Verification and Validation

Prepared by	M.B Marissa Bowen, Project Manager and Enclosure Design lead	Date 28/10/2022
Checked by	A.S Alex Switala, Target Acquisition and Image Processing co-lead	Date 28/10/2022
Approved by	M.B Marissa Bowen, Project Manager and Enclosure Design lead	Date 28/10/2022
Authorised for use by	 Dr. Felipe Gonzalez, Project Coordinator	Date 28/10/2022

Queensland University of Technology

Gardens Point Campus
Brisbane, Australia, 4001.

Revision Record

Document Issue/Revision Status	Description of Change	Date	Approved
1.0	Initial Issue	28/10/2022	M.B

Table of Contents

Paragraph **Page No.**

Definitions

ASP	Advance Sensor Payload
UAV	Unmanned Aerial Vehicle
ASL	Airborne System Lab

1 Introduction

The team members of Group 19 have been appointed to research, design, plan and implement an Advance Sensor Payload (ASP) for Unmanned Aerial Vehicle (UAV) target detection and air quality monitoring in GPS denied environments. The group has committed to the specified budget whilst implementing the project requirements stated by the client. The team has also committed to meeting the deadline date specified by the client with a full functioning ASP that has been tested to ensure the client requirements have been met. The purpose of this verification and validation is to show whether all requirements were met and tested.

1.1 Scope

The scope of the project is to research, plan, design, implement and test the ASP for UAV target detection in GPS denied environments. This documentation outlines with of the system requirements from RD/2 verified and validated.

1.2 Background

The Queensland University of Technology's Airborne System Lab (ASL) has commissioned the group UAVPAYG19 to design and develop a payload capable in detecting specific objects, recording air quality data to be displayed on a web interface and to pierce a ground sample. This payload is to be attached to a S500 UAV which will complete an automated flight path. The payload is mounted on the bottom of the UAV using a provided bracket. This payload must contain all components to complete its required tasks. These components are:

- Raspberry Pi 3b+
- Raspberry Pi Camera
- Pimoroni Enviro+ sensor
- DF15RSMG 360 Degree Motor

The payload is required to identify three targets, a valve (In open or closed position), a fire extinguisher and an ArUCO marker. The Pimoroni sensor is to be used to record air temperature, pressure humidity, light and potentially hazardous gas level data. This data along with a live feed of the Raspberry Pi Camera is to be visualized on a Web Interface. Lastly a soil sample must be obtained using a sampling mechanism.

2 Reference Documents

2.1 QUT avionics Documents

RD/1	UA–System Requirements	UAVPayloadTAQ System Requirements
RD/2	UA –Customer Needs	Advanced Sensor Payload for UAV Target Detection and Air Quality Monitoring in GPS Denied Environments
RD/6	UAVPAYG19-ED-PD-02	ED Preliminary Report
RD/7	UAVPAYG19-AQS-PD-02	AQS Preliminary Report
RD/8	UAVPAYG19-TAIP-PD-02	TAIP Preliminary Report
RD/9	UAVPAYG19-ST-PD-02	ST Preliminary Report
RD/10	UAVPAYG19-WVI-PD-02	WVI Preliminary report
RD/20	UAVPAYG-19-ED-TR-01	Enclosure Test Report
RD/21	UAVPAYG-19-AQS-TR-01	Air Quality Sensor Test Report
RD/22	UAVPAYG-19-ST-TR-01	Sampling Tube Test Report
RD/23	UAVPAYG-19-TAIP-TR-01	Target Acquisition and Image Processing Test Report
RD/24	UAVPAYG-19-WVI-TR-02	Web Vision Interface Test Report
RD/25	UAVPAYG-19-AQS-TAIP-WVI-TR-01	Air Quality Sensor, Target Acquisition and Image Processing, Web Vision Interface Integration Report
RD/26	UAVPAYG-19-ED-AQS-TAIP-ST-TR-01	Enclosure, Air Quality Sensor, Target Acquisition and Image Processing, Sampling Tube Test Report
RD/27	UAVPAYG-19-ED-AQS-TAIP-WVI-ST-TR-01	Enclosure, Air Quality Sensor, Target Acquisition and Image Processing, Sampling Tube Integration Report
RD/28	UAVPAYG-19-TR-AT-01	Acceptance Test Report
RD/35	UAVPAYG-19-ED-AQS-TAIP-TR-01	Enclosure, Air Quality, Target and Image processing Test Report
RD/30	UAVPAYG19-ED-FD-01	Enclosure Final Design Report
RD/31	UAVPAYG19-AQS-FD-01	Air Quality final Design Report
RD/32	UAVPAYG19-TAIP-FD-01	Target and image Final Report
RD/33	UAVPAYG19-ST-FD-01	Sampling tube final report
RD/34	UAVPAYG19-WVI-02	Web Visualization and Interface Final report

2.2 Non-QUT Documents

3 Verification Matrix

Requirements	HLO-M-1	HLO-M-2	HLO-M-3	HLO-M-4	HLO-M-5	HLO-M-6	HLO-M-7	Clients Brief	PM&ED	AQS	WVI	TAIQ	ST
REQ-M-01				X				X	X				
REQ-M-02	X									X			
REQ-M-03	X	X	X							X	X	X	
REQ-M-04		X	X								X	X	
REQ-M-05	X		X							X	X		
REQ-M-06		X	X								X	X	
REQ-M-07			X								X		
REQ-M-08		X				X						X	X
REQ-M-09						X							X
REQ-M-10							X		X				
REQ-M-11					X					X	X		
REQ-M-12	X				X					X			
REQ-M-13					X					X			
REQ-M-14							X		X	X	X	X	X
REQ-M-15			X								X		
REQ-M-16		X								X			
REQ-M-17		X										X	
REQ-M-18		X										X	
REQ-M-19	X	X	X							X	X	X	

4 Verification Testing

4.1 Physical Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-01	The UAVPayloadTAQ shall remain under the maximum weight of 320 g and comply with an IP41 rating. The air quality sensors must be exposed to the environment to allow for accurate reading.	Demonstration / Measured	Pass	RD/20 RD/21 RD/22 RD/27 RD/35	Final weight was 240g
REQ-M-02	The UAVPayloadTAQ must measure hazardous gases , humidity, pressure, temperature and light via on-board sensors.	Demonstration	Pass	RD/21	All sensors were sending correct data to server

4.2 Functional Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-03	The UAVPayloadTAQ shall communicate with a ground station computer to transmit video, target detection and air quality data.	Demonstration	Pass	RD/24 RD/25	Data and images were successfully being transmitted to the server
REQ-M-04	The target identification system shall be capable of alerting the GCS of a target's type.	Demonstration / Simulation	Pass	RD/23 RD/24 RD/25	The server was able produce an alert when a target was detected
REQ-M-05	The Web Interface is required to display real time air sampling data that is recorded directly from the UAVPayloadTAQ and updated dynamically throughout the duration of the flight.	Demonstrated	Pass	RD/24 RD/25	The data was dynamically displayed on the web interface

REQ-M-06	The Web Interface is required to display the images of the targets that are taken directly from the UAVPayloadTAQ and updated every time a new picture is taken.	Demonstrated	Pass	RD/24 RD/25	The web interface displayed updated images of the targets
REQ-M-07	The Web Interface shall be designed and run as a web server, which is to be accessible by any computers on the local network. This shall store logged sensor data and target detections with corresponding timestamps.	Demonstrated	Pass	RD/24	The web interface was able to be access by local devices using the correct IP address
REQ-M-08	The payload shall include a sampling tube design to collect a simulated soil sample. The payload system must protrude or push into the simulated soil. A mark must be left on the simulated soil (10mm deep, 10mm diameter hole), to ensure the sampling tube has made contact with the soil.	Demonstrated	Pass	RD/22 RD/26 RD/27	The sampling tube was able to collect the required soil sample measurement
REQ-M-09	The payload shall activate the sampling tube mechanism to collect a simulated soil sample only after the UAV has landed on a designated Aruco marker. Once the soil is sampled the sampling tube must retract to its original position.	Demonstrated	Pass	RD/22 RD/26 RD/27	The sampling tube was able to be activated once ArUCO marker was in range and tube was able to retract back to initial position

4.3 User Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-10	Preliminary designs shall be completed by week 7	Submitted Documentation	Pass	RD/6 RD/7 RD/8 RD/9 RD/10	All documents were submitted by week 7
REQ-M-11	The payload should display its IP address via the integrated Enviro sensor LCD screen.	Demonstrated	Pass	RD/35	The IP was able to be displayed on the LCD screen
REQ-M-12	The LCD screen should display live feed of target detection as well as temperature readings from the Pi and the Enviro sensor board.	Demonstrated	Pass	RD/26 RD/35	The LCD was successfully able to display a live feed and temperature from the pi
REQ-M-13	The LCD screen shall be placed on the side of the payload in order for the user to easily see its operation during flight	Demonstrated	Pass	RD/20 RD/21 RD/35	The LCD screen was visible from the side of the payload
REQ-M-14	Developed solution shall conform to the systems engineering approach	Submitted Documentation	Pass	RD/20 RD/21 RD/22 RD/23 RD/24	The entire project was completed using the System Engineering Approach

4.4 Performance Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-15	The system shall have logged functioning operation for a minimal period of 10 minutes prior to acceptance test.	Demonstration	Pass	RD/24	The web interface was able to display the data logged for 10 minutes prior acceptance test

REQ-M-16	The UAVPayloadTAQ shall process all imagery on-board via the on-board computer.	Demonstration	Pass	RD/23	All imagery processing was able to be processed on the Raspberry Pi
REQ-M-17	The processing must be able to analyse all data acquired from the camera and sensors while the UAV moves at a maximum speed of 2 m/s.	Demonstration	Pass	RD/23	The data from the Pi camera and sensors was able to be processing with the UAV moving at 2m/s
REQ-M-18	The processing must be able to analyse all data acquired from the camera and sensors while the UAV operates at an altitude of between 1 to 3m.	Demonstration	Pass	RD/23	The payload was able to analysis data when the UAV was between altitude of 1m-3m
REQ-M-19	Live data from the UAV must be made available through the web server within 10 seconds of capture.	Demonstration	Pass	RD/24	The live feed was viewable through the Web interface within 10 seconds of capture

5 Verification testing conclusions

Through the Test Reports and Integration Test reports all verification tests were passed without many issues. There were a few failed tests however issues that occurred was fixed and tested again until successful.

6 Validation Matrix

Requirements	HLO-M-1	HLO-M-2	HLO-M-3	HLO-M-4	HLO-M-5	HLO-M-6	HLO-M-7	Clients Brief	PM&ED	AQS	WVI	TAIQ	ST
REQ-M-01				X				X	X				
REQ-M-02	X									X			
REQ-M-03	X	X	X							X	X	X	
REQ-M-04		X	X								X	X	
REQ-M-05	X		X							X	X		
REQ-M-06		X	X								X	X	
REQ-M-07			X								X		
REQ-M-08		X				X						X	X
REQ-M-09						X							X
REQ-M-10							X		X				
REQ-M-11					X					X	X		
REQ-M-12	X				X					X			
REQ-M-13					X					X			
REQ-M-14							X		X	X	X	X	X
REQ-M-15			X								X		
REQ-M-16		X								X			
REQ-M-17		X										X	
REQ-M-18		X										X	
REQ-M-19	X	X	X							X	X	X	

7 Validation Testing

7.1 Physical Requirements

Requirement	Description	Validation	Status	Reference Document	Additional information
REQ-M-01	The UAVPayloadTAQ shall remain under the maximum weight of 320 g and comply with an IP41 rating. The air quality sensors must be exposed to the environment to allow for accurate reading.	Demonstration/ Measured	Pass	RD/28	Final weight was 240g
REQ-M-02	The UAVPayloadTAQ must measure hazardous gases , humidity, pressure, temperature and light via on-board sensors.	Demonstration	Pass	RD/28	All sensors were sending correct data to server

7.2 Functional Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-03	The UAVPayloadTAQ shall communicate with a ground station computer to transmit video, target detection and air quality data.	Demonstration	Pass	RD/28	Data and images were successfully being transmitted to the server
REQ-M-04	The target identification system shall be capable of alerting the GCS of a target's type.	Demonstration/ Simulation	Pass	RD/28	The server was able produce an alert when a target was detected
REQ-M-05	The Web Interface is required to display real time air sampling data that is recorded	Demonstrated	Pass	RD/28	The data was dynamically displayed on the web interface

	directly from the UAVPayloadTAQ and updated dynamically throughout the duration of the flight.				
REQ-M-06	The Web Interface is required to display the images of the targets that are taken directly from the UAVPayloadTAQ and updated every time a new picture is taken.	Demonstrated	Pass	RD/28	The web interface displayed updated images of the targets
REQ-M-07	The Web Interface shall be designed and run as a web server, which is to be accessible by any computers on the local network. This shall store logged sensor data and target detections with corresponding timestamps.	Demonstrated	Pass	RD/28	The web interface was able to be access by local devices using the correct IP address
REQ-M-08	The payload shall include a sampling tube design to collect a simulated soil sample. The payload system must protrude or push into the simulated soil. A mark must be left on the simulated soil (10mm deep, 10mm diameter hole), to ensure the sampling tube has made contact with the soil.	Demonstrated	Pass	RD/28	The sampling tube was able to collect the required soil sample measurement
REQ-M-09	The payload shall activate the sampling tube mechanism to collect a simulated soil sample only after the UAV has landed	Demonstrated	Pass	RD/28	The sampling tube was able to be activated once ArUCO marker was in range and tube was able to

	on a designated Aruco marker. Once the soil is sampled the sampling tube must retract to its original position.				retract back to initial position

7.3 User Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-10	Preliminary designs shall be completed by week 7	Submitted Documentation	Pass	RD/28	All documents were submitted by week 7
REQ-M-11	The payload should display its IP address via the integrated Enviro sensor LCD screen.	Demonstrated	Pass	RD/28	The IP was able to be displayed on the LCD screen
REQ-M-12	The LCD screen should display live feed of target detection as well as temperature readings from the Pi and the Enviro sensor board.	Demonstrated	Pass	RD/28	The LCD was successfully able to display a live feed and temperature from the pi
REQ-M-13	The LCD screen shall be placed on the side of the payload in order for the user to easily see its operation during flight	Demonstrated	Pass	RD/28	The LCD screen was visible from the side of the payload
REQ-M-14	Developed solution shall conform to the systems engineering approach	Submitted Documentation	Pass	RD/28	The entire project was completed using the System Engineering Approach

7.4 Performance Requirements

Requirement	Description	Verification	Status	Reference Document	Additional information
REQ-M-15	The system shall have logged functioning operation for a minimal period of 10 minutes prior to acceptance test.	Demonstration	Pass	RD/28	The web interface was able to display the data logged for 10 minutes prior acceptance test
REQ-M-16	The UAVPayloadTAQ shall process all imagery on-board via the on-board computer.	Demonstration	Failed	RD/28	Not successful in identifying all targets correctly Erroneous detection of fire extinguisher
REQ-M-17	The processing must be able to analyse all data acquired from the camera and sensors while the UAV moves at a maximum speed of 2 m/s.	Demonstration	Pass	RD/28	The data from the Pi camera and sensors was able to be processing with the UAV moving at 2m/s
REQ-M-18	The processing must be able to analyse all data acquired from the camera and sensors while the UAV operates at an altitude of between 1 to 3m.	Demonstration	Pass	RD/28	The payload was able to analysis data when the UAV was between altitude of 1m-3m
REQ-M-19	Live data from the UAV must be made available through the web server within 10 seconds of capture.	Demonstration	Pass	RD/28	The live feed was viewable through the Web interface within 10 seconds of capture

8 Validation Conclusions and Recommendations

Through the acceptance test almost all requirements were validated. However, a requirement was not completely successful which was **REQ-M-16.** Due to two misreads that occurred during the demonstration the system was unable to have flawless flight. Recommendations to fix this issue is to train another image processing model to have a higher success rate when identifying targets.