CAPSTONE Group 062
Validation Document

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List of Abbreviations

C3 Design Document Constraint 3. 9, 16, 21, 23

C5 Design Document Constraint 5. 8, 10, 11

FR1 Design Document Functional Requirement 1. 9, 25, 26, 45, 53, 55

FR2 Design Document Functional Requirement 2. 8–14, 26, 30, 34, 53, 55

FR3 Design Document Functional Requirement 3. 10, 34, 38

NFR1 Design Document Non-Functional Requirement 1. 9, 25, 32, 35, 45, 50, 59

NFR2 Design Document Non-Functional Requirement 2. 8–12, 14–17, 21, 27, 34, 38, 58, 59

NFR3 Design Document Non-Functional Requirement 3. 9, 18, 20, 30

1 Introduction

This document confirms the mitigation of risks and the conformation to guidelines as defined by SEEDS at the onset of this project. It also provides validation that the system satisfies and corroborates the design specifications and choices outlined in two documents: the Design Document and the Requirement Document.

The results and classifications of the validation tests are concluded in Table 1. The types of tests are software tests, hardware tests, and integrated systems tests. Completed tests are considered passed or failed.

Table 1: This is the test results summary: ”Design Components” refers to the design components (of the Design Document) that are investigated; ”Requirements and Constraints” refers to requirements and constraints (of the Requirement Document) that are met by a passed test.

Test	**Test Type**	**Design Components**	**Requirements and Constraints**	**Result**
Validation of WiFi Network	Software	Section 4: Communication System	FR2, NFR2, C5	Passed

Communications Tests	Software	Section 4: Communication System, Section 5: Data Storage	FR2, NFR2	Passed
Validation of Power Source	Hardware	Section 6: Power Source	NFR2, C3	Passed
Validation of Cayenne Dashboard	Software	Section 8: User Interface	NFR3	Passed
Sensor Mounting Test	Hardware	Section 7: System Setup	NFR2	Passed
Impact Detection Reliability Test	Hardware	Section 3: Detection System	FR1, NFR1	Passed
Integrated Systems Test	Integrated Systems	All Sections	FR1, FR2	Passed
Integrated Systems Reliability Test	Integrated Systems	All Sections	NFR2	Passed

2 Validation of WiFi Network

The UBC Visitor network is demonstrated to be a reliable WiFi network for the Bird Impact Detection System. This means it is validated for use in the system.

Table 2 summarizes the requirements and constraints validated by the investigation of the UBC Visitor WiFi Network. The purpose of this section is to verify that WiFi, specifically the UBC Visitor network available on campus(1), is sufficient for the Communication System (Design Document Section 4) to function. To be viable in the project, the WiFi network must be able to transmit characteristic data packets within the specifications presented (Section 2.1).

Table 2: The components that are investigated in the Validation of WiFi Network test.

Document	**Design Component/Specification Tested**
Design Document	Section 4: Communication System
Requirements Document	FR2, FR3, NFR2, C5

2.1 WiFi Validation Specifications

Table 3 presents the expectations required of the UBC Visitor WiFi network to be approved for use in the Bird Impact Detection system. The UBC Visitor WiFi network meets all of the minimum expectations for proper system function. These expectations are defined as reasonable specifications the WiFi network must meet to ensure the connection does not obstruct the functionality of the other subsystems.

Table 3: These are the minimum expectations for the WiFi network of the communication system.

Specification	**Minimum Expectation**	**UBC Visitor WiFi**
Network Coverage	Campus-wide	Campus-wide
Characteristic Data Packet Transmission Rate	3.34B/s	0.4325MB/s
Uptime/Availability	Continuous	Continuous

2.1.1 Minimum Expectations Explanation

To meet C5 the WiFi network must be available for access by the system in all of the buildings across UBC Campus. For the system to meet FR2 and the Data Storage (Design Document Section 5) to consistently function properly, the WiFi network must be able to support sending characteristic data packets from the Detection System (Design Document Section 3) to the Data Storage. Data packets are estimated to be a maximum of 100B based on the information required by the client. The reasonable maximum amount of time for these data packets to be sent is 30 seconds. This means the minimum expectation of the network is a data transmission rate of approximately 3.34B/s. To ensure NFR2 are met, the network must be continuously available to the Bird Impact Detection system.

3 Communication and Data Storage Tests

The communications (Design Document Section 4) and data storage (Design Document Section 5) systems are demonstrated to be reliable components of the Bird Impact Detection system.

Table 4 summarizes the requirements and constraints validated by the communications and data storage tests. The purpose of these tests is to verify that data is able to be sent by the detection system to the data storage using the UBC Visitor WiFi network. A successful communication and data storage system is able to transmit characteristic data packages throughout the day that are parsed correctly by a database.

Table 4: These are the system components that are verified by the Communication and Data Storage Tests

Document	**Design Component/Specification Tested**
Design Document	Section 4: Communication System Section 5: Data Storage
Requirements Document	FR2, NFR2

Table 5 presents the current completion status of the communications tests and the results of each test.

3.1 Connection Test

The communication system (Design Document Section 4) and data storage (Design Document Section 5) have passed this test. Therefore, it is validated for sending data packets using the UBC Visitor WiFi network (1) that are

Table 5: This is a summary of the Communications Test results.

Test Name	Completion Progress	Result
Connection	Completed	Passed
Data Packet Size	Completed	Passed
Communication Reliability	Completed	Passed

parsed correctly and stored by Data Storage. This ensures that, on the event of a bird impact, the Bird Impact Detection System will be able to wirelessly transmit a data package for that impact that may be accessed in the online databases by a user.

See Appendix A for a detailed description of this test, including detailed conclusions. The purpose of this test is to verify that data is able to be sent by the data collector to data storage using WiFi, to satisfy FR2. A successful communication system is able to transmit a characteristic data package that is parsed correctly by data storage. This test consists of sending a single characteristic data package from the microcontroller (Design Document Section 3.3) to data storage (Design Document Section 4). These data packages are sent using the communication system (Design Document Section 4). The data package received by Cayenne must match the sample data package exactly to ensure the communication system functions as expected.

3.2 Data Packet Size Test

The communication system (Design Document Section 4) and data storage (Design Document Section 5) have passed this test. Therefore, it is validated for sending the full required range of characteristic data packets using the UBC Visitor WiFi network(1) that are all parsed correctly and stored by data storage. The full range of characteristic data packets is defined as a single number from 1-4 digits for the Cayenne database. This ensures that, on the event of a bird impact, the Bird Impact Detection System will be able to reliably wirelessly transmit the required range of potential impact counts, location markers, and timestamps.

See Appendix B for a detailed description of this test, including detailed conclusions. The purpose of this test is to verify that the full range of characteristic data packet sizes is able to be sent using the communication system (Design Document Section 4), to satisfy FR2 and NFR2. A successful communication system is able to transmit characteristic data packages with impact counts that range from 1-4 characters that are all parsed correctly by data storage. This test consists of sending 4 total data packages from the microcontroller (Design Document Section 3.3) to data storage (Design Document Section 5), with location data segment size increasing by 1 each package. The maximum number of characters per segment is determined by the sample data provided by the client (Requirements Appendix A). 4 digits is estimated to exceed the maximum number of impacts the system will detect before the 7 day period before maintenance concludes.

3.3 Communication and Data Storage Reliability Test

The communication system (Design Document Section 4) and data storage (Design Document Section 5) have passed this test. Therefore, they are validated for sending characteristic data packets using the UBC Visitor WiFi Network(1) consistently throughout the day. Consistently is defined as within two minutes of the expected times, at all hours of the day. This ensures that bird impact events may be recorded wirelessly at any time in the day.

See Appendix C for a detailed description of this test, including detailed conclusions. The purpose of this test is to verify that the communication system (Design Document Section 4) is able to consistently send data packets that are successfully parsed by data storage (Design Document Section 4) for a 24 hour time period. Due to time constraints, it is assumed that if the system works consistently through a full day, it will fulfill the 7 day period before maintenance defined in NFR2. This test is designed to validate that the system satisfies NFR2. A successful communication system is able to transmit all of the characteristic data packages at the expected times, over the long-term time period outlined. This test consists of transmitting a characteristic data packet once every hour for 24 hours, for a total of 24 data packets sent. The timestamps of the data packets are compared to ensure that they were received at approximately the expected time.

4 Validation of Power Source

The power adapter demonstrates to be a reliable power source for the Bird Impact Detection System.

Table 6 summarizes the requirements and constraints validated by the power adapter. The purpose of this section is to verify that power adapter is sufficient for the Dectection System (Design Document Section 3) to function. To be verified for use in the project, the power source must be able to power the system in an integrated systems test presented (Section 8, 9).

4.1 Power Source Validation Specifications

Table 7 presents the expectations required of the power source to be verified for use in the Bird Impact Detection System. The power source meets all of

Table 6: The components that are investigated by the Power Source Verification Test.

Document	**Design Component/Specification Tested**
Design Document	Section 6: Power Source
Requirements Document	NFR2, C3

the minimum expectations for proper system function, so it is validated for use in the project. These expectations are defined as reasonable specifications the power source must meet to ensure the connection does not obstruct the functionality of the other subsystems.

Table 7: The minimum power source requirements needed by the system.

Specification	**Minimum Expectation**	**Power Adapter**
Power Capacity	2000 mAh	Unlimited
Compatible with the Microcontroller (Design Section 3.3)	Yes	Yes
Obtrusiveness of the Window	< 10%	0%

4.1.1 Minimum Expectations Explanation

To meet C5, the power source must obscure less than 10% of the window that it is installed on. To ensure that this constraint is met, area covered by the power source is measured; This information is presented as a percentage with respect to the size of the window. For the system to meet NFR2 and for the Detection System (Design Document Section 3) to consistently function properly, the power source must be able to support the functionality of the microcontroller (Design Document Section 3.3) to receive information from the accelerometer (Design Document Section 3), process analog data from the sensor, and then transmit the data as data packets to the online storage (Design Document Section 5). It must have a power capacity of more than 2000 mAh. The power source must be compatible with the microcontroller (Design Document Section 3.3). It must have a center 2.1mm center positive plug, have a VDC output of 9-12V and have an output current of 250mA (2).

5 Validation of Cayenne Dashboard

The Cayenne dashboard demonstrates to be a reliable user interface (Design Document Section 8) for the Bird Impact Detection System.

Table 8 presents the requirements and constraints validated by the investigation of the Cayenne Dashboard. The purpose of this section is to verify that user interface, specifically the Cayenne Dashboard is sufficient for the user interface (Design Document Section 8) of the Bird Impact Detection System.

5.1 User Interface Validation Specifications

Table 9 presents the specification required of the Cayenne Dashboard to be verified for use in the Bird Impact Detection System. The user interface meets all of the minimum expectations for a usable user interface. These specifications are defined as reasonable specifications the user interface must

Table 8: The components that are investigated in the Validation of the Cayenne Dashboard.

Document	**Design Component/Specification Tested**
Design Document	Section 8: User Interface
Requirements Document	NFR3

meet (Section 5.1.1).

Table 9: This is a summary of the Cayenne Dashboard investigation.

Minimum Expectation	**Cayenne Dashboard**
Specification 1	Passed
Specification 2	Passed
Specification 3	Passed

Specification 1 is that the Cayenne Dashboard places users in control of the interface. Cayenne Dashboard meets this expectation: Users can easily be adept at using the Cayenne dashboard. The Cayenne Dashboard allows for the user to visualize bird-window impact rates in different ways (their choice of time scale, graph type). It is easy for users can backtrack if they choose the wrong option of data visualization: exploring different options of data visualization is not discouraged by the user interface. These different options are shown in Figure 1. The user can look at data from each individual system by choosing a specific building location with the bird impact detection system of their interests shown in Figure 2.

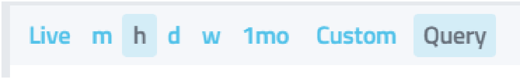


Figure 1: Data visualization Options on the Cayenne dashboard.

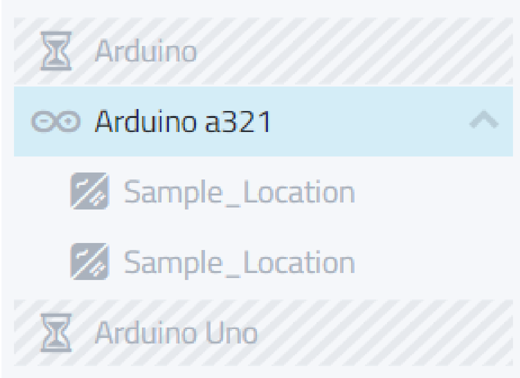
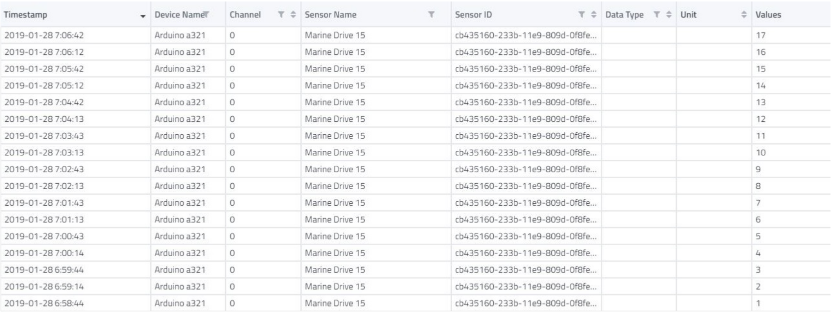


Figure 2: Sensor Location Options on the Cayenne dashboard

Specification 2 is that the Cayenne Dashboard must make it comfortable for a user to interact with the interface. Cayenne Dashboard meets this expectation: There are no unnecessary elements on the page that are not pertinent to bird-impact collision rates, or the accessing bird-impact collision rate information. The language on Cayenne Dashboard is easy to understand as are the abbreviations presented to the user. Those abbreviations are seen in Figure 1. And as for the locations in Figure 2, these locations can be named by the user of the system.

Specification 3 is that the Cayenne Dashboard reduces the cognitive load for a user to interact with the interface. Cayenne Dashboard meets this expectation: The items (bird-impact collisions) are grouped together, either in list format or as a line plot - depending on the users preference (Figure 3, 4).



Timestamp	Device Name	Channel	Sensor Name	Sensor ID	Data Type	Unit	Values
2019-01-28 7:06:42	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			17
2019-01-28 7:06:12	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			16
2019-01-28 7:05:42	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			15
2019-01-28 7:05:12	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			14
2019-01-28 7:04:42	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			13
2019-01-28 7:04:13	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			12
2019-01-28 7:03:43	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			11
2019-01-28 7:03:13	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			10
2019-01-28 7:02:43	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			9
2019-01-28 7:02:13	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			8
2019-01-28 7:01:43	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			7
2019-01-28 7:01:13	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			6
2019-01-28 7:00:43	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			5
2019-01-28 7:00:14	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			4
2019-01-28 6:59:44	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			3
2019-01-28 6:59:14	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			2
2019-01-28 6:58:44	Arduino a321	0	Marine Drive 15	cb435160-233b-11e9-809d-0f8fe...			1

Figure 3: Cayenne Data Presentation with Sample Data

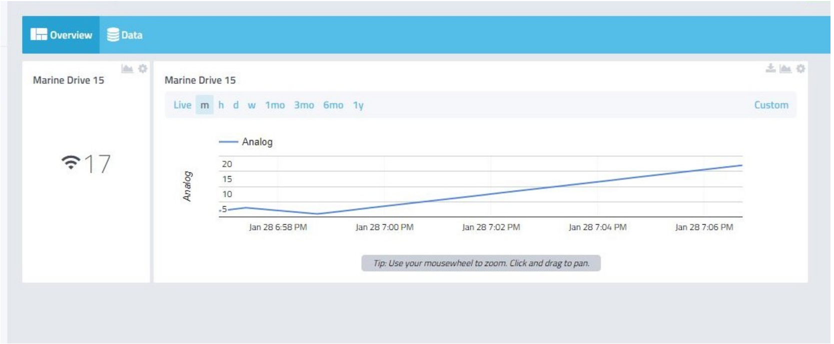


Figure 4: Cayenne Dashboard UI featuring numerical counter (left) and line plot (right) widgets, populated with sample data.

5.1.1 Minimum Expectations Explanation

For the Cayenne Dashboard to meet NFR3, data must be stored in a manner such that a user possessing basic spreadsheet skills can access and interpret the data. Thus, for the Cayenne Dashboard to be a validated user interface for the system, it must have the qualities of an effective user interface with a general-public user base. (3):

- places users in control of the interface
- makes it comfortable for a user to interact with the interface
- reduces cognitive loads

These principles are identified using Jakob Nielsen's ”10 Usability Heuristics for User Interface Design”, Ben Shneiderman's The Eight ”Golden Rules of Interface Design”, and Bruce Tognazzini's ”Principles of Interaction Design”.

6 Sensor Mounting Test

Table 10 summarizes the requirements and constraints validated by the mounting test, as well as the design components involved.

The purpose of this test is to verify that the detection system mounting process (Design Document Section 7) is able to keep the system secure on the window. A successful system is able to be installed to a window and stay installed until removed manually.

Table 10: The components that are investigated by the Sensor Mounting Test.

Document	**Design Component/Specification Tested**
Design Document	Section 7: System Setup
Requirements Document	NFR2, C3

The mounting process is tested for the following components:

1. Accelerometer
2. Microcontroller inside Plastic Enclosure Box

The accelerometer mounting is validated experimentally (Section 6.1), while the microcontroller mounting is validated using research (Section 6.2). Table 11 presents the current completion status of the installation tests and the results of each test.

Table 11: Sensor Mounting Test results.

Test/Validation Name	**Completion Progress**	**Result**
Accelerometer Mounting	Completed	Passed
Microcontroller Mounting	Completed	Passed
Window Footprint	Completed	Passed

6.1 Accelerometer Mounting

The accelerometer mounting method has passed this test, so it is validated for use in the system. See Appendix D for a detailed description of this test, including detailed conclusions. This test consists of attaching the accelerometer to the window using the sensor installation method (Design Document Section 7.2.2). The system is then left attached to the window undisturbed for a 24-hour time period. The locations of the sensor after this period is compared to the original installation location. This is done to ensure that the system is securely affixed to the window and will remain attached until removed by the user. The sensor must be within 0.2cm of its original location measurements in all directions with reference to the window for the system to be successful.

The accelerometer mounting method meets the condition required to pass this test. This validates the mounting method is reliable for securing the system to the window for the full 7 day period before maintenance. The maximum drift value for both the horizontal and vertical directions is 0cm, which is below the maximum allowable value of 0.2cm. This means the accelerometer will remain attached to the window for as long as needed, ensuring the system will be able to monitor for bird impacts continuously.

6.2 Microcontroller Mounting

The microcontroller mounting method has passed this test, so it is verified for use in the system. The microcontroller is mounted inside of a plastic box enclosure, which is attached to the metal window frame using double sided mounting tape(4). The microcontroller and plastic enclosure box together weigh 0.275lb. The weight of the sensor wires and power connection are considered to have a negligible effect on the mounted weight of the microcontroller. Therefore, the mounting method for the microcontroller must be able to support at least 0.3lbs to ensure that the system is securely attached. The double sided mounting tape used to attach the microcontroller to the window frame is rated to hold up to 2lb, so it exceeds this minimum requirement. Table 12 compares the weight of the microcontroller in the plastic box enclosure to the maximum weight allowed by the microcontroller mounting method.

Table 12: The microcontroller mounting method maximum weight compared to the microcontroller's actual weight.

Microcontroller Mount Max Weight	**Microcontroller weight**
2lb	0.275lb

6.3 Window Footprint

The Bird Impact Detection System has passed this test, so it is verified to not obscure more of the window than what is acceptable. To meet C3, the system components installed on the window must not obscure more than 10% of the window area. Footprint refers to the area of the window glass that is obscured by the components of the system. Table 13 compares the footprint of the components compared to the maximum allowed footprint on the window. The components considered in the overall footprint are:

1. The accelerometer (Design Document Section 7.2.2)
2. The microcontroller, installed in plastic enclosure (Design Document Section 7.2.1)

Table 13: This is the system footprint on the window compared to the maximum allowed footprint.

System Window Footprint	**Maximum Allowable Footprint**
0.7%	10%

The test window is 24”x36”, so the footprint of the system on the window must be less than 864in^2. The dimensions of the sensor footprint on the window is 1.25”x1.25”, or 1.5625in^2, and the dimensions of the microcontroller box are 3”x1.5”, or 4.5in^2. This means the combined footprint of the system is approximately 6.0625in^2. Due to their relatively small size and the proximity of the system components to one another on the window, the footprint of the wires is not factored into the overall device footprint. The device footprint is then 0.7%, which is within the value that is required.

7 Impact Detection Reliability Test

The Impact Detection Reliability Test is passed by the Bird Impact Detection System.

Table 14 summarizes the requirements and constraints validated by the impact detection reliability test, as well as the design components involved. See

Appendix E for a detailed description of the test.

The purpose of this test is to verify that the detection system (Design Document Section 3) is able to detect bird impacts reliably. This test consists of attaching the system to a window; bird-window collisions and other disturbances (rain, human noise) that may occur on windows are then simulated. The number of recorded bird impacts to the window is compared to the number of simulated bird impacts to the window. A successful system has an false negative rate and a false positive rate of less than 5% from any individual source.

Table 14: The components investigated by the Impact Detection Reliability Test.

Document	**Design Component/Specification Tested**
Design Document	Section 3: Detection System
Requirement Document	FR1, NFR1

8 Integrated Systems Test

The Bird Impact Detection System passes the Integrated Systems Test.

Table 15 summarizes the requirements and constraints validated by the integrated systems test, as well as the design components involved. See Appendix F for a detailed description of the test.

The purpose of this test is to ascertain that the system is able to detect bird-window collisions on the window that it is installed on, and transmit the information (bird impact location, bird-window collision instance, bird-window collision time) to Cayenne, the online database, accessible by the Cayenne Dashboard. This test consists of simulating a single bird impact to the window and monitoring the Cayenne Dashboard for the data package of the bird impact.

Table 15: The components that are investigated by the Integrated Systems Test.

Document	**Design Component/Specification Tested**
Design Document	All Sections
Requirements Document	FR1 FR2

9 Integrated Systems Reliability Test

The Integrated Systems Reliability Test is passed by the Bird Impact Detection System.

Table 16 summarizes the requirements and constraints validated by the impact detection reliability test, as well as the design components involved. See Appendix G for a detailed description of the test.

The purpose of this test is to verify that the system is able to function for 7 days without maintenance. This test consists of attaching the system to a window; the Bird Impact Detection System is powered for 7 days and continuously monitored for functionality by the simulation of a bird-window collision every 24 hours.

Table 16: The components investigated by the Integrated Systems Reliability Test.

Document	**Design Component/Specification Tested**
Design Document	All Sections
Requirement Document	NFR2

References

1 UBC. ubcvisitor wireless network. [Online]. Available: https://it.ubc.ca/services/email-voice-internet/wireless-internet-access/ubcvisitor-wireless-network

2 Arduino. Arduino uno wifi rev2. [Online]. Available: https://store.arduino.cc/usa/arduino-uno-wifi-rev2

3 A. Blog. The 4 golden rules of ui design. [Online]. Available: https://theblog.adobe.com/4-golden-rules-ui-design/

4 Staples. Scotch mounting tape. [Online]. Available: https://www.staples.ca/en/Scotch-Mounting-Tape/product_11189_1-CA_1_20001

5 MyDevices. Cayenne, the world's first drag-and-drop iot project builder. [Online]. Available: https://mydevices.com/cayenne/features/

6 UBC. Current system status and maintenance notifications. [Online]. Available: http://bulletins.it.ubc.ca/

7 K. Morton, "Communications validation test," https://github.com/Alpaca99/ELEC491/blob/master/Communications_Validation_Tests/communications_validation_test_1.ino, 2019, commit 0a28763.

8 ——, "Data packet size test," https://github.com/Alpaca99/ELEC491/blob/master/Communications_Validation_Tests/communications_data_packet_test_2.ino, 2019, commit 0a28763.

9 ——, "Communications and data storage reliability test," https://github.com/Alpaca99/ELEC491/blob/master/Communications_Validation_Tests/communications_uptime_test_3.ino, 2019, commit 80d9320.

10 ——. (2019) Communications reliability test data. [Online]. Available: https://docs.google.com/spreadsheets/d/1ipAGKzQ80G-WJsdtl1n2tpVXgUz9Hic54XmnX4U53vY/edit?usp=sharing

11 S. C. E. X. K. M. David He, Stevan Vicentijevic, “Version5_3_with_reset,” https://github.com/Alpaca99/ELEC491/blob/master/intergratecode/Version5_3_with_reset/Version5_3_with_reset.ino, 2019, commit e0b8e21.

Appendix A: WiFi Connection Test

Purpose

The purpose of this experiment is to verify that data is able to be sent by the detection system to the data storage using WiFi, to satisfy FR2 and NFR3. A successful communication system is able to transmit a characteristic data package that is parsed correctly by data storage.

This experiment is designed to ensure that the microcontroller in the detection system (Design Document Section 3.3) is able to connect to a WiFi network, then use that network to send data to data storage (Design Document Section 5).

Test Setup

The data storage location being monitored in this experiment is:

1. MyDevices Cayenne(5)

The testing setup for this experiment includes:

- An Arduino Uno WiFi Rev2
- A stable, accessible UBC Visitor WiFi connection on UBC Campus
- A device with access to MyDevices Cayenne

Ensure that the device being tested is able to connect to the UBC Visitor WiFi network, and that the network is currently available(6).
Figure A1 displays the connection between these components. The ID and password (if applicable) for the WiFi connection should be included in the Arduino code(7).

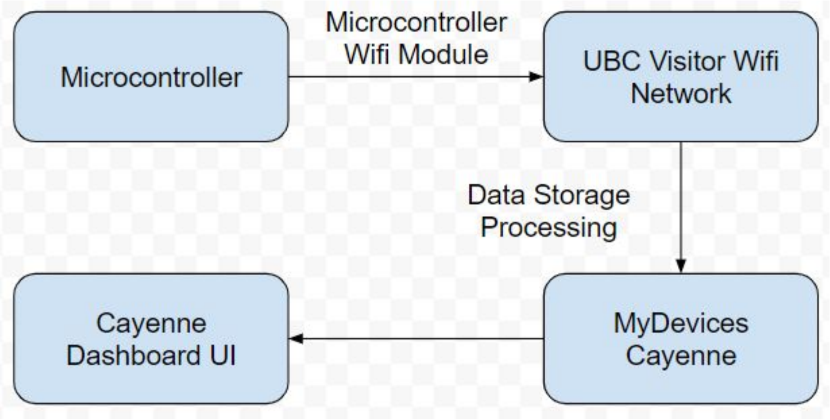


Figure A1: Base Data Communications Test Setup

Procedure

The test is conducted as follows:

1. Upload the code to upload data to Cayenne(7) to the Arduino Uno WiFi Rev2.
2. Monitor the Cayenne dashboard for the test data from the Arduino Uno WiFi Rev2. Table A1 presents the test data for Cayenne in the 'Sample Data' column.
3. Record the Cayenne output in the appropriate column of Table A1.

Observations

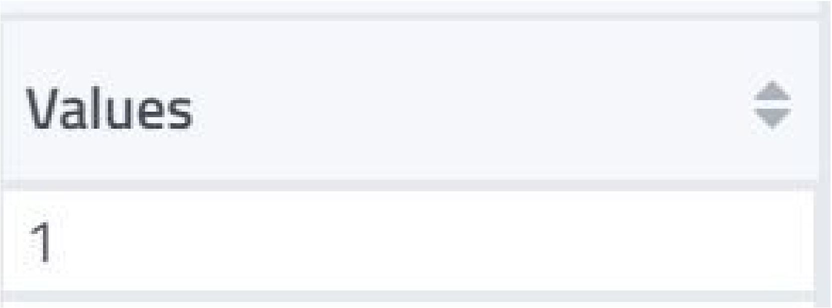
To pass this test, the data received in Cayenne must match the sample data included in the Arduino code. This pass condition is determined by the need for data from the detection system (Design Document Section 3) to be accurately recorded in data storage (Design Document Section 5). Errors in data transmission are not tolerable for the system, as it would decrease the ability of the system to meet NFR1.

Data portion in Table A1 indicates what specific portion of the data package sent by the Arduino is expected. Impact count in Table A1 refers to the number presented on the counter included in the Cayenne Dashboard user interface.

Table A1: Cayenne Sample Data

Data Portion	**Sample Data**	**Cayenne Data**
Impact count	1	1

Figure A2 displays the information received from the data packet by Cayenne, which matches the sample data in Table A1.



Values
1

Figure A2: Validation Data Parsed by Cayenne

All of the data parsed by both Cayenne exactly matches the expected test data. This indicates that the detection system (Design Document Section 3) is able to connect to the communication system (Design Document Section 4), and send data packets that are parsed by data storage (Design Document Section 5).

Conclusion

The communication system and data storage meet all of the conditions required to pass this test. This validates that the communication system is able to send characteristic data packets from the Arduino Uno WiFi Rev2 using the UBC Visitor WiFi network that are then parsed correctly by the data storage component, Cayenne. The result of this test is used in conjunction with the other communications tests (Validation Document Section 3) to validate the communication system (Design Document Section 4) and data storage (Design Document Section 5) for use in the Bird Impact Detection system.

Appendix B: Data Packet Size Test

Purpose

The purpose of this experiment is to verify that the data communication system (Design Document Section 4) is able to send the characteristic data packets that are successfully parsed by data storage (Design Document Section 5). This is to satisfy FR2, FR3, and NFR2. These characteristic data packets will cover the full required range of data packets defined as a single number to Cayenne, ranging from 1-4 digits. Cayenne handles the timestamp and location identifier in the database itself, so those data segments are not considered in this test.

This experiment is designed to ensure that the microcontroller in the detection system (Design Document Section 3) is able to package the full range of characteristic data packets, then use the UBC Visitor WiFi network on UBC Campus (Design Document Section 4) to store this information in data storage (Design Document Section 5)

Test Setup

This experiment is set up using the test setup from the WiFi Connection Test (Validation Document Appendix A), with the exception of using the code for the Communications Test 2 uploaded to the Arduino(8).

Procedure

The test is conducted as follows:

1. Upload the code to transmit data from the Arduino to Cayenne(8) to

the Arduino Uno WiFi Rev2.

2. Monitor the Cayenne dashboard for the first row of test data located in Table B1 for Cayenne.
3. Record the Cayenne output in Table B1.
4. Repeat steps 2-3 for the rest of the data rows in Table B1, recording database data stored in the appropriate table rows and columns.

Observations

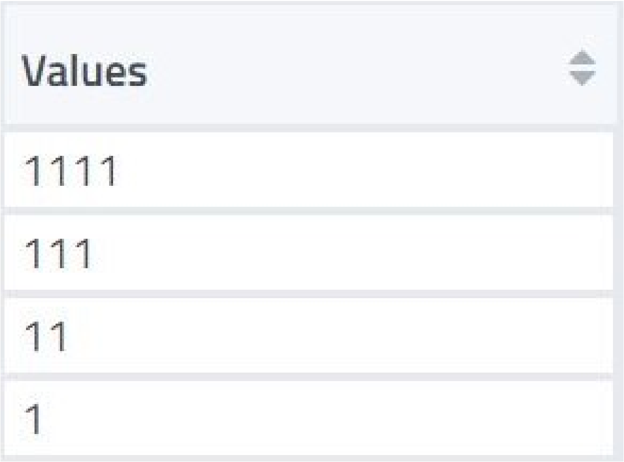
To pass this test, the data received in Cayenne must match the sample data included in the Arduino code exactly. This pass condition is determined by the need for data from the detection system (Design Document Section 3) to be accurately recorded in data storage (Design Document Section 5). Errors in data transmission are not tolerable for the system, as it would decrease the ability of the system to meet NFR1.

Data portion in Tables B1 indicate what specific portion of the data package sent by the Arduino is expected. Impact count in Table B1 refers to the number presented on the counter included in the Cayenne Dashboard user interface. Based on expected number of impacts, the impact count is only counted up to 4 digits.

Table B1: Cayenne Data Packet Sample Data

Sample Impact Count	**Cayenne Impact Count**
1	1
11	11
111	111
1111	1111

Figure B1 displays the information received by Cayenne from all of the data packets, with the first data packet at the bottom of the list and the last data packet at the top of the list. The Cayenne received data exactly matches the expected sample data in Table B1.



1111
111
11
1

Figure B1: Data Packets Parsed by Cayenne

All of the data parsed by both Cayenne exactly matches the expected test data. This indicates that the detection system (Design Document Section 3) is able to send the full range of characteristic data packets required for system function to the data storage (Design Document Section 5) using the communication system (Design Document Section 4).

Conclusion

The communication system and data storage meet all of the conditions required to pass this test. This validates that the communication system is able to send the required range of characteristic data packets defined in Table B1 to the Arduino Uno WiFi Rev2 using the UBC Visitor WiFi network. Cayenne is also validated in successfully parsing the full range of characteristic data packets and storing them. The result of this test is used in conjunction with other communication tests (Validation Document Section 3) to validate the communication system (Design Document Section 4) and data storage (Design Document Section 5) for use in the bird impact detection system.

Appendix C: Communication Reliability Test

Purpose

The purpose of this experiment is to verify that the data communications system is able to consistently send characteristic data packets over a 24-hour time period that are then parsed by data storage. This is to satisfy FR3 and NFR2. A successful communication system is able to transmit all of the characteristic data packages at the expected times.

This experiment is designed to ensure that the system will consistently be able to send data packages using the UBC Visitor WiFi network at various times of the day.

Test Setup

This experiment is set up using the test setup from the WiFi Connection Test (Validation Document Appendix A), with the exception of using the code from the Communications test 3 uploaded to the Arduino(9).

Procedure

The test is conducted as follows:

1. Upload the code to transmit data from the Arduino to Cayenne(9), to the Arduino Uno WiFi Rev2.
2. Monitor the Cayenne dashboard for the first data packet to be received.
3. Allow the system to run continuously uninterrupted for 24 hours.

4. Use the timestamps of the data packages collected by Cayenne to determine the maximum difference between the expected timestamps and actual timestamps.

Observations

To pass this test, all of the data packets received in Cayenne must reasonably match the sample data. Reasonably is defined as within 2 minutes of the expected timestamp for Cayenne. The expected timestamp is defined for the test as exactly one hour later from the previous timestamp. Lenience is allowed in the timestamp as the primary focus of the timestamp is identifying the approximate time of day impacts often occur, rather than the precise time each impact occurs. In addition, some significant error is anticipated due to the use of the Arduino for timing, which would not be translated into the final product.

Due to the volume of information collected for this test, the data is collected in a separate file(10). Table C1 presents the maximum difference between any two timestamps for Cayenne. All of the timestamps in Cayenne fit within a reasonable margin of the expected time frames, as specified above. This indicates that the communication (Design Document Section 4) and data storage (Design Document Section 5) work reliably throughout a 24-hour time period.

Conclusion

The communication system and data storage meet all of the conditions required to pass this test. This validates that the communication system is able to send characteristic data packets from the Arduino Uno WiFi Rev2 using

Table C1: Cayenne Dashboard Packet Parsed Data

Maximum Allowable Timestamp Difference	**Cayenne Maximum Timestamp Difference**
120 seconds	74 seconds

the UBC Visitor WiFi network that are then parsed correctly by Cayenne consistently throughout the day. The result of this test is used in conjunction with the other communications tests (Validation Document Section 3) to validate the communication system (Design Document Section 4) and data storage (Design Document Section 5) for use in the Bird Impact Detection System.

Appendix D: Sensor Mounting Test

Purpose

The purpose of this experiment is to verify that the detection system mounting process (Design Document Section 7) is able to keep the system secure on the window. This experiment is designed to ensure that the ADXL337 accelerometer for the system will stay securely attached to the window for the entire 7 day period before maintenance.

Test Setup

The apparatus for this experiment includes:

- The 2'x3' test window
- ADXL337 accelerometer
- Plastic accelerometer cover
- Duct Putty

Figure D1 displays how the accelerometer is affixed to the window.

Procedure

The test is conducted as follows:

1. Attach the accelerometer to the window in the location indicated in Figure D1 using duct putty. Ensure that the duct putty has a thickness of approximately 1mm, and that the sensor is securely placed in the duct putty.

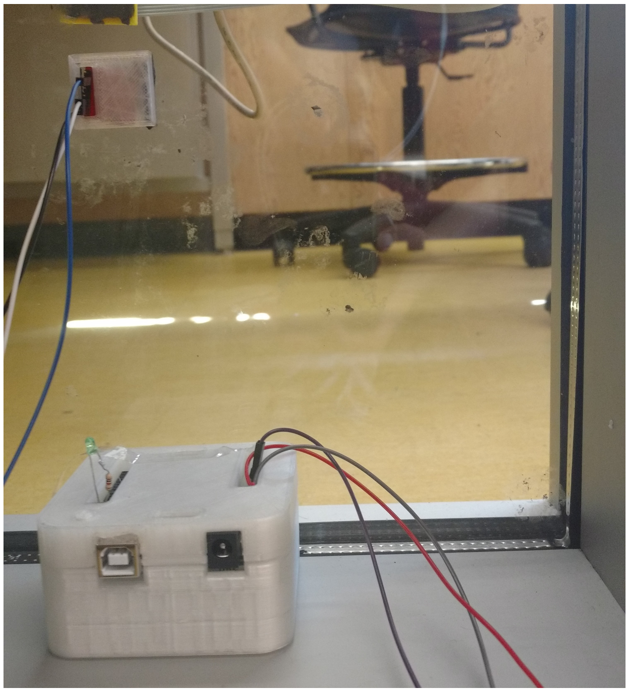


Figure D1: System Mounted to Test Window. The Accelerometer is Placed in the Top Left of Image

2. Ensure the accelerometer is placed approximately 6 inches from the bottom and right side of the window frame. The accelerometer should be mounted on the inside of the window glass.
3. Place the accelerometer cover over the accelerometer, securing it using more duct putty.
4. Measure the distance from the metal frame of the window to the closest edge of the accelerometer cover. Record the vertical and horizontal distance in Table D1.
5. Leave the test window with sensor attached for 7 days. Ensure that the setup will not be disturbed in this time.

6. Measure the distances from Step 4 again, recording the values in the appropriate cells of Table D1.
7. Calculate the drift value for each measurement and record the values in Table D1.

Observations

To pass this test, each of the measurements recorded in Table D1 must display a drift of less than 0.2cm. Drift is defined as a difference between the measurement taken at the beginning of the 24 hour period and the measurement taken at the end. Drift is taken as an absolute value, as direction is unimportant compared to distance moved over the time period. High drift indicates that the system components are not secure, so it is the metric for this experiment.

Table D1: Drift measurements of system components.

Measurement	**Start Value (cm)**	**End Value (cm)**	**Drift (cm)**
Accelerometer Horizontal	15.24	15.24	0
Accelerometer Vertical	15.24	15.24	0

The accelerometer did not move a significant amount in either the horizontal or vertical directions, with a drift value of 0 cm for both. This indicates that it remained securely attached to the window for the entire 7 day period.

Conclusion

The accelerometer mounting method meets the condition required to pass this test. This validates the mounting method is reliable for securing the system to the window for the full 7 day period before maintenance. The maximum drift value for both the horizontal and vertical directions is 0cm, which is below the maximum allowable value of 0.2cm. This means the accelerometer will remain attached to the window for as long as needed, ensuring the system will be able to monitor for bird impacts continuously.

Appendix E: System Reliability Test

Purpose

The purpose of this test is to validate that the Bird Impact Detection System meets FR1 and NFR1; it is designed to test that the detection system can detect bird-window collisions. It is also designed to test the accuracy of the detection system (Design Document Section 3) by testing the system's performance.

Events by/on windows that can trigger the detection system (Design Document Section 3) asides from bird-window collisions pose a major technical risk to our project. The test is designed to ensure that the detection system (Design Document Section 3) is able to record bird-window collisions, at the same time, ignoring environmental disturbances (rain, talking).

Test Setup

The bird-impact collisions are monitored in this experiment on the:

1. Arduino IDE.

The apparatus for this experiment includes:

- The 2'x3' test window
- ADXL337 accelerometer
- An Arduino Uno WiFi Rev2
- A 10 nF capacitor

- Duct putty
- A pendulum with 57g mock bird attached (Steps for this setup is in the Design Document Appendix C)
- A USB B Cable (to connect the Arduino Uno WiFi Rev 2 to a computer)
- A computer with Arduino IDE installed
- A UE WonderBoom bluetooth speaker
- A Decibel X application for iPhone
- A Android or iPhone smartphone
- A hose
- A sprinkler nozzle
- A water outlet compatible with the hose

The best sensor location is identified to be at 6” by 6” from the bottom corner of the window. The worst-case scenario bird-window collision is at approximately 3” by 3” from the top corner of the window. To determine the reliability of the system at detecting bird impacts, only the worst-case scenario bird-impact collision locations are used in testing. (The optimal sensor location and the worst-case scenario bird impact collision location are determined in Design Document Appendix D).

See the Design Document for the mock rain disturbance setup (Design Document Appendix E), and for the mock human disturbance setup (Design Document Appendix E).

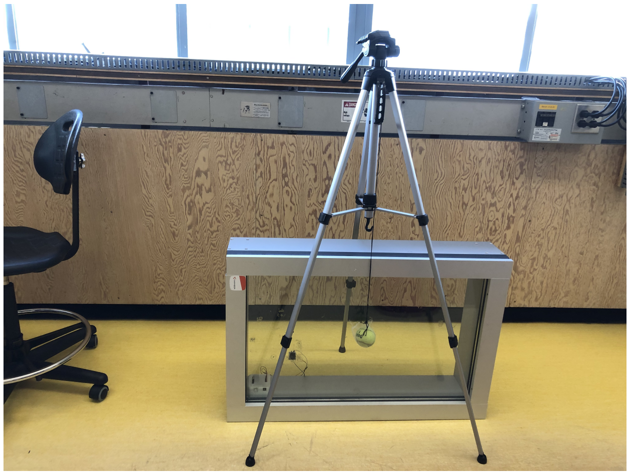


Figure E1: The system setup for the system reliability test. The accelerometer is placed in an appropriate location on the window.

Procedure

The test is conducted as follows:

1. Connect the accelerometer to the microcontroller running the system code(11) according to the wiring schematic instruction/diagram (Design Document Section 7.1).
2. Place the accelerometer with duct putty approximately 6 inches by 6 inches from the bottom and right side of the window pane and tape the Plastic Box with the microcontroller in it onto the window frame.
3. Setup the mock bird-pendulum frame. (Instructions are found in the Design Document Appendix C).
4. Place the window underneath the pendulum (see Figure E1).

5. Power the microcontroller with the USB B cable.

6. If at any point in the following testing steps a false positive impact (defined above) occurs, record it in Table E1 in the appropriate column. Additionally, if any point in the following steps an impact is not detected, record it in Table E2 in the appropriate column.

7. Use the pendulum setup to impact the window at the minimum angle that corresponds to the lowest speed of a common kinglet (Design Document Section Table C2) in the top left corner of the window (exactly 3” by 3” from the corner). If the impact is detected correctly, record it in Table E2 below. A properly detected impact is observed in the Arduino IDE as seen in Figure E2.

8. Repeat step 6 39 more times, recording each detected impact in the appropriate column.

9. Using the test setup in the Design Document Section Appendix E for the rain disturbance test, impact the window in the top left corner of the window (exactly 3” by 3” from the corner). If the impact is detected correctly, record it in Table E2 below.

10. Repeat step 8 39 more times, recording each detected impact in the appropriate column.

11. Using the test setup in the Design Document Section Appendix E for the human disturbance test, impact the window in the top left corner of the window (exactly 3” by 3” from the corner). If the impact is detected correctly, record it in Table E2 below.

12. Repeat step 10 39 more times, recording each detected impact in the appropriate column.

13. Compare the number of true positives to the number of false positives to determine the precision of the system.
14. Compare the number of true positives to the number of false negatives to determine the miss rate of the system.

Calculations

Bird-window collisions are of binary classification; Every bird-window collision detected is either a collision (positive case) or not a collision (negative case). Thus, there are four possible collision classifications:

- True Positive (TP)—Correctly detected bird-window collision;
- True Negative (TN)—Non-bird-window collision event not detected as a bird-window collision;
- False Positive (FP)—Classified as a bird-window collision when none occurred
- False Negative (FN)—A bird-window collision which was not detected

These values help predict the actual data compared with the bird impact detection system's predictions when an event has occurred to the window.

We are concerned with the miss rate of the bird impact detection system which is given by the formulas

$$Sensitivity = TP/(TP + FN)$$
$$MissRate = FN/(FN + TP) = 1 - Sensitivity$$

Observations

To pass this test, the system must have error rates of:

- Less than 5% false positives
- Less than 5% misses

Both of these error rates are with respect to the total number of impacts conducted over all three environments outlined above. This is designed to mimic the error in the environments that will be common in regular operation of the Bird Impact Detection system.

A detected impact in Table E2 is defined as a test impact that is deliberately performed that is registered by the system and appears in the Arduino IDE. A false positive in Table E1 is defined as an impact that appears in the Arduino IDE that does not correspond to an impact that was deliberately performed on the window. An undetected bird impact in Table E2 is defined as an impact that is deliberately performed on the window that does not appear in the Ardiuno IDE.

The detection system did not exceed 5% false positives or 5% misses (as presented by Table E3), with bird-window collisions being recorded in three different environments (ideal, rain, with human disturbances). This indicates that the detection system can accurately determine bird-window collisions with an accuracy that meets NFR1.

Conclusion

The detection system meets the condition required to pass this test. This

Table E1: Recorded False Positives and Misses for Bird Impact Detection System.

Testing Environments	**Number of False Positives**	**Number of False Negatives**
Ideal	0	1
Rain	0	0
Human	0	2

Table E2: Impacts Recorded in Reliability Test Environments.

Testing Environments	**Number of Impacts Performed**	**Number of Impacts Detected**
Ideal	120	119
Rain	120	120
Human	40	38

Table E3: False Positives and Miss rates Summary.

Testing Environments	**False Positives Rate**	**Miss Rate**
Ideal	0%	0.008%
Rain	0%	0%
Human	0%	0.017%

validates the detection algorithm is reliable for detecting bird-window collisions with a less than 5% miss rate and false positives rate. The maximum miss rate for detection in the three environments is .017%, which is below the maximum allowable value of 5%. The false positive rate in the three testing environments is 0%. This means the detection will record bird-window collisions with a desired accuracy in the three test environments.

Appendix F: Integrated Systems Test

Purpose

The purpose of this experiment is to verify that the system architecture being considered for the system has the ability to detect bird-window collisions and then output bird impact information to the user interface solution. The two functional requirements that this test addresses are:

- FR1
- FR2

This experiment will ensure that the system architecture designed can detect bird impacts: the microcontroller in the detection system (Design Document Section 3), powered by a power adapter (Design Document Section 6), is able to connect to a WiFi network (Design Document Section 4), then use that network to send data to data storage. The data in the data storage (Design Document Section 5) is tested to be accessible to users.

Test Setup

The user interface being monitored in this experiment is:

1. MyDevices Cayenne(5)

The apparatus for this experiment includes:

- The 2'x3' test window
- ADXL337 accelerometer
- An Arduino Uno WiFi Rev2

- A 10 nF capacitor
- Duct putty
- Double-sided tape
- A pendulum with 57 g mock bird attached (Steps for this setup is in the Design Document Appendix C)
- A power adapter (to connect the Arduino Uno WiFi Rev 2 to a wall plug)
- A stable, accessible UBC Visitor WiFi connection on UBC Campus
- A device with access to MyDevices Cayenne

The test window (mock bird, pendulum) is set up according to Figure E1.

The best sensor location is identified to be at 6” by 6” from the bottom corner of the window. The worst-case scenario bird-window collision is at approximately 3” by 3” from the top corner of the window. To determine the reliability of the system at detecting bird impacts, only the worst-case scenario bird-impact collision location identified are used in testing. (The optimal sensor location and the worst-case scenario bird impact collision location are is investigated in Design Document Appendix D.

<u>Procedure</u>

The test is conducted as follows:

1. Connect the accelerometer to the microcontroller running the system code(11) according to the wiring schematic instruction/diagram (Design Document Section 7.1).

2. Place the accelerometer with duct putty approximately 6 inches by 6 inches from the bottom and right side of the window pane and tape the Plastic Box with the microcontroller in it onto the window frame.

3. Setup the mock bird-pendulum frame. (Instructions are found in the Design Document Section Appendix C).

4. Place the window underneath the pendulum (see Figure E1).

5. Power the microcontroller with the power adapter.

6. Ensure that the WiFi connection for the experiment is working properly using another device, such as a smartphone or laptop.

7. Drop the mock bird onto the worst impact location at the minimum angle that corresponds to the lowest speed of a common kinglet (Design Document Table C3).

8. Monitor the Cayenne dashboard for the data from the Arduino Uno WiFi Rev2. Table F1 presents the test data for Cayenne in the 'Sample Data' column.

9. Record the Cayenne output in Table F1.

Observations

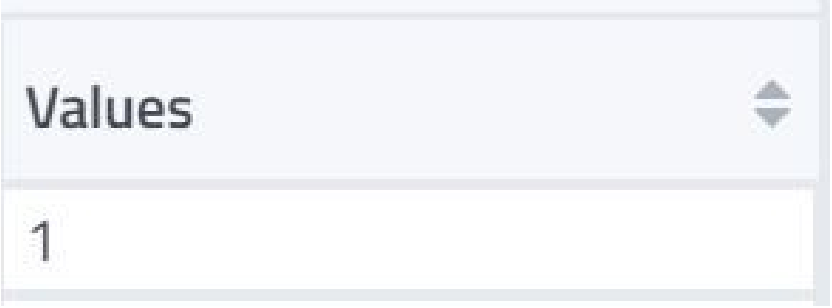
To pass this test, the bird-window collision received in Cayenne must occur when a simulated bird-window collision is conducted by this test exactly. This pass condition is determined by the need for the whole system architecture (Design Document Section 1) to operate and accurately record bird-window collisions. Errors are not tolerable for the system, as it would demonstrate the inability the ability of the system to meet FR1 and FR2.

Data portion in Table F1 indicates what specific portion of the data package sent by the Arduino is expected. Impact count in Table F1 refers to the number presented on the counter included in the Cayenne Dashboard user interface.

Table F1: Cayenne Sample Data.

Data Portion	**Sample Data**	**Cayenne Data**
Impact Counts	1	1

Figure F1 displays the information received from the data packet by Cayenne, which matches the sample data in Table F1.



Values
1

Figure F1: Validation Data Parsed by Cayenne

All of the data parsed by both Cayenne exactly matches the expected test data. This indicates that the system architecture (Design Document Section 1) is able to function as a bird-window detection device, detect bird-impact collisions and send data packets that are parsed by data storage (Design Document Section 5), accessible by the Cayenne Dashboard.

Conclusion

The system architecture meets all of the conditions required to pass this test. This validates that the system architecture is able to function as a bird-impact detection monitoring system. The result of this test validates the subsystems for use as components that function reliably in the Bird Impact Detection system.

Appendix G: Integrated Systems Reliability

Purpose

The purpose of this test is to validate that the Bird Impact Detection System meets NFR2; it is designed to test the system's architecture (Design Document Section 1) reliability by testing the system's performance throughout a 7 day period. A bird-window collision is simulated every 24 hours. A successful system is able to detect all of the impacts in an ideal environment in a span of 7 days.

Test Setup

This experiment is set up using the test setup from the Integrated Systems Test (Validation Document Appendix F).

Procedure

The test is conducted as follows:

1. This experiment has the same Step 1-5 as the Integrated System Test (Validation Document Appendix E).
2. After 24 hours of the system being powered on, drop the mock bird onto the top left corner of the window (exactly 3" by 3" from the corner) at the minimum angle that corresponds to the lowest speed of a common kinglet (see the Design Document Table C3).
3. Monitor the Cayenne dashboard for the first row of test data located in Table G1 for Cayenne.
4. Record the Cayenne output in Table G1.

5. Repeat Steps 2-4.
6. Repeat Steps 2-5 for 7 days.

Observations

To pass this test, a bird impact must be recorded by Cayenne every 24 hours in a 7 day span. This pass condition is determined by the need for data from the system architecture (Design Document Section 1) to function for at least 7 days without needing maintenance. Errors in the detection of bird-impact simulations are not tolerable for the system, as it would decrease the ability of the system to meet NFR2 and NFR1.

Table G1 indicates the number of bird-window collisions expected to be recorded. This is cumulative; a bird-impact collision is recorded if one occurs exactly after each 24 hour simulation. Impact count in Table G1 refers to the number presented on the counter included in the Cayenne Dashboard user interface.

Table G1 presents that all simulated bird-window collisions were recorded by Cayenne. The recorded data matches exactly the expected amount of recordings. This indicates that the Bird Impact Detection System can function reliably for a 7 day period, meets NFR1.

Table G1: Recorded data from the Integrated Reliability Test.

Expected Impact Counts	**Recorded Impact Counts**
7	7

Conclusion

The system architecture meets the condition required to pass this test. This validates the, system architecture (Design Document Section 1) as a whole, of the Bird Impact Detection System able to continuously operate for 7 days without a need for maintenance.