Cover Page

Title of Design:	The Wingman 360: A Practical Approach to Automated Wingtip Collision Avoidance
Design Challenge Addressed:	IV. Airport Management and Planning
University Name:	University of Rhode Island
Team Member Names:	Mitchell Contente
	Laura Corvese
	Cody McMillian
	Gilbert Resto
Number of Undergraduates:	4
Number of Graduates:	0
Advisor Name:	Dr. Bahram Nassersharif

The Wingman 360

A practical approach to automated wingtip collision avoidance

Team Members:
Mitchell Contente - Design Engineer
Laura Corvese - Team Leader/Coordinator
Cody McMillian - Market Analyst
Gilbert Resto - Electrical Design Engineer

Faculty Advisor
Dr. Bahram Nassersharif

Sponsors
Delta Airlines
Rhode Island Airport Corporation

Submission Date
April 27, 2016

Executive Summary

The goal of the Airport Cooperative Research Program design competition is to challenge engineering students to find creative and innovative solutions to everyday problems that plague airports and airlines every day. This team selected a challenge relating to airport management and planning, specifically creating an aircraft wing tip collision avoidance system.

Wing tip collisions incur major costs to airlines yearly in repairs, re-qualifying, and aircraft downtime; repair costs for collisions can exceed $200,000 (Files, 2015). Many of these wing tip collisions occur during hangar operations, where current method for collision avoidance is heavily reliant on human response and judgment. The goal of the device developed by this team is to remove the human error factor and completely automate the 'wing walker' position, giving the tug driver more assurance that he or she will not damage the aircraft they are moving.

The team worked closely with representatives from Delta Air Lines to complete a rigorous design schedule, from project planning, to prototype building and testing. The final product was designed to successfully detect an object up to 10 feet away, using ultrasonic sensors, and give an audible warning to the tug driver to alert of a close object, using radio frequency transmission and LED lights. This device is lightweight, easy to use, and able to withstand a drop of up to 20 feet. The Wingman 360 was proven to work in field testing and is an applicable and cost effective solution to the wingtip collision problem.

Table of Contents

List of Figures

List of Tables

1 Problem Statement and Background

1.1 Problem Definition

Aircraft wingtip collisions are issues that plague major airlines every year. These collisions occur when an aircraft is being taxied; on the ground in runway or hangar operations. Most commonly, wingtip collisions occur in hangar operations, where many aircraft are being moved in close proximity to hangar walls, and one another. The current solution for this problem is typically to have an employee called a wing walker, follow the aircraft wing and watch to make sure it does not hit anything. If the wing walker feels as though the aircraft is getting too close to something, he will signal to the tug driver using an air horn and hand signals. This method has a high amount of human error, as detection distances are often subjective, and any distraction can result in disaster.

The 2014 FAA competition winners from the University of Rhode Island explored this problem and created the Wingman (Wheeler, 2014). This device is applicable for smaller aircraft as it relies on LED lights and a buzzer. This would require the tug driver to be able to see both wings and monitor the LED lights, which is less applicable for larger aircraft. The goal of the 2016 design team was to redesign the Wingman to create a device that can be used on commercial aircraft. This problem falls within the airport management and planning category of the 2015-2016 ACRP design competition.

1.2 Prior Work and Considerations

Solutions to stopping aircraft wingtip collisions have been proposed and researched by many companies. These solutions include permanently installing cameras into the wingtips, and implementing built in radar sensors. The FAA recently rejected a proposition to require aircraft to have a built in collision detection system due to the potential decrease in fuel economy (Broderick, 2013). Such a system is also not desirable for commercial airlines as this would require all aircraft to be taken out of service to install the system.

Currently, solutions have been put in place to minimize these collisions; however the methods are not currently 100% effective. This is clear as companies like Delta Air Lines claim to have at least four aircraft wingtip collision incidents occur in hangar operations per year. As the FAA has rejected the proposition to require a permanent wingtip collision avoidance system, research on the topic may have slowed.

1.3 Effect on the Industry

Major airline companies, like Delta, spend hundreds of thousands of dollars every year in repairs, down time, and requalification of aircraft that have experienced a wingtip collision. Delta reported that within two years, they experienced six hangar wingtip collisions. These collisions totaled $778,416 in aircraft repair. (Files, 2015). These costs, however, do not include fairs lost due to aircraft down time. It is clear that these collisions impose a major cost to airlines. This cost, coupled with the downtime of an aircraft greatly inconveniences the company

1.4 Proposed Solution

The solution explored by the 2015-2016 ACRP competition team's design is an improvement and expansion upon the 2013-2014 FAA competition design. The Wingman 360 consists of a non-permanent module that mounts to an aircraft wing using suction cups. This device contains ultrasonic sensors that detect when an object has come within 10 feet of the aircraft. To alert the tug driver of such an incident, the device communicates through radio frequency with a handheld module that will be kept on the dashboard of the tug. This device contains LEDs and a buzzer that will light up and sound when an object is detected within the specified range. This solution does not require permanent installation or maintenance that would ground an aircraft, making it desirable to major airlines.

2 Summary of Literature Review

2.1 ACRP design competition goals

The Airport Cooperative Research Program (ACRP) is a program of the National Academies' Transportation Research Board and is sponsoring a design competition for colleges across the country. The call for competition asks students to select a challenge from a category such as runway safety, or airport management and planning, and create an innovative, unique, and applicable solution to the problem. To aid in the designing process, student groups must work with professionals in the aviation industry. The main goals of the ACRP design competition are to raise awareness of the benefits of the ACRP, to increase the involvement of the community in ACRP, and to engage students at colleges and universities around the countries in the design process for creating a product that is capable of addressing a serious issue. The purpose of the ACRP design competition is also to raise awareness and incite excitement for the fields of engineering and technology as they relate to airports and airport safety (ACRP, 2015).

2.2 Delta Air Lines Wingtip Collision Incidents

As the design team worked closely with Delta Air Lines, the company provided figures for their aircraft wingtip collision repair costs. The data provided was from the 2014 calendar year and reports that 6 incidents occurred, incurring a cost of $778,416 in repairs. It is clear that Delta's current system is not fully reliable as they still have multiple wingtip collisions per year.

Most commonly, these collisions occur between an aircraft and the hangar wall, see Figure (1). When the aircraft is being moved into a hangar, the tug driver is pushing the plane at approximately 2 miles per hour. The slow speed is required for moving aircraft in and out of the hangar. This slow speed coupled with the current wingtip collision prevention system that Delta has implemented, however is not successful. The amount of time that it takes for a warning to reach the tug driver from the wing walker may be too long, and because the aircraft is very heavy, it takes the tug driver several feet to stop.

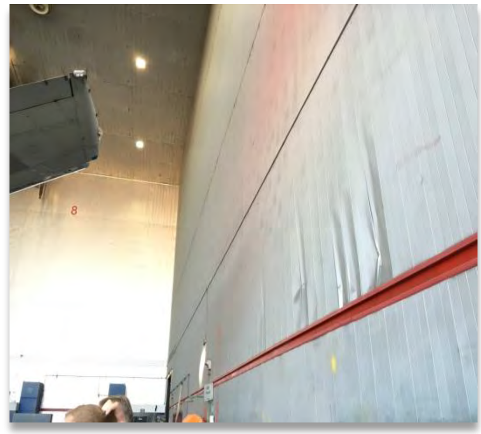
Figure 1: Damage on the Delta Air Lines hangar wall from wingtip collisions in Atlanta, GA

2.3 Research and Patent Search

As previously stated, the Wingman 360 project is an improvement and redesign of the original Wingman project. Due to the unique nature of the original project, the 2015-2016 design team needed to fully research the original design by testing the prototype, as well as reading the original design report. Prior to beginning work on the project, the team performed a literature review and performed a patent search to understand the history of the approaches to solving this problem. It was found that many companies, including those like Honeywell, have been working to create solutions to this problem; however most were based on permanent systems being installed in an aircraft wing.

One example of this permanent solution is patent number 9,037,392: Airport Surface Collision-Avoidance System by Honeywell (*U.S. Patent #9,037,392,* 2012). This design consists of cameras mounted in the wings themselves that live stream video to the pilot within the cockpit, see Figure (2). The design also implements lasers that point out directly from the cameras to give a visual on distances. Honeywell's patented design would require maintenance on all aircraft to permanently install the system, as well as regular maintenance to ensure that it continues working properly. Another drawback of the design is that it sends information from the cameras to the pilot himself. When most aircraft wingtip collisions occur, the pilot is not controlling the motion; the aircraft is being taxied by a tug operator.

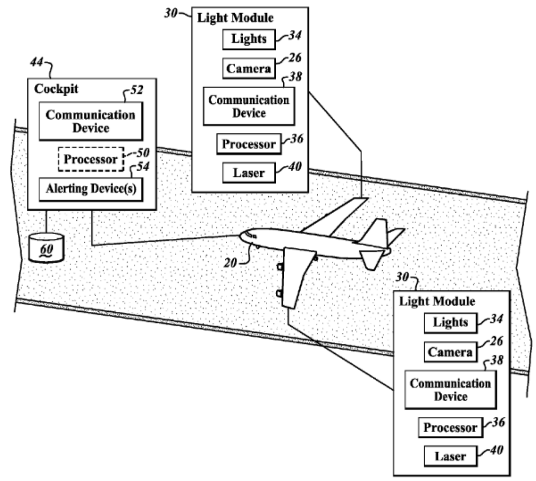

Figure 2: Schematic of Honeywell's collision avoidance system

Another design that aims to solve this problem is patent number 6,963,293: System and Method of Preventing Aircraft Wingtip Ground Incursion (*U.S. Patent #6,963,293*, 2005). This design uses light sockets that are already on aircraft wings to project a pattern out on an object that comes in the path of the aircraft, see Figure (3). This system would not require any additional wiring directly into the aircraft; however it is a permanent solution that would need to be installed. Another issue with this device is that it would somehow need to be

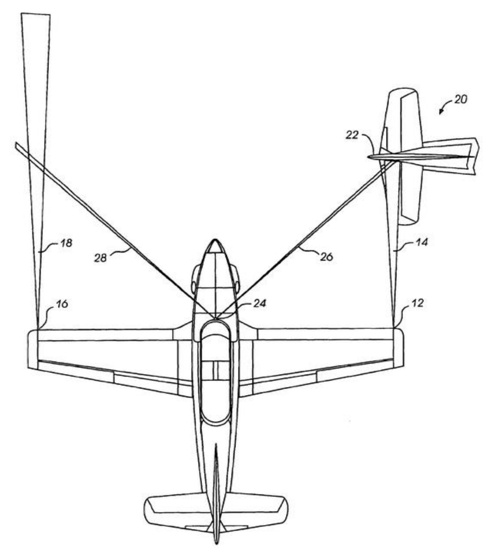

Figure 3: Schematic of patent 6,963,293

turned on during these taxi operations. This would not be a problem during runway operations as the pilot will be in the cockpit, however during hangar operations, there is no one in the aircraft to turn the system on.

Through the patent search, the team was able to learn what ideas have already been developed to solve the wingtip collision problem. After the patent search and researching process, the team was able to create their list of possible solutions. The research portion was very important as the team needed to ensure they were not creating something that has already been patented or done before.

2.4 Methods of Wingtip Collision Prevention

Currently airlines are implementing methods for preventing wingtip collision, mostly involving using employees called wing walkers. For each tug operation, two wing walkers are required, one for each wing. These employees will walk with the wing and watch the tip to ensure the tug driver does not get too close to any objects. When the wing walker feels as though the aircraft has gotten too close to something, he signals the tug driver with his hands, and sometimes a small air horn. This method is subjective as different employees may have a different ideas of an appropriate detection distance.

Another method that some airlines have used is a system called the WingWalker Collision Avoidance System (Conney Safety, 2015). This system is comprised of wands that are held by the wing walkers, a receiver device and strobe that the tug driver has. The system works by the wing walker pressing the button on the wand if he feels as though a collision will occur. This then sends a signal to the receiver box in the tug, which then vibrates and emits a sound up to 120 dB and lights up the strobe. The system which includes two transmitting batons, a wireless beacon, vibrating alarm pager, and charging stations costs a total of $630 and is shown in Figure (4).

This system, however, does not remove the human error issue, as a wing walker is still required to make the system work. Representatives from Delta Air Lines also mentioned that they tried a similar system and had issues with reliability (Files, 2015). The team therefore understands that the Wingman 360 must provide reliable collision avoidance in order to be used in industry.

Figure 4: The WingWalker Collision Avoidance System

3 Team's Problem Solving Approach

At the start of the design process, it was clear that to work efficiently as a team, tasks and responsibilities needed to be divided. Laura Corvese was appointed as the team leader based on management ability and prior work experience. The remainder of the team were given roles related to the mechanical design, construction, electrical design, financial management/analysis, based off of individual strengths. A Gantt chart was created, for project planning, and constantly updated to schedule tasks and help keep the team on time and meeting deadlines. The team held regular meetings throughout the competition period. In the beginning of the project, these meetings were centered around selecting a challenge area, and beginning concept generation.

3.1 Concept Generation and Refinement

The team selected the challenge area of airport management and planning, to improve upon a previous teams competition design. After challenge selection, each member was responsible for coming up with at least 30 unique concepts to solve the problem of aircraft wingtip collisions. The team then collaborated with Rhode Island Aviation Corporation (RIAC) personnel at Theodore Francis Green (T.F. Green) airport to discuss the possible ideas. Among the standout concepts brainstormed in the meeting was one involving setting up zones and boundaries on taxiways and aircraft parking spaces. Sensors could be used to alert vehicles when they were inside these zones and remind them to slow down. The system would also be able to detect if any vehicles or personnel were inside the perimeter established and warn the tug driver. Another idea involved using a laser positioning device to mark the boundaries that the plane should be within. If the plane crossed this boundary and got too close to a wall or another planes zone an alert would sound. The third idea involved making a removable wing mounted sensor system which would detect when the plane wing tips came too close to surrounding objects.

The team was soon contacted by Delta Air Lines who were interested in a device which could help prevent collisions frequently happening in their main hanger in Atlanta, Georgia. A meeting with Delta's hangar operations team was arranged to discuss details of the project and the team's ideas. Once meeting with Lorraine Dimarco, Tim Files, and Jordan Lyle, it was decided that a non permanent wing mounted sensor system would be most practical and effective for their situation.

After meeting with Delta representatives, the team created a comprehensive list of design specifications. These specifications needed to be met by the final product in order for it to be most effective. The specifications can be seen in Table (1).

Table 1: Design Specifications

Parameter	Specification
Impact survivability	Survive drop test from 20 feet
Detection Distance	10 feet
Weight	Less than 10 lbs
Battery Life	At Least 8 Hours
Device hold time on wing	Minimum 1 Hour
LED Visibility	Easily identifiable by tug operator
Alert Buzzer SPL	At Least 90db at tug driver position
Weatherproof	Fully waterproof in outdoor storm conditions
Mounting	Mounts to either the bottom or side of the wing

After this milestone, the team was able to begin the preliminary design process. A design was agreed upon and drawn up in SolidWorks for prototyping. The team also researched and selected the best components to meet the design specifications put forward by Delta Air Lines. The team decided that 3D printing the initial prototypes would be most effective as it gave quick results and was very cost effective.

3.2 Testing

To ensure that all of the design specifications put forth by Delta Air Lines were addressed, extensive testing was required. Electrical components, such as the sensors and radio frequency devices, as well as mechanical components such as the suction cups and material strength, needed to be tested. Each individual component is critical to the proper functionality of the Wingman 360 device and was thoroughly tested. Data analysis was performed on the results including statistical analysis where appropriate.

3.2.1 Sensor Testing

The Wingman 360 system utilizes eight (8) Maxbotix ultrasonic sensors, arranged at angles such that a full 180 degree field of view is visible when the device is mounted under the aircraft wing, or on the side of the aircraft winglet. These sensors were tested for both accuracy and detection area using a 24 X 36 inch board. Accuracy tests were run by aligning a sensor straight down a long hallway, and moving a board away from it, in increments of 6 inches, see Figure (5).

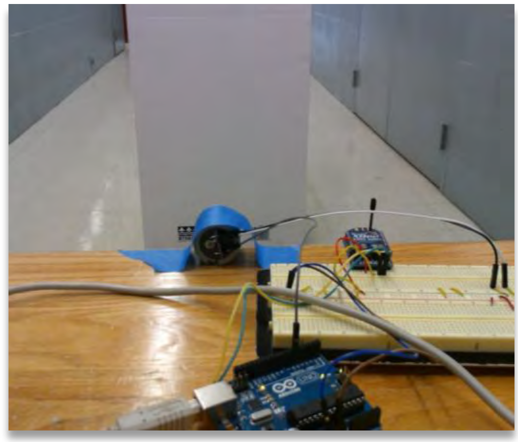

Figure 5: Ultrasonic sensor testing setup

The reading from the sensor was output on a serial monitor and recorded for comparison versus the actual distance. The test was run on each sensor for both analog and digital wiring configurations. The results of four of the sensors that were tested can be seen in Figure (6). For the analog wiring, it was found that with 95% confidence, the sensors were able to read within 0.92 inches of the actual distance, up to 16 feet away. This error is acceptable, however the team wanted to explore the digital wiring option to compare accuracy.

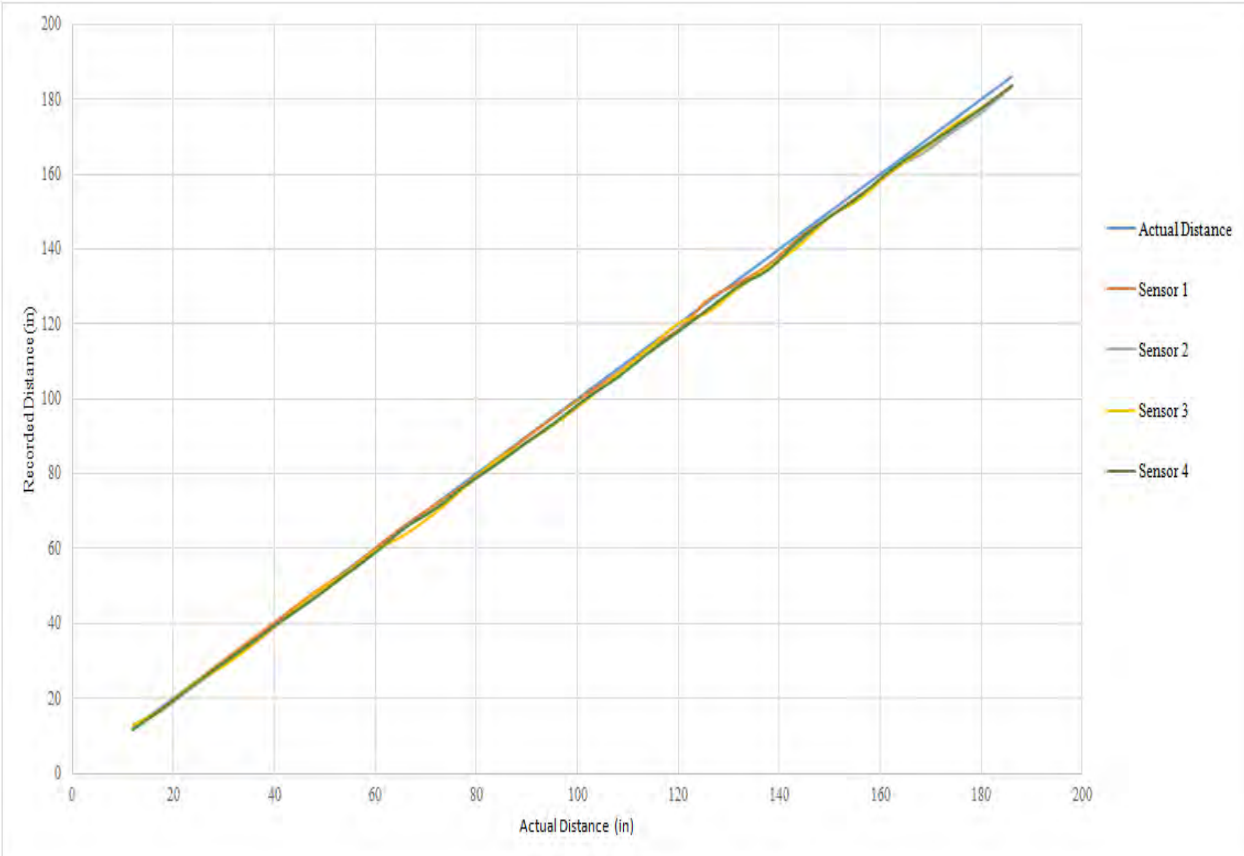

Figure 6: Plot of actual distance vs. recorded distance for ultrasonic sensors (analog wiring)

The same tests were run again with the digital wiring, results are shown in Figure (7). It is clear from the plot that the digital wiring of the sensors gave more accurate readings. It was found that with 95% confidence, the sensors would read accurately within 0.87 inches. This is a slight improvement upon the analog wiring. It was also found that the fluctuations in readings were much less frequent with the digital wiring as opposed to the analog configuration, so the team decided to use the digital wiring for the Wingman 360.

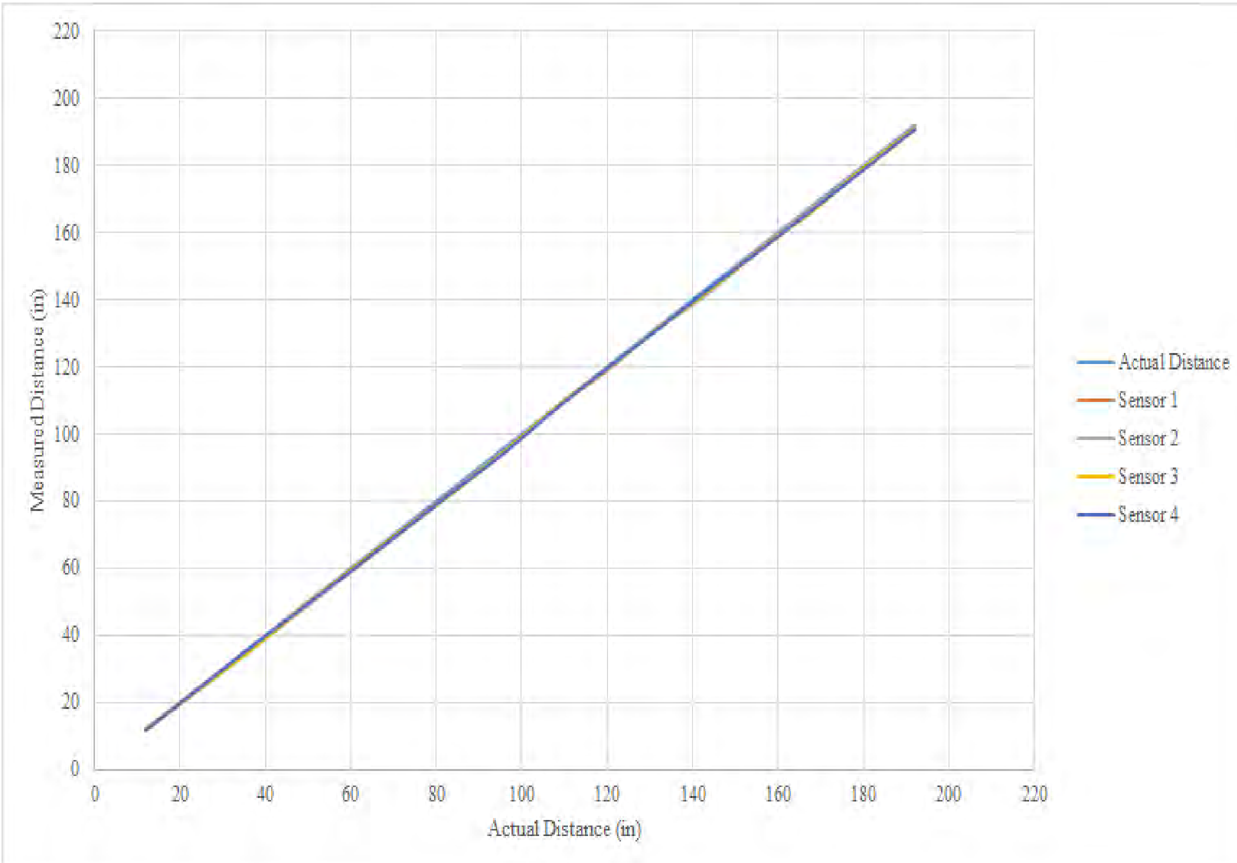

Figure 7: Plot of actual distance vs. recorded distance for ultrasonic sensors (digital wiring)

The second set of sensor tests that were run were the range mapping tests. These tests were executed in a similar manner as the accuracy testing, where a board was set at a specific distance away from the sensor, and the serial monitor was read to see if the sensor was picking up the board. This test was only run in the digital wiring configuration as it was proven to be more accurate. The resulting sensor map found from these tests is shown in Figure (8).

This map shows the sensor detection area within the blue lines. The sensor can read a wide area close to the sensor, up to two feet on either side, up to two feet away. Between two and thirteen feet in front of the sensor, an object can be detected up to one foot on either side of the direct line of sight of the sensor. Between 13 and 16 feet, the sensor can only read an object that is immediately in front of it. This behavior is mostly expected, however the team worried about the width of the map immediately near the sensor. The team then tested if the sensor could pick up an object that was parallel to the sensor (rather than a board that was perpendicular to it). The team found that the sensor was not able to pick up a parallel object, five inches or closer to the side of the sensor until the object reaches a distance of approximately two feet away. This means that the device needs to be placed closer to two feet from the edge of the wing tip to ensure that it will not detect the wing itself.

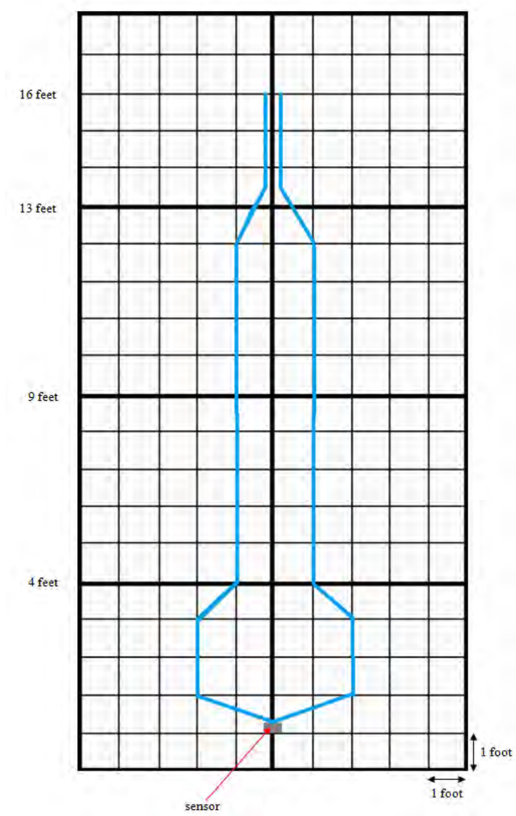

Figure 8: Ultrasonic range map

3.2.2 Suction Cup Testing

The suction cups are an integral component for the Wingman 360 system, as they keep the wing module attached to the aircraft. The suction cups need to stay attached to the wing for at least an hour in varying weather conditions such as cold, heat, and humidity. With these specifications in mind, the team chose five inch diameter vacuum release suction cups (Suction Cups, 2015). The testing for the suction cups was completed using an environmental chamber at the University of Rhode Island. Various conditions were tested

Figure 9: Horizontal mounted suction cup test

including extreme heat (104 F) and extreme cold (-4F). Tests were also completed on the two different orientations of the Wingman 360 device (see Figures (9) and (10)).

Figure 10: Vertical mounted suction cup testing

Both clean and dirty suction cups were tested as it is important that the device is able to attach to an aircraft wing with a layer of dirt and brake dust. The team achieved the dirty suction cup by using a combination of dust and dirt on the cup itself, see Figure (11).

Figure 11: Dirtied suction cup

It was found that with the clean suction cups, the device was able to hold for the full hour for nearly each temperature tested. The results from the suction cup testing can be seen in Table (2).

Table 2: Suction cup testing results

Temperature (F)	**Surface**	**Hanging Time (horizontal/vertical)**
-4	Clean	58 min / 60 min
-4	Dirty	60 min / 31 min
75	Clean	60 min / 60 min
75	Dirty	60 min / 60 min
104	Clean	60 min / 60 min
104	Dirty	53 min / 60 min

Dirtying the suction cups clearly impacted the holding time of the device. For both the room temperature experiments, the device held for the required hour, but only one suction cup remained attached. This proved to the team that the decision to add redundancy with three suction cups was indeed successful. In the high temperature experiment with dirtied suction cups, the device was able to remain attached for the full hour in the vertical orientation (on the side of the wall) and for 53 minutes in the horizontal orientation (under the wing). The cold temperature, however, impacted the device more. When the device was mounted horizontally, it was able to hold for the hour, with two out of the three suction cups failing within the first ten minutes. The vertical mounting of the device, however, only remained attached for 31 minutes. The temperatures tested were extreme, and it is unlikely that the temperature in Delta's Atlanta hangar will reach such low temperatures, however if this device is to be used in other states, the data on its hanging time in a range of temperatures is required.

To combat the issue of the lower hanging times with dirtied suction cups, the team tried to moisten the dirty suction cups with a water spritzer. This increased the vacuum of the suction cups and kept the device attached for the desired hour for all temperature conditions and orientations.

3.2.3 Material Selection and Testing

As the device needed to be impact resistant, the team needed to carefully consider the casing material. After researching, the material chosen for the case was ultra high molecular weight polyethylene (UHMW polyethylene). It is one of the most impact resistant materials. As seen in Figure (12) (Aetna Plastics, 2016), UHMW Polyethylene has a rating of 0 for moisture absorption, which is important since the device will be used in all weather conditions. To compliment this it also has the highest impact strength and one of the lowest costs of any of the other materials. The impact strength helps it hold up in case of accidental drops and the cost is very important in keeping the project and final device on budget.

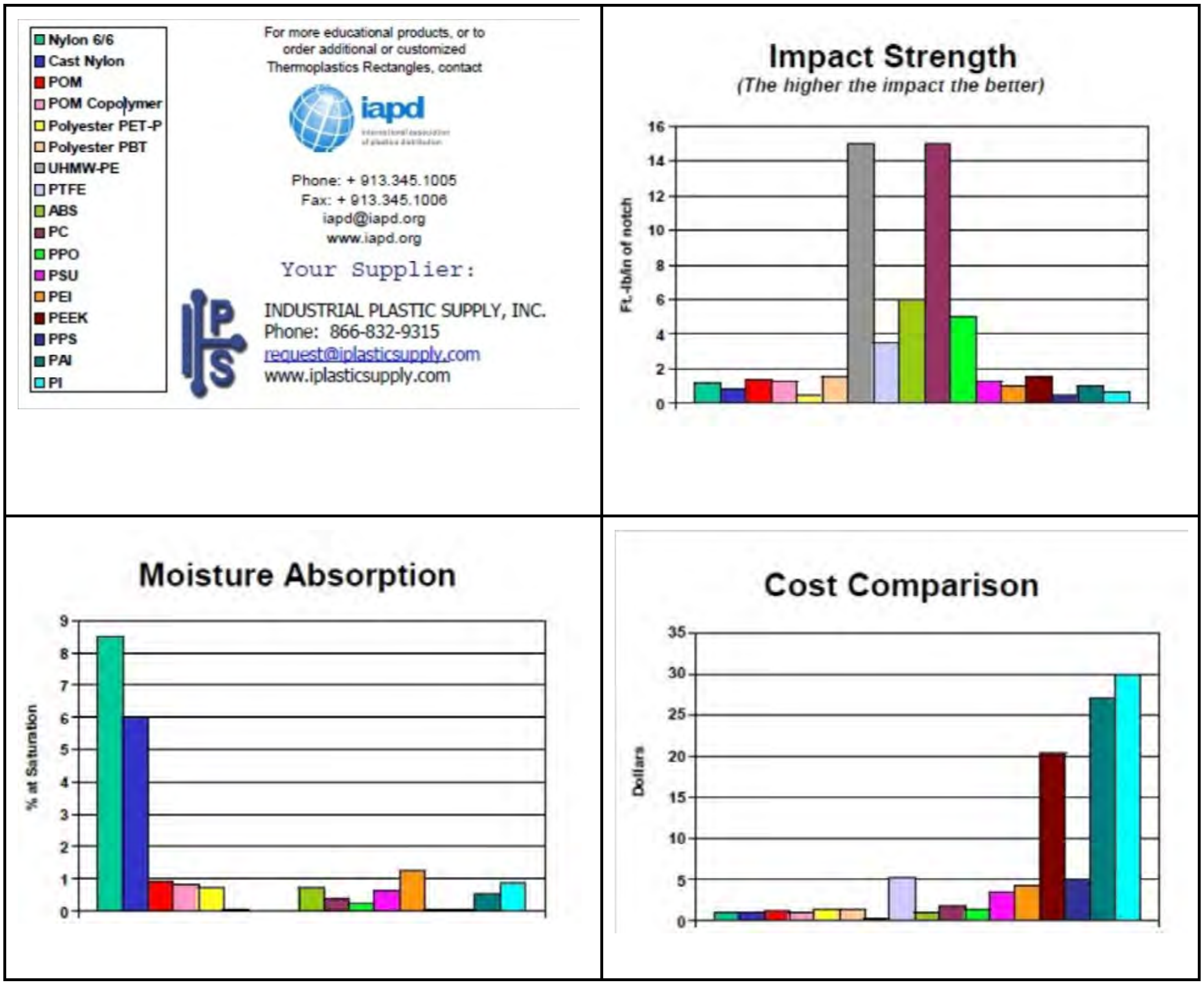

Figure 12: Material properties of UHMW-Polyethylene

To ensure that the device would be able to withstand a drop of 15 feet, a drop test was simulated in SolidWorks using finite element analysis (FEA). The material properties for the simulation were set to those of the UHMW polyethylene. The results of this can be seen in Figure (13). The highest stress areas are near the holes cut for the sensors and well below the yield strength of 7,740 psi. This study therefore proved to the team that the device would not break if it fell from an average aircraft wing.

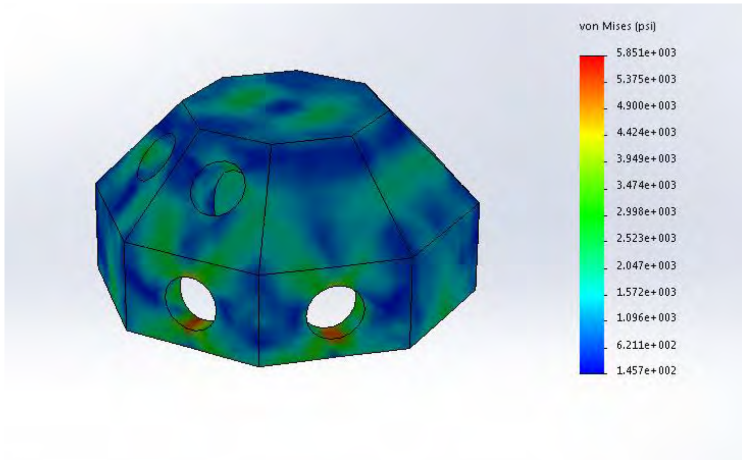

Figure 13: Results of the SolidWorks FEA drop test simulation

3.2.4 Field Testing

To ensure that the Wingman 360 would work properly when attached to an aircraft, the team performed field testing at the Providence Jet Center, located in Quonset, RI. The team was able to test the device on a stationary aircraft that had a winglet; allowing for both orientations to be tested, Figure (14).

Figure 14: Both orientations of the Wingman 360 on an aircraft

The team found that the device stuck well both to the underside of the wing, as well as on the winglet. The suction cups attached without excessive force being required to activate the vacuum. A prolonged suction cup test was not able to be run due to time restrictions, however no apparent loosening of the suction cups occurred for the 20 minute time period that it was attached to the wing for each orientation. Since the aircraft was not able to be moved due to its size, the team utilized a board to simulate a wall (see Figure (15)).

Figure 15: Testing the detection of a board while the Wingman 360 is attached to an aircraft

The device was able to detect the board when it breached the test limit, which was set at five feet. The receiver module was held at least 50 feet away, and the buzzer properly sounded when the board crossed the five foot mark. Field testing of the Wingman 360 provided the team confidence in the design, and ensured that the device would not detect the wing itself causing false alarms.

4 Safety Risk Assessment

Safety is a major concern in designing any product. The purpose of the product is to ensure the safety of the aircraft, without compromising the safety of those in its proximity. The device was therefore designed to be small and lightweight so that in the event that the device falls off of the wing, it does not seriously injure anyone who may be nearby. The device is also designed to absorb the energy from the fall so that it does not bounce once it hits the ground, which could also become a safety hazard.

While speaking with Delta Air Lines, the issue was raised that a device like this could potentially damage the surface of the wingtip depending upon the attachment method. The idea of using a clamp to attach to the plane wing had been previously discussed, but after careful consideration, the suction cup attachment method was chosen. Suction cups were the least obtrusive method of attachment and removed the possibility of damaging the wings of the plane.

Another important consideration in safety is the noise level which the audible alert reaches. According to the Occupational Safety & Health Administration (OSHA) standard for occupational noise exposure (part number 1910) the average noise level for an 8 hour work day should not exceed 85 decibels (OSHA, 2015). The standard also has a table that shows allowable exposure levels per time of exposure, shown in Figure (16).

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1 1/2	102
1	105
1/2	110
1/4 or less	115

Footnote(1) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C(1)/T(1) + C(2)/T(2) C(n)/T(n) exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Figure 16: OSHA daily noise level standard (OSHA 2015)

If noise exposure exceeds the levels in Figure (16), appropriate hearing protection must be worn. The Wingman 360 will be used in airplane hangars, which are often already high in noise levels. The hangars have a special noise detection system that when the ambient noise reaches 100 db, a light in the hangar goes off and the workers must put on hearing protection. This means that the alert on the Wingman 360 must be loud enough to hear if the workers are wearing hearing protection, but not loud enough to cause pain if they are not. This is why the team selected buzzers that would sound at approximately 90dB at the distance of the tug driver.

This device could also cause a safety hazard if left on the aircraft during flight. To ensure that the device is not left on the aircraft, long, red ‘Remove before Flight’ ribbons are attached. These long ribbons not only ease the process of removing the device from the wing, but also ensure that the device will be removed prior to flight. These ribbons are adjustable so that they can be the appropriate length for different sizes of aircraft and are made out of a durable nylon material.

Delta Air Lines also told the team that they usually teach employees to use new equipment purchased for their day to day activities. Once this was brought up the team thought the easiest and most effective way to help teach new users about the device was to write a detailed instruction manual which covered the entirety of the wingman device. This will help teach employees how to use the device correctly and safely, thus avoiding the risks of improper attachment to the wing.

5 Technical Aspects

The Wingman 360 device can prevent common wingtip collisions which occur in hangar operations while moving aircraft on and off the premises. The device can function on virtually any aircraft, but is specifically designed for larger passenger aircraft, which utilize a standard wing end, or a winglet. The device is small and easily held in one hand, without strain. Lightweight materials were also chosen for the product to ensure that anyone lifting the device would not be injured in the installation process. The design of this product was made such that a person could easily apply this force while holding the Wingman 360 in place under the wing without added strain. Ultrasonic ranging sensors were utilized as they gave both very accurate and reliable readings over a larger detection area than other comparable technologies. It was known from the beginning that a practical housing design would need to be utilized which could be used in nearly every situation, and stand up to the toughest weather conditions. Both visual and audible warnings are also present to alert the tug operator when the sensors pick up an impending collision. These warnings are not located on the wing module itself, like in the previous FAA team's design, but are located in a separate receiver module that communicates wirelessly with the wing device.

The design of this device contains two main components: electrical and mechanical design. The mechanical design encompasses the case design, attachment methods, and other hardware used on the device. The electrical design consists of the circuitry, module communication, sensors, LEDs and buzzers. All of the assorted parts used in the creation of the wingman 360 are readily available off the shelf items for ease of production, and the main cone, base plate, and receiver module can be machined on a CNC machine. If mass production was desired, injection molding could become a more cost effective and speedy process.

5.1 Mechanical Design

The attachment system is a critical component to the design. It is the part which will temporarily adhere the Wingman 360 to the wing ends. It had to be easy to attach and take off, and work in multiple scenarios, depending on if the device had to be mounted on the side of a winglet or on the bottom of a wing tip. The most important design considerations was that it could not fall off mid operation or possibly damage the wing surface. With all of these aspects taken into consideration, a suction cup mount system was designed. It was decided that three large five inch diameter suction cups will be attached to the bottom plate of the device to maximize reliability (Figure (17)).

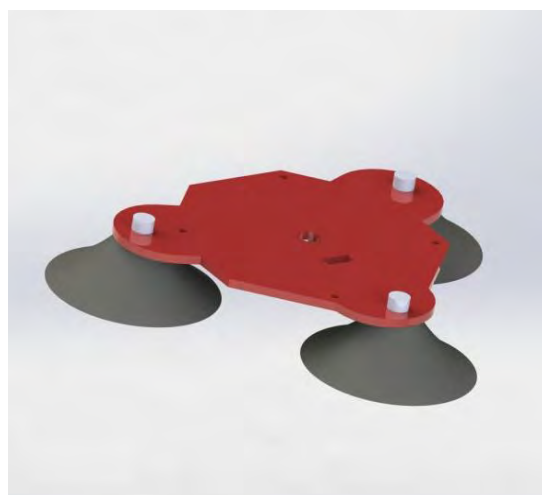

Figure 17: Base plate and suction cups

Using three suction cups is not to account for the weight being held up, but rather for redundancy, for the circumstance of one suction cup not creating a good seal. With each suction cup rated to 37.5 pounds, if just one of the three cups holds on during an operation, the device will not fall off; it weighs less than 10 lbs (Suction Cups, 2015). This greatly improves the safety of the device by reducing the chances of it falling. Vacuum release pins were added to the suction cups, allowing for quick and easy removal.

The housing system for the sensors required a lot of thought and design iterations to get something that would work well in all situations. The representatives of Delta Air Lines wanted a device that had a broad detection area while being mounted on either the winglets or the underside of a plane wings, without any modification to the device. The main body of the device is based off of a rhombicuboctahedron shape cut in half (Figure 18). It has 17 faces in addition to the flat bottom, which is open to accommodate the internal components. The exterior faces are positioned at 135 degree angles to each other, allowing sensors to be placed at the proper angles for the best coverage. The flat faces facilitate easier sealing between the sensors and the case with o-rings, for water proofing. The team considered using a dome shape instead of the rhombicuboctahedron, however, creating a water-tight seal would have been much more difficult. The main case is hollow with 8 sensor mount holes drilled into it. The geometry of the inside of the device is circular for easier

Figure 18: Wingman 360 wing module

machinability. The bottom plate attaches with 4 heavy duty screws to the main cone. It has a hole cut into it for an on/off switch as well as a slot for a charging port; the device does not have to be disassembled to charge the battery. A rubber stopper is used to seal the charging port hole to help with waterproofing.

As stated previously, the design the team created utilizes eight (8) ultrasonic sensors, all facing critical angles to give a comprehensive picture of possible obstructions around the aircraft. While mounted on the bottom of the wing, two (2) sensors will cover the forward and backward motion of the aircraft. Two (2) additional sensors, placed at 45 degree angles, will help to cover the area at the end of the wing tips, as well as minimizing blind spots should the aircraft be turned, see Figure (19). While the device is mounted on the winglets, in addition to the sensors facing forward and backward, there are four (4) sensors which look upwards towards the top of the winglet to ensure their safety. These sensors will be held in place by one inch locking nuts (Amazon, 2016) to ensure they remain attached to the device.

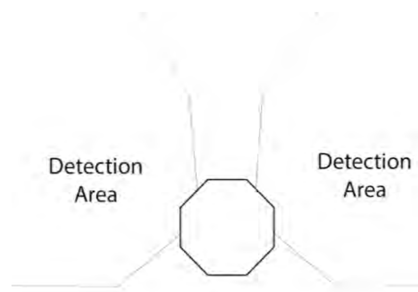

Figure 19: Detection area of wing module

Remove before flight streamers were introduced to the team while touring Delta's headquarters by Tim Files and Jordan Lyle, Figure (20) (Aircraft Spruce, 2016). These ribbons are added to many maintenance devices which are not meant to be left on during flight, such as engine plugs. If such devices are left on the aircraft during takeoff or flight, they could become safety hazards. The bright red ribbons are therefore very visible, and

Figure 20: Remove before flight ribbons (AS, 2016)

aid the operator in remembering to remove them. By adding these ribbons to the Wingman 360 device, the chances of it getting left on a plane are significantly reduced, as removing these red ribboned items is already part of the operators routine before takeoff.

The receiver module, which communicates with the wing mounted unit, will be the device responsible for alerting the tug driver if he is approaching an obstruction. It will be mounted on the tug directly next to the operator, see Figure (21). By placing the alerts closer to the driver instead of on the main device attached to the wing, they become much more noticeable and the driver has a better chance of responding faster. Its small design allows it to be placed virtually anywhere and is easily carried around. The alerts included consist of using two (2) led strips, one for the right wing and one for the left, in addition to a buzzer. The LED's have a high luminosity output and are spaced at 60 per meter; having high density light sources makes them more attention grabbing (Adafruit, 2015). The strip lighting can be set up to display a multistage alert with green, yellow, and red zones, or a simple two stage alert which would just tell the operator if he was clear or he had to stop. These functions can be easily programmed based on the purchaser's preference. The team chose piezoelectric buzzers chosen with a maximum output of 115db at 10cm away. This means at a more reasonable distance of 3ft away from the tug operator the buzzer will reach about 96dB

Figure 21: Receiver module box with LEDs and buzzer

(Digikey, 2015). This will be loud enough to hear over a busy hanger, but not loud enough to do any damage to the operator's hearing.

Fabrication of Wingman 360 was completed with the help of University of Rhode Island's machinists in their shop located in Gilbreth Hall. Initial prototypes were 3D printed due to easy of operation and minimal time required. However, for the more production ready model a CNC was used to make the parts out of UHMW Polyethylene. UHMW Polyethylene boasts very high abrasion resistance and excellent impact resistance (see section 3.2.3).

5.2 Electrical Design

The electrical design of this system is a key component of the Wingman 360. Not only is the electrical design important, but the coding behind it is critical for the proper functionality of each component, as this system relies strictly on its design and sensors. The eight ultrasonic sensors are connected to an Arduino Uno R3 (Atmega328) microcontroller, which is considered the 'brain' of the system, see Figure (22). All of the coding is conducted on an Arduino IDE software, which can then be transferred to the microcontroller. The Arduino Uno has 14 digital input/output pins, 6 analog inputs, a 16 MHz quart crystal. A USB connection, Power Jack, and an ICSP header and a reset button (Adafruit, 2015). For this system's sensors, eight digital input ports being used. All of the electronics in the Wingman 360 are powered by a 3.7 V battery that is connected directly to the Arduino Uno.

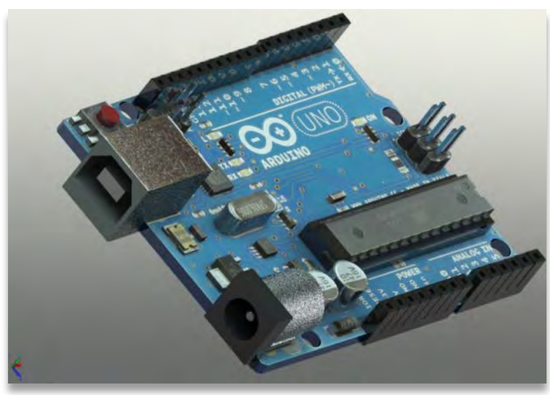

Figure 22: Arduino Uno

The sensors used in the Wingman 360 device are MB7380 HRXL, from Maxbotix, Figure (23). These sensors are completely weather resistant with a range of 16 feet. The factory specifications state that they are accurate down to 1mm, and they have a very low profile design, which allows the sensors to sit nearly flush with the casing (Maxbotix Datasheet, 2015). These sensors also draw very little power, making them very easy to run off of the Arduino without draining the battery quickly. Their threaded design makes them fit snugly within the case. Once locknuts and O-rings are added, the result is a solid weather and contamination resistant design.

Figure 23: Maxbotix ultrasonic sensor

The Wingman 360 communicates with a wireless module that can be placed on the dashboard of the tug. Since the Arduino Uno does not come with any integrated source of communication, it was necessary to add a communication source. To solve this problem the team integrated two XBee radio frequency (RF) transmitter and receivers (XBee Module - ZB Series 2 - 2mW with Wire Antenna - XB24-Z7WIT-004)(Figure (24)) into the system (Adafruit, 2016). XBee RF modules are embedded solutions providing wireless connectivity to devices. These modules use networking protocol for fast point-to-multipoint networking. The XBees are being used to communicate between the Wingman 360 and the box module, to provide timely object detection to the tug driver directly.

Figure 24: XBee module

Other components of the system are two buzzers and a pair of LED strips mounted in the receiver module. These components are connected to a second Arduino Uno within the receiver module. The buzzer and the LED's are used to alert the tug driver when he is approaching an object, when they receive a command from the wing mounted device. The Buzzer and the LED's work along with the sensors to give the tug driver the signal.

The electric diagram shown in Figure (25) shows how all of the Wingman 360 wing module components are wired together. All wires for the device are soldered to a breadboard. As shown in the electrical diagram, there are 8 sensors connected to digital pins 5 to 12. All the sensors are sharing ground and power (5V), which is being provided by the Arduino Uno. the Arduino Uno is also connected to a 3.7 V battery, which is the component providing the power source.

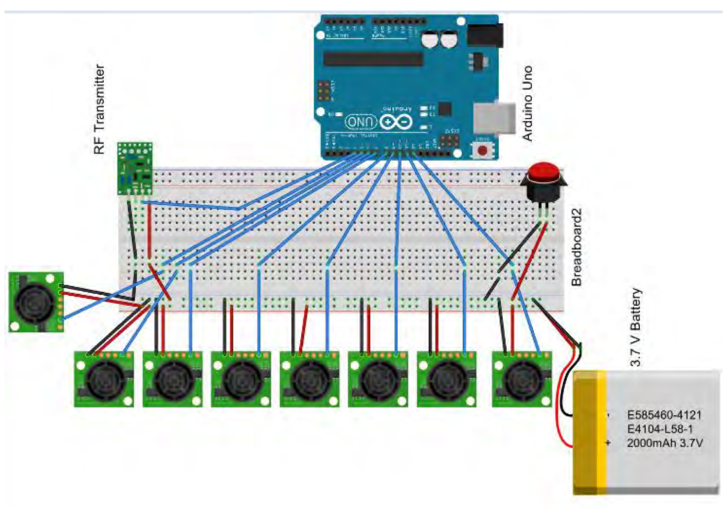

Figure 25: Wing module electrical diagram

The receiver module electric circuit is presented in Figure (26). This circuit diagram shows two buzzers, two LED's representing the LED strips, a button, the Arduino Uno, and the RF receiver.

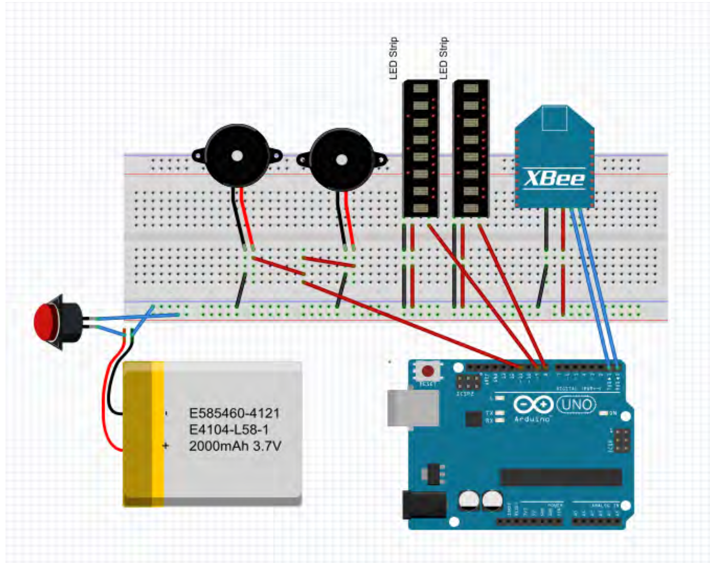

Figure 26: Receiver module electrical diagram

5.2.1 Coding

The Arduinos are able to communicate with each other through the XBee's RF transmitter and receiver. The XBee's are programmed so that the communication is specifically between those two modules and nothing else can interfere with them. The Wingman 360's microcontroller is programmed so that it sends the character "B" if the readings from the sensors are greater than 10 ft. and "A" if the readings are less than 10 ft, meaning it has detected an object. When the receiver module receives the letter "A" the LEDs and buzzers turn on, indicating the tug driver that he is approaching an

Upload

Reciever

```
int Buzzer = 8;
char value;

void setup () {
    pinMode (Buzzer, OUTPUT);
    Serial.begin (9600);
}

void loop() {
    if (Serial.available() > 0) {
        value = Serial.read();

if (value == 'A'){
Serial.println(Serial.read());
digitalWrite(Buzzer, HIGH);
}

else if (value == 'B'){
            Serial.println(Serial.read());
            digitalWrite(Buzzer, LOW);
            }
      }
}
```

Figure 27: Receiver module Arduino code

object. Otherwise, the transmitter is constantly sending the letter "B" to tell the receiver that nothing is approaching the wingtip and he is free to move forward. The microcontrollers are coded to perform each task in a loop, which means that they are constantly reading. Figure (27) shows the Arduino Uno IDE, which is the software used to program the microcontrollers; the particular code shown is that of the receiver. In the loop, the code is constantly reading the serial communication that is being sent by the transmitter.

The transmitter code, Figure (28), constantly sends the letter "B" if the sensor readings are greater than 10 ft, this tells the receiver module to keep the LEDs and buzzers off.

Figure 28: Wing module Arduino code

Arduino IDE is a major tool for the electrical composition of this system. By utilizing this software, it is possible to code the microcontrollers any way the users want. The code can be modified to have the sensors read up to 16ft and also to change the settings for the buzzer and LEDs. This software also allows the user to see the actual sensors readings on the serial monitor, which is helpful for calibration or sensor error detection.

6. Description of Interactions

Throughout the design process, the team met with individuals from the Rhode Island Airport Corporation (RIAC) as well as Delta Air Lines representatives, to aid in the development and creation of the final product. On October 9th, 2015 the team met with RIAC officials, Alan Andrade, James Warcup, and Jay Brolin, at Theodore Francis Green Airport (T. F. Green) in Warwick, Rhode Island. The objective of the meeting was to ask for guidance from the local airport officials on what they felt were the most relevant issues that they witness during daily operations. The team's focus was to exit the meeting with a clear idea of which aspect of the design competition to attack. The team brainstormed which areas of the competition interested them the most and looked to compare that to what the RIAC officials deemed as most important to their needs at T.F. Green Airport.

Entering their first meeting with RIAC, the team had major interests in the airport management and planning section of the design competition. During the meeting the Alan Andrade and his team gave the design team many suggestions of projects that would benefit the local airport on a daily basis.

On October 20th, 2015 the design team met with their faculty advisor, Dr. Bahram Nassersharif. During that meeting Dr. Nassersharif informed the team that he had been contacted by Delta Air Lines, who were interested in supporting a capstone project that would help prevent wingtip collisions in hangars. The design team was excited to hear that a major airline was interested in supporting a project, so the team decided to improve upon a previous URI competition team in creating a wingtip collision avoidance system.

Following the first meeting with Dr. Nassersharif, the next focus was to generate concepts with respect to the interests of Delta. The team listed one hundred and twenty concepts to be used for further consideration.

On November 10th, 2015 the design team had a follow up meeting with Dr. Nassersharif in preparation for a meeting with RIAC and Delta Air Lines later in that week. He asked the team to interview the RIAC officials to see if they had any concept ideas they could add, given their expertise in airport operations.

The team then met with both Alan Andrade and James Warcup on the morning of November 13, 2015. During the meeting, the topic of the wingtip collision issue was discussed. The design team presented some of their best concepts and allowed Mr. Andrade and Mr. Warcup to expand on those ideas and add some of their own.

With the input of the RIAC officials in mind, the team met with representatives of Delta Air Lines on the afternoon of November 13th, 2015. Delta Air Lines' General Manager of Base Maintenance Operations, Lorraine DiMarco, brought her Duty Manager of Base Operations, Jordan Lyle, and Aircraft Systems Analyst, Timothy Files, to the University of Rhode Island to meet with the design team. During the meeting, the Delta representatives encouraged the idea of a device that was attachable to the aircraft wings. Also, certain design specifications were discussed, such as a reliable reading of ten feet past each wingtip, a one hour hang-time for the device on the wing, and a desire for the device to operate without recharging for at least an eight hour shift. Section 3.1 details the remainder of the design specifications. The meeting closed with the Delta representatives asking the design team to do a site visit to their Atlanta, Georgia Headquarters to observe hangar operations and take necessary measurements needed for further design.

After the meeting the team met with Dr. Nassersharif on November 16th, 2015 to review some of the planned tests the team would perform on their trip down to Delta Headquarters.

The team arrived in Atlanta on November 20th, 2015. While in Atlanta, the team interviewed the Delta mechanics, who are key in the aircraft tug operations. They asked the mechanics about design ideas and worker preferences. The team was also able to get a better idea of how hangar operations occur, and where the collisions happen most often. Their input helped shape the design of the Wingman 360, which goes into depth in section 5.1.

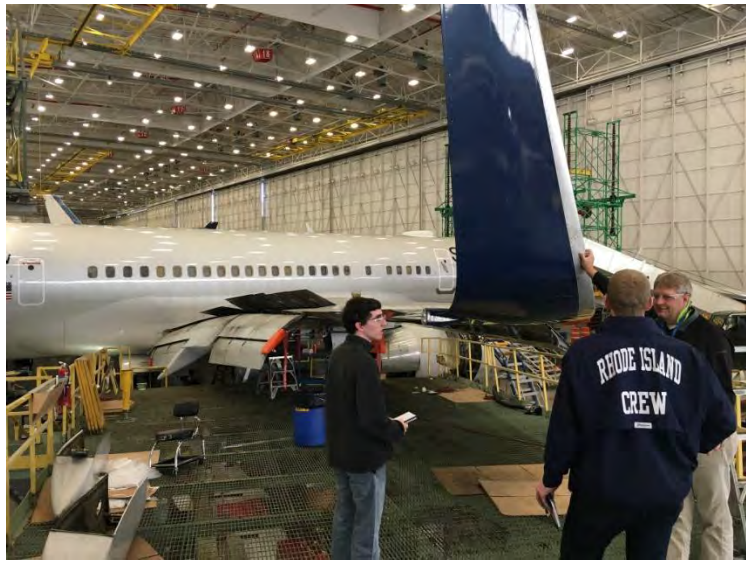

Figure 29: Team members speaking with Timothy Files at the Delta hangar in Atlanta

The team began the design and test spring semester with a meeting with Dr. Nassersharif to go over their plan for testing the design. The meeting took place on February 19th, 2016. The tests the team conducted are detailed in section 3.2 and Dr. Nassersharif directed the team to the proper university personnel that would need to know which equipment the team desired to use.

Jordan Lyle and Timothy Files visited the University of Rhode Island again on the 18th of March 2016. At the meeting, Lyle and Files were briefed on the project progress. A sensor demonstration was performed and they were extremely pleased with the progress. They offered some suggestions for the receiver module design, mostly commenting on the LED light configuration. At this meeting, a survey, created by the team, was presented to Lyle and Files. This survey asked questions relating to settings of the receiver module (alert settings) and was directed toward the tug drivers who would be using the system. Lyle and Files agreed to distribute the survey to their tug drivers and hangar workers for the team to have a better idea of what the workers actually want and need.

The team then reached out to their Rhode Island Airport Corporation contacts and inquired about performing field tests at one of RIAC's locations. The team was pleasantly surprised at how helpful their contacts were at finding a location and making the necessary arrangements to put the Wingman 360 on an actual aircraft. RIAC officials, Alan Andrade and Dave Lucas, met with the design team on April 25th, 2016 at Quonset State Airport in Quonset, Rhode Island. During the meeting, the design team briefed the officials on how the Wingman 360 system works and about some preliminary testing detailed in Section 3.2. After being briefed, Dave Lucas took the team to one of the hangars to test the Wingman on one of their small jets. Figure (30) shows design team members Gilbert Resto, Mitchell Contente, and Cody McMillian talking to Alan Andrade and Dave Lucas; while the Project Lead, Laura Corvese, captured the picture. After successful testing, the team left Quonset feeling even more optimistic for the future of the Wingman 360 system at Delta Air Lines.

Figure 30: Team members speaking with RIAC officials at Quonset

7. Projected Impacts

The Wingman 360 will make a significant impact on Delta's hangar operations. The team requested a financial report detailing the costs absorbed by the company for various incidents involving wingtip damage due to tug maneuvers. Over a span of two years, Delta Air Lines has spent $778,416 on six of these types of incidents. The three quarters of a million dollar value is only the direct costs associated with the repair of each of the aircraft. The direct costs include parts and labor for each repair. The labor is done primarily in-house, to minimize Delta's costs when accidents occur. However, if they can reduce, or even prevent, further accidents by investing in a reliable prevention device, then that would a good business decision; saving them time and money.

In addition, there are also indirect costs associated with repairing an aircraft wing. The lost revenue on unscheduled repair is one impact the company is focusing on. The Bureau of Transportation Statistics lists an average ticket price of $370.74 for domestic United States travel (US DOT). Delta Air Lines has a fleet of 809 aircraft, depicted in Figure (31), with varying seating capacities that carry an average of 176 passengers, illustrated by Figure (32) (Delta, 2016).

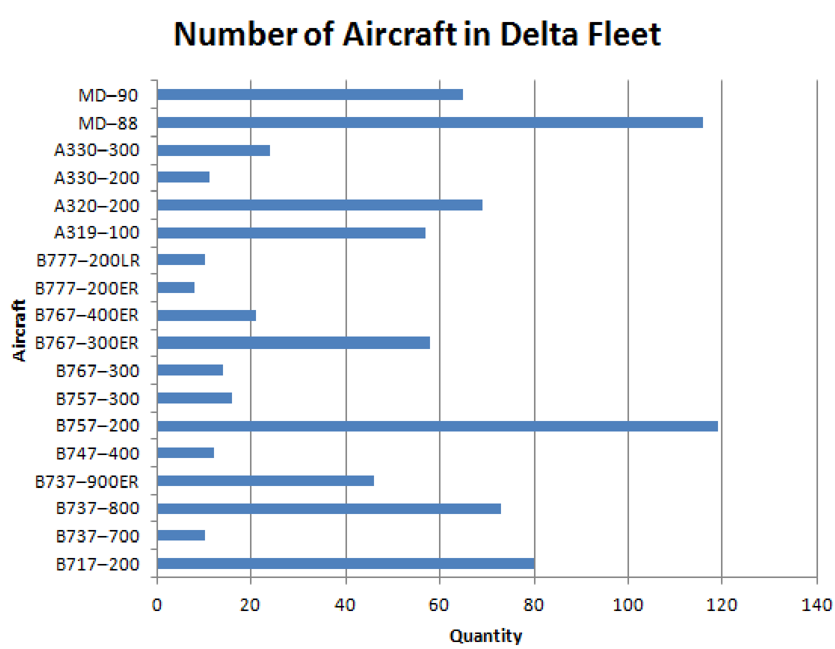

Figure 31: Delta Air Lines fleet

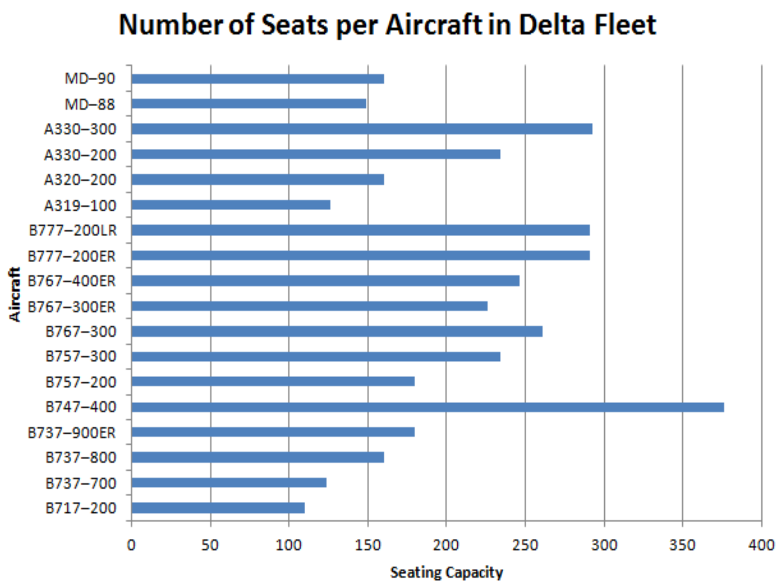

Figure 32: Seating capacity of aircraft in Delta's fleet

Delta, as any company that practices good business techniques, routinely has planes that they pull from their fleet for repairs. However, if an aircraft is damaged in hangar operations and grounded when it previously wasn't supposed to be, the aircraft can be considered a capital item that is losing money for the company. Using the numbers previously stated, each flight that is fully booked will bring in an average of $65,250.24 in revenue for the company. With it being quite complex to give an accurate estimate of the average number of flights for an average aircraft per day, the next series of calculations is an approximation, but easily shows the quick impact a damaged plane can have on Delta's finances. If the average plane made just 1 flight per day, Delta would face a loss of $65,000 dollars with each day that the damaged aircraft is in the hangar for unscheduled repair. Since data already shows that an average wingtip repair costs the company $130,000; after just two days Delta will miss out on the equivalent amount in revenue. However, a plane will make more than one flight per day. If the average flight time for an airplane is two and a half hours, with approximately 45 minutes in between flights, then it is safe to say that an “all inclusive” flight operation lasts about three hours and fifteen minutes. Based on local airports being open between an eighteen and twenty-four hour period, if a plane were run continuously, then it could potentially fly between five and seven times. If this is the case then an airline would lose almost half a million dollars in revenue per day that a plane is grounded.

Delta has a series of hangars at its Atlanta headquarters, where the company does general aircraft upkeep and repair. Since the company has this infrastructure in place it can keep the costs of maintaining its aircraft down. However, when the average cost to repair one of their planes nears $130,000, it is a smart business decision to seek methods to reduce that cost. Thus the Maintenance and Operations representatives of Delta Air Lines inquired with the University of Rhode Island’s Mechanical Engineering Department seeking a design team that could come up with a solution. With cost in mind, the design team aimed to keep the cost of the Wingman 360 low.

The final materials cost for the Wingman 360 is $2,795.11 which includes the two wingtip devices and a receiver module; enough to outfit one aircraft. The team has estimated that Delta Air Lines will need to manufacture ten sets in order to cover their hangar needs; thus the total materials cost will be about $28,000. The labor involved is not a number that the design team can accurately predict however, with machine shop times estimated by University machinists of at least $100 per hour, the team expects Delta to save a large amount when machining these cases in-house. If Delta Air Lines wants to mass produce these devices, investing in a mold would decrease machining time drastically. Furthermore, once the hangar is outfitted with Wingman 360s, Delta Air Lines will save what they spent on manufacturing if one wingtip collision is avoided. The Wingman 360 investment is a smart choice that will have a significant impact on the company's financial future.

Down the road the Wingman 360 could have a significant impact on the rest of the industry if Delta wishes to pursue that route. With funding this design team's Capstone project they will be the recipients of the details that go into making the Wingman 360. By updating the design based upon real world performance and experiences, the design team foresees this device being useful on runways during taxiing operations and gate procedures. Overall, the eventual adoption of the Wingman 360 system into Delta Air Lines' hangar operations would be a cost saving business decision. The team has created a product that can be easily implemented into daily hangar operations with little training required, easing the adoption process.

Appendix A – Contact Information

Advisor

Bahram Nassersharif
bn@egr.uri.edu

Team Members

Mitchell Contente
mcontente@my.uri.edu

Laura Corvese
lcorvese@my.uri.edu

Cody McMillian
cody_mcmillian@my.uri.edu

Gilbert Resto
gilbert_resto@my.uri.edu

Appendix B - Description of the University

The University of Rhode Island (URI) was founded in 1892, with its main campus located in Kingston, RI. The Feinstein Campus in Providence, RI, the Narragansett Bay Campus, located in Narragansett, RI, and the W. Alton Jones Campus in West Greenwich make up the remainder of the university's campuses. Currently, there are approximately 13,500 undergraduate and 2,900 graduate students enrolled at the university. The university is comprised of seven colleges including Engineering, Business Administration, Arts and Sciences, Human Science and Services, Environment and Life Sciences, Nursing and Pharmacy, and the University College.

The college of Engineering houses mechanical, electrical, civil, computer, biomedical, chemical, ocean, and industrial engineering programs which are all ABET accredited. The mission of the college is to prepare graduates to be global leaders and to create new knowledge, products, and services. The vision of the college is to be a leader in engineering education and research. The mechanical and industrial engineering department, within the college of engineering, houses the university machine shop, as well as thermal/fluids, solid mechanics, and mechanical systems laboratories. Graduates of this program participate in laboratory classes and complete a senior capstone design course to give hands on experience (URI, 2016).

Appendix C – A Description of Non-University Partners

Rhode Island Airport Corporation

The Rhode Island Airport Corporation, a government agency, was formed in 1992 as a branch of the Rhode Island Economic Development Corporation, formerly known as the Rhode Island Port Authority. The corporation is an organization that oversees the planning, development, management, acquisition, ownership, operations, repair, construction, improvement, maintenance, sale, lease, or other disposition of any "airport facility" as defined in Rhode Island General Law. The airports that RIAC oversees are T.F. Green Airport, North Central Airport, Quonset Airport, Westerly Airport, Newport Airport, and Block Island Airport

.

Delta Air Lines

Delta Air Lines was founded in 1924 and has since grown to become a major American airline. Its headquarters are located at Hartsfield- Jackson Atlanta International Airport in Atlanta, Georgia. Originally the company was known for crop dusting and later graduated to carrying passengers as the aviation industry developed. Delta Air Lines has grown to be a dominant airline through mergers with smaller airlines. Since 1924, Delta Air Lines has merged with seventeen other companies. As of 2013, Delta Air Lines is considered the largest global airline in passengers carried, at 120.6 million yearly.

Appendix E – Evaluation of Educational Experience

Students

The Airport Cooperative Research Program (ACRP) design competition provided a meaningful, and enriching learning experience for the members of the Wingman 360 team. The team was able to learn about the full design process, from concept generation and financial planning to prototyping and testing. The team also learned from our mistakes throughout the year, allowing us to create better solutions with every design iteration. An integral part of the design process was the testing of the final prototype. The team learned about different testing methods, as well as the importance of repeatability in experimentation. The experience also taught the group the importance of teamwork and organization, as the project was far too expansive for any one individual to conquer alone. In addition to team work within the group itself, the team learned about working with professionals in the industry when Delta Air Lines became a sponsor.

During the course of the year, the team encountered many challenges that needed to be worked through in order to complete a successful design. The first challenge the team faced was selecting a topic among the countless provided by the ACRP competition. Each team member had similar interests in mechatronics, which made the selection process slightly easier. After weeks of discussion and idea generating, the team decided to improve upon a design previously submitted to the FAA competition by a University of Rhode Island team. This created a new challenge, improving upon an existing design. This challenge proved difficult as the previous team had solved the problem in a creative way, however the team felt there was room for improvement and worked hard to re-design a completely new product. The team was able to overcome this challenge by brainstorming new ideas in terms of the geometry and the communication strategy of the device.

The Wingman 360 team used previous research to ensure that our product design would be successful. Before beginning the designing process, the team performed an extensive patent search and literature review to find previous work done on this topic. To design a product, the team devised a list of design specifications that needed to be met by the final design. This list was continually revised throughout the design process, specifically after meetings with RIAC and Delta Air Lines. The list of design specifications shaped how the team approached the problem. With the design specifications in mind, the team created a list of 120 concepts and narrowed the list down to the top three designs. These designs were refined to the final Wingman 360.

Receiving guidance from industry officials from RIAC and Delta Air Lines was a rewarding and meaningful experience for the team. Before interactions with industry professionals, the team was more scattered about the design process and the direction in which they wanted to go. The first meeting with RIAC professionals gave the team a starting point, and the meeting with Delta allowed the team to begin refining their design. Delta Air Lines was an invaluable partner throughout the design process, aiding the team throughout the entire design process through several meetings. The team was invited to visit the Delta Air Lines hangar in Atlanta, Georgia, to see the operation first hand, and speak with Delta engineers. This was a rewarding experience and gave the team valuable information for the design of the Wingman 360. Delta executives helped guide the team's product design specifications, and ultimately funded the testing and prototyping. The interactions with industry professionals from both RIAC and Delta Air Lines gave the team an idea of how the design process works in industry, as well as an understanding of the importance of budgeting and researching before creating a product.

Throughout the design process this academic year, there was a very high learning curve for the team. At the beginning of the fall semester, the team did not fully understand the design process or realize how much work goes into creating a product. Interactions with professionals also taught the team about how business is conducted by major companies and organizations. This project prepared the team members for work after graduation as it gave an opportunity to solve a real world problem in a new and creative way. From this experience, the team learned organizational skills, time and resource management, and most importantly, teamwork and networking, valuable life skills that will be useful in their future endeavors.

Advisor

THE
UNIVERSITY
OF RHODE ISLAND
COLLEGE OF
ENGINEERING

THINK BIG WE DO

DEPARTMENT OF MECHANICAL, INDUSTRIAL AND SYSTEMS ENGINEERING
92 Upper College Rd, 203 Wales Hall, Kingston, RI 02881 USA p: 401.874.2524 f: 401.874.2355 mcise.uri.edu

April 26, 2016

To: Airport Cooperative Research Program: University Design Competition for Addressing Airport Needs, 2016 review panel

This is the seventh year that our university and engineering program participates in this design competition. I selected this competition as one of the projects for my senior capstone design course in mechanical engineering because the program description and particularly timeline was an excellent match for my project requirements. Our senior capstone design sequence starts in the fall of the senior year and concludes in the following spring semester.

The value of the educational experience for students participating is absolutely outstanding. In particular, interactions with our local Rhode Island Airport Corporation (RIAC) were outstanding and we received tremendous support from the engineering staff there. The students conducted a broad and comprehensive search through the problem space outlined by the design competition and identified a problem of significance to the airports and airlines that is also of significant interest nationally (and perhaps internationally).

The most significant challenge for the students at the beginning was to identify, define, and research the problem(s) of interest. This search was conducted over a period of two months, which delayed them somewhat during the fall semester. This delay was necessary because of the broad scope definition of problems provided by the design competition call and the necessary interaction time with the state airport corporation staff.

The student team has done an excellent job in thoroughly exploring their problem (*Wingman 360*). They have designed a practical and very economical solution that is relatively inexpensive to build and implement. They have prototyped their solution and have obtained excellent results to pursue the creation of a marketable product and of specific interest to Delta Airlines. Their survey of airport operators, and airport and airline executives shows high interest in this product. This is exactly the type of process and experience that we expect for our students on design projects.

I am very pleased with the competition process, project solicitation, and organization of the ACRP design competition for addressing airport needs. I will definitely use this competition again in the future. If you have any questions or need additional information, please contact me.

Sincerely,

Bahram Nassersharif, Ph.D.
Distinguished University Professor

Appendix F- References

ACRP. (August 2015). *Airport Cooperative Research Program University Design Competition for Addressing Airport Needs*. Retrieved from http://vsgc.odu.edu/ACRPDesignCompetition/2015/ ACRPDesignCompetitionGuidelines_2015_ElectronicVersion.pdf

Adafruit. (2015, October 8). Arduino Uno R3 (Atmega328). Retrieved from https://www.adafruit.com/products/50

Adafruit. (2016, March 10). XBee Module - ZB Series 2 - 2mW with Wire Antenna - XB24-Z7WIT-004. Retrieved from https://www.adafruit.com/products/968

Aetna Plastics. (2016, April 5). Plastic Property Comparison Graph. Retrieved from http://www.aetnaplastics.com/site_media/media/attachments/aetna_product_aetnaproduct/249/Plastic%20Properties%20Graph.pdf

Aircraft Spruce. (2016, February 10). ASA Remove Before Flight Banner. Retrieved from http://www.aircraftspruce.com/catalog/pspages/asa17.php

Amazon. (2016, February 15). Zinc Flanged Locknut for 1" NPS Drains. Retrieved from http://www.amazon.com/Zinc-Flanged-Locknut-NPS-Drains/dp/B00P9J77AS/ref=sr_1_5?ie=UTF8&qid=1461769814&sr=8-5&keywords=E02-4090

Broderick, S. (2013, October 5). NTSB's Aircraft Taxi-Assist Camera Recommendation RejectedBy FAA. Retrieved from Aviation Week: http://www.aviationweek.com/Article.aspx?id=/article-xml/avd_03_29_2013_p02-02-564029.xml.

Conney Safety. (2016). Wingwalker Collision Avoidance System. Retrieved from https://www.conney.com/Product_-Wingwalker-CollisionAvoidance-System_50001_10051_-1_253826_22752_22751_22751.

Delta Air Lines. (2016, April 2). Delta Air Lines Aircraft Fleet. Retrieved from http://www.delta.com/content/www/en_US/about-delta/corporate-information/aircraft-fleet.html

Digikey. (2015, November 12). AI-5025-TWT-R. Retrieved from http://www.digikey.com/product-search/en?WT.z_se_ps=1&keywords=668-1289-ND

Files, T. (2015, November 13). Personal interview.

McMaster-Carr. (2015, November 19). Hand Held Suction Cup Lifter 5717A22. Retrieved from http://www.mcmaster.com/#5717a22/=125nnvq

Maxbotix. (2015, November 4). MB7380 Data Sheet. Retrieved from http://www.maxbotix.com/documents/HRXL-MaxSonar-WR_Datasheet.pdf

Maxbotix. (2015, November 4). MB7380 Outdoor Ultrasonic Sensor. Retrieved from http://www.maxbotix.com/Ultrasonic_Sensors/MB7380.htm

Occupational Safety & Health Administration [OSHA]. (2015). Regulations (Standards-29 CFR 1910.95). Retrieved from https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735

Rhode Island Department of State. (2016, April 15). Airport Corporation, Rhode Island. Retrieved from http://sos.ri.gov/govdirectory/index.php?page=DetailDeptAgency&eid=283

University of Rhode Island. (2016, April 10). The University of Rhode Island. Retrieved from http://web.uri.edu/about/

U.S. Patent #9,037,392. (2012, September 27). Retrieved from United States Patent and Trademark Office: http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=9037392.PN.&OS=PN/9037392&RS=PN/9037392

U.S. Patent #6,963,293. (2005, November 8). Retrieved from http://www.google.ch/patents/US6963293

Wheeler, R., Clark, C., KellaGrotta, K., Higgisn, L., & Powers, D. (2014, April 18). The Wingman: A Portable Wingtip Collision Avoidance System. Retrieved from http://vsgc.odu.edu/ACRPDesignCompetition/competitionwinners/2014/Management%20-%20First%20Place.pdf