

ASPECTS - Airport Secure Perimeter Control System

-Engineering a Safer Airspace-

Airport Cooperative Research Program:
University Design Competition for Addressing Airport Needs
Runway Safety/Incursions/Excursions



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Executive Summary

This report provides an in-depth summary of a solution to implement a drone landing and notification system. The major aspects of this project include a national database of airport coordinates, a notification system, and an autopilot system to direct sUAS away from critical airspaces. The project is entered into the 2015-2016 FAA Design Competition for Universities by a team of four electrical engineering undergraduates at the University of Massachusetts, Amherst.

Drones and sUAS are becoming increasingly popular among hobbyists, and with this popularity comes the risk of a runway incursion between a commercial aircraft and sUAS around airports. Despite a five mile safe airspace designated by the FAA, there are increasing reports of close encounters between sUAS and aircraft as well as full on collisions. To keep airports safe and secure, this project proposes to create a module that can be attached to every hobbyist's sUAS for the purpose of notification and prevention. Upon startup the module installed on the sUAS connects to a database containing the central coordinates of every airport in the United States. A five mile critical radius as well as an additional one mile buffer region is established around each point. The buffer region is created in order to inform the user that he or she is approaching a safe airspace and needs to take corrective action. The one mile radius was chosen to be sufficiently large enough to give the user time to react after receiving a warning message. If the user breaches the five mile safe region, autopilot software takes over the manual controls, and the sUAS is landed in a controlled manner. As the drone is being landed, the user still has lateral control of the vehicle in order to avoid any potential hazards below it. Upon landing and disarming the operator and the airport receive messages that a sUAS has entered the five mile critical space, and has been landed via autopilot software.

With the help of faculty advisors, a prototype was developed that successfully implemented this system, and was formally presented to a faculty review panel.

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I. Problem Statement and Background

As sUAS operation has become increasingly popular among hobbyists, there is a growing risk of runway incursions around secure airspaces such as airports. This is a relatively new hobby that people have begun to take up and current laws are struggling to adapt as quickly as the sUAS technology and capabilities becoming available to the public. There have been a number of stories in the news recently that are making the public more aware of the potentially deadly consequences of not abiding by federal regulations concerning sUAS use.

USA Today stated in 2015, “An examination of 891 drone sightings reported to the Federal Aviation Administration over a 17-month period found more than half flew too close to an airport, prompting lawmakers to renew calls to tag the popular remote-controlled aircraft with electronic collars that would keep them away” [1]. On top of these sightings which clearly present a very real danger to the safety of aircraft leaving and entering airports, there have been a variety of instances that nearly had catastrophic consequences. According to BBC news on April 17th, 2016, “The British Airways flight from Geneva, with 132 passengers and five crew on board, was hit as it approached the London airport at 12:50 BST on Sunday. No debris has been found and police have asked for anyone who finds drone parts in the Richmond area to come forward...After safely landing the plane, the pilot reported the object had struck the front of the Airbus A320” [2]. Earlier in 2016, at the same airport as the previously mentioned collision, there was a near miss between an Airbus carrying over 150 passengers and an sUAS.

BBC news reported that a “near miss at Stansted saw a drone fly over the Boeing 737 by about 16ft, as the aircraft was at about 4,000ft during take-off. In another incident, a drone narrowly missed hitting the wing of a Boeing 777 shortly after take-off from Heathrow Airport on 22 September...It is calling for stricter rules and a registration system so drone operators can

be easily traced and prosecuted for any ‘irresponsible flying’. Pilots also want technology routinely fitted to drones to stop them from being able to fly in areas where they could meet commercial traffic” [3]. Although there is a major threat imposed on airport safety and security by sUAS, there is currently no universal means to ensure that the FAA mandated five mile radius around airports is not breached. Whether or not the actions of sUAS pilots are malicious or simply ignorant, there needs to be a way to ensure the safety of all passengers aboard commercial aircraft.

Previously, students have addressed this issue using this competition as the platform to introduce their solution to the world. One such solution that captured our group’s attention was the first place winner of the 2014-2015 ACRP University Design Competition for Addressing Airport Needs: Runway safety/incursions/excursions section 1st place winners - *Eye in the Sky - Drone Detection & Tracking System*. In summary, this particular solution proposed that manufacturers install RFID chip on each individual unit sold. The corresponding RFID tracking systems with individual Adjustable Active RFID Readers would be responsible for detecting drones in the critical airspace set up all around the perimeter of the FAA mandated 5 mile radius. The range of these RFID tracking systems were expected to be 200-300 meters each, and individually cost around \$700 (USD) [4]. Upon breach of this critical airspace by a sUAS, the airport would be notified of the sUAS RFID tracking number, which would be a part of a national database of all sUAS registered to users. The implementation of this entire innovative system would cost an airport approximately \$34,212.56 (USD) [4]. This solution would drastically reduce the security threat of sUAS breaching the critical five mile critical regions surrounding airports, and its implementation is relatively simple.

Although the previously discussed solution would effectively eliminate the threat of sUAS breaching critical airspaces, our group is proposing a unique solution which we believe to be more effective. It is our firm belief that the responsibility of any unforeseen consequences resulting from improper sUAS operation should lie with the user, and not with the airport that was breached. When a hobbyist makes the decision to purchase and operate a sUAS, they take on all the responsibility of its operation whether or not they are aware of federal laws and regulations. The operation of a sUAS is a privilege, not a right. On top of this shift of responsibility from the airport to the user, our solution can be implemented with zero additional cost to airports, which includes the cost of equipment damage and maintenance. The details of this solution are summarized in the following sections of this document.

II. Summary of Literature Review

Overview of Research Process

Our design team consulted a wide range of resources as we progressed through the stages of the project from initial conception all the way to final systems testing and public demonstration. In the earlier stages, our research focused on surveying news and media outlets in order to identify specific areas of public need with respect to airport runway safety. The pros and cons of existing geofencing systems were also researched and evaluated early on. As the project evolved into its current form, the focus of our research became significantly more technical and economic in nature. The design team consulted numerous handbooks and manuals in order to familiarize ourselves with the multiple software interfaces involved in our design. We also researched vendors, part prices, and part specifications for various system components in order to minimize overall system cost and footprint.

News and Media Survey

Our survey of recent news concerning sUAS activity has shown a rise in several noteworthy trends. The number drone sightings within the restricted FAA 5-mile radius has been steadily increasing, as has the number of close-calls or collisions reported between sUAS and commercial aircraft. Intel and AT&T also recently announced a partnership to design integrated 4G LTE and other enhanced smart capabilities for future sUAS, indicating that recreational drone activity will only continue to rise in popularity and sophistication going forward [5].

In response to this increased risk, political action towards developing more robust sUAS regulation has been picking up steam as well. On April 21, 2016 the U.S. Senate voted 95-3 in favor of requiring the FAA to develop new sUAS safety standards that include geo-fencing [6]. This bill is moving onto the U.S. House of Representatives for consideration this term and if enacted would commence the FAA rulemaking process immediately.

Review of Existing Geofencing Systems

In addition to consulting current news for inspiration, we also reviewed existing geofencing solutions in order to examine potential areas for improvement. Some of these systems were previous project winners such last year's *Eye in the Sky* RFID-based system. We also looked at emerging GPS-based geofencing technology being implemented by certain sUAS manufacturers on their higher end consumer models. Existing manufacturer solutions tend to be expensive, proprietary, and specific to particular models or firmware—none of which is conducive to an affordable and generalized solution for all recreational users [20].

Review of Technical Literature

Once we settled on a conceptual design, the team had to review necessary technical documentation in order to identify system components that could meet our desired specifications.

Our communications subsystem uses the AT interface, which required us to become familiar with the AT Commands: Interface Guide [7]. Similarly, our autopilot subsystem uses the MAVLink interface, requiring us to become proficient in the MAVLink Common Message Set [8]. Lastly, our main controller executes approximately 400 lines of Python code in order to automate control over our GPS, communications, and autopilot subsystems. Gaining the necessary proficiency with Python required the team to study the Python Language Reference and other supporting documentation extensively [9].

Conclusions Drawn from Literature Review

Based on our multipronged review of current news and technology, the team determined that the consumer sUAS market is missing a universal geofencing solution with robust features such as autopilot landing override and a mobile-based notification system capable of leveraging existing cellular infrastructure. With mandatory nationwide geofencing likely on the horizon for the FAA in 2016, regulators, manufacturers, and other stakeholders will need reliable and affordable solutions that meet those criteria and more. The ASPECTS final design was fueled with these key literature considerations in mind.

III. Problem Solving Approach

Our team took on the challenge of improving runway safety for commercial airplanes due to the steadily increasing popularity of sUAS. When speaking with drone users we found that most were unaware of the no fly zones and did not know where to access information on restricted areas. We wanted to design a solution which would be financially and logistically feasible from the perspective of both the airport and the user. To serve the airports' needs, we wanted to create an autonomous system which would not require any additional action by air traffic control and would not incur any monetary expense for the airport. For the user, the

marginal cost would have to be low in comparison to the overall cost of the sUAS, since excessive financial burden would likely discourage compliance. The ultimate goal was to regulate traffic in the airspace and prevent potentially dangerous and fatal interference with passenger planes.

Through our preliminary research we encountered the concept of *geofencing* as a way of defining virtual geographical boundaries by setting a central point and a radius around that point (as illustrated in Fig. 1). Geofencing has many industrial and marketing applications; when paired with hardware and software, it can be used to simulate a physical barrier to keep aircraft

outside (or inside) of the specified area. Further research revealed that some higher-end sUAS already incorporated geofencing through firmware updates [20]. However, this did not apply to less expensive models and those which are built entirely by the user. Our new goal was to provide a geofencing module which could be retrofitted on an existing sUAS or a “do-it-

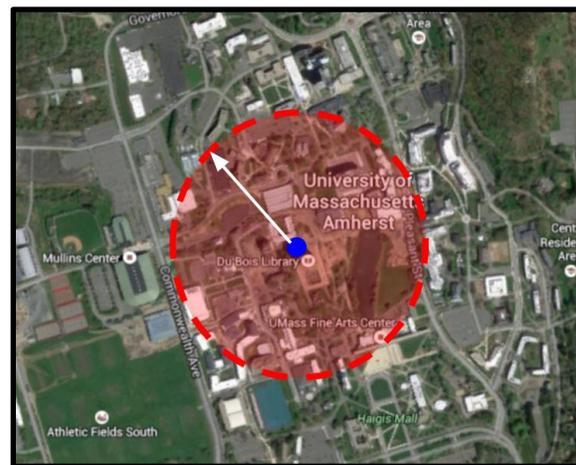


Figure 1: Graphical representation of geofencing.

yourself” model, and therefore address the vast majority of drones that do not currently have geofencing capabilities.

Making use of existing infrastructures was another priority in minimizing costs, and so we used the cellular network to set up our communication with the user. Outside of the no fly zone, a designated buffer zone can be defined, where the user must fly cautiously. This is where he or she receives the first warning that there is a restricted area nearby. While high-end sUAS often rely on a smartphone application to interface with the user and display warnings or alerts



Figure 2: Text notifications to user.

[20], our SMS notification, captured in a screenshot in Fig. 2, is simple and compatible with any phone. Several possibilities were considered when deciding on the best way to establish contact with the pilot, and it was concluded that a 3G device would serve our purpose well. Among the other options was a Hotspot which would connect our on-board processor to the internet via 4G and facilitate the sending of an email to the local

airport, but this would require a data plan which costs the user approximately \$30 USD per month.

Once the geofencing module was conceptualized (the technical details of which are discussed in Section V), we began to consider what kind of sUAS we would need for testing. Below in Table 1 is a comparison chart defining some of the desired specifications we envisioned for an ideal sUAS.

	Flight Time (minutes)	GPS Enabled	Price (USD)
SeresRoad CXHOBBY CX-20	15	Yes	320
Storm RC X3	12-15	Yes	300
Parrot AR Drone 2.0	12	Yes	349
Custom Arduino-based Quadcopter	~12	No	~400

Table 1: Specifications for commercial drones researched during design process.

Ultimately we decided, however, that the most effective way to provide proof of concept for our project would be to build our own sUAS and build the module for one of the most

widely-used flight controllers in DIY as well as commercial sUAS: the 3D Robotics Pixhawk [21]. This would allow us an open-source platform, more control over the software, and a deeper understanding of the functionality and capabilities of the drone itself. Furthermore, our module will work with any flight controller featuring a telemetry input port, ensuring compatibility with about 75% of publicly available sUAS.

With the software complete and the hardware integrated, we set up a testing site to assess the overall system performance. We assigned a coordinate to an open field on the university campus and set LEDs as a visual indication of where the drone was relative to the buffer “warning” zone and the no fly zone. Preliminary tests involved simply walking through the area to ensure that the module recognized its current location. After the autopilot commands were proven to function smoothly, we were able to execute full test flights. Finally, all hardware was assembled in a custom-designed and 3D-printed case, shown in Fig. 3, which is lightweight (approximately 450 grams) and simple to mount.

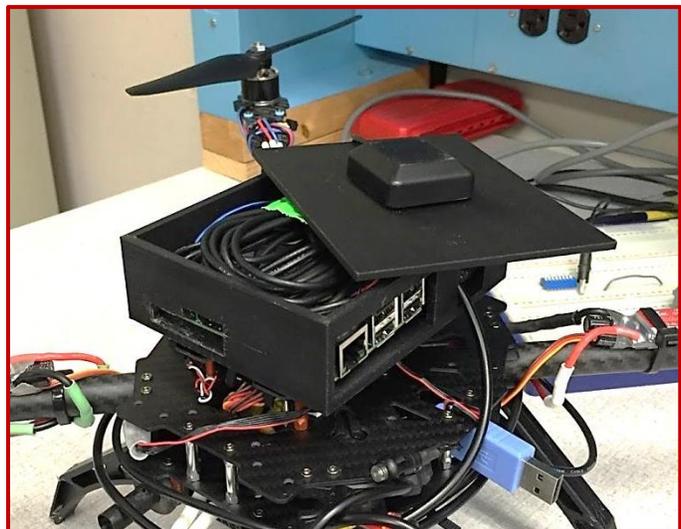


Figure 3: Completed ASPECTS prototype mounted on the sUAS.

IV. Safety Risk Assessment

In order to fully consider the safety concerns of this project, the group consulted the Introduction to Safety Management Systems in the FAA Advisory Circular 150/5200-37. According to the document, a successful Safety Management System (SMS) involves identifying and evaluating the risk associated with a particular hazard, engineering a solution, and finally

analyzing the solution and altering it if needed. [14] We used this approach in our design process by developing a universal module for sUAS which tracks the frequency of flights near airports and includes built-in fail safes to reduce the likelihood of a breach.

Safety is, of course, a major concern with the implementation of the ASPECTS system, and redundancies are added in order to ensure that the system does not fail. According to the FAA Safety Management System Manual, redundancy is a key focus point for equipment defense strategies [15]. The primary function of the system is to avoid breaches of the five mile safe airspace surrounding an airport, so the fundamental subsystem on the prototype is the autopilot landing software. This software has been thoroughly tested and has been shown to respond within 10 seconds of a breach. Although there is a bit of latency regarding the speed of the software response, it is negligible on the scale of five miles. The autopilot itself has the feature of allowing the user to laterally control the sUAS as it descends. This allows the operator to avoid collision with hazardous objects, especially in adverse weather conditions. Once the sUAS is landed, it disarms itself and fails to rearm until the user takes the vehicle outside of the restricted airspace and resets the system via reboot. If the autopilot fails to respond to the drone entering a restricted airspace, the notification system adds redundancy that notifies the airport as well as the user that a breach has occurred and corrective action needs to be taken. This ensures that the airport will have time to respond to the undesired sUAS if the user fails to take any action. Also, because this prototype module is powered from the sUAS power supply, instead of an external source, it will continue to operate as long as the vehicle is able to operate. The multiple redundancies that the ASPECTS system maximizes the probability that corrective action will be taken in some form upon a breach of a restricted airspace.

V. Technical Aspects

The Airport Secure Perimeter Control System (ASPECTS) was designed to eliminate the threat of hobbyist sUAS within the critical five mile restricted airspace mandated by the FAA around all airports in the United States. In order to successfully demonstrate complete

functionality, many individual systems were integrated as shown in Fig.4. These subsystems include: geofencing module, notification system, and static file server system, which were integrated to implement the final design.

(i) Geofencing Module

The geofencing module of the ASPECTS system is the portion of the system that acts much like an electric dog fence in order to keep sUAS threats out of an airport's restricted airspace. Fig. 5 is an illustration of the overall system, with two radii surrounding the airport to depict the five-mile no fly zone mandated by the FAA (in red) and the additional buffer zone created for this project where the user is permitted to fly with caution (in blue). The module itself also consists of two main subsystems: the GPS antenna/receiver, and the controller hardware. The Geofencing module is responsible for monitoring geofenced areas associated with airports by interpreting location information from the GPS antenna/receiver and comparing the location of the sUAS with any nearby no-fly zones. This process is done using software programmed into the control hardware. The distance between the sUAS and any nearby airports is monitored by continuously by the programmed controller hardware in real time. When that distance is

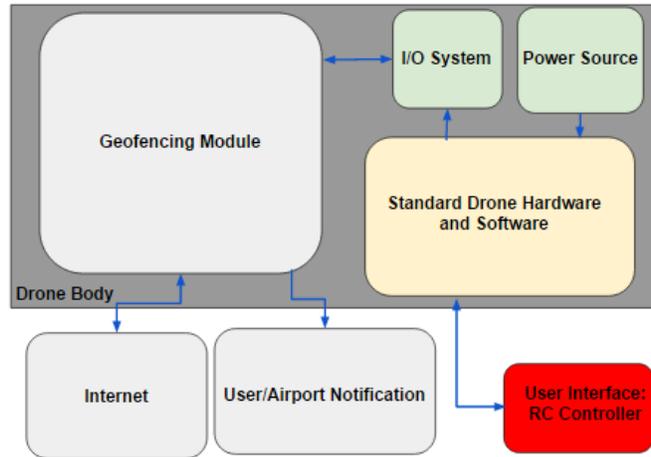


Figure 4: ASPECTS system block diagram.

calculated to be inside of the five mile critical radius, the controller hardware signals the notification system and then proceeds to execute a program which takes over the flight controller on the sUAS in order to safely land the vehicle.

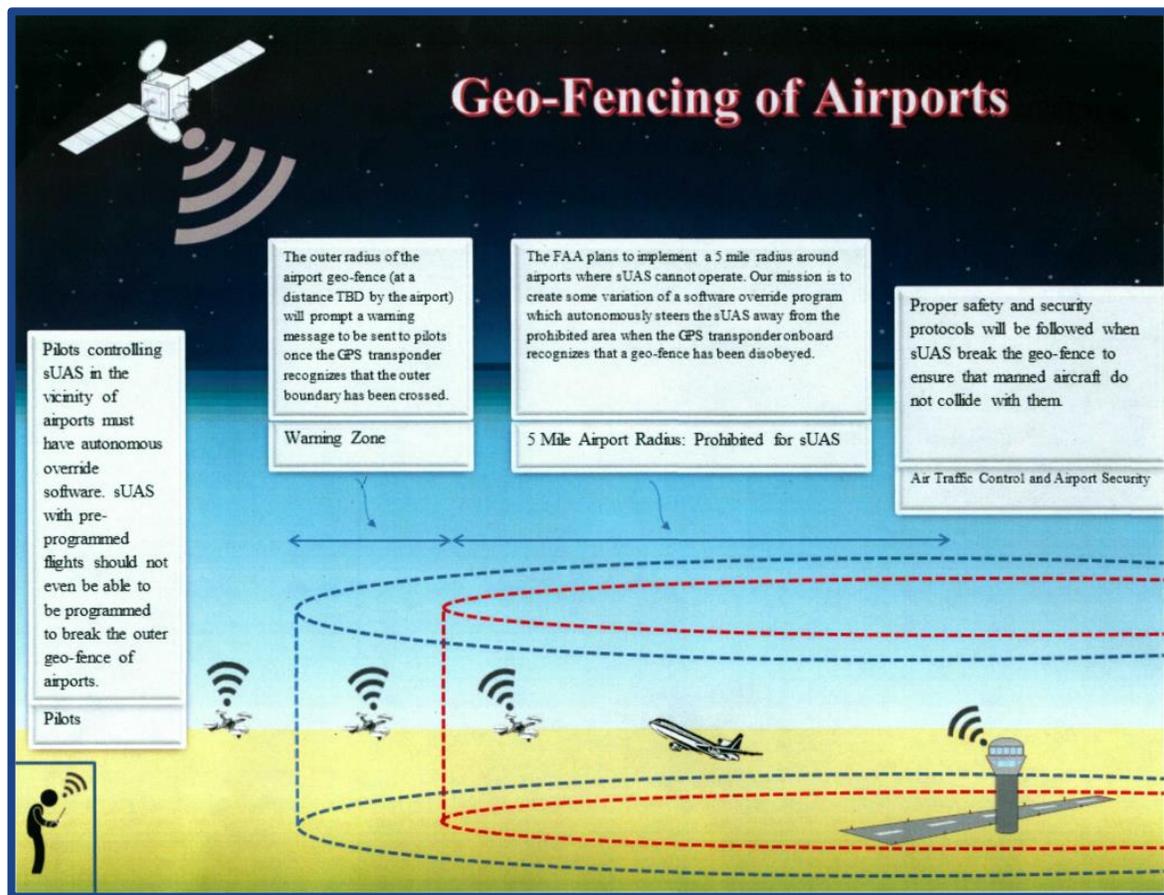


Figure 5: Pictorial overview of the system indicating no fly zone (red) and buffer (blue). Artist: Jared Geller (CEE, '17)

Controller Hardware

The most important part of the Geofencing module is the controller hardware used in the on-board module. This hardware acts as the brains behind the entire system. The hardware that was chosen for this application is a Raspberry Pi 2 Model B. For the low price of \$39.99, the Raspberry Pi essentially provides all of the functionality of a basic computer. Driven by a 900 MHz quad-core ARM Cortex-A7 CPU, the Pi provides 1GB of RAM, 4 USB ports, 40 GPIO

channels with a compatible +3.3-5 VDC design. At only \$39.99, this chip provides a fast location refresh rate of 10 Hz while exhibiting minimal power consumption due to the maximum 20mA current draw during navigation. The chip also provides some data logging capability due to some internal flash memory in its on-board microcontroller. [6]

The corresponding Adafruit external active antenna, which is compatible with the GPS breakout chip mentioned above, uses a 3-5 V, 5 meter long uFL to SMA adapter cable. This antenna (Fig. 10) is suitable due to its adequate 28 dB of signal amplification while only drawing an average of 10 mA of current. It also provides a substantial operating bandwidth of 10 MHz along with an operating temperature range of -30-85 degrees Celsius. One issue is that the 5 meter long cable is the shortest that comes with this particular antenna. A smaller cable would correspond to a smaller enclosure for our module and also a lower overall weight of the system. [6]



Figure 10: External active antenna for GPS.

(ii) Notification System

The user is alerted of their proximity to a no fly zone by a text message to the phone number they submitted when registering the sUAS. He or she will receive one of three messages. The initial message is a warning that the sUAS is near a no fly zone. If the user continues to fly towards the no fly zone and breaches the perimeter, a second message tells them that the drone is in autopilot mode until it has safely landed. At that time a text is sent to a Google Voice account associated with the email set up for the project. The information from the text message, which includes the name of the airport and a user identification number, can be parsed and forwarded to

	Latitude	Longitude	Airport Name	Contact Info
171	41.8031	-78.6401	Bradford_Regional_Airport	amherstairport@gmail.com
172	41.938889	-72.683222	Bradley_Intl	amherstairport@gmail.com
173	19.760056	-155.553717	Bradshaw_Aaf	amherstairport@gmail.com
174	46.398308	-94.138078	Brainerd_Lakes_Rgnl	amherstairport@gmail.com
175	41.9335691	-85.0522935	Branch_County_Memorial_Airport	amherstairport@gmail.com
176	39.5924	-75.3455	Brandywine_Airport	amherstairport@gmail.com

Figure 12: Database of United States no fly zones. Email addresses as placeholders.

ASPECTS’s file server system is essentially just another Raspberry Pi 2 Model B (same specifications as the geofencing module’s controller hardware) [7] hooked up through its Ethernet port to a static IP address location. Software programmed onto the Raspberry Pi allows the system to parse and reformat all of the airports in the United States into a Microsoft Excel spreadsheet from an online database of no fly zones [13]. This file is stored and ready to be accessed by the on-board controller hardware system of the ASPECTS module every time the sUAS is powered up. Our team also configured a cloud-based backup server that can perform the same functions as the primary server in the event of an interruption.

VI. Interactions with Airport Operators and Industry Experts

In November of 2015 our team visited Bradley International Airport in Connecticut to present our design plan and to gauge the level of interest in finding a solution to the growing number of unmanned aircraft vehicles in use by hobbyists. Our team prepared several questions regarding Bradley Airport’s experience with drones and whether they considered it a major issue. The project was met with overwhelming support from both FAA officials and Bradley administrators.



Figure 13: Entrance to Bradley International Airport in Windsor Locks, CT.

According to Air Traffic Manager Ayaz G. Kagzi, the recent proliferation of drone use has been a significant

cause of stress for air traffic control. Most sUAS are undetectable by their radars, making it difficult to monitor unknown objects in the vicinity of the airport and impossible to keep track of every breach of their airspace. The geofencing technology alone “would solve a significant part of the problem” by relieving air traffic control of the responsibility to police their no fly zone [22].

We then discussed the possibility of sending an additional notification: after the user has received a text message saying his or her sUAS is in autopilot mode and will begin landing, the airport will receive a message that an sUAS has attempted to breach their no-fly zone, along with an identification number assigned to that user upon registration. (This is contingent upon the airport supplying contact information, which we include in our database.) The notifications not only alert the airport of nearby unauthorized aircraft, but also serve to provide important data. While drones have received more media attention recently due to incidents with passenger and commercial planes, the issue has not been adequately addressed by drone manufacturers or legislators. Mr. Kagzi expressed his concern that it is not until a tragic incident occurs that people begin to take notice of issues like this one [22]. In order to express the magnitude of the problem, they must have a way to quantify it. By sending an email each time a drone flies too close to the critical zone, we give airports statistics on how many near-breaches occur as well as which users may be repeat offenders. They may in turn use this information to identify trends, recognize problems, and define their needs so that the necessary laws and restrictions are imposed on sUAS operators in the future.

The team also worked with Dr. John Collura, a professor emeritus in the Department of Civil and Environmental Engineering at UMass Amherst whose research focuses on “transportation management and operations with an emphasis on work zone safety” [16]. Dr. Collura met with the team several times over the course of the project and lent his extensive knowledge of the current FAA policies and regulations surrounding use of sUAS.

VII. Projected Impact

This project satisfies the ACRP goals by taking a number of suggested ideas and implementing them into a single system. The system utilizes direct warning systems to alert air traffic controllers for situations leading to runway incursion, innovative approaches to reducing runway excursions and associated risks, and innovative processes to identify the hazards that present the greatest risk to air carrier operations within the runway environment and strategies to mitigate those hazards and improve safety of airport surface operations. All of the above solutions were suggested by this competition as general guidelines for determining a sufficient plan [4]. The national database of all the coordinates that require a geofence addresses the issue of identifying the areas that are at the greatest risk of a runway incursion. The software is flexible enough to be able to alter the radius of the restricted airspace with ease, which would allow the system to change its geofence radius based on the needs of the specific airport or no fly zone. The notification system implements a warning system for sUAS operators and air traffic controllers for situations leading to runway incursions. Finally, the autopilot software is a direct solution to reducing runway incursions and associated risks.

As sightings of sUAS operation in the vicinity of airports is increasing, legislation is being proposed that all drone manufacturers install geofencing software that prevent them from breaching critical airspaces [1]. This implies that manufacturers will need to devise a solution to not only recognize every location that requires a geofence, but also to prevent drones from physically entering these regions. This project takes that solution a step further by also implementing a notification system for both the sUAS operator and the airport. The prototype module created by this group has proven to negligibly reduce the flight time of a drone over a single battery life, and it should be sufficiently cheap to manufacture on a broad scale. Table 2

summarizes the cost analysis of producing the prototype as well as projected costs for mass production.

In this case, mass manufacturing refers to the cost to build 100 units, which implies that production on a larger scale would be even cheaper per unit. As previously stated, the solution proposed by the *Eye in the Sky - Drone Detection & Tracking System* in the 2014-2015 competition submission would cost each airport approximately \$34,212.56 USD per unit [4]. While simple to implement, this solution places a high cost on each airport that agrees to use the system. The solution that this group has proposed takes this responsibility off of the airports and places it on the user. At \$145 USD or less per unit, this solution is affordable, and the cost is nearly negligible compared to cost of most publicly available drones. Reaching out to drone manufacturers with a prototype that is affordable and has been demonstrated to be reliable would be the first step of the process of getting this system mass produced. Installing this prototype module on each publicly available drone would allow manufacturers to adhere to legislation that is predicted to become federal law.

Component	Prototype Development	Production (prices per 100 units)
Raspberry Pi (on board)	39.95	34.31
GPS Chip	39.95	31.96
GPS Antenna	12.95	10.36
TTL to USB Adapter	9.95	7.96
FONA 3G Chip	79.99	31.96
FONA Battery	9.95	7.96
FONA Battery Charger	12.50	10.00
SD Card with OS	11.95	7.96
Enclosure	19.40	5.00
Monthly Texting Plan	3.00	3.00
Raspberry Pi (server)	29.99	—
TOTAL	269.54	145.47

Table 2: Price comparison (USD) for prototype development and mass manufacturing.

VIII. Appendices

Appendix A: Contact Information for All Advisors and Team Members

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Appendix B: Description of the University

The University of Massachusetts Amherst is a nationally ranked public research university which boasts a wide range of undergraduate as well as graduate degrees for its nearly 30,000 students. Research is a fundamental aspect of the culture at UMass, as research activities added up to more than \$200 million in the fiscal year 2014. This statistic makes UMass the largest public research university in New England. The university is ranked 29th among the country's leading public universities, ranked among the top 10 research universities across the nation, and ranked 25th most efficient among top colleges in the nation. UMass is known to compete at the highest level of research activity, especially regarding the life sciences.

On top of academics, UMass is home to 21 NCAA Division I level sports teams, a Fine Arts Center which attracts nationally famous theater and music to the university, and the largest state-supported institution in New England, the Dubois Library. The university is also involved in a variety of community outreach programs, and contributed \$1.9 billion to the Massachusetts economy in 2013 [5].

The College of Engineering offers four- and five-year bachelor of science degrees and is accredited by the Engineering Accreditation Commission of ABET [18]. The college provides its students with both theoretical and practical knowledge necessary for the work force through a rigorous curriculum and various hardware and software projects. The Student Chapter of the Institute of Electrical and Electronics Engineers (IEEE) hosts workshops and networking events for Electrical Engineering students to stimulate interest and impart essential professional skills [19].

Appendix C: Description of Non-University Partners

All partners involved with this project are affiliated with the University of Massachusetts, Amherst.

Appendix D: Sign-Off Form

Please see page 34 for sign-off sheet with an electronic signature from Professor Daiheng Ni. Handwritten signature is included in hard copy of report submitted by mail.

The team lead is Sandra McQueen, who can be contacted by phone at (781) 941-0656 or by email at sandramcqueen@gmail.com. Below is the permanent address for the team lead:

67 Lincoln Road
Medford, MA
02155

Students

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airports Needs provide a meaningful learning experience for you? Why or why not?

Our involvement in the ACRP Design Competition coincided with a year-long capstone Senior Design Project for the UMass College of Engineering. Our participation in the competition prompted further research beyond the technical aspects of the design: We gained an understanding of the regulations surrounding drone use, learned how airports are affected by recreational flights, and predict how various solutions would impact aircraft safety in the future.

2. What challenges did you and/or your team encounter in undertaking the competition? How did you overcome them?

One of the biggest challenges our team faced throughout this project was the vast amount of research that was necessary to come up with a system that would be cheap, reliable, and compatible with the majority of recreational drones. Technical problems were difficult especially concerning the quick response of the notification and autopilot system, but compiling all of our research into a single system posed the biggest challenge.

3. Describe the process you or your team used for developing your hypothesis.

The process our team used for developing a hypothesis was very structured and planned due to the fact that this project was also submitted as a senior design project. The project planning went through a great deal of trial and error at each scheduled design review, and some specific problems couldn't be solved until we actually tried to build a working system. The system was designed by individually building each subsystem, and then later integrating each

part into a presentable coherent project.

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

Our interactions with Bradley Airport were critical to the success of the project. The opportunity to meet with experts in the field reaffirmed the need for regulation of sUAS near airports and further motivated us to develop a working prototype.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

Working in industry as engineers requires us to meet the needs of the client and design a system to meet a set of given specifications. This competition gave us the experience of learning what the clients (in this case, the airports) want, and finding creative ways to solve their problems in a way that is simple to implement and cost-effective.

Faculty

1. Describe the value of the educational experience for your student(s) participating in this competition submission.

Through this project, the students not only strengthened their own knowledge in Electrical and Computer Engineering by building the drone from scratch, coding, and testing but also obtained substantial understanding on civil engineering, in particular the operation of airports and the issues caused by UAV. The knowledge and experience learned from this competition will inspire the students in their future careers.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

Yes. The students were able to apply what they have learned in building the geo-fencing prototype. With some input and support from outside of their domain, they are able to connect what they have learned to a new area, i.e. the drone issue at airports, and effectively address the new challenge.

3. What challenges did the students face and overcome?

The primary challenge for the team was to narrow down preliminary ideas to choose the best possible implementation. In our weekly meetings we discussed several possibilities for solving the drone safety issue, as well as numerous different types of technology which could be used. They researched and tested multiple approaches before setting on the final product.

4. Would you use this competition as an educational vehicle in the future? Why or why not?

Yes, it is very practical and inspiring. This is an ideal opportunity to motivate students' creativity.

5. Are there changes to the competition that you would suggest for future years?

I would suggest more interaction between the teams and the ACRP over the course of the competition and, perhaps more importantly, that the ACRP connect the teams to airports for local support.

Appendix F: References

- [1] Jansen, Bart. "Drone Sightings Spur Legislation to Fence Them in Away from Planes." *USA Today*. Gannet, 21 Oct. 2015. Web. 15 Nov. 2015
- [2] "'Drone' Hits BA Plan: Police Investigate Heathrow Incident." *BBC News*. BBC, 18 Apr. 2016. Web. 20 Apr. 2016
- [3] "Drones Involved in near Misses at UK Airports." *BBC News*. BBC, 29 Jan. 2016. Web. 26 Apr. 2016
- [4] Federal Aviation Administration. FAA Design Competition for Universities.
http://faadesigncompetition.odu.edu/Apps/FAAUDCA.nsf/2013_DesignComp_Booklet.pdf?OpenFileResource. Web. 25 Apr. 2016
- [5] "AT&T and Intel Want Drones Connected to an LTE Network" *Ars Technica*. Web. February 22, 2016. <<http://arstechnica.com/business/2016/02/att-and-intel-want-drones-connected-to-an-lte-network>>.
- [6] "US Senate Passes Legislation to Let Airports Disable Nearby Drones" *Business Insider*. Web. April 22, 2016 <<https://www.schumer.senate.gov/newsroom/press-releases/after-schumers-urging-drone-geo-fencing-proposal-passes-the-senate-newtechnology-could-prohibit-drones-from-flying-near-airports-sensitive-areas-sporting-events-and-above-500ft>>.
- [7] "AT Commands GSM Reference Guide - Wireless Modem Family - Interface Guide" *Multi-Tech Systems*. Web. 23 Oct. 2015
<<http://www.arcelect.com/GSM%20Developer%20Guide%20-%20GSM%20AT%20Commands%20-%20Rev%20%20A.pdf>>.

- [8] "MAVLink Common Message Set" *QGroundControl.org*. Web. December, 2015.
<<http://mavlink.org/messages/common>>.
- [9] "The Python Language Reference — Python 2.7.11 Documentation" *Python Software Foundation*. Web. Nov. 2015 <<https://docs.python.org/2/reference/>>.
- [10] "Points of Pride." Home. N.p., n.d. Web. 25 Apr. 2016
<http://www.umass.edu/gateway/about/points-pride>
- [11] "Adafruit Ultimate GPS Breakout - 66 Channel W/10 Hz Updates." *Adafruit Industries Blog RSS*. N.p., n.d. Web. 17 Nov. 2015 <<http://www.adafruit.com/product/746>>
- [12] "Raspberry Pi 2 - Model B - ARMv7 with 1G RAM." *Adafruit Industries Blog RSS*. N.p., N.d. Web. 23 Oct. 2015 <<https://www.adafruit.com/products/2358?gclid=CM62pZTIrcwCFQcfhgodJpgE8w>>
- [13] "DJI - Fly Safe: No Fly Zones." *DJI - Fly Safe: No Fly Zones*. Web. 6 Feb. 2016.
- [14] "Introduction to Safety Management Systems for Airport Operators." FAA Advisory Circular 150/5200-37 (2007). Web. 26 Apr. 2016.
<http://www.faa.gov/documentlibrary/media/advisory_circular/150-5200-37/150_5200_37.pdf>.
- [15] United States. Federal Aviation Administration. Air Traffic Organization. Safety Management System (SMS) Manual. 4th ed. Washington, DC: FAA, 2014. Print.
- [16] "Civil and Environmental Engineering." Dr. John Collura. Web. 27 Apr. 2016.
- [17] "Adafruit FONA 3G Cellular Breakout - American Version." *Adafruit Industries*. Web. 25 Apr. 2016. <<https://www.adafruit.com/product/2687>>.
- [18] "Electrical and Computer Engineering." Accreditation. University of Massachusetts Amherst. Web. 25 Apr. 2016.

- [19] "IEEE UMass Student Chapter «." IEEE. 2012. Web. 25 Apr. 2016.
- [20] "No FLY Zones." DJI. Web. 24 Apr. 2016. <<http://www.dji.com/fly-safe/category-mc?www=v1>>.
- [21] "3DR Pixhawk." 3D Robotics. Web. 25 Apr. 2016. <<https://store.3dr.com/products/3dr-pixhawk>>.
- [22] Ayaz G. Kagzi, personal communication, 18 November 2015.

Airport Cooperative Research Program University Design Competition for Addressing Airport Needs Design Submission Form (Appendix D)

Note: This form should be included as Appendix D in the submitted PDF of the design package. The original with signatures must be sent along with the required print copy of the design.

University University of Massachusetts Amherst

List other partnering universities if appropriate: No

Design Developed by: Individual Student Student Team

If individual student:

Name _____

Permanent Mailing Address _____

Permanent Phone Number _____ Email _____

If student team:

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Competition Design Challenge Addressed:

II. Runway Safety/Runway Incursions/Runway Excursions

F. Safety considerations for drones operating in or near the airport environment—issues and constraints as well as benefits and costs.

I certify that I served as the Faculty Advisor for the work presented in this Design submission and that the work was done by the student participant(s).

Signed Daiheng Ni Date 04/27/2016

Name Daiheng Ni

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