# A.I.R.E. - Autonomous Intelligent Roof Enclosure

**UCF Senior Design 1 - Fall 2019**
**Divide and Conquer**

*Group 8*
Sarah Riseden - Electrical Engineering
Lauren Miller - Computer Engineering
Christopher Smith - Electrical Engineering
Ronald Acevedo - Electrical Engineering

*Sponsor*
OpenAire - Retractable Roofs and Skylights

## Project Narrative

As the idea of a smart item, a.k.a. the Internet of Things technology grows in popularity, it has begun to appear in everything. The most demand being found in the smart home. In order to take the automation of a building even further, the next step would be an automated roof. In order to create a comfortable experience at any location, the roof would be retractable and glass, bringing the outside in. This system would be appropriate over facilities that can only operate comfortably in specific weather conditions, but would like to continue functioning even when Mother Nature isn't cooperating. These include water facilities, hotels, shopping centers, restaurants, cruise ships, and even residential homes. In the current market, roof systems like this exist, as created by our sponsor OpenAire. However, this collaboration will allow for further research into the system, by testing any updates and modifications before creating something full scale. This can aide in the company's growth, in order to go above and beyond any other competitors on the market.

In an attempt to solve the issue of weather restrictions, we propose a fully automated retractable glass roof. The automation would come from various sensors to provide the most comfortable outdoor/indoor experience. These sensors would be used primarily for weather predictions to detect the following characteristics of weather: rain, wind speed, air pressure, temperature, humidity, and cloud coverage. The roof will act preemptively according to the outside weather conditions, and will be able to detect if unwanted weather is on its way, not just when it arrives. The sensors would be programmable to connect to an app, where when certain thresholds are met, the roof will operate automatically. Depending on the environment that the roof will be placed over, and the climate it is built in, the roofs sensors could also be adjusted to work well in all conditions.

This system will also come with a locked app available on iPhone, that only allows owners of the roof access. This allows the user to control the system via app, and set their own thresholds for operation of the roof and lighting depending on the setting the roof encompasses. With this app, the user can build their own packages of settings and create a schedule on the roofs operation to fit business hours, daylight hours, etc. Along with providing full control of the system, the app will include the statistics read in from the weather sensors, allowing the user to make educated decisions when creating their own roof settings. The app will mainly connect via Wi-Fi as well as having Bluetooth capabilities for backup. In case of emergencies such as a power outage, Wi-Fi outage, or sensor failure, the roof will be connected to an emergency power source, and building will have a main switch inside which will override all app settings and sensor data, and close the roof.

Another pressing issue in today's society is the matter of energy efficiency. Everyone wants to save money and energy whenever possible. This roof would assist in this by the addition of solar panels to power the sensors used for automation. Along with this solar energy, the indoor lighting would have photometric sensors and connect to switch to the roof, so that they are only on when it is darker outside and/or when the roof is closed. The HVAC systems would also have a kill switch connected to the roof, turning it off when the roof is open, so as not to waste excess energy. The roof would be fit with a tinting glass which helps for controlling the inside temperature, and the indoor HVAC would be able to adjust to a user specified temperature and humidity.

Overall, this system aims to create a comfortable indoor experience for any market, especially businesses that can only operate in certain weather conditions. Energy and money will be saved by the various attributes of the roof including, tinting glass, solar panels, photometric lighting, and HVAC control. According to our sponsor, OpenAire, their customers saw up to 30% in savings for one year of energy costs. Our goal is to increase this percentage via the automation of the roof. Lastly, the system will be easily customizable by the user via iOS app, which allows for full customization of the roof's operation dependent on the needs of the building owner.

## Project Requirement Specifications

The engineering requirement specifications are broken into the key aspects of the project: enclosure, hardware, and software. The specifications, and their subsidiaries, are laid out in their respective tables below.

*Table 1: Enclosure Specifications*

| Description | Value | Unit |
|---|---|---|
| The enclosure shall be built to emulate an Olympic-sized pool environment | 18.6 x 14.4 x 8.2 | inches |
| The acrylic for the roof will be light weight | 3.5 | pounds |
| The enclosure shall have a motor capable of closing or opening the roof quickly | 20 | seconds |

*Table 2: Electrical Hardware Specifications*

| Description | Value | Unit |
|---|---|---|
| The power module shall contain a solar photovoltaic panel capable of supplying viable voltage to power the project. | +5 | Volts |
| The power module shall contain a solar photovoltaic panel capable of supplying enough amperage to power the project | 25 | Watts |
| The power module shall contain a lithium-based battery as a backup power source | 3.5 - 4.5 | Volts |
| The power module shall contain a battery management system compatible with the lithium-based battery and the photovoltaic panel | Output +5 | Volts |
| The power module shall contain a buck-boost converter capable of accepting a range of voltages at least +3.5 V and at most +46 V, and outputting the proper voltage | Output +5 | Volts |
| The power module will contain a master switch that, when activated, will close the roof and power down all devices. The switch will draw no power. | 0 | Volts |
| The barometric pressure sensor shall be capable of outputting a temperature to 1 degree Celsius accuracy. | +/- 1 | Degree Fahrenheit |
| The temperature sensor shall be capable of accepting a +5V power supply, and outputs a temperature of 2 degrees Celsius accuracy in the range of 0-50 degrees, and 5% RH accuracy in the range of 20%-90% | +/- 2<br><br>+/- 5 % | Degree Celsius<br><br>Relative Humidity |
| The anemometer shall be capable of accepting +12V power supply with a measuring accuracy of 0-45m/s. | 0 – 45 | Meters/Second |
| The light sensor shall be capable of accepting +5V power supply and reading the ambient light to an accuracy of 50 lux. | 50 | Lux |
| The pressure plate sensor shall be capable of accepting +5V power supply and can sense a range of 0-25 lbs. per square inch (PSI) | 0 – 25 | Pounds |
| The microcontroller shall have at least 6 input channels with 10-bit resolution for Analog-to-Digital conversion | 6<br><br>10 | Channels<br><br>Bits |
| The microcontroller shall be capable of accepting +5 V for its power input | 5 | Volts |

*Table 3: Hardware Constraints*

| Description |
|---|
| The wireless communication system shall contain a Bluetooth module compliant with the Bluetooth 5 standard |
| The wireless communication system shall contain a wi-fi module compliant with IEEE 802.1 |
| All devices shall be compliant with UART, SPI, and/or I2C capability for communication with the microcontroller |

*Table 4: Software Requirements*

| Description | Value | Unit |
|---|---|---|
| The board will poll the status of the multiple sensors every 5 seconds | 5 | Seconds |
| A “raining” state will be defined in the program as a point in time when air pressure is less than or equal to 1000 millibars (29.54 inches of mercury) | 1000 | Millibars |
| A raining condition will be determined within a reasonable time of the start of the storm | 60 | Seconds |
| A “windy” state will be defined in the program as 25 miles per hour winds measured 3 times in one minute | 25 | Miler per Hour |
| A “damaging sun” state is defined as 8 UV | 8 | Ultraviolet Index |
| The light ambiance will be adjusted in relation to the light external to the enclosure in a reasonable time | 10 | Seconds |
| Users will be able to select from a variety of colors for the internal ambiance | 5 | Colors |
| Each “unit” will be programmed with a 32-bit identification number | 32 | Bits |

*Table 5: Hardware Constraints*

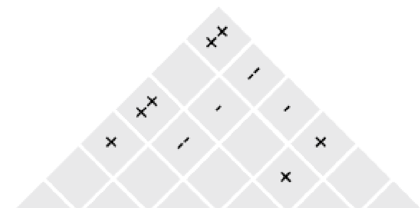
| Description |
|---|
| iOS application constraints will be based on the iOS version and phone model for design and layout of the app |
| App release will be constrained by Apple Inc.’s app requirements. |

## House of Quality

*Figure 1: House of Quality*

Legend*:*

- + Positive Polarity (Increase requirements)
- - Negative Polarity (Decrease requirements)
- ↑↑ Strong positive correlation
- ↑ Positive correlation
- ↓ Negative correlation
- ↓↓ Strong negative correlation




| | | Cost | Power Consumption | Dimensions | Sensor Accurasy | Weather API | LED Light Abilities |
|---|---|---|---|---|---|---|---|
| | | - | - | - | + | + | + |
| Building energy efficiency | + | | ↓ | | ↑↑ | ↑ | ↑ |
| Customizable | + | | | | | ↑ | ↑↑ |
| Cost | - | ↓↓ | ↓↓ | ↓ | ↑ | ↓ | ↓ |
| Accurate Predictions | + | | | | ↑↑ | ↑↑ | ↑ |
| Effiectiveness | + | | | | ↑↑ | ↑ | ↑ |
| | Target: | $835 | < 12 Volts | < 1.5 $ft^3$ | < 25% | 80% Accurate | Color control |

**Estimated Project Budget and Financing**

*Table 6: Initial Budget Proposal*

| Module | Item | Qty | Item Price ($) | Cost Estimate ($) |
|---|---|---|---|---|
| uC | Microcontroller | 4 | 50 | 200 |
| | uC JTAG interface | 1 | 100 | 100 |
| Power | Power Module | 1 | 20 | 20 |
| | Battery Management System | 1 | 20 | 20 |
| | PV panels | 2 | 15 | 30 |
| Sensors | Temperature Sensor | 1 | 10 | 10 |
| | Barometric Pressure Sensor | 1 | 50 | 50 |
| | Pressure Plate Sensor | 1 | 15 | 15 |
| | Humidity Sensor | 1 | 25 | 25 |
| | Anemometer (Wind speedometer) | 1 | 50 | 50 |
| | Adaptive light sensor | 1 | 10 | 10 |
| ADC | Analog-to-Digital Converter | 4 | 10 | 40 |
| Wireless | Wi-Fi Module | 1 | 20 | 20 |
| | Bluetooth Module | 1 | 20 | 20 |
| Peripherals and Drivers | Motor Driver | 1 | 10 | 10 |
| | Fan Driver | 1 | 10 | 10 |
| | Stepper Motor | 1 | 20 | 20 |
| | Fan | 1 | 10 | 10 |
| Miscellaneous | Miscellaneous Passives | 1 | 50 | 50 |
| | PCB Design and Fabrication | 5 | 5 | 25 |
| | Glass Tinting | 1 | 100 | 100 |
| | Waterproof Enclosure | 1 | 200 | 200 |
| Total Cost | | | | $835 |

**Initial Project Milestones and Deadlines**

*Table 7: Initial Project Timeline*

| Number | Milestone | Completion By |
|---|---|---|
| 1 | Divide and Conquer v1 Discussion with Richie | Sept 25 |
| 2 | Sponsorship and financial details finalized | Sept 27 |
| 3 | Major electrical component orders placed | Sept 30 |
| 4 | Build structure foundation | Oct 11 |
| 5 | Complete build of roof and mechanical operations | Oct 13 |
| 6 | Finish research stage | Oct 19 |
| 7 | Implement power | Oct 25 |
| 8 | Begin iOS app development | Nov 1 |
| 9 | Research write up 50-70% complete | Nov 3 |
| 10 | Master switch for open/close functionality on prototype board complete | Nov 10 |
| 11 | Begin programming microcontroller | Nov 11 |
| 12 | Begin PCB designing stage | Nov 18 |
| 13 | Add sensor connections to PCB | Dec 14 |
| 14 | Implement WiFi & Bluetooth on PCB | Jan 3 |
| 15 | Master switch for open/close functionality on app | Jan 10 |
| 16 | Implement software onto board | Jan 25 |
| 16 | Sensor Testing | Feb 8 |
| 17 | App Testing | Feb 15 |
| 18 | Full comprehensive Testing | Mar 20 |
| 19 | Senior Design Showcase | End of April |

## Hardware Block Diagram

The high-level lay out for the hardware aspects for this project is depicted below. An iOS app will be the main interface for users to interact and set certain parameters. The sensors and weather API will be the driving force for the autonomous movement of the roof. The high-level logic for the sensors is depicted in the flow chart on the next page.

*Figure 2: Hardware Flow Chart*

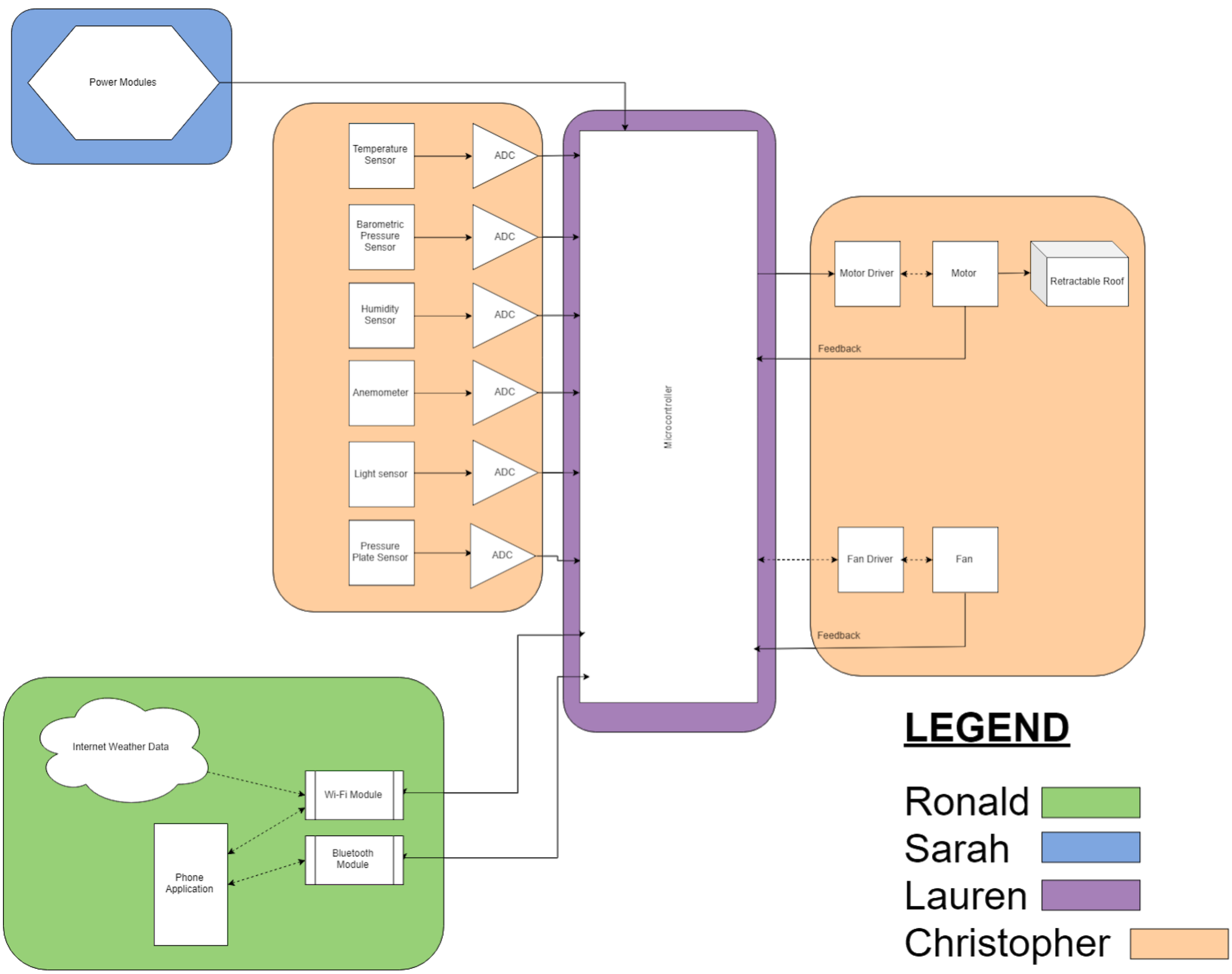


*Figure 3: Software Logic Flow Chart*