (each): 55g