SAN DIEGO STATE UNIVERSITY

Risk Analysis and Prototype Proposal

EE/COMPE 496A Senior Design

Team 14, Project 25: Rapid Deployment Runway Closure System

The Blockage Brigade

ME Team: Alyssa Elkins, Jack Greenwood, Timothy Turner, Nicolas Wolford, Ala Zeidan

ECE Team: Sean Connolly, Khalid Nunow, Jomari Paguia, Marc Tanwangco, Bianca Yousif

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Executive Summary

The Rapid Deployment Runway Closure System (RDRCS) will allow one person to deploy multiple rapid deployment systems across the runway to prevent any unauthorized aircraft from landing based on the situation. However, there are a few risks that come into play when designing the system. Some that can be eliminated through technical analysis and trade studies. The first risk that the deployment system can encounter is battery failure. Since the lead acid battery will be operating in desert-like conditions (i.e 48℃), then the battery may overheat and cause it to fail. The battery will be powering up the entire system and if it fails, then the entire deployment system will not be able to function. The second and third risk that the deployment system can encounter is the solar panel not being able to output power due to dust conditions and the solar panel not being able to output power due to its lifespan. Every solar panel is going to die down due to panel degradation which is why it could be a risk to the system since the main function of the solar panel is to charge the battery which runs the entire system. The last two risks that the system can encounter is hardware/firmware malfunction and system interconnections. If the system deploys the inflatable when it is off rather than when it is on, there would be issues with either the firmware or hardware. Lastly, through soldering and screwing the components together on a PCB, it is possible for the connections to be in the wrong place or not working.

Now, a prototyping activity must be proposed in order to tackle several of the risks listed above. The proposed prototyping activity is to have the Arduino Due Microcontroller turn a motor on and off while simultaneously analyzing the output voltage, current, and temperature of the system when in operation. The motor would be roughly 8 amps of current. A detailed TeamGantt schedule is listed below to show how the prototyping activity is going to be implemented.

Initial Risk Mitigation

There were many unknowns when the team started working on the project. Some unknowns could be managed by small amounts of research. One unknown was that team members may not have worked with PCB software before.

There was not much experience collectively when it came to how solar panels delivered power to the system, but after a little research this risk was eliminated. However, the other aspects of solar panels such as connecting one to a battery and working with them in general is still part of our risk analysis.

Another small and avoidable risk would have been using a motor in step with the solar panel and how it would be connected to each other. After a bit of research, it was found that connecting a DC motor is the easiest and best choice of motor to power with solar panels. However, if an AC motor is needed then that is also possible but will need a power inverter to change the DC to AC current to be fed into the motor.

Soldering is a skill that will be very useful in the development of the prototype. A big portion of the team has had some past experience with soldering but a quick refresher would be needed on the skill. This can easily be accomplished with a little research and practice so this is also an initial risk that can be mitigated.

Risk Analysis

Electrical/Computer Engineering Risk Table/Cube

Risk List			
Risk	**Description**	**Probability/ Likelihood**	**Impact**
1) Battery Failure	Since the battery will be operating in desert-like conditions,(i.e 48℃) it may overheat causing it to fail. As lead acid batteries absorb high heat, chemical activity in the battery accelerates. This will reduce the life of the battery at a rate of 50% for every 10℃ increase from 25℃. In order to reduce this from happening, a battery management system (BMS) can be used. Using a BMS can monitor and manage all of the battery's performance. Most importantly, it keeps the battery from operating outside of its safety margins (i.e calculates how much current can safely go in and come out without damaging the battery).	In the likelihood that the battery is dead or overheats due to environmental conditions, using a BMS can help with this risk. The probability of the risk occurring is estimated to be a 2.	After researching BMS, the impact this can have on the system is a 1.

2) Solar Panel Condition Issue	Since the Solar Panel would power up the battery. If it fails, the system would not function. In desert-like environments (i.e winds up to 95mph/80 knots), dust can build up and block sunlight which can negatively impact the solar electricity output.	The probability of the risk occurring is estimated to be a 3.	The solar panel is the main component for getting power to the system. This impact is a 4.
3) Solar Panel Durability	Over time, the solar panel will die down and eventually not work. If a solar panel is constantly in high temperatures (i.e over 25℃) then it will accelerate panel degradation. This means that a solar panel will lose its power output over time. Most of the solar panels degrade at a rate of about 0.5% every year which will generate around 12-15% less power at the end of their 25-30 year lifespan.	Since it is estimated for a solar panel to last 25-30 years, the probability would be a 1.	The solar panel's purpose is to charge the battery that is running the system therefore, if the solar panel dies down, the battery will continue to work and power the system. The impact is a 4.
4) Hardware/ Firmware Malfunction	Since the Arduino will use C code for managing the input and outputs of the system, there may be issues with the firmware/hardware that causes the system to not work correctly.	If the system deploys the inflatable when it is off rather than when it is on, there would be issues with either the firmware or hardware. The probability of the risk occurring is estimated to be a 3.	The Arduino is the main source for all the buttons and switches to function and communicate with the system. This impact is a 4.

5) System Interconnections	The PCB will have connections between the Arduino, motor, solar panel and battery.	Through soldering and screwing the components together on a PCB, it is possible for the connections to be in the wrong place or not working. The probability of the risk occurring is estimated to be a 2.	If the PCB had connections that were not correctly placed, the system would not operate correctly. This impact is a 4.

Likelihood

5					
4					
3				2,4	
2	1			5	
1				3	
	1	**2**	**3**	**4**	**5**

Impact

Figure 1: Risk Cube for ECE Risk Table

Mechanical Engineering Risk Table/Cube

Risk List				
Item	Risk Statement	Consequence	Likelihood	Mitigation Method
1	If a materials supplier only sells our chosen material in bulk, then we might have to resort to a more expensive option or change the material entirely	3	2	If the team reaches out to material suppliers early on to see what buying conditions look like, we can have more time to find a new supplier or different material.
2	If the materials required to build the device exceed the established budget, then more funds will have to be requested from our sponsor, which might not be available.	2	3	If all materials are researched and cross checked with multiple sellers to find the lowest but most effective price, we can maximize funds and project more accurate cost estimates for our sponsor.
3	If the school is required to go virtual due to a covid outbreak, then in person project time will be eliminated & access to campus resources will be limited	5	2	If the team creates a covid action plan to establish project time and find exterior shops to allow for essential facility use, the negative effects of the lockdown will be diminished.
4	If delivery is postponed due to covid or other circumstances, then materials and prototype testing will be delayed	4	4	If we plan to order early and utilize in store components as much as possible, we can increase the time we have to make purchase adjustments and avoid waiting for deliveries all together.
5	If the inflatable experiences a point of weakness ruining the air tight system, then the overall intended function of the device will be mostly lost.	4	2	If the inflatable material is extensively researched for strength properties and UV resistance, we will be better equipped to create an airtight system resistant to defects.
6	If the retraction system fails, then the aircraft will be forced to land over the device and it will be required to be manually retracted	3	3	- If the prototype is tested to identify any mechanical weaknesses, the retraction system will be less likely to fail. - If the material is researched so that a light and safe choice is selected, then it will not damage the aircraft in the event of a forced landing.
7	If the electrical components experience failure, then most of the device's mechanical roles will lose functionality	4	2	If the team works with ECEs to determine temperature constraints of all components and prioritize using electrical components with high temperature ratings, then the integrity of the electrical system will be strengthened.

8	If the solar panel does not generate the required energy demands, then the entire system will not function.	5	3	- If the team calculates, estimates, and tests energy demands of every energy utilizing component, then a better understanding of system energy demands will be clear. - If climate data is considered to gage weather patterns, then an energy income estimate will be available to manage power expectations.

Likelihood						
	5					
	4					
	3					
	2		1	6	4	3
	1			2	5, 7	
		1	**2**	**3**	**4**	**5**

Consequence

Figure 2: Risk Cube for ME Risk Table

Prototype Activity

1) For the prototyping activity, the team plans on prototyping with a motor that puts out about 8 amps of current and an Arduino Due Microcontroller that allows for the Arduino Due to have the motor turn on and off. The risks that the prototyping activity would cover are one (battery failure) and four (hardware/firmware malfunction). In the testing phase, the team plans on having the motor turn on for two minutes and off twenty minutes at least ten times and analyze output voltages, current, and temperature.
2) For this prototyping activity, the team plans on developing the C code required for the Arduino to interact with the motor to turn on and off. For the first two weeks, the team would develop the code necessary to have the Arduino communicate with the motor to turn on and off while also ordering the necessary components needed for the prototype. In the final two weeks, the team would test and debug our prototype while also developing our prototype activity report.
3) In order to test our prototyping activity, the team will look at the output voltages that the battery is sending to the Arduino and if enough voltage is being applied to the motor. Also, the team will analyze the current from the Arduino to the motor so that it allows for enough current to operate at its fullest potential. Temperature is the last measurement the team will be looking at since the system should not be overheating the Arduino or the battery. For this prototyping activity, the team will be needing an infrared thermometer to measure the temperature of our system when in operation, a digital multimeter to measure the voltage and current, and an oscilloscope to view the outputs of voltages when the system is running.

Schedule

Week 1:

- Order Items Needed for Prototype
- Start Writing Code for Arduino/Interface

Week 2:

- Continue Coding for Arduino
- Start Wiring the Items Together

Week 3:

- Begin Debugging and Start Testing

Week 4:

- Finish Testing
- Work on Prototyping Activity Report

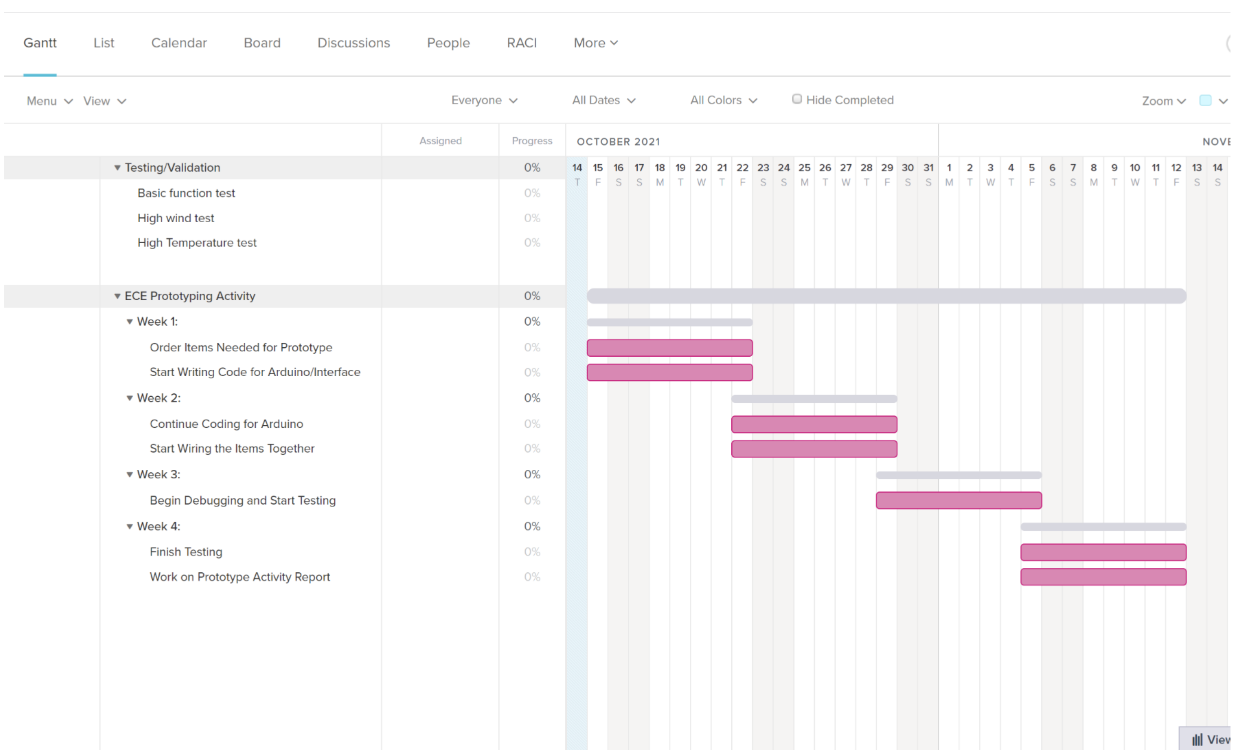

Figure 3: ECE Prototyping Activity TeamGantt 4 Week Expectations

Appendix

San Diego State University

System Description, Requirements, and Validation Document

EE/COMPE 496A Senior Design

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Executive Summary

The Rapid Deployment Runway Closure System (RDRCS) will allow one person to deploy multiple rapid deployment systems across the runway to prevent any unauthorized aircraft from landing based on the situation. The user of the RDRC system will use a series of buttons and switches to activate the blower to release the bright-colored inflatable across the 60-foot runway. If an aircraft needs to land on the runway, the inflatable will be able to deflate so that the aircraft could land safely. Once the inflatable has done its job, it will retract back into the system within 3-5 minutes. In order for the system to get power, the solar panel will use the photons produced by sunlight to generate DC then flow to the systems inverter where it's converted to AC then with the help of a charge controller will be able to store excess into battery during peak sunlight hours.

The core of the Rapid Deployment Runway Closure System is using an Arduino Due Microcontroller which is a dominant component to the system. The RDRCS will include writing firmware, containing C code, to allow for the buttons and switches to work properly as shown in Figure 3. For more information and descriptions on the different components can be found in the “Development and Procurement” section of this report.

A stretch goal for the Rapid Deployment Runway Closure System is to create a remote control where a user within a certain distance could activate the system. Utilizing radio signals is one of the ideas in order for the controller to respond to the deployment system and within a certain time frame.

Functionality

The Rapid Deployment Runway Closure System (RDRCS) will allow aviation workers to deploy multiple rapid deployment systems across a personal aircraft runway in order to prevent any unauthorized aircrafts from landing. These remote runways are used by owners/operators rather than a full team of people like normal airport runways. Therefore, the user of the RDRC system will have to first toggle the ON switch in order to turn the system on, and then press a button to activate the blower fan. This will then create an inflatable bouncy house type of object that will be laid out across the runway as shown in Figure 3. The system will be powered through the solar panel and will use the photons produced by sunlight to generate DC then flow to the systems inverter where it's converted to AC then with help of a charge controller will be able to store excess into battery during peak sunlight hours. These runways contain no type of lighting therefore, the RDRCS would be a way for pilots to see the runway easier. If an aircraft is going to land on the runway, the inflatable will deflate from the system and the aircraft will be able to safely land on it. Once there is no need for the inflatable, it will retract back into the system.

Inputs/Outputs

For the inputs and outputs, Figure 3 shows the layout of the control system and in Figure 4, shows the layout of the PCB. One of the inputs that would be used would be a pin switch, which has a maximum AC voltage rating of 125 to 250 volts and maximum current rating of 8 to 16 amps. Another input would be a push button and it has a power rating of mac 50mA 24V DC. Figure 4 under the physical description shows the PCB layout. On one side of the PCB, it shows the inputs such as the ON/OFF switch, pin switch, and push button switch; while, there is also an output which is the RGB LED at the bottom. On the other side of the PCB, there is the Arduino Due Microcontroller and the dimension of it is shown as 4 x 2.2''. Adding the step down DC voltage to the PCB allows the 12V from the solar panel to "step down" to a maximum of 3.3V needed for the Arduino Due Microcontroller. This project also requires a 200W ruggedized solar panel. On average, a 200W 12 volt solar panel delivers up to 18 volts when it charges therefore producing 11.1 amps. It is not possible to have the voltage panel the same as the battery voltage. The panel would not work. However, this information is not exact because there can be days of no sunlight which could affect the amount of power that can be provided. This is why the battery will be in charge of powering up the entire system.

Use Case

The purpose of the Rapid Deployment Runway Closure system is to deploy an obstacle on the aircraft runway in order to prevent any unwanted individuals from landing their aircraft without any authorizations or permissions. This system shall be able to operate with a single person and inflate and deflate through a powered system. In Figure 1 and Figure 2, both show the basic system while also showing how an individual may use the system.

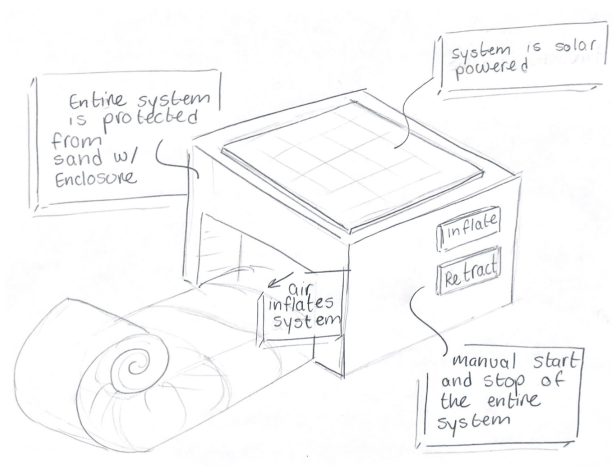

Figure 1: Basic System with Expectations

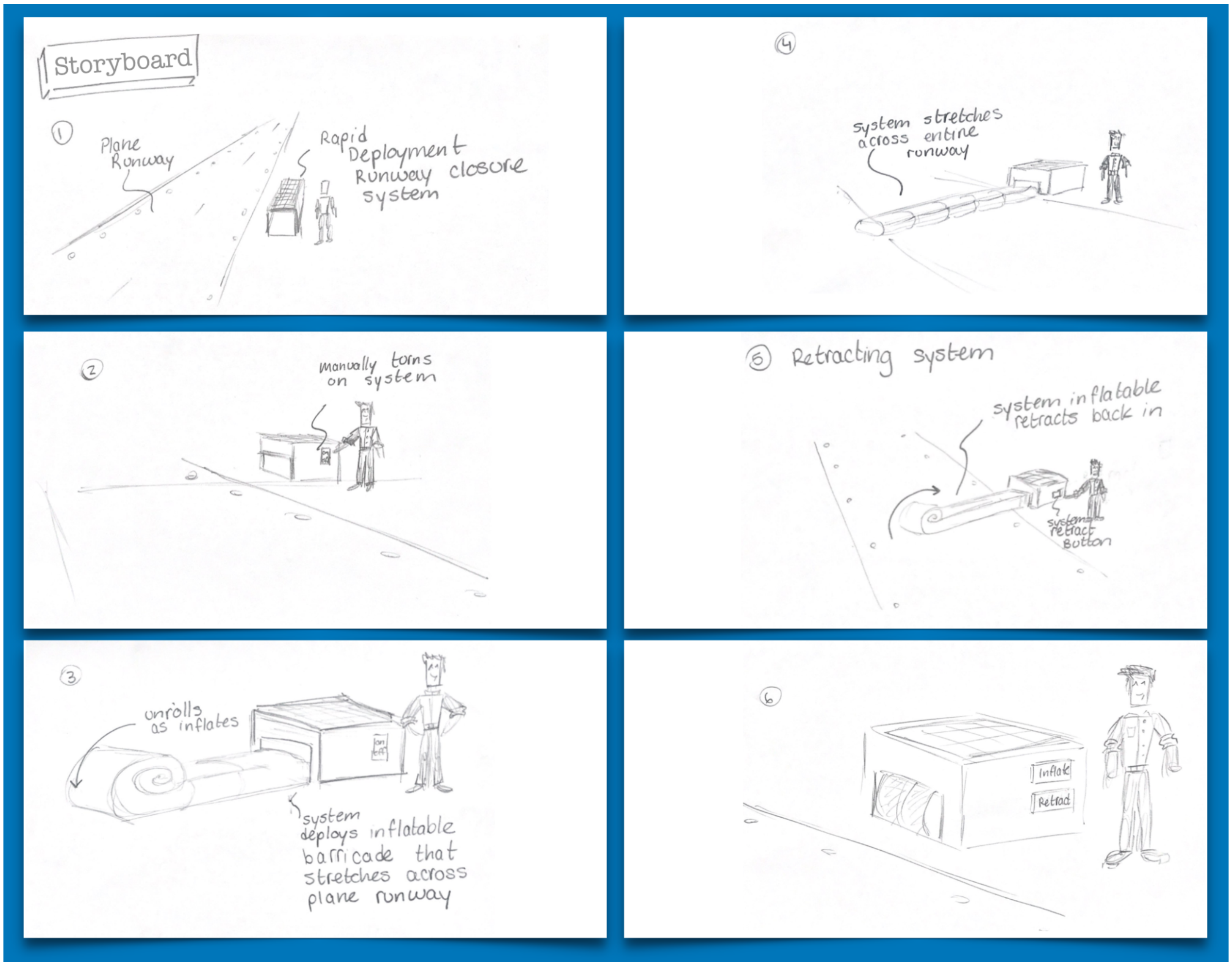

Figure 2: Storyboard of Use Case

Physical Description and User Interface

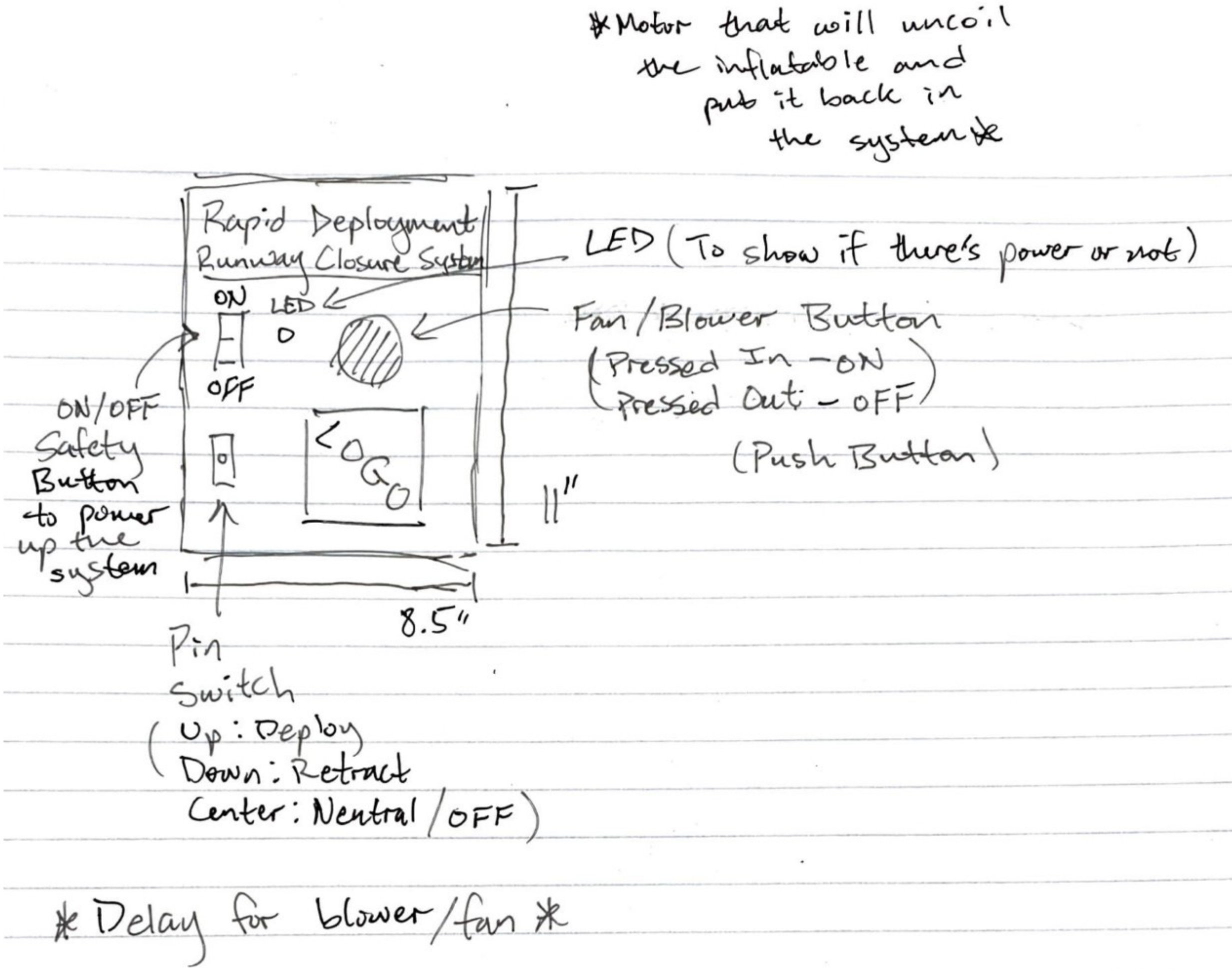

Figure 3: Sketch of the Rapid Deployment Runway Closure System

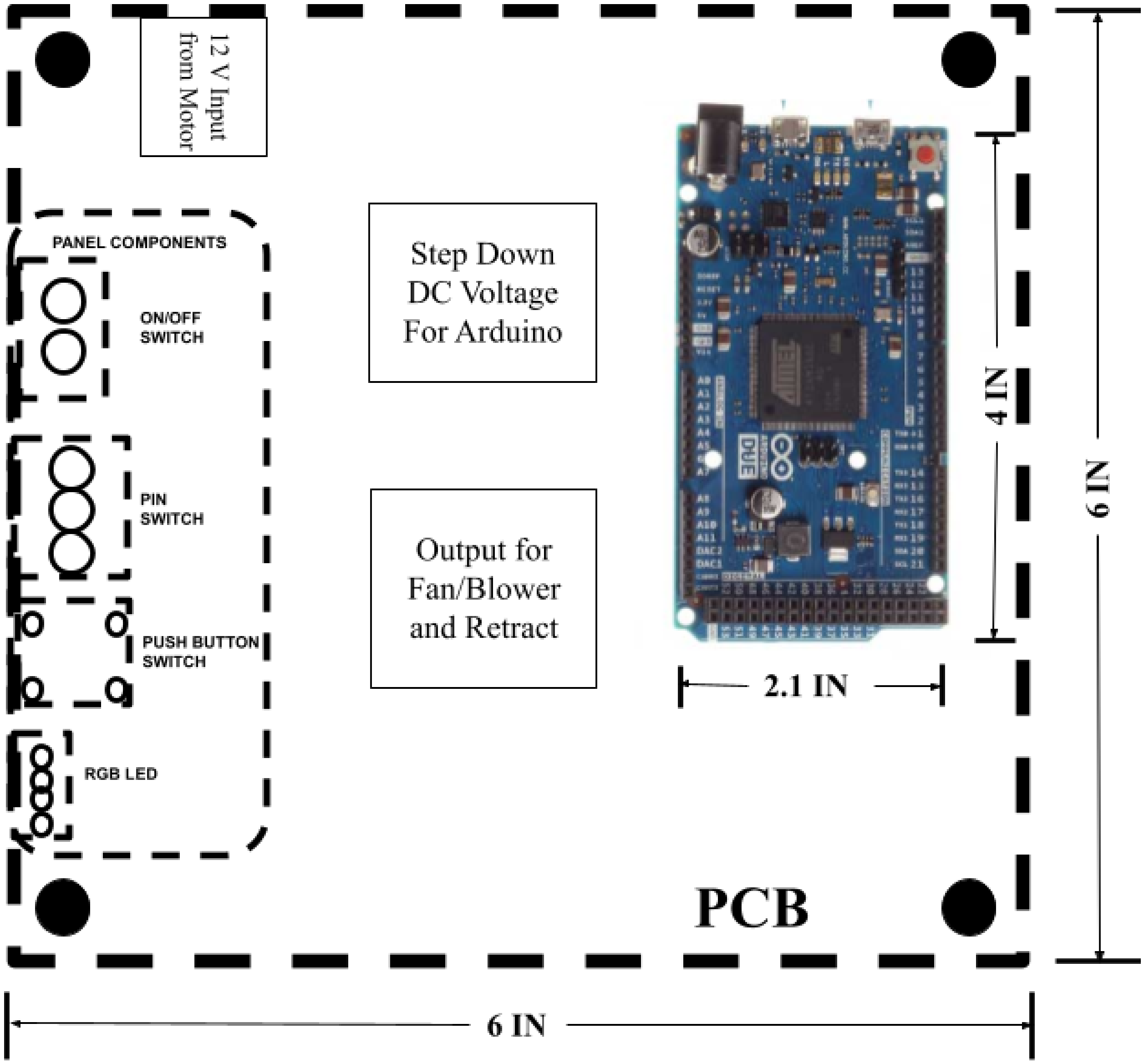

Figure 4: Sketch of the PCB going into the system

Development and Procurement

Arduino Due Microcontroller:

The Arduino Due Microcontroller will be used as the base for the Rapid Deployment Runway Closure System where this is all the firmware and hardware aspects of the system. This microcontroller allows for the system to use buttons/switches to operate the system when needed. The Arduino Due Mircrocontroller runs on 3.3V and the maximum voltage that the I/O pins can tolerate is 3.3V. Applying voltages higher than 3.3V to any I/O pin could possibly damage the board.

Embedded Systems:

The Rapid Deployment Runway Closure System will induce an embedded system that deals with interrupts and delays. In order to be able to use interrupts and delays within the Arduino Due Microcontroller, C code will have to be used. After this, the downloaded code that was created into the microcontroller, will be attached to the PCB.

Electromechanical Hardware:

The Rapid Deployment Runway Closure System will use an ON/OFF switch, pin switch, RGB LED, and a push button. These components will allow for the system to work correctly with the physical system and power supply. These components and the layout could be seen in the physical description section of the report.

Power Systems:

The Rapid Deployment Runway Closure System will have two sources of power and they are from a roughly 200W ruggedized solar panel and a 12V lead acid battery. These two sources would be connected so that energy from the sun would go through the solar panel and store the energy into the battery where we would get most if not all of the power for the entire system.

Specifications

1) The system shall operate during the daytime hours (R1-003) and withstand any environmental issues (R1-002) (desert-like temperatures, sand, dust, etc).
2) The system shall be operable at 50 knots of wind and survivable at 80 knots (R1-005).
3) The system must be able to operate by a single person (R1-004).
4) The system shall deflate when an aircraft must make an emergency landing.
5) The inflatable system shall retract (S1-001) within 3-5 minutes.
6) The system must use a 200W ruggedized solar panel as per sponsor's request.

Table 1: Rapid Deployment Runway Closure System ECE Test Fixture Specifications

Reference	Title	Specification	Notes
Material Cost			
TF-1	Material Cost	The Material Cost of the Rapid Deployment Runway Closure System shall be less than $2500.	What the sponsor provided
Construction			
TF-2	PCB Components	The Rapid Deployment Runway Closure System shall use through-hole PCB components.	
Physical			
TF-3	PCB Dimensions	The PCB shall have dimensions less than 6.0 x 6.0"	
TF-4	Enclosure	The enclosure that the system is stored in shall be 1 cubic yard.	May change depending on sponsor's preference
TF-5	Ruggedized Solar Panel	A 200W ruggedized solar panel that must be on top of the system.	Sponsor's Request

TF-6	Pin Switch	Pin switch that shall be used to deploy, retract, and turn off the inflatable	
TF-7	RGB LED	The LED shall be used to let the user know if the system has enough power or not	There will be a few color codes such as: RED: OFF GREEN: ON ORANGE: NOT ENOUGH POWER
TF-8	Push Button	The push button must be used when it is pressed in and when it is pressed out it's off.	
TF-9	ON/OFF Switch	The ON/OFF switch shall be used to power up the system.	
TF-10	Arduino Due Microcontroller	The Arduino Due Microcontroller must be used to allow for delays and connections of the power supply with the control system and placed on the PCB.	Will use C to code the interrupts/delays needed for the switches and buttons
TF-11	Fan	The fan must be used for the electrical box so that the system won't overheat inside.	
TF-12	Heat Sink	The heat sink must be attached to the PCB.	
Power Supply			
TF-13	Input Voltage	The Rapid Deployment Runway Closure System must pass all performance tests with an input voltage of 12V.	
TF-14	Operating Current	The Rapid Deployment Runway Closure System shall have 10-12 amps of power coming from the solar panel per hour.	

Table 2: Functional and Physical Requirements and Details

Requirement Number	Priority Level (1-highest 5- lowest)	User Requirement	Justification	User Requirement Information Sources
R1-001	1	System shall retract fast	An operator of the device needs to be able to open the runway quickly	Sponsor Request
R1-002	1	System shall be sand resistant	System will be operating in remote locations including the southern california desert	Sponsor Request, it will operate in remote locations
R1-003	1	Shall be daylight operable	Planes will only use the runway in the daytime, system needs to work during that time	Sponsor Request
R1-004	1	The system shall be operable by a single person	Remote runways are used by owner/operators, not a team of people	Sponsor Request
R1-005	1	System shall survive high winds	System will be operating in remote locations including the southern california desert	Sponsor request
R1-006	1	System shall span 60 feet	A remote runway is typically that wide	Airport Design and Operation Antonín Kazda and Robert E. Caves, page 96
R1-007	1	System shall operate using solar power	Typical runway will be in a remove environment without power to it	Sponsor request

Table 3: Functional and Physical Specifications and Details

Specification Number	User Requirement	Engineering Specification	Justification	Engineering Specification Information Sources
S1-001	System shall retract fast	System shall retract within 3-5 minutes	Sponsor requirement, need to verify with sponsor	Sponsor Request
S1-002	System shall be sand resistant	System shall operate to Mil-STD-810 sand and dust testing, or equivalent ASME specification	System will be operating in remote locations including the southern california desert	Sponsor request

S1-003	Shall be daylight operable	System shall last for 5 years without becoming inoperable due UV	System will be operating in remote locations including the southern california desert	Sponsor Request, need to do some research
S1-004	The system shall be operable by a single person	Each sub system shall weigh less than 51 lbs,	Remote runways are used by owner/operators, not a team of people	NIOSH 94-110
S1-005	System shall survive high winds	System shall survive 80 knots (92 mph)	System will be operating in remote locations including the southern california desert	Sponsor request
S1-006	System shall span 60 feet	System shall span 20 m (60 feet)	A remote runway is typically that wide	Airport Design and Operation Antonín Kazda and Robert E. Caves, page 96
S1-007	System shall operate using solar power	System shall use 200 watt ruggedized solar system	Sponsor request	Sponsor request

Validation and System Test

System Test: Rapid Deployment Runway System

Procedure:

1) Verify that the device is aligned with the runway and facing the runway

2) Flip open the shield panel

3) Verify that the power switch is in the OFF position

4) Verify that the power LED is dim (OFF)

5) Switch the power switch to the ON position

6) Verify that the power LED is lit green (ON) and is bright enough to see in bright desert daylight

7) Switch the PIN switch to the up (deploy) position

8) Press the red button until completely recessed

9) Verify that the device deploys the inflatable material onto the runway evenly and consistently

10) When the inflatable is completely deployed after 3-5 minutes, press the red button until reset to original position to stop the fan/blower

11) Switch the PIN switch to the down (retract) position to begin retraction process

12) Verify that the inflatable is being retracted back into the device evenly and consistently and within 180 seconds (per sponsor request)

13) Once inflatable is completely retracted, switch the PIN switch to the middle (neutral) position

14) Switch the power switch to the OFF position

15) Verify that the power LED is dim (OFF)