QUEENSLAND UNIVERSITY OF TECHNOLOGY

System Requirements

EGH450: Advanced Unmanned Aircraft Systems

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Definition of Terms

ASL	Airborne Systems Lab
BEC	Battery Eliminator Circuit
CAD	Computer Aided Design
Csen	Current Sensor Pin
ESC	Electronic Speed Controller
EKF	Extended Kalman Filter
GUI	Graphical User Interface
GCS	Ground Control Station
HUD	Heads Up Display
HLO	High Level Objective
MAVROS	Micro Air Vehicle ROS
mAh	Milliamp-hours
N&C	Navigation & Control
OBC	On-board Computer
OIS	Operator Interface Software
PRM	Payload Release Mechanism
PX4	PixHawk 4
PID	Proportional Integral Derivative
QGC	QGroundControl
QUT	Queensland University of Technology
QFS	QUT Flight Stack
RP4	Raspberry Pi 4
RC	Remote Control
ROS	Robot Operating System
SAR	Search and Rescue
SMS	System Management Software
UAV[A]SR	UAV (Antarctica) SAR
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
VRPN	Virtual Reality Peripheral Network
Vsen	Voltage Sensor Pin
WBS	Work Breakdown Structure

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1.0.0 Introduction

The following section outlines the system requirements of the project that has been commissioned by the QUT Airborne Systems Lab (ASL). The purpose of this document is to ensure that the UAV will meet the specifications needed to complete the mission successfully and satisfy the client. The system requirements outlined in this section have been traced from the HLOs in the Customer Needs (RDP.001) document.

1.1.0 Scope

The objectives for this document are:

1. Achieve clarity and highlight the customer needs that were provided to the team through providing a labelled requirement system.
2. Provide further detail as to how the project will be split into subsystems according to the customer needs.
3. Provide a link to where the requirements were derived from.
4. Outline the methodology as to how each of the subsystems will be verified to ensure that the customer needs have been met.

1.2.0 Background

The Queensland University of Technology (QUT) Airborne Systems Lab (ASL) conducts research into autonomous technologies and aircraft. QUT ASL is part of a large project in Antarctica to conduct remote sensing tasks. QUT ASL has commissioned Group 6 from EGB349-EGH450 to design and build an unmanned aircraft vehicle (UAV) for search and rescue (SAR) purposes in Antarctica. The SAR UAV is required to conduct a search in a simulated environment meant to emulate the environment of Antarctica. The UAV must identify and locate two simulated human targets, of which the UAV is used to deploy the correct simulated medication to each person. The UAV must autonomously navigate around the cluttered simulated environment, where the platform is to be operated via a remote ground control station (GCS). The GCS is to display and log telemetry and imagery from the UAV. The UAV will be designed and developed with systems engineering processes, ensuring all requirements are met.

1.3.0 Referenced Documents

Reference	Document Code	Document
RDP.001	SR21G6-PMT-CND	Customer Needs Document
RDP.002	SR21G6-PMT-PMP	Project Management Plan
RDP.003	SR21G6-PMT-SRQ	System Requirements
RDP.004	SR21G6-PMT-ICD	Interface Control Document
RDP.005	SR21G6-PMT-WPD	Work Packet Document
RDP.006	SR21G6-PMT-VAV	Verification and Validation Document
RDP.007	SR21G6-PMT-MMC	Meeting Minutes Compiled
RDP.008	SR21G6-PMT-WBS	Work Breakdown Structure
RDP.010	SR21G6-PDD-STT	Preliminary Design Document ARM/PLD
RDP.011	SR21G6-PDD-SSM	Preliminary Design Document PWR/PPL
RDP.012	SR21G6-PDD-ATP	Preliminary Design Document ATP
RDP.013	SR21G6-PDD-CTL	Preliminary Design Document GCS/CMM
RDP.014	SR21G6-PDD-IPS	Preliminary Design Document IPS
RDP.015	SR21G6-FDD-STT	Final Design Document ARM/PLD
RDP.016	SR21G6-FDD-SSM	Final Design Document PWR/PPL
RDP.017	SR21G6-FDD-ATP	Final Design Document ATP
RDP.018	SR21G6-FDD-CTL	Final Design Document GCS/CMM
RDP.019	SR21G6-FDD-IPS	Final Design Document IPS
RDP.020	SR21G6-TRD-ARM-SA	Test Report Document ARM Suite A
RDP.021	SR21G6-TRD-PWR-SA	Test Report Document PWR Suite A
RDP.022	SR21G6-TRD-PPL-SA	Test Report Document PPL Suite A
RDP.023	SR21G6-TRD-PAY-SA	Test Report Document PAY Suite A
RDP.024	SR21G6-TRD-ATP-SA	Test Report Document ATP Suite A
RDP.025	SR21G6-TRD-IPS-SA	Test Report Document IPS Suite A
RDP.026	SR21G6-TRD-GCS-SA	Test Report Document GCS Suite A
RDP.027	SR21G6-TRD-CMM-SB	Test Report Document CMM Suite A
RDP.030	SR21G6-TRD-ARM-SB	Test Report Document ARM Suite B
RDP.034	SR21G6-TRD-ATP-SB	Test Report Document ATP Suite B
RDP.035	SR21G6-TRD-IPS-SB	Test Report Document IPS Suite B
RDP.036	SR21G6-TRD-GCS-SB	Test Report Document GCS Suite B
RDP.037	SR21G6-TRD-CMM-SB	Test Report Document CMM Suite B
RDP.044	SR21G6-TRD-ATP-SC	Test Report Document ATP Suite C
RDP.045	SR21G6-TRD-IPS-SC	Test Report Document IPS Suite C
RDP.046	SR21G6-TRD-GCS-SC	Test Report Document GCS Suite C
RDP.047	SR21G6-TRD-CMM-SC	Test Report Document CMM Suite C
RDP.050	SR21G6-TRD-ITT-SA	Test Report Document Integration Suite A
RDP.051	SR21G6-TRD-ITT-SB	Test Report Document Integration Suite B
RDP.052	SR21G6-TRD-ITT-SC	Test Report Document Integration Suite C
RDP.053	SR21G6-TRD-ITT-SD	Test Report Document Integration Suite D
RDP.060	SR21G6-SDS-CHK	Operational Checklists
RDP.061	SR21G6-SDS-TDC	Technical Documents Compiled

1.4.0 System Requirements Scheme

The system requirements presented in this document are derived from the provided client's brief. Initially, the high-level objectives (HLOs) were obtained from the client's brief. After this, the client's brief and HLOs were further deconstructed into subsequent specific requirements interpreted by the team, which define each system and subsystem requirement. Hence, each requirement (or series of sub-requirements) is defined as to satisfy the HLO. Each requirement is numbered to reflect which HLO it was obtained from in the client's brief. The requirements will provide a description of the requirement, a rationale of why it is a requirement, where in the brief the requirement was traced from, and a verification scheme on how the requirement will be fulfilled.

A verification table has been additionally provided to depict how each requirement satisfies corresponding high-level requirement. Each requirement is defined as a functional, user, performance and physical in addition to its subsystem categorisation. The verification table provides a level of traceability to ensuring the work satisfies all of the original customer needs.

1.5.0 Numbering Scheme

The system requirements are categorised in this report as follows: [**REQ-HN.N**]

- REQ - The statement is a requirement.
- H – Referencing the requirement is traced from a high-level requirement.
- N.N - Numerical identifier of the requirement.
    - First number indicates the HLO from which it was acquired.
    - Each subsequent decimal denotes the requirement and sub-requirement indices.

2.0.0 Requirements

2.1.01 REQ-H1.1

Description: The UAVSR shall be capable of fully autonomous flight during operation.
Traced from: HLO-M-1
Rationale: The client requires the UAVSR to automatically locate wounded personnel in the field.
Verification: [**REQ-H1.1**] shall be verified with a fully autonomous flight demonstration.

2.1.02 REQ-H1.2

Description: The UAVSR operation commencement shall be triggered by the user.
Traced from: HLO-M-1
Rationale: The client shall manually actuate the UAVSR when it is required, following which no further input is required.
Verification: [**REQ-H1.2**] shall be verified by commencing a fully autonomous flight demonstration via manual command at ground control.

2.1.03 REQ-H1.3

Description: The combined total weight of the UAVSR and payload shall be no more than 1.5kg at take-off.
Traced from: HLO-M-1
Rationale: Weight of the UAVSR shall be minimised to preserve cost and flight capabilities.
Verification: [**REQ-H1.3**] shall be verified with inspection by weighing the final product and payload.

2.1.04 REQ-H1.4

Description: The UAVSR shall utilise QUT ASL ROS UAV software as the base control system.
Traced from: HLO-M-1
Rationale: Client request.
Verification: [**REQ-H1.4**] shall be verified with an inspection of the product's base control system.

2.1.05 REQ-H1.5

Description: The UAVSR shall successfully complete two navigation flight tests prior to the final demonstration to the client.
Traced from: HLO-M-1
Rationale: The UAVSR shall be flight-capable before the final demonstration.
Verification: [**REQ-H1.5**] shall be verified through implementing [**REQ-H1.5.1**], [**REQ-H1.5.2**] and [**REQ-H1.5.3**].

REQ-H1.5.1

Description: The UAVSR shall be able to autonomously take-off, hover for 10 seconds, and land.
Traced from: HLO-M-1
Verification: [**REQ-H1.5.1**] shall be verified by demonstrating the UAVSR can autonomously take-off, hover for 10 seconds, and land.

REQ-H1.5.2

Description: The UAVSR shall be able to autonomously take-off, navigate to four waypoints in a square pattern, and land.
Traced from: HLO-M-1
Verification: [**REQ-H1.5.2**] shall be verified by demonstrating the UAVSR can autonomously take-off, navigate to four waypoints in a square pattern, and land.

REQ-H1.5.3

Description: The UAVSR shall demonstrate stable flight with a norm tracking error of less than 0.1m.
Traced from: HLO-M-1
Verification: [**REQ-H1.5.2**] shall be verified with a test to monitor the tracking error of the UAVSR during flight, ensuring the norm tracking error stays below the 0.1-metre threshold.

2.2.01 REQ-H2.1

Description: The UAVSR shall be able to successfully deliver simulated medication in a single flight to two markers in a 4-metre by 4-metre area without any collisions.
Traced from: HLO-M-2
Rationale: The UAVSR shall be able to deliver the medication quickly and safely.
Verification: [**REQ-H2.1**] shall be verified with a demonstration of the simulated medication delivery in a single flight to both markers. This will occur within a controlled 4-metre by 4-metre area, and the flight shall not result in any collisions with obstacles.

2.2.02 REQ-H2.2

Description: The UAVSR shall be deployed at the coordinates [-1 metre, -1 metre] from the centre of the area.
Traced from: HLO-M-2
Rationale: The UAVSR shall be able to accurately determine its own location and travel to predetermined coordinates.
Verification: [**REQ-H2.2**] shall be verified with inspection using measuring equipment to show the initial location matches the desired coordinates.

2.3.01 REQ-H3.1

Description: The UAVSR shall collect and share real time flight telemetry and imagery via a ground control station.
Traced from: HLO-M-3
Rationale: The UAVSR shall relay telemetry and visual data to help operators identify the locations of wounded personnel.
Verification: [**REQ-H3.1**] shall be verified through implementing [**REQ-H3.1.1**], [**REQ-H3.1.2**], [**REQ-H3.1.3**], [**REQ-H3.1.4**], [**REQ-H3.1.5**], [**REQ-H3.1.6**], [**REQ-H3.1.7**], [**REQ-H3.1.8**] and [**REQ-H3.1.9**].

REQ-H3.1.1

Description: The required telemetry data shall be acquired using sensors on the UAVSR.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.1**] shall be verified with a demonstration to the PRO such that the telemetry is visible in ROS.

REQ-H3.1.2

Description: The UAVSR shall transmit the current mode of each flight-reliant sub-system.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.2**] shall be verified with a demonstration to the PRO such that the current mode of flight is visible in ROS.

REQ-H3.1.3

Description: The UAVSR shall transmit the current navigation state of the system including position and attitude.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.3**] shall be verified with a demonstration to the PRO such that the current navigation state of the system is visible in ROS, including position and attitude.

REQ-H3.1.4

Description: The UAVSR shall transmit the current navigation goal of the system including position and attitude.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.4**] shall be verified with a demonstration to the PRO such that the current navigation goal of the system is visible in ROS, including position and attitude.

REQ-H3.1.5

Description: The UAVSR shall transmit live imagery from the camera.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.5x**] shall be verified with demonstration of the live imagery feed to the PRO.

REQ-H3.1.6

Description: When a marker has been detected, the UAVSR shall transmit the camera imagery with an overlay present.
Traced from: Further details section, Customer Needs document
Verification: [**REQ-H3.1.6**] shall be verified with a demonstration of the camera imagery with overlay to the PRO.

REQ-H3.1.7

Description: The ground control station shall graphically display and log all live data acquired from the telemetry and imagery links.
Traced from: HLO-M-3
Verification: [**REQ-H3.1.7**] shall be verified with a demonstration of the GCS's ability to log telemetry and imagery links to the PRO, including a live feed.

REQ-H3.1.8

Description: On the detection of a marker, the ground control station shall alert the operator by vocalising the person's location and injury type.
Traced from: HLO-M-3
Verification: [**REQ-H3.1.8**] shall be verified with a demonstration to the PRO of the GCS's ability to alert the operator with the person's location and injury type, audibly.

REQ-H3.1.9

Description: On the detection of a marker, the ground control station shall display a 3D visualisation of the search area.
Traced from: HLO-M-3
Verification: [**REQ-H3.1.9**] shall be verified with a demonstration to the PRO of the 3D visualisation of the search area when a marker is detected.

2.3.02 REQ-H3.2

Description: All data used in detection shall use standardised ROS messages in favour of other methods where possible.
Traced from: HLO-M-3
Rationale: Client request.
Verification: [**REQ-H3.2**] shall be verified via inspection of the transmitted message format.

2.4.01 REQ-H4.1

Description: An on-board Socket on Chip computer shall be used for the identification of markers.
Traced from: HLO-M-4
Rationale: Client request.
Verification: [**REQ-H4.1**] shall be verified via visual inspection of on-board processing unit.

2.4.02 REQ-H4.2

Description: All markers shall be identified distinctly with no false positives.
Traced from: HLO-M-4
Rationale: The UAVSR shall not read any false positive readings to avoid deploying its payloads in the wrong locations.
Verification: [**REQ-H4.2**] shall be verified through implementing [**REQ-H4.2.1**] and [**REQ-H4.2.2**].

REQ-H4.2.1

Description: The UAVSR shall be able to identify the marker representing a person with anaphylaxis.
Traced from: HLO-M-4 and appendix A1 of Customer Needs document
Verification: [**REQ-H4.2.1**] shall be verified with a demonstration of the computer vision and image processing software. The software must be able to detect the marker for anaphylaxis with no false positives.

REQ-H4.2.2

Description: The UAVSR shall be able to identify the marker representing a person with a haemorrhage.
Traced from: HLO-M-4 and appendix A2 of Customer Needs document
Verification: [**REQ-H4.2.2**] shall be verified with a demonstration of the computer vision and image processing software. The software must be able to detect the marker for haemorrhage with no false positives.

2.4.03 REQ-H4.3

Description: The UAVSR shall localize the marker to an accuracy of 50 cm.
Traced from: HLO-M-4
Rationale: The UAVSR shall be able to accurately identify the location of injured personnel so that the payload can be deployed to the correct location.
Verification: [**REQ-H4.3**] shall be verified with a test where the true location of the marker is measured and compared with the UAVSR's estimate of the marker location.

2.5.01 REQ-H5.1

Description: Once a marker has been identified, the UAVSR shall hover over it for 5 seconds.
Traced from: HLO-M-5
Rationale: The UAVSR needs time to stabilise before dropping the payload.
Verification: [**REQ-H5.1**] shall be verified with a test where the hovering duration is timed.

2.5.02 REQ-H5.2

Description: The UAVSR shall drop the correct deployment object after the 5-second waiting period.
Traced from: HLO-M-5
Rationale: The UAVSR shall deliver the correct medication to treat the injured personnel.
Verification: [**REQ-H5.2**] shall be verified through the implementation of [**REQ-H5.2.1**], [**REQ-H5.2.2**].

REQ-H5.2.1

Description: The UAVSR shall drop the deployment object representing an EpiPen when a marker representing a person with anaphylaxis has been identified.
Traced from: HLO-M-5 and appendix D of Customer Needs document
Verification: [**REQ-H5.2.1**] shall be verified through a demonstration of the correct medical deployment once the anaphylaxis marker has been detected.

REQ-H5.2.2

Description: The UAVSR shall drop the deployment object representing an emergency bandage when a marker representing a person with a haemorrhage has been identified.
Traced from: HLO-M-5 and appendix D of Customer Needs document
Verification: [**REQ-H5.2.2**] shall be verified through a demonstration of the correct medical deployment once the haemorrhage marker has been detected.

2.5.03 REQ-H5.3

Description: The landing position of the payload shall be accurate to within 20cm of the intended marker.
Traced from: HLO-M-5
Rationale: The medication must be delivered close enough to the patient, such that the medication is reachable in case they are immobile.
Verification: [**REQ-H5.3**] shall be verified with an inspection where the distance from the landing position to the intended marker is measured to ensure it is within 20 cm.

2.6.01 REQ-H6.1

Description: Manual flight control shall be demonstrated
Traced from: HLO-M-6
Rationale: Client request.
Verification: [**REQ-H6.1**] shall be verified through implementing [**REQ-H6.1.1**], [**REQ-H6.1.2**] and [**REQ-H6.1.3**].

REQ-H6.1.1

Description: UAV shall change elevation when prompted by manual control.
Traced from: HLO-M-6
Verification: [**REQ-H6.1.1**] shall be verified during a manual flight test, where the UAVSR shall increase and decrease its altitude when prompted by manual ground controls.

REQ-H6.1.2

Description: UAV shall change rotational position when prompted by manual control.
Traced from: HLO-M-6
Verification: [**REQ-H6.1.2**] shall be verified during a manual flight test, where the UAVSR shall manoeuvre when prompted by manual ground controls.

REQ-H6.1.3

Description: UAV shall move forwards, backwards, left and right when prompted by manual control
Traced from: HLO-M-6
Verification: [**REQ-H6.1.2**] shall be verified during a manual flight test, where the UAVSR shall move forwards, backwards, left, and right when prompted by manual ground controls.

2.6.02 REQ-H6.2

Description: Progress on subsystems shall be demonstrated.
Traced from: HLO-M-6
Rationale: Client request.
Verification: [**REQ-H6.2**] shall be verified through implementing [**REQ-H6.2.1**], [**REQ-H6.2.2**], [**REQ-H6.2.3**], [**REQ-H6.2.4**], [**REQ-H6.2.5**] and [**REQ-H6.2.6**].

REQ-H6.2.1

Description: CAD model of the airframe and the cowl/cover for autopilot and electronics shall be provided.
Traced from: HLO-M-6
Verification: [**REQ-H6.2.1**] shall be verified by presenting the CAD models of the airframe and electronics cover to the PRO.

REQ-H6.2.2

Description: An animated CAD model of the payload release mechanism shall be provided.
Traced from: HLO-M-6
Verification: [**REQ-H6.2.2**] shall be verified by demonstrating the payload release mechanism to the PRO through a CAD animation.

REQ-H6.2.3

Description: Results from battery logs and thrust tests shall be provided.
Traced from: HLO-M-6
Verification: [**REQ-H6.2.3**] shall be verified by presenting valid battery logs and thrust test results to the PRO.

REQ-H6.2.4

Description: Evidence of autopilot: calibration and configuration, mounting, remote connection, and two-way communication with the GCS shall be provided.
Traced from: HLO-M-6
Verification: [**REQ-H6.2.4**] shall be verified by presenting the detailed technical documentation of the autopilot system to the PRO.

REQ-H6.2.5

Description: Live Video from the Raspberry Pi 4 (RP4) camera module shall be provided for image processing
Traced from: HLO-M-6
Verification: [**REQ-H6.2.5**] shall be verified by demonstrating to the PRO that the live video feed from the RP4 camera module can be viewed by the GCS.

REQ-H6.2.6

Description: Mock-up GUI window shall be provided using existing QUTAS plugin
Traced from: HLO-M-6
Verification: [**REQ-H6.2.6**] shall be verified by providing a mock-up of the planned GUI to the PRO for final revision.

2.7.01 REQ-H7.1

Description: The UAVSR design shall conform to the preferred equipment options supplied by the customer.
Traced from: HLO-M-7
Rationale: The UAVSR shall make use of resources already possessed by the client.
Verification: [**REQ-H7.1**] shall be verified through accurate reporting of the project budget and parts lists.

2.7.02 REQ-H7.2

Description: An electronics canopy cover for the autopilot and middle deck shall be designed to a rating of IP21.
Traced from: HLO-M-7
Rationale: The UAVSR shall be resilient to environmental contamination.
Verification: [**REQ-H7.2**] will be verified through demonstrating that the electronics canopy does not allow touch or objects greater than 12-millimetre to make physical contact with the electronics. The demonstration will also show that the canopy will protect the electronics from a variety of potential hazards such water droplets and condensation.

2.8.01 REQ-H8.1

Description: Systems Engineering Methodology shall be used during development.
Traced from: HLO-M-8
Rationale: Tried and tested systems engineering theory shall be applied to ensure a professional product is produced.
Verification: [**REQ-H8.1**] shall be verified by providing the PRO with relevant systems engineering documents as the project progresses for review and comment.

2.8.02 REQ-H8.2

Description: All preliminary designs shall be completed by weeks 11.
Traced from: HLO-M-8
Rationale: The project designs shall be completed in a timely manner.
Verification: [**REQ-H8.2**] shall be verified by providing all design documentation to the PRO for final revision three days prior to the Wk11 milestone.