QUEENSLAND UNIVERSITY OF TECHNOLOGY

Verification and Validation

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
VER	Verification
VRPN	Virtual Reality Peripheral Network
Vsen	Voltage Sensor Pin
WBS	Work Breakdown Structure

Contents

List of Project Documents

All project documents have been listed below. Note that 001 – 009 are related to project management, 010 – 019 are preliminary design documents, and 020 to 059 are test r

Reference	Document Code	Document
RDP.001	SR21G6-CND	Customer Needs Document
RDP.002	SR21G6-PMP	Project Management Plan
RDP.003	SR21G6-SRQ	System Requirements
RDP.004	SR21G6-ICD	Interface Control Document
RDP.005	SR21G6-WPD	Work Packet Document
RDP.006	SR21G6-VAV	Verification and Validation
RDP.007	SR21G6-MMC	Meeting Minutes Compiled
RDP.008	SR21G6-WBS	Work Breakdown Structure
RDP.009	SR21G6-ACT	Acceptance Tests Document
RDP.010	SR21G6-PDD-ARMPLD	Preliminary Design Document ARM/PLD
RDP.011	SR21G6-PDD-PWRPPL	Preliminary Design Document PWR/PPL
RDP.012	SR21G6-PDD-ATP	Preliminary Design Document ATP
RDP.013	SR21G6-PDD-GCSCMM	Preliminary Design Document GCS/CMM
RDP.014	SR21G6-PDD-IPS	Preliminary Design Document IPS
RDP.015	SR21G6-FDD-ARMPLD	Final Design Document ARM/PLD
RDP.016	SR21G6-FDD-PWRPPL	Final Design Document PWR/PPL
RDP.017	SR21G6-FDD-ATP	Final Design Document ATP
RDP.018	SR21G6-FDD-GCSCMM	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.031	SR21G6-TRD-PWR-SB	Test Report Document PWR 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-ITR-SA	Test Report Document Integration Suite A
RDP.051	SR21G6-TRD-ITR-SB	Test Report Document Integration Suite B
RDP.052	SR21G6-TRD-ITR-SC	Test Report Document Integration Suite C
RDP.053	SR21G6-TRD-ITR-SD	Test Report Document Integration Suite D
RDP.060	SR21G6-SDS-CHK	Operational Checklist
RDP.061	SR21G6-SDS-TDC	Technical Documents Compiled

1.0.0 Introduction

The following section outlines the Validation and Verification 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 has met 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 for UAV Search and Rescue (SAR) (ISSUE: 26 Feb 2021). A complete list of the system requirements can be found in the System Requirements Document (RPD.003). Verification testing is completed before presenting the product to the client. Validation is completed whilst demonstrating the product to the client to ensure requirements are satisfied as requested. This document will summarise the project results and success.

1.1.0 Scope

The objectives for this document are:

1. Present a verification table to document the relationship between system requirements, related subsystems, and item success.
2. Provide further detail as to how each project requirement was verified and satisfied
3. Provide further detail as to how each project requirement was validated by the clients.
4. Provide recommendations for future projects.

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.

2.0.0 Verification Table

Table 1: Verification Table for System Requirements

Requirements	HLO-M-1	HLO-M-2	HLO-M-3	HLO-M-4	HLO-M-5	HLO-M-6	HLO-M-7	HLO-M-8	Client Brief	Measurement	Inspection	Demonstration	Functional	Performance	User	Physical	PMT	GCS	ARM/PWR/PPL	ATP	MSS/CMM	PLD	Validation
REQ-H1.1	X								X			X	X					X					✓
REQ-H1.2	X								X			X	X					X					✓
REQ-H1.3	X								X	X						X			X				✓
REQ-H1.4	X								X		X				X			X		X			✓
REQ-H1.5	X								X			X		X			X			X			✓
REQ-H1.5.1	X								X			X		X			X	X	X				✓
REQ-H1.5.2	X								X			X		X			X	X	X	X			✓
REQ-H1.5.3	X								X			X		X					X	X	X		✓
REQ-H2.1		X							X			X	X							X	X	X	✓
REQ-H2.2		X							X		X					X	X		X	X			✓
REQ-H3.1			X						X			X		X	X					X	X		✓
REQ-H3.1.1			X						X			X		X						X	X		✓
REQ-H3.1.2			X						X			X		X			X	X					✓
REQ-H3.1.3			X						X			X		X						X			✓
REQ-H3.1.4			X						X			X		X						X			✓
REQ-H3.1.5			X						X			X		X							X		✓
REQ-H3.1.6			X						X			X	X	X						X	X		✓
REQ-H3.1.7			X						X			X	X	X							X		✓
REQ-H3.1.8			X						X			X	X	X		X		X		X	X		✓
REQ-H3.1.9			X						X			X	X	X		X		X		X	X		✓
REQ-H3.2			X						X		X			X						X			✓
REQ-H4.1				X					X		X			X						X	X		✓
REQ-H4.2				X					X			X	X	X							X		✓
REQ-H4.2.1				X					X			X	X	X							X		✓
REQ-H4.2.2				X					X			X	X	X							X		✓
REQ-H4.3				X					X		X		X	X						X	X		✓
REQ-H5.1					X				X			X	X						X	X		X	✓
REQ-H5.2					X				X			X	X		X	X		X	X	X		X	✓
REQ-H5.2.1					X				X			X	X		X	X		X	X	X		X	✓
REQ-H5.2.2					X				X			X	X					X		X		X	✓
REQ-H5.3					X				X		X		X	X				X		X	X	X	✓
REQ-H6.1						X			X			X		X	X		X	X	X				✓
REQ-H6.1.1						X			X			X		X	X		X	X	X				✓
REQ-H6.1.2						X			X			X		X	X		X	X	X				✓
REQ-H6.1.3						X			X			X		X	X		X	X	X				✓
REQ-H6.2						X			X	X	X	X				X	X	X	X	X	X	X	✓
REQ-H6.2.1						X			X		X		X			X			X	X			✓
REQ-H6.2.2						X			X			X			X				X			X	✓
REQ-H6.2.3						X			X	X					X				X				✓
REQ-H6.2.4						X			X		X		X	X			X	X	X	X	X	X	✓
REQ-H6.2.5						X			X			X	X								X		✓
REQ-H6.2.6						X			X		X		X				X						✓
REQ-H7.1							X		X		X					X	X	X	X	X	X	X	✓
REQ-H7.2							X		X			X	X						X				✓
REQ-H8.1								X	X		X		X						X				✓
REQ-H8.2								X	X		X				X		X	X	X	X	X	X	✓

3.0.0 Verification Testing Matrix

The verification table will describe the success of the project before demonstration to the client. The requirements will be sorted by requirement type. Given some system requirements identify with multiple requirement types, the requirement will be documented in which ever definition is displayed first. Each requirement will only be verified once.

3.1.0 Functional Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.1	The UAVSR shall be capable of fully autonomous flight during operation.	D	PASS	RPD.052	The UAV demonstrated fully autonomous flight throughout the testing.
REQ-H1.2	The UAVSR operation commencement shall be triggered by the user.	D	PASS	RPD.052	The UAV was armed, and the mission commenced through the MAVROS GUI on GCS station triggered by the user.
REQ-H2.1	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.	D	PASS	RPD.052	The UAV completed the mission within one flight deploying both payloads while avoiding the simulated obstacles.
REQ-H3.1.6	When a marker has been detected, the UAVSR shall transmit the camera imagery with an overlay present.	D	PASS	RPD.052	The UAVSR transmitted camera imagery with overlay present to be displayed through RVIZ.
REQ-H3.1.7	The ground control station shall graphically display and log all live data acquired from the telemetry and imagery links.	D	PASS	RPD.036	The GCS graphically displayed battery voltage, UAV location, imagery, ROS messages through RQT applications.
REQ-H3.1.8	On the detection of a marker, the ground control station shall alert the operator by vocalising the person's location and injury type.	D	PASS	RPD.052	GCS vocalised the person's location and injury type through eSpeak software once a marker was detected.
REQ-H3.1.9	On the detection of a marker, the ground control station shall display a 3D visualisation of the search area	D	PASS	RPD.053	GCS displayed a maker representing the person's location and injury type in the RVIZ 3D map once a marker was detected.
REQ-H4.2	All markers shall be identified distinctly with no false positives.	D	PASS	RPD.035	No false positives were detected during final stages of integration of image processing subsystem.
REQ-H4.2.1	The UAVSR shall be able to identify the marker representing a person with anaphylaxis.	D	PASS	RPD.035	UAVSR successfully identified the marker representing a person with anaphylaxis.
REQ-H4.2.2	The UAVSR shall be able to identify the marker representing a person with a haemorrhage	D	PASS	RPD.035	UAVSR successfully identified the marker representing a person with a haemorrhage

REQ-H4.3	The UAVSR shall localize the marker to an accuracy of 50 cm.	I	PASS	RPD.045	The UAVSR localized the marker to an accuracy of 30cm.
REQ-H5.1	Once a marker has been identified, the UAVSR shall hover over it for 5 seconds.	D	PASS	RPD.053	The UAVSR hovered over both markers for 5 seconds before deploying payload
REQ-H5.2	The UAVSR shall drop the correct deployment object after the 5-second waiting period.	D	PASS	RPD.053	The UAVSR hovered over both markers for 5 seconds before deploying the correct payload
REQ-H5.2.1	The UAVSR shall drop the deployment object representing an EpiPen when a marker representing a person with anaphylaxis has been identified.	D	PASS	RPD.053	The UAVSR deployed the object representing an EpiPen when a marker representing a person with anaphylaxis was identified during test flights.
REQ-H5.2.2	The UAVSR shall drop the deployment object representing an emergency bandage when a marker representing a person with a haemorrhage has been identified.	D	PASS	RPD.053	The UAVSR deployed the object representing an emergency bandage when a marker representing a person with a haemorrhage was identified during test flights.
REQ-H5.3	The landing position of the payload shall be accurate to within 20cm of the intended marker.	I	PASS	RPD.053	The landing position of the payload was accurate to within 20cm of the intended marker.
REQ-H6.2.1	Progress on subsystems shall be demonstrated.	I	PASS	RPD.010 - RPD.019	Test and Design Reports have been written documenting the progress of each subsystem.
REQ-H6.2.4	Evidence of autopilot: calibration and configuration, mounting, remote connection, and two-way communication with the GCS shall be provided.	I	PASS	RPD.052	The Pix-Racer autopilot was calibrated, configured, mounted with the ability to communicate to the Turnigy Remote and GCS.
REQ-H6.2.5	Live Video from the Raspberry Pi 4 (RP4) camera module shall be provided for image processing	D	PASS	RPD.036	Live imagery taken by Raspberry Pi 4 (RP4) camera module was sent to the GCS through raspicam_node.
REQ-H6.2.6	Mock-up GUI window shall be provided using existing QUTAS plugin	I	PASS	RPD.026	The GCS display (RQT) consisted of RVIZ, Generic HUD, TF tree, and MAVROS GUI from the QUTAS plugins.
REQ-H7.2	The UAVSR design shall conform to the preferred equipment options supplied by the customer.	D	PASS	RPD.010 - RPD.019	The UAVSR was designed using all equipment provided by customer.

REQ-H8.1	An electronics canopy cover for the autopilot and middle deck shall be designed to a rating of IP21.	I	PASS	RPD.015	The electronics canopy cover met the criteria of a minimum rating of IP21.

3.2.0 Performance Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.5	The UAVSR shall successfully complete two navigation flight tests prior to the final demonstration to the client.	D	PASS	RPD.052	The UAV completed two navigation flight tests prior to demonstration. Several flights were documented as there were numerous hardware issues
REQ-H1.5.1	The UAVSR shall be able to autonomously take-off, hover for 10 seconds, and land.	D	PASS	RPD.044	The UAVSR was able to autonomously take-off and land during the week 8 demonstration.
REQ-H1.5.2	The UAVSR shall be able to autonomously take-off, navigate to four waypoints in a square pattern, and land.	D	PASS	RPD.052	The UAVSR was able to autonomously take-off, navigate four waypoints and land as directed by demo_wp.
REQ-H1.5.3	The UAVSR shall demonstrate stable flight with a norm tracking error of less than 0.1m.	D	PASS	RPD.044	The UAVSR was able to be tracked through the VICON server with less than 0.1m tracking error.
REQ-H3.1	The UAVSR shall collect and share real time flight telemetry and imagery via a ground control station.	D	PASS	RPD.052	The UAVSR demonstrated its ability to share telemetry and imagery through RVIZ and RQT plugins on the GCS
REQ-H3.1.1	The required telemetry data shall be acquired using sensors on the UAVSR.	D	PASS	RPD.034	The position of the UAVSR could be collected as a ROS topic using the Pix-Racer.
REQ-H3.1.2	The UAVSR shall transmit the current mode of each flight-reliant sub-system.	D	PASS	RPD.036	The UAVSR was able to send battery voltage and flight readiness data to the GCS through the RP4s.
REQ-H3.1.3	The UAVSR shall transmit the current navigation state of the system including position and attitude.	D	PASS	RPD.053	The VICON server was used to transmit the location and position of the UAVSR to the GCS.
REQ-H3.1.4	The UAVSR shall transmit the current navigation goal of the system including position and attitude.	D	PASS	RPD.036	The location and position of the current navigation goal was transmitted as a ROS topic from the UAV to the GCS.
REQ-H3.1.5	The UAVSR shall transmit live imagery from the camera.	D	PASS	RPD.025	The UAVSR can transmit live imagery from the RP4 Camera via ROS to the GCS.
REQ-H3.2	All data used in detection shall use standardised ROS	I	PASS	RPD.026	All data received in regard to detection were

	messages in favour of other methods where possible.				communicated with standardised ROS messages.
REQ-H4.1	An on-board Socket on Chip computer shall be used for the identification of markers.	I	PASS	RPD.014	The code used to identify the markers via the Raspberry Pi 4 Camera was stored on the OBC.
REQ-H6.1	Manual flight control shall be demonstrated	D	PASS	RPD.018	Manual flight was demonstrated in week 13 demonstration Semester 1.
REQ-H6.1.1	UAV shall change elevation when prompted by manual control.	D	PASS	RPD.015	The UAVSR responded as expected when prompted by manual control.
REQ-H6.1.2	UAV shall change rotational position when prompted by manual control.	D	PASS	RPD.015	The UAVSR responded as expected when prompted by manual control.
REQ-H6.1.3	UAV shall move forwards, backwards, left and right when prompted by manual control.	D	PASS	RPD.015	The UAVSR responded as expected when prompted by manual control.

3.3.0 User Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.4	The UAVSR shall utilise QUT ASL ROS UAV software as the base control system.	I	PASS	RPD.018, RPD.0.19	UAVSR utilised the suggested software supplied on QUTAS wiki to serve as the base of the control system.
REQ-H6.2.2	An animated CAD model of the payload release mechanism shall be provided.	D	PASS	RDP.016	Clients received a demonstration on the payload release mechanism during week 8 demonstration.
REQ-H6.2.3	Results from battery logs and thrust tests shall be provided.	M	PASS	RPD.016	Battery logs and thrust tests were documented for the team and clients
REQ-H8.2	All preliminary designs shall be completed by weeks 11.	I	PASS	RPD.002	All preliminary designs for each subsystem were completed by week 11 Semester 1

3.4.0 Physical Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.3	The combined total weight of the UAVSR and payload shall be no more than 1.5kg at take-off.	M	PASS	RPD.020	The UAVSR weighs a total of 1.38kg at take-off
REQ-H2.2	The UAVSR shall be deployed at the coordinates [-1 metre, -1 metre] from the centre of the area.	I	PASS	RPD.052	The UAVSR was deployed from the coordinates [-1,-1] during test flights.

REQ-H6.2.1	CAD model of the airframe and the cowl/cover for autopilot and electronics shall be provided.	MID	PASS	RPD.030	The updated CAD model of the airframe and cowl is provided to the client in the final design documents.
REQ-H7.1	The UAVSR design shall conform to the preferred equipment options supplied by the customer.	I	PASS	RPD.020	The equipment used for the UAVSR complies with the requests from the client.

4.0.0 Verification Testing Conclusions and Recommendations

As shown in section 3, the product satisfies all system requirements. Additionally, an acceptance will be conducted to document the clients satisfaction with the product during the final demonstration.

5.0.0 Validation Testing Matrix

The evidence of the validation process is documented in the Acceptance Tests Document (RDP.009). The acceptance tests use the processes performed during the final demonstration to determine if the system requirements were fulfilled to the clients standard.

5.1.0 Functional Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.1	The UAVSR shall be capable of fully autonomous flight during operation.	D	PASS	RDP.009	The UAV demonstrated fully autonomous flight throughout the test demonstrations
REQ-H1.2	The UAVSR operation commencement shall be triggered by the user.	D	PASS	RDP.009	The UAV was armed, and operation commenced through the GCS station triggered by the user when directed by client.
REQ-H2.1	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.	D	PARTIAL	RDP.009	The UAV completed the mission within one flights. Delivering the anaphylaxis medication during first flight and haemorrhage medication during second flight.
REQ-H3.1.6	When a marker has been detected, the UAVSR shall transmit the camera imagery with an overlay present.	D	PASS	RDP.009	The UAVSR transmitted camera imagery with overlay present to be displayed through RVIZ during demonstration
REQ-H3.1.7	The ground control station shall graphically display and log all live data acquired from the telemetry and imagery links.	D	PASS	RDP.009	The GCS graphically displayed battery voltage, UAV location, imagery, ROS messages through RQT applications.
REQ-H3.1.8	On the detection of a marker, the ground control station shall alert the operator by vocalising the person's location and injury type.	D	PASS	RDP.009	GCS vocalised the person’s location and injury type through eSpeak software once a marker was detected.
REQ-H3.1.9	On the detection of a marker, the ground control station shall display a 3D visualisation of the search area	D	PASS	RDP.009	GCS displayed a maker representing the person’s location and injury type in the RVIZ 3D map once a marker was detected.
REQ-H4.2	All markers shall be identified distinctly with no false positives.	D	PASS	RDP.009	No false positives were detected during demonstration
REQ-H4.2.1	The UAVSR shall be able to identify the marker representing a person with anaphylaxis.	D	PASS	RDP.009	UAVSR successfully identified the marker representing a person with anaphylaxis.
REQ-H4.2.2	The UAVSR shall be able to identify the marker representing a person with a haemorrhage	D	PASS	RDP.009	UAVSR successfully identified the marker representing a person with a haemorrhage

REQ-H4.3	The UAVSR shall localize the marker to an accuracy of 50 cm.	I	PASS	RDP.009	The UAVSR localized the marker to an accuracy of 30cm.
REQ-H5.1	Once a marker has been identified, the UAVSR shall hover over it for 5 seconds.	D	PASS	RDP.009	The UAVSR hovered over both markers for 5 seconds before deploying payload
REQ-H5.2	The UAVSR shall drop the correct deployment object after the 5-second waiting period.	D	PASS	RDP.009	The UAVSR hovered over both markers for 5 seconds before deploying the correct payload
REQ-H5.2.1	The UAVSR shall drop the deployment object representing an EpiPen when a marker representing a person with anaphylaxis has been identified.	D	PASS	RDP.009	The UAVSR deployed the object representing an EpiPen when a marker representing a person with anaphylaxis was identified during demonstration.
REQ-H5.2.2	The UAVSR shall drop the deployment object representing an emergency bandage when a marker representing a person with a haemorrhage has been identified.	D	PASS	RDP.009	The UAVSR deployed the object representing an emergency bandage when a marker representing a person with a haemorrhage was identified during demonstration.
REQ-H5.3	The landing position of the payload shall be accurate to within 20cm of the intended marker.	I	PASS	RDP.009	The landing position of the payload was accurate to within 20cm of the intended marker.
REQ-H6.2.1	Progress on subsystems shall be demonstrated.	I	PASS	RDP.009	Test and Design Reports have been written documenting the progress of each subsystem.
REQ-H6.2.4	Evidence of autopilot: calibration and configuration, mounting, remote connection, and two-way communication with the GCS shall be provided.	I	PASS	RDP.009	The Pix-Racer autopilot was calibrated, configured, mounted with the ability to communicate to the Turnigy Remote and GCS. The process was demonstrated to the client during demonstration.
REQ-H6.2.5	Live Video from the Raspberry Pi 4 (RP4) camera module shall be provided for image processing	D	PASS	RDP.009	Live imagery taken by Raspberry Pi 4 (RP4) camera module was sent to the GCS through raspicam_node.
REQ-H6.2.6	Mock-up GUI window shall be provided using existing QUTAS plugin	I	PASS	RDP.009	The GCS display (RQT) consisted of RVIZ, Generic HUD, TF tree, and MAVROS GUI from the QUTAS plugins.
REQ-H7.2	The UAVSR design shall conform to the preferred	D	PASS	RDP.009	The UAVSR was designed using all

	equipment options supplied by the customer.				equipment provided by customer.
REQ-H8.1	An electronics canopy cover for the autopilot and middle deck shall be designed to a rating of IP21.	I	PASS	RDP.009	The electronics canopy cover met the criteria of a minimum rating of IP21.

5.2.0 Performance Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.5	The UAVSR shall successfully complete two navigation flight tests prior to the final demonstration to the client.	D	PASS	RDP.009	The UAV completed two navigation flight tests prior to the final demonstration.
REQ-H1.5.1	The UAVSR shall be able to autonomously take-off, hover for 10 seconds, and land.	D	PASS	RDP.009	The UAVSR was able to autonomously take-off and land during the week 8 demonstration.
REQ-H1.5.2	The UAVSR shall be able to autonomously take-off, navigate to four waypoints in a square pattern, and land.	D	PASS	RDP.009	The UAVSR was able to autonomously take-off, navigate four waypoints and land as directed by demo_wp.
REQ-H1.5.3	The UAVSR shall demonstrate stable flight with a norm tracking error of less than 0.1m.	D	PASS	RDP.009	The UAVSR was able to be tracked through the VICON server with less than 0.1m tracking error.
REQ-H3.1	The UAVSR shall collect and share real time flight telemetry and imagery via a ground control station.	D	PASS	RDP.009	The UAVSR demonstrated its ability to share telemetry and imagery through RVIZ and RQT plugins on the GCS
REQ-H3.1.1	The required telemetry data shall be acquired using sensors on the UAVSR.	D	PASS	RDP.009	The position of the UAVSR could be collected as a ROS topic using the Pix-Racer.
REQ-H3.1.2	The UAVSR shall transmit the current mode of each flight-reliant sub-system.	D	PASS	RDP.009	The UAVSR was able to send battery voltage and flight readiness data to the GCS through the RP4s.
REQ-H3.1.3	The UAVSR shall transmit the current navigation state of the system including position and attitude.	D	PASS	RDP.009	The VICON server was used to transmit the location and position of the UAVSR to the GCS.
REQ-H3.1.4	The UAVSR shall transmit the current navigation goal of the system including position and attitude.	D	PASS	RDP.009	The location and position of the current navigation goal was transmitted as a ROS topic from the UAV to the GCS.
REQ-H3.1.5	The UAVSR shall transmit live imagery from the camera.	D	PASS	RDP.009	The UAVSR can transmit live imagery from the RP4 Camera via ROS to the GCS.
REQ-H3.2	All data used in detection shall use standardised ROS	I	PASS	RDP.009	All data received in regard to detection were

	messages in favour of other methods where possible.				communicated with standardised ROS messages.
REQ-H4.1	An on-board Socket on Chip computer shall be used for the identification of markers.	I	PASS	RDP.009	The code used to identify the markers via the Raspberry Pi 4 Camera was stored on the OBC.
REQ-H6.1	Manual flight control shall be demonstrated	D	PASS	RDP.009	Manual flight was demonstrated in week 13 demonstration Semester 1.
REQ-H6.1.1	UAV shall change elevation when prompted by manual control.	D	PASS	RDP.009	The UAVSR responded as expected when prompted by manual control.
REQ-H6.1.2	UAV shall change rotational position when prompted by manual control.	D	PASS	RDP.009	The UAVSR responded as expected when prompted by manual control.
REQ-H6.1.3	UAV shall move forwards, backwards, left and right when prompted by manual control.	D	PASS	RDP.009	The UAVSR responded as expected when prompted by manual control.

5.3.0 User Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.4	The UAVSR shall utilise QUT ASL ROS UAV software as the base control system.	I	PASS	RDP.009	UAVSR utilised the suggested software supplied on QUTAS wiki to serve as the base of the control system.
REQ-H6.2.2	An animated CAD model of the payload release mechanism shall be provided.	D	PASS	RDP.009	Clients received a demonstration od the initial payload release mechanism.
REQ-H6.2.3	Results from battery logs and thrust tests shall be provided.	M	PASS	RDP.009	Battery logs and thrust tests were documented for the team and clients
REQ-H8.2	All preliminary designs shall be completed by weeks 11.	I	PASS	RDP.009	All preliminary designs for each subsystem were completed by week 11 Semester 1

5.4.0 Physical Requirements

REQ	Description	VER	Status	RDP	Notes
REQ-H1.3	The combined total weight of the UAVSR and payload shall be no more than 1.5kg at take-off.	M	PASS	RDP.009	The UAVSR weighs a total of 1.38kg at take-off
REQ-H2.2	The UAVSR shall be deployed at the coordinates [-1 metre, -1 metre] from the centre of the area.	I	PASS	RDP.009	During the final demonstration, week 12 Semester 2, the UAVSR was deployed from the coordinates [-1,-1]

REQ-H6.2.1	CAD model of the airframe and the cowl/cover for autopilot and electronics shall be provided.	MID	PASS	RDP.009	The updated CAD model of the airframe and cowl is provided to the client in the final design documents.
REQ-H7.1	The UAVSR design shall conform to the preferred equipment options supplied by the customer.	I	PASS	RDP.009	The equipment used for the UAVSR complies with the requests from the client.

6.0.0 Validation Testing Conclusions and Recommendations

During the final demonstration, the acceptance tests displayed that all requirements were successfully met except for REQ-H2.1. This requirement was partially successful due to the UAVs ability to complete all parts of the requirements except for the mission to be completed within a single flight. On the day of demonstration, the team discovered the SD had snapped, this meant all recent software changes were lost. The team was required to attempt to recover all unsaved changes and test the UAV with the new system for the first time during the final demonstration. This event severely impacted the team's performance; however, the team was still able to present an acceptable model at the end of the demonstration. It is recommended, that the software be connected to GitHub to store backup files. This will eliminate any potential hardware issues effecting software capability.