UAVPayloadTAQ

Subsystem Unit Testing – Data Acquisition

Project: UAVPayloadTAQ-G2 **WP Name**: Subsystem Integration Testing **WP Number**: WP-DAT-5	**Type of Test**: Sensor Test	
Test Article: Pimoroni Enviro+ Sensor Board	**Part Number**:PIM458	**Serial Number**:N/A
System Requirements: REQ-M-2, REQ-M-3, REQ-M-5, REQ-M-11	**Test Equipment**: Raspberry Pi 3B+, Pimoroni Enviro+ sensor hat, permanent marker, thermocouple & multi-meter with temperature reading, torch, sound emitting device.	
Test Operators: Adrian Hiltunen	**Test Engineers**: Adrian Hiltunen	
Project Manager: Alexander Iftene	**Project Supervisor**: Dr Felipe Gonzalez	

Revision Record

Document Issue/Revision Status	Description of Change	Date	Approved
1.0	Initial Document	6 October 2020	Adrian Hiltunen

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Definitions

UAV	Unmanned Aerial Vehicle
UAVPayload	Unmanned Aerial Vehicle Payload
GCS	Ground Control Station
DAT	Air Quality Data
REQ	Requirement
HLO	High Level Objective

1 Introduction

This document will outline the testing procedures employed to verify the operation of a subsystem for a project task provided by EGH455 Advanced Systems Engineering at QUT.

1.1 Scope

The subsystem under test in this document is the air quality data acquisition (DAT) subsystem. The document will discuss the testing methods and requirements for testing the operation. Real time data was verified by inspecting the console output via a secure shell connection to the host Raspberry Pi. The data was acquired via an on-board sensor hat attachment locally on the Raspberry Pi.

1.2 Background

The Queensland University of Technology (QUT) Airborne Sensing Lab have appointed Group 2 of the EGH455 (Advanced Systems Design) class to design a UAV Payload for indoor air quality to be installed on a S500 UAV designed for navigating in GPS denied environments. The UAVPayloadTAQ is required to conduct constant air quality sampling in a simulated underground mine. During monitoring, it must find and identify multiple markers placed by miners around the mine. Additionally, QUT Airborne Sensing Systems requires that the UAVPayloadTAQ is designed and developed using Systems Engineering to ensure QUT Airborne Sensing Systems requirements are met. Taken from RD/2.

2 Reference Documents

2.1 QUT Avionics Documents

RD/1	CN-UAVPayloadTAQ-01	UAV Payload Customer Needs
RD/2	SR-UAVPayloadTAQ-01	UAV Payload System Requirements

2.2 Non-QUT Documents

RD/3	https://www.mdpi.com/1424-8220/19/2/233	Review of Portable and Low-Cost Sensors for theAmbient Air Monitoring of Benzene and OtherVolatile Organic Compounds

3 Test Objectives

RD/2 outlines the requirements for the entire project. Below are the most important requirements relating to the DAT subsystem.

i. **REQ-M-02/HLO-M-1**: The UAV Payload device must measure and return readings of hazardous gases, air pressure, humidity, temperature, light, and noise levels via sensors on-board the device.
ii. **REQ-M-03, HLO-M-1**: The UAV Payload must communicate wirelessly to a GCS via a standalone embedded system.
iii. **REQ-M-05, HLO-M-3**: Real time air sampling data must be recorded and dynamically updated throughout the UAV's flight through a Web Interface.
iv. **REQ-M-11, HLO-M-1**: A minimum period of 10 minutes' worth of logged data is mandatory pre-demonstration, known hereafter as an acceptance test.

These requirements enabled the project team to set up and methodically test the performance of the subsystem.

4 Testing Setup and Equipment

The functional testing for the DAT subsystem was completed before system integration to avoid any confusion that might have arisen from device failure or communication faults between the devices. Once the subsystem had all the sensors operational, only then would integration testing be viable.

4.1 Functional Testing Setup and Equipment

Functional testing was performed methodically through the stages of operational and software development. Each sensor required a unique test to ensure functionality was correct and the output value was meaningful. The table below describes the sensor and the equipment utilised to test the operation.

Sensor	Equipment
Gas	Permanent marker
Humidity	Moisture generator (/breath)
Pressure	Vacuum tank (not available)
Temperature	Thermocouple (multi-meter equipped)
Light	Torch
Noise	Sound emitting device (/speech)

Table 1: Test equipment requirements per sensor

The python script module that would be considered the device driver had to be completed before any testing could be attempted. Once the software was written and the data formatted, the testing could begin. As noted in the table above, a vacuum tank would have been ideal to test the pressure sensor on the device, however this was not available to the project team.

There were no special circumstances or conditions required for the device testing. As the device is intended for use in a partially open or closed air environment (down a mine shaft), the testing was performed in a closed air environment with adequate ventilation.

4.2 Integration Testing Setup and Equipment

The testing equipment remains the same as the previous section, as integration does not affect the operation of the sensors unless the frequency of update is considered. It is considerably slower once integrated with the image processing software, as this is a time cost that slows down the available refresh rate of the sensors.

Once integrated the device remains testable with the equipment mentioned in 4.1 and was tested in similar ways. The only difference was the previous testing methods were used for calibrating some of the devices and after integration the tests were purely used to confirm operation is satisfactory.

Additional equipment necessary was a Raspberry Pi Camera module and the software for the server and image detection suite. Provided the enclosure for the device had adequate ventilation holes in the sides, no change would be necessary to test the devices once put inside the enclosure.

5 Testing Procedures

The below testing procedures relate to the design brief (RD/2) requirements REQ-M-02 and REQ-M-05 which are derived from HLO-M-01 and HLO-M-03, respectively.

5.1 Functionality Test Procedures

REQ-M-02 includes the following: The UAV Payload device must measure and return readings of hazardous gases, air pressure, humidity, temperature, light, and noise levels via sensors on-board the device.

A test was devised for each of the sensors listed above, excluding the air pressure sensor due to the project team not having access to a vacuum tank. A calibration was performed instead, and operation was proved by visual inspection of the sensor output data when cross referenced with expected readings at altitude.

Test 1: Gas Sensors

The gas sensors were partial to changes in atmospheric gases and without access to dangerous chemicals and suitable protection, a simpler test was devised utilising a common household item. A permanent marker is known to contain xylene and toluene within its ink, and these compounds will affect a resistive gas sensor and can be harmful to humans if the exposure is chronic, noted in RD/3. Simply placing an uncapped permanent marker that contains these compounds will have a drastic effect to the output of an operational resistive gas sensor.

Test 2: Humidity Sensor

Humidity sensor testing was approached in a similar as test 1, common household items utilised keep the budget low, as this project was designed to do. With consideration for the sensitive electronics that the sensor board is connected to, too high a humidity value could cause short circuits between small components, if a molecular bridge of droplets formed between two terminals. Attempting to reach extremely high humidity test case conditions were avoided. Breathing deeply within close proximity to the sensor was sufficient to inject a change in the environment humidity.

Test 3: Temperature Sensor

The temperature sensor could be calibrated and tested in this stage using a thermocouple connected to a multimeter that displayed the current temperature. The thermocouple element was positioned as close to the temperature sensor as possible without touching the metal case itself.

Test 4: Light Sensor

The light sensor responds to light availability through a small optical viewing window on the top of the device. Shining a bright light at the device provides a certain method for testing the operation of the light sensor. Alternatively, covering the sensor with your finger will cause the sensor to display the opposite extremity under blackout.

Test 5: Noise Sensor

The noise sensor reacts to any sound source. The human voice carries a significant portion of the audio spectrum that the microphone is sensitive to and is a suitable source for testing the device. Speaking with a clear tone and a moderate volume will be a suitable test for operation. To calibrate the operation, a device that has a measured output level and a calibrated sound meter would be required which is also unavailable to the project team.

Test 6: Real time data

REQ-M-05 included the data displayed must be shown in real time. Tests 1-5 all require real time updating to complete the tasks quickly. This was achieved as quickly as possible with the only limitation being the time required for the audio capture for analysis in noise metering. This small delay is negligible and is still considered real time data even with a 250 ms delay time.

5.2 Integration Testing Procedures

As mentioned previously, testing the device operation after integration is much the same as before with any differences noted below.

Test 7: Sensor operation while integrated

The performance of test 1-5 required to be performed again to ensure that the device will perform satisfactorily when the device has undergone integration with the other subsystems. The real time data display test will be expected to increase in delay time due to additional processing added by the image processing subsystem.

Test 8: Communication with GCS

REQ-M-03 required the sensor data to be a python module and importable into another script running the server for the Ground Control Station (GCS). A simple enough test to prove communication was to observe real time data output through the wireless link accessing the server.

6 Test Results

Below are the results obtained by performing tests 1-5 before and after integration.

6.1 Functional Test Results

Shown here is an image with all the sensors functional and reacting in real time to stimulus. The stimulus the device is responding to in the image below is a spoken word test for the noise value 73.89, where the noise floor fluctuated at approximately 22 or lower.

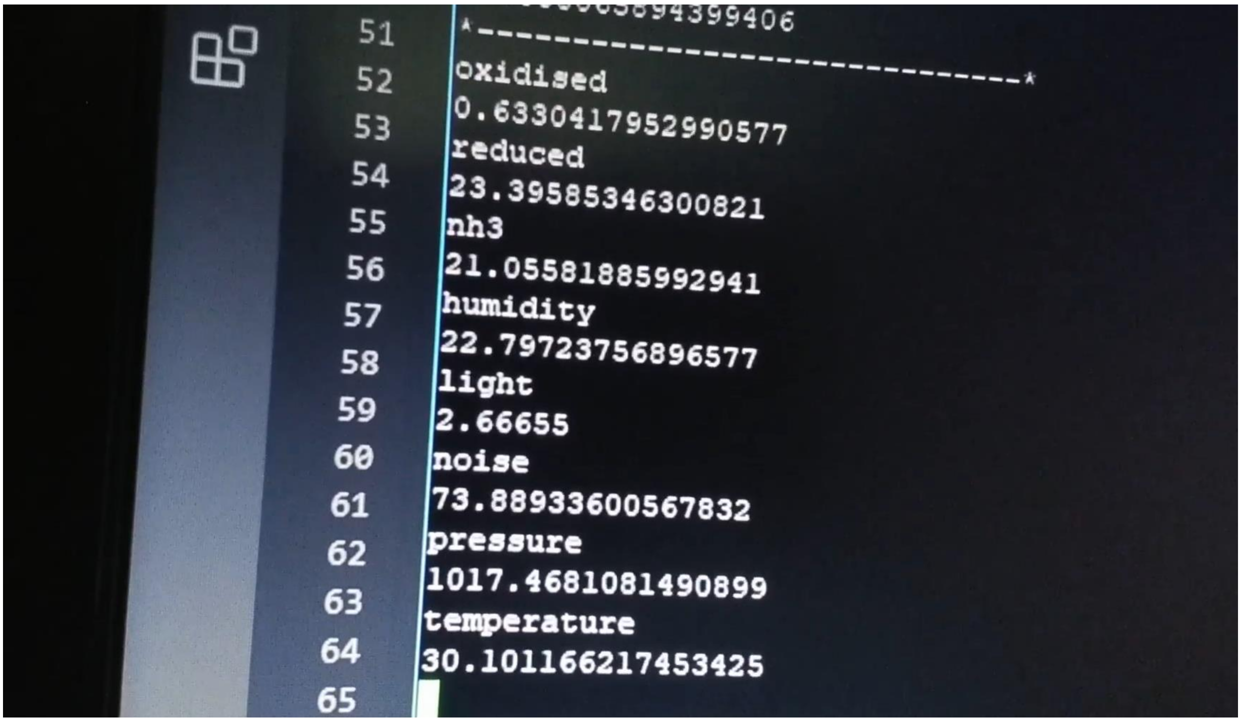

Figure 1: Sensor data output in console shell

Test Result 1: Gas Sensors

When the permanent marker was placed close to the gas sensors, the NH3 and Reducing sensors both indicated variability in output data, verifying operation.

Test Result 2: Humidity Sensor

Breathing heavily on the humidity sensor indicated an increase in up to 20% more humidity at times, verifying sensor operation.

Test Result 3: Temperature Sensor

The temperature sensor indicated a higher than ambient temperature readout which could have been because of an additional heatsink that was added to the Raspberry Pi. This heatsink was directly underneath the sensor board and could have been affecting the temperature sensor due to the proximity. Using a thermocouple and equipped multi-meter the devices output was calibrated and lowered from 2.25 to 1.3. This required some iterative testing before the temperature sensor return a temperature that was within +/- 1°C. Operation subsequently verified.

Test Result 4: Light Sensor

The light sensor very quickly reduces to a reading of 0 lux when a finger was draped across the sensor. Removing the obstruction returned the light output value to approximately 3 in a low-light room. A torch shining directly on it raised it into the hundreds.

Test Result 5: Noise Sensor

The noise sensor was operational as previously mentioned at the beginning of section 6.1. Calibrating this device proved difficult without sensitive calibrating tools however a relative noise level increase or decrease was evident when speaking close to the microphone on the sensor board.

Test Result 6: Real time data

Capturing 250 ms of audio information every cycle returned a delay of greater than 250 ms but less than a noticeable amount of latency between stimulus input and data output.

6.2 Integrated Testing Results

Test Result 7: Repeated test results with module integrated

Once integrated, all tests were repeated, and all the sensors passed the tests again. This time, no calibration was necessary and the only notable difference was the refresh rate of the data had decreased with the addition of the image processing software, however this is to be expected with limited processing on a budget.

Test Result 8: Communication with GCS

This was not easily achieved at first, however after some time rearranging file path directories within the calling script, success was achieved and REQ-M-03 was also verified.

7 Conclusion

This document has outlined the DAT subsystem meeting all requirements provided to the project team. Although some hindrances were encountered, reiterative testing allowed for success in the end.