COVER PAGE

Title of Design: Vehicle Incursion Prevention System

Design Challenge Addressed: Runway Safety/Runway Incursions/Runway Excursions

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Vehicle Incursion Prevention System

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Executive Summary

A central goal of the Federal Aviation Administration (FAA) is to ensure safe and efficient ground operations at airports nationwide. A real and present issue impeding this goal is misinterpretation of air traffic control (ATC) instruction by ground vehicle operators, as well as other possible sources of confusion. A lack of situational awareness on the part of ground vehicle operators and ATC staff can lead to dangerous situations on the airfield that have the potential to cause an accident, possibly one that results in loss of life. Such incidents can incur unexpected costs upon airports, and have the potential to cause operational shortcomings such as flight delays and an overall lack of efficiency in ATC operations.

Proposed herein is a Vehicle Incursion Prevention System (VIPS), conceptualized by students at Binghamton University – State University of New York, that will allow ATC staff to more concisely relay instructions to ground vehicle operators, thus providing airports with the ability to greatly reduce the risk of accidents resulting from errors in ground vehicle operation. The system integrates information and systems that are currently in use, including airport layouts and runway use data. The VIPS then integrates this information with the real-time locations of all ground vehicles on the airfield. Based on this aggregated data, the VIPS will be capable of generating safe routes between locations on the airfield, and displaying this information visually to both ground vehicles and ATC staff. This in turn will allow tower staff to more clearly convey information to ground vehicle operators, as well as alleviate the workload of ATC staff by generating ground vehicle routes automatically, while still allowing for this output to be modified if necessary. By introducing an automated system that may be overridden as necessary by tower staff, the VIPS reduces accident risk while increasing airport efficiency, improving the current system of verbal direction of ground vehicles.

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I. Problem Statement and Background

a. FAA Goals

The Federal Aviation Administration (FAA) created a list of priorities and goals in order to maintain standards and provide the safest and most efficient methods of aviation transportation. For the FAA, safety is the top priority. One goal of the FAA, as described in its *Destination 2025*, is to change safety standards to improve aviation safety worldwide. To do so, the FAA focuses on hazards in order to set their goals; one of the goals is to make sure serious runway incursions remain at, or recede below, 20 per 1,000 incidents.

b. Current Methods for Meeting FAA Goals

A team of engineers was tasked with creating a method of preventing runway incursions. They decided to create a phone application (app). One function of this app is to capture the instructions from the air traffic control (ATC) tower and display them on the display panel. Another function of this app is to track pilots' locations so it can compare them to the received instructions. After receiving promising test results, the FAA decided to fund this project [1].

Runway signs are very important in preventing runway incursions as well and they must be visible to all pilots and drivers in different sized vehicles. Other obstacles such as stop bars and guard lights are also beneficial to airports because they control whether a vehicle or aircraft may pass a certain intersection. To make sure they are most helpful, they must be functioning correctly and yielding the correct signals at all times of airport operation [2].

One up-and-coming method of reducing runway incursions is called NextGen. This is a system that aids communication between pilots, controllers and operators, which significantly increases runway awareness. One way it accomplishes this is by switching from ground-based navigation and surveillance to satellite-based navigation. Instead of viewing everything with just the human eye, controllers will have the ability to view everything through satellite cameras. This new perspective will give air traffic controllers a much clearer view of their airports. NextGen also involves placing a display with moving maps in the cockpits of aircrafts to improve pilots' situational awareness. These maps will display the location of both aircraft and ground vehicles. NextGen has not been fully implemented at airports around the country yet, but has certainly improved the functioning of those that have it [3].

A light gun is a hand-held device that emits green, red and white lights. This light gun is used when electronic communication between ATC and the vehicles is not functioning. The color and flash patterns of the light will either approve or disapprove of the vehicle's actions [4].

c. Moving the Industry Forward

As long as there are moving aircraft and vehicles on a runway, there will always be the threat of a runway incursion. There are many runway incursion prevention methods, but none of them are popular or effective enough to spread on a national scale. Accidents can occur in many different ways, which is why they are so difficult to prevent. The newly proposed method for preventing runway incursions has been created in consideration of where other plans failed. Once the rate of occurrence of runway incursions has significantly decreased, the FAA will finally be able to put this issue to rest and focus on other matters more efficiently.

II. Summary of Literature Review

a. FAA Goals

The FAA not only oversees air traffic and funds aviation research and development, but also creates standards for guaranteeing safe travel. With the goal of providing the "safest, most efficient aerospace system in the world [5]," the FAA has put an effort into uncovering, analyzing, and preventing system errors and fatal accidents. The FAA's *Destination 2025* strategic plan reiterates that the agency's first priority is safety. The plan also places a strong emphasis on efficiency, from the individual level of passengers, to the aviation system as a whole. The agency's strategies to mitigate this risk include strengthening and improving technology, infrastructure, and procedures of all stages of flight, including ground operations [5].

b. Incursions

A runway incursion is any occurrence at an airport that involves aircraft, vehicles, or people in a specific area (generally designated for taking off and landing) where one or two of the three are not supposed to be present at that specific time. There are three types of runway incurrences: Operational Errors (OE), Pilot Deviations (PD), and Vehicle/Pedestrian Deviations (V/PD). OEs involve a problem caused by air traffic control (ATC), PDs involve a mistake caused by the pilot, and V/PDs occur when an unauthorized vehicle or unauthorized personnel enter a restricted area on the runway. About 20% of runway incursions occur due to V/PDs [6]. The FAA aims to keep the rate of serious runway incursions at or below 20 per 1,000 events.

c. Assessment

The FAA lays out the current procedure for ground vehicle operations at airports, including different regulations for towered and non-towered airports. Non-towered airports tend to have much less traffic than larger towered airports, and will therefore inherently have less risk. There may be intersections between a runway and taxiway, or between two taxiways. These high-risk locations are known as "hot spots." Hot spots are specially marked on the airport maps, which are required to be available in each ground vehicle operating at the airport [6].

The FAA categorizes risks in three levels: high, which is an unacceptable level of risk requiring immediate intervention and a cease in activity; medium, which is an acceptable level of risk permitting that there is active monitoring; and low, which is the ideal level in which the activity's risk is recorded but the activity itself is allowed to continue without close monitoring [7]. Using the Safety/Risk Assessment process as described in the Advisory Circular [8], there are five steps (system description, hazard identification, risk determination, risk assessment, and risk treatment, in sequential order) to rectifying an issue [7]. Following these, the process for incursions would most likely involve a description of the obstruction; an assessment of the level of danger the obstruction is in, categorization of the incursion, and appropriate reactions to counter it.

d. Current Management

For a majority of airports, the communication between the driver of the ground vehicle and the ATC are essentially the same. The driver first identifies him/herself and indicates where s/he which to proceed to. Then, the tower indicates itself, addresses the driver, and then gives them clearance repeating where the driver wishes to go. Finally, the driver acknowledges the tower and for one last time, repeats where s/he is proceeding to [9]. While communicating with the ATC, ground vehicles are required to "always use standard aviation phraseology and proper communications procedures when contacting ATC in order to facilitate clear and concise communications [9]." Ground operators must learn and use this specific aviation terminology. The FAA provides a glossary of words that must be used. Vehicle drivers also must memorize a phonetic alphabet to reduce confusion while contacting the control tower.

e. Solutions

The first device is a simple Global Positioning System (GPS). This system has many features including a colored moving map, turn-by-turn directions, and voice directions. This device can be placed in a vehicle to raise the driver's knowledge of his surroundings at all times. The second device the FAA created combined GPS technology with computer software. This device gives a driver or pilot an aerial view of the airport and of their location. This system can be linked with other vehicles and aircrafts with all devices cooperating to show the locations of each vehicle on every map. This device can also be used as a two-way communication system between active vehicles, which helps give drivers/pilots a sense of where they are in relation to each other [10].

"NextGen" is a system that provides efficiency of performance regarding vehicle congestion and demand. It increases accuracy and the communication between pilots, controllers, and operators, thus allowing a significant increase in runway awareness. There are current devices that airports use in order to track vehicles. These devices include GPS, Wide Area Augmentation System (WAAS), and Local Area Augmentation System (LAAS). These systems are able to display the locations of aircrafts and ground vehicles on moving maps [11].

There are specific lights an airport uses to perform different functions. Specific to ground vehicles, there are Runway Status Lights (RWSL). RWSL exist to alert drivers and pilots whenever the runway may not be safe for driving or landing. The three types of RWSL are runway entrance lights (REL), runway intersection lights (RIL) and takeoff hold lights (THL). If radios ever fail, the air traffic control tower has red, green, and white lights to indicate their different meanings (e.g. steady green means clear to cross runway/taxiway, steady red means stop) [6].

The FAA currently offers four different systems that help with runway incursion prevention. These four systems are: Final Approach Runway Occupancy Signal (FAROS); Airport Surface Detection Equipment, Model X (ASDE-X); Airport Surface Detection Equipment, Model 3 (ASDE-3)/Airport Movement Area Safety System (AMASS); and Electronic Flight Bag (EFB) with Moving Map Displays. ASDE-3/AMASS is ground movement signaling system that has video and audio. It has the ability to detect any potential collisions on the runway. This system is currently installed at 34 of the busiest airports in the United States. ASDE-X is a system that provides location and identification of vehicles. It also has the ability to alert the ATC of any potential collisions. FAROS is a system that provides a visual for pilots who intend to use the runway. EFB is a system that allows pilots to see their exact location on the runway, thus increasing awareness and lowering potential incursions [12].

f. Proposed Solution

Our project goal is to significantly reduce the number of runway incursions caused by miscommunication/lack of communication between the operator and the ATC as well as to help the operator maintain better situational awareness regarding his location at the airport. This falls in line with the FAA goals and strategies as runway incursions are one of the main sources of accidents. By creating a system which allows for both the air traffic controller as well as the vehicle operator to keep track of the whereabouts of ground vehicles we can greatly reduce the number of runway incursions and therefore the number of potential accidents. This system would also improve the efficiency of ground vehicles by improving the speed with which they can receive permissions as well as instructions from the control tower. Right now, vehicles must receive permission from the tower as well as a directed route to get from point A to point B. Our project would streamline this process.

The danger of operations on an airfield comes in large part from its complexity and from the large number of vehicles, both planes and ground vehicles, present on it. Today, the vehicles keep track of themselves and ask permission when they need to cross key areas, usually trouble spots where accidents have been frequent. Using current technology, a virtual, interactive map could be created and installed in each vehicle. Those who wish to move across the airfield would simply indicate on the map where they intend to go and this information would be relayed to ATC, which would either approve or deny the request. ATC would be presented with two buttons, one green and one red, to either approve or deny (respectively) the request. This exchange of basic information would ensure communication and reduce the risk of dangerous incursions due to unauthorized movement.

III. Problem Solving Approach

Prior to the start of the semester, project leader David Bremer worked with Adjunct Professors Zachary Staff and Chad Nixon to narrow down the list of potential project ideas. They identified areas of interest based on the applicability to local as well as larger airports and the estimated impact that such a project would have. Ideas that were deemed to address a particular airport problem or improve an area of operation in at least a moderate way were considered. The top categories included Air Traffic Control Vehicle Awareness, Automated Cost Estimation, Adjustable Terminal to Aircraft Boarding Bridges, Runway Friction Improvements and Automated Tracking of Airport Traffic. These ideas were then brought to the class's consideration and further refined.

After a lengthy discussion, the original five ideas were narrowed down to one. The creation of adjustable boarding bridges was ruled out because the current need was decided to be too insignificant. While an adjustable boarding bridge would be helpful in that it would be amenable to aircraft of varying sizes/heights from a terminal that may only have one floor, it was determined that the project as a whole would not create a large enough impact seeing as how airports seem to be easily operating without it. We also eliminated the possibility of improving friction on runways to aid in aircraft landing because we identified too many potential limitations. For example, the design would likely require much upkeep to keep the frictional component effective, it may interfere with the plowing and removal of snow on the runways in the winter and it was expected to have a negative effect on aircraft tires and landing gear, therefore requiring more maintenance and repair on those systems. Our team also decided not to pursue the automated tracking of aircraft because we decided that larger airports had a sufficient system to do so and other technologies may be available to accomplish the task.

Once our team had narrowed the topics down to the final two ideas, the team decided to pursue the Air Traffic Control Vehicle Awareness System. The team was more passionate about this idea and thought it would have more of a direct and positive impact on local and regional airports than the estimated cost analysis project. The team began to work on the project by investigating what types of tracking technology already exist and are already implemented in the airport setting. With this research, we were able to identify the weaknesses of current systems to thus focus our broad idea on a more specific area of focus.

The team was comprised of eleven undergraduate students, ten members and a project leader, under the guidance of two faculty advisors with experience in the aviation industry. Due to the varying demands of the project, our team was divided into four smaller sub-groups composed of two to three students each. The four groups were each responsible for a different component of the project while the project leader ensured that there was communication and cohesiveness between the groups. The Design team was responsible for creating the overall project solution, in this case a way to reduce runway incursions and better monitor vehicle movement. The Engineering and Graphics team worked with the Design team to create visual representations to better convey the proposed solution. This team was also in charge of taking photos to show the overall group progress. The Risk Assessment and Research team worked to ensure that the proposed solutions were fit for application and solved a problem in a novel and innovative way. Finally, the Strategies and Approach team was in charge of detailing how the various teams interacted to create a vehicle monitoring system and document the various contributions from outside resources.

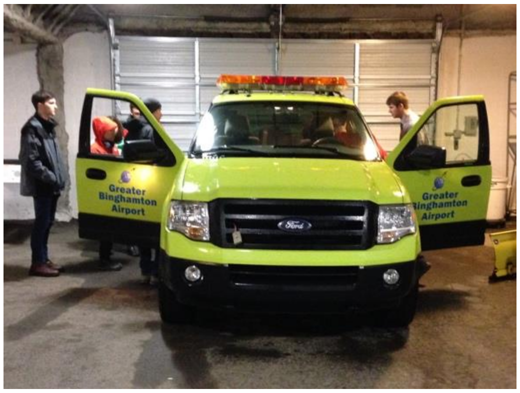

Figure 1 – Members of the team take a drive in a ground vehicle at the Greater Binghamton Airport with Mark Heefner, Deputy Commissioner of Aviation.

Each team met regularly, both in and out of class to complete the various tasks assigned to them. Most people on the team had little to no background knowledge about aviation, so it was important that everyone initially did some outside research, looking into topics such as interactions between people in ground vehicles and people in the air tower, how the ground vehicles successfully travel on the airport runways, etc. As a group, the whole team visited the Greater Binghamton Airport to meet with industry professionals and gain a better perspective of the kinds of problems that needed to be dealt with. As shown in Figure 1, the team was able to go inside a ground vehicle and get a first-hand look at how the driver of the vehicle interacted with the people in the control tower.

The team also brought professionals to class to give us information about their experiences with the topics we were investigating. These interactions were very helpful in our efforts to design a system that most effectively reduced runway incursions and promoted the safety of airport traffic as well as an ease for Air Traffic Controllers.

IV. Technical Aspects Addressed

Runway confusion is a major cause of runway incursions [13]. This confusion can be mitigated by proper route planning. As the air traffic controller controls ground vehicle operations, it is also important for the Air Traffic Control (ATC) staff to have complete awareness of every part of the airfield. There is currently a system for locating aircraft and vehicles, Airport Surface Detection Equipment, Model X (ASDE-X), but has only been installed at 35 American airports [14]. ASDE-X increases awareness for air traffic controllers at select airports, but fails to increase situational awareness for the ground vehicle operators themselves.

Several factors can cause this lack of situational awareness, but it can most simply be explained by general confusion. Therefore, it is important that the system is easily understandable, both for the day-to-day ground vehicle operation staff at the airport, and especially for those who are less familiar with the airport. For example, this could include a contractor on site at the airport working on an airport improvement project. Considering this, the proposed system uses Global Positioning Service (GPS) technology. Personal GPS devices, including modern cell phones, are commonly used for navigation and are becoming more prevalent [15]. Mimicking technology that ground vehicle operators will likely already recognize and know how to use further decreases potential confusion, especially so in people with less experience in ground vehicle operation protocol and less familiarity of the airport layout.

a. Technology Used

Vehicle Incursion Prevention System (VIPS) combines several current technologies into one system, including GPS navigation systems and turn-by-turn routing systems, ASDE-X, and touch screen technology. All technologies used in the design are intended to have ideally been used before by airport operators, and failing that, are simple to use.

i. Navigation systems

Global positioning device services are operated through a series of satellites orbiting earth. These satellites are capable of locating individual GPS devices with an accuracy of better than 3.5 meters [16]. Navigation systems are able to use a GPS device's precise location to show the user where they are on a map, in addition to telling the user exactly how to get from one point to another through turn-by-turn navigation. Turn-by-turn navigation has been optimized, as even a simple journey may have many potential route variations. These routes can be optimized for the fastest route, or the most direct route, in addition to others. Commercial GPS devices contain data on hundreds of thousands of miles of road. The GPS devices used in the proposed system will only contain data on potential vehicle routes within the airport. This can allow for even further route optimization as ATC staff can adjust routing preferences to the best and safest way to navigate the airport.

ii. ASDE-X

ASDE-X allows ATC staff to know exactly where every aircraft is within the movement area of the airport, in addition to the location of nearby aircraft on final approach to the airport. This information is displayed to ATC staff on a map. This greatly increases awareness of where all aircraft are in relation to each other for ATC staff. However, this system is expensive, and is only implemented at busier airports. At these airports with ASDE-X, the proposed system can give ATC staff even more information on vehicle locations, including the intended route of all ground vehicles. At airports that do not have ASDE-X, VIPS can act as a partial replacement to the functionality of ASDE-X at a fraction of the cost.

iii. Touchscreen Technology

Another feature of VIPS is a touchscreen map of the airport in the ATC tower. This map can display vehicle locations, routes, and hotspot locations. Through the use of a touchscreen, the tower operator would have a great deal of interactivity with the map. For example, the ATC staff will be able to toggle which class of vehicle he or she wants shown on the map, as well as the ability to pick a specific vehicle and view the vehicle’s intended route. The touchscreen map would be fluid, with real-time vehicle locations updated as often as GPS data will remain accurate.

a. How VIPS Works

The VIPS is based on the use of GPS so that ATC can track the location of airport vehicles in real time. It also allows the vehicles to the ability to see their location as well as the ability to see their route. Only vehicles that have access to the movement area would need to be GPS enabled.

In the ATC tower, the staff would have access to a touchscreen computer on which he would have a map of the airport in question. He would be able to see the real time locations of all ground vehicles on the airport. These would be color coded by the kind of vehicle, for example, fire and emergency vehicles would appear as red dots while maintenance vehicles would appear as yellow. The vehicle's number would also appear next to the dot. That way if the ATC staff was notified of a vehicle in a restricted area without permission, they would immediately be able to identify and contact it. Information from ASDE-X would also be incorporated into the system so that the ATC staff can see for themselves if there are any planes potentially in the path of a vehicle. A series of filters would then allow the ATC staff to choose which information he wants on his display.

Assigning a route for a vehicle would also be very simple. Once the vehicle identifies itself to the ATC, he simply types in the vehicle number which would highlight it on the display. The ATC staff then hits the "assign a destination" button and taps the chosen destination on the screen. The program would then automatically assign a route and send it to the vehicle. The ATC staff would still verbally relay the command and then wait for his command to be repeated as we feel this verbal confirmation is still very important.

In the vehicle, the driver would have a small portable GPS unit similar to those found in regular vehicles. On the GPS unit, he would only be able to see his own vehicle and path on a map of the airport. He would not be able to see other vehicles on it as this forces the driver to still keep his head up looking out for other vehicles instead of concentrating on the GPS. The GPS would also highlight hot spots as well as locations requiring the vehicle to hold short. When the vehicle approaches a hold short location, the GPS would provide a vocal reminder to call into ATC and request permission to continue. This will be particularly useful for drivers who are new to the airport. The key is to provide clear instructions for the drive without distracting him.

This section provides a demonstration of how the system would work for a vehicle attempting to make it from one side of the airport to another. In this case, we will use the example of the Greater Binghamton Airport, which has the layout seen in Figure 2.

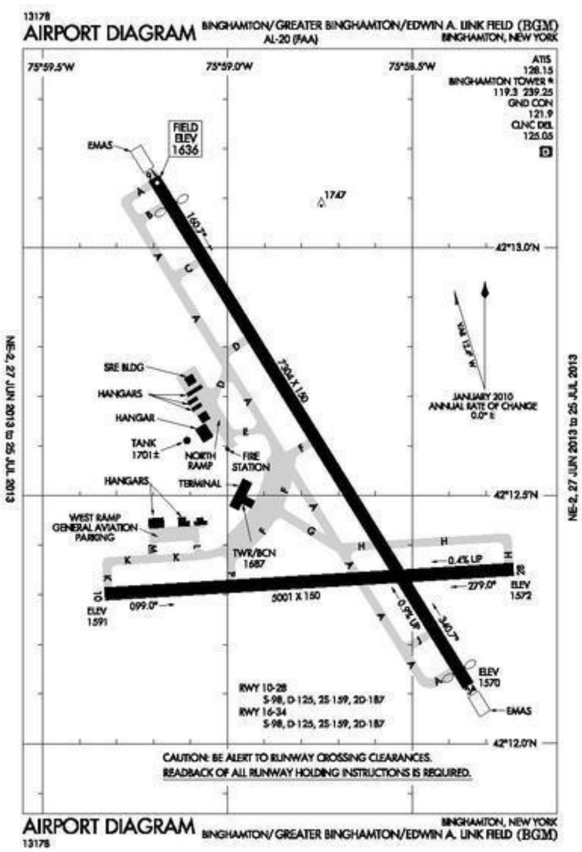

Figure 2 – Layout of Greater Binghamton Airport.

The first step is for the vehicle to contact the ATC via radio with his or her request to move along Taxiway Alpha to Taxiway J:

"Binghamton ground, Vehicle A76325 would like to cross Runway 10/28 via Taxiway Alpha and proceed to Taxiway Juliett."

The ATC staff would then type in the vehicle number into his or her computer thereby selecting it. His or her screen would appear as in Figure 3 on the following page.

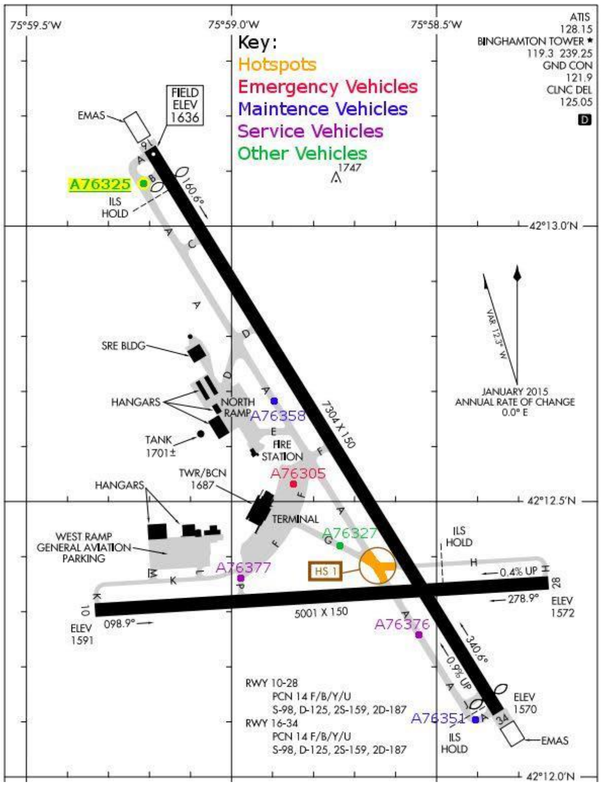

Figure 3 – VIPS as viewed from within the control tower.

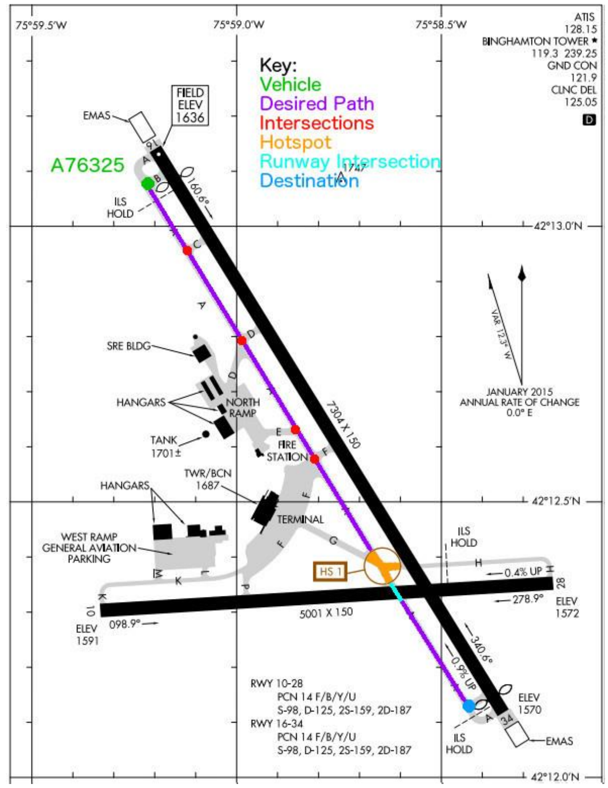

Figure 4 – VIPS as viewed from within the vehicle.

The software then produces the best route, which appears on the controller's screen and is sent to the driver, as seen in Figure 4.

Having done this, the ATC staff must still verbally confirm the instructions in accordance with current FAA procedure, as follows:

"Vehicle A76325, Binghamton Ground, proceed via Alpha and hold short of Runway 10/28." -Controller

"Roger, Vehicle A76325, proceeding via Alpha, will hold short of runway 10/28." -Driver

The vehicle would then be free to continue down Taxiway Alpha. The GPS would provide with his real time location and when the vehicle gets close to Runway 10/28 will provide a verbal reminder of the hold short order and to call into the ATC for permission to continue. The proposed system will help cut down on runway incursions through increased ground vehicle operator situational awareness.

It is anticipated that the VIPS will greatly reduce the number of runway incursions that occur daily. This will occur through the implementation of a new GPS-based system. This system is designed to aid people on the ground by giving them visual directions other than just vocal ones. This will greatly help limit runway incursions for those unfamiliar with the airport as this method is simpler to follow. This will also give drivers clearer instructions because they can see the exact path they need to take. This will allow the drivers of the vehicles to be accustomed to where they are going. Also, as the VIPS will not be placed in an obscure place it will not be a hazard to drivers by making them take their eyes off the road. Therefore, drivers will have the same alertness as before with the added benefit of seeing the route they should actually take. It also helps the drivers because it gives them extra warning about where they have to hold short so it makes them less likely to confuse or make a mistake with the ATC instructions. However, since the VIPS is not completely replacing the old system the drivers should remain comfortable with the system so there will not have to be a large learning curve.

The ATC will also be greatly impacted by the implementation of VIPS. VIPS will make giving out orders to vehicles much simpler. It will help the ground controller save a lot of time giving out orders and will reduce the amount of radio chatter. Even though a verbal component is still necessary, it can be reduced by increasing the clarity of the message by displaying it in two forms. This will limit the amount of incursions because all the directions will be clearer without extra radio chatter. Also, the ATC staff will be able to be more vigilant of the airfield since they do not have to be constantly focusing on giving or clarifying the directions. Since the VIPS will implement the screen within all vehicles, the controllers will have access to a lot more data about what is happening on the airfield at their fingertips. This will allow them to be able to better predict potential incursions by knowing what each of the vehicles routes are so they can watch the progress of the vehicles.

In the long term the implementation of the VIPS will greatly reduce the number of runway incursions. It will allow both ATC staff and vehicles operators to have more information about what is happening on the airfield. By giving this excess information there will be less confusion present which is one of the biggest causes of runway incursions. With the implementation of VIPS, current technology will not be replaced but rather improved. Therefore, all the same functions will be available but modernized through the addition of the VIPS system.

V. Safety and Risk Assessment

It is one of the key objectives of the FAA to maintain and improve the safety of air travel, as stated in the 2010 Fiscal Year (FY) Portfolio of Goals. The FAA explains in the portfolio that a safety management system is “critical to meeting the challenges of a rapidly changing and expanding aviation system [17].” The FAA’s system of safety management depends on the use of “standardized language, processes, and tools” that can be applied to help in minimizing the amount of danger that occurs in an airport. The system of safety risk management works by undergoing five phases. These phases include describing the system, identifying the hazards, determining the risk, assessing and analyzing the risk, and treating the risk [18].

		A	B	C	D	E
		Negligible	Minor	Moderate	Significant	Severe
E	Very Likely	Low Med	Medium	Med Hi	High	High
D	Likely	Low	Low Med	Medium	Med Hi	High
C	Possible	Low	Low Med	Medium	Med Hi	Med Hi
B	Unlikely	Low	Low Med	Low Med	Medium	Med Hi
A	Very Unlikely	Low	Low	Low Med	Medium	Medium

Figure 5 – FAA Risk Matrix [19].

Risks can be assessed by using the FAA risk matrix as seen in Figure 5.

According to this biaxial matrix, projects are deemed as high, medium high, medium, low medium, or low risk based on their expected effects. The vertical axis of the matrix represents the likelihood of the event occurring, with ratings ranging from "very likely" to "very unlikely". The horizontal axis evaluates the severity of the consequences for the event, from "negligible" to "severe". Simply connecting these two factors allows for an assessment of the risks. As seen on the matrix, colors of green, yellow, and red have been used to classify the risks. Immediate action must be taken to mitigate the potential effects of risks in the high risk area. We believe the VIPS is very safe system and is virtually free of risk. It decreases the likelihood of vehicle incursions, while decreasing any time wasted when an operator wants to find a safe pathway for travel. Any possible risk linked with the VIPS was compared against the FAA safety risk matrix and produced promising results.

If the VIPS is implemented via the method proposed, then the likelihood of any incursion occurring would be very unlikely. This is because if there is ever a problem with the system, the operators will always be able to revert back to their current method of communication.

There are several areas in which this system could be a source of risk. The biggest concern for airport operators using this new system is that the Global Positioning System (GPS) screen could potentially become a hazard. Ground operators may be more focused on the screen than on what is in front of them or what is in their surroundings. It may be difficult to look at the screen and look out the front window simultaneously. This can likely be mitigated with adequate training and opportunities for the existing Air Traffic Control (ATC) staff to gain further experience with the new system. Learning how often to look up between information inputs is something we are unable to control.

Another risk is the possible occurrence of computer malfunctions that could give false instructions to the driver. These inaccuracies could be any malfunction or spurious electrical signal caused by a brief, unwanted surge of electric power. If a driver went off track by following a malfunctioning GPS and the ATC staff did not notice this deviation, there is a high risk for incursion and collision. However, these can be fixed using most glitch removal tools. Therefore, the possibility of this occurring is present, but not overwhelming.

Overall, the VIPS system proposed would be very safe and reliable. VIPS can help the ATC more readily keep track of numerous ground vehicles at a time and it will help vehicles navigate through airports. A combination of this system and the one currently in place should be able to eliminate almost any possible vehicle incursions at an airport. Our team believes the two systems can be effectively used together. If the verbal communication system used now ever experiences any problems at an airport, the system will also be able to provide a safe, alternative form of communication. This can be especially useful at larger airports, where many vehicles may be moving at a time and many a number of ATC communications may be occurring at one. Also, the VIPS may not only be an alternative one, as it has potential to be an even faster, more efficient method of communication.

VI. Interaction with Airport Operators

a. Team Visit to Greater Binghamton Airport

Our team visited The Greater Binghamton Airport on February 16, 2016. During the visit, the team, pictured at the Airport in Figure 6, had the opportunity to talk to Mark Heefner, Deputy Commissioner of Aviation, and David Hickling, Commissioner of Aviation. On the trip, the team was also able to talk to two air traffic controllers from the FAA, Jeremy Polhamus and Bill Peterson. During the time at the airport, the team was able to learn about the job of an air traffic controller, their protocols and their training. The team also learned the differences in operations of a smaller airport like Binghamton when compared to a larger airport such as John F. Kennedy International in New York City. The entire airport staff was very insightful and helpful in providing background knowledge about air traffic, ground traffic and basic airport operations.

Figure 6 - The team on the runway at the Greater Binghamton Airport.

The team described the design to the controllers and asked for their opinions. Mr. Polhamus had doubts about the original idea of having a Global Positioning System (GPS) or heads-up display, because the drivers would have to take their eyes off the road. He said that most of all airport collisions occur due to drivers not paying attention to where they are going. Through the team's interactions with the controllers, the team learned that there is a preexisting light system in case of emergency if the radio were to go down. This process involves light signals for directing vehicles and planes where to go. They suggested integrating this system into the team design. Mr. Peterson stressed to the team that air traffic controllers have a very strict and regulated set of rules and regulations and that making changes would be very difficult. To fix this issue, he suggested that the team does not create a new system and instead just tweak the system already in place.

Half of the team went to the Air Traffic Control (ATC) tower, where they were able to examine current procedures for tracking airport traffic both in the air and on the ground. Due to the poor weather conditions, they were not able to observe any interactions between the air traffic controllers and aircraft. However, they were able to hear radio transmissions between the controllers and ground vehicles traveling on the airport. Mr. Peterson and Mr. Polhamus also gave a general overview of how ATC operates, what procedures are in place, and how a typical conversation with ground and air traffic tends to happen. The other half of the team had the opportunity to take a ride on the runway in an airport ground crew vehicle. During this ride, the team was able to see first-hand how the air traffic controllers interact with ground crew. The team was able to see all of the different equipment in the truck and learned a few of the command protocols between controllers and drivers.

b. Industry Official Jared Moore Visits Binghamton University

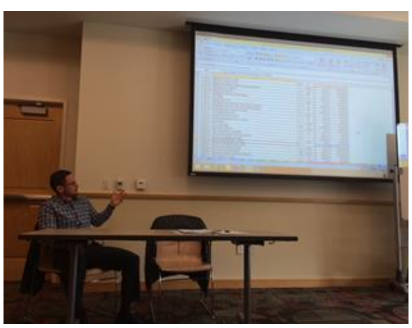

Figure 7 – Jared Moore answers questions about the project during a trip to Binghamton University.

In early March, industry expert Jared Moore, who works for McFarland Johnson, visited the team at Binghamton University to review project designs and offer his professional advice. Mr. Moore, pictured in Figure 7, provided important information about ATC and ground vehicle operations. This information helped the team organize and develop appropriate ideas for the design solution. In addition, he made himself available to answer all of the team's questions about the project and was able to provide insight on a few topics that relate to this project. For example, he explained that most ground vehicle incursions at airports are caused because of a lack of familiarity with the airport layout and a lack of clearance. Therefore, having a GPS inside of the vehicles would be very helpful in preventing these kinds of incursions. Additionally, Mr. Moore explained that a head's up display may be distracting because it is best for the airport operators to not take their eyes off of the road while they are driving down runways. Large airports generally have a lot of controllers talking over each other when there is a lot of traffic, and Mr. Moore agreed that having some sort of automated system to control when and where ground vehicles can drive on the runway could make things a lot easier for many airports.

VII. Projected Impacts

a. FAA Goals

The FAA's Destination 2025 strategic plan states that the FAA intends to "maintain the rate of serious runway incursions at or below 20 per 1000 events." One of the FAA's listed strategies is to "strengthen and improve technology, infrastructure, training, [and] procedures… to reduce the risk of accidents from all causes in all phases of operations" [5]. The Vehicle Incursion Prevention System (VIPS) will do exactly this.

VIPS is not a paradigm shift in Air Traffic Control (ATC) tower-to-ground vehicle interaction, nor is it an entirely new way for ground vehicles to travel along the airfield. VIPS will install technology to give both the ATC and ground vehicle operators greater situational awareness. Tower operators will have access to the location of each and every ground vehicle at their fingertips, and ground vehicle operators will have exact knowledge of where they are, especially their proximity to hot spots and high risk areas. These tools will therefore help lower the rate of runway incursions.

b. Commercial Potential

The VIPS gets its commercial potential from its simplicity. All the elements necessary are either already in existence or could easily be derived from current technology. The GPS used in the vehicles could be the same variety as those found in thousands of private vehicles. As a matter of fact, due to the simplicity of airport layouts and the fact that each GPS only needs data for one airport, the cheapest GPS would likely suffice. Large touchscreens are also becoming much more common and affordable. Finally, the software that would produce the route given the starting point and desired destination already exists in forms such as Google Earth and other mapping software currently in use.

Installing the hardware would also be relatively simple both in the vehicles and in the ATC. For the latter, installation would consist of simply installing a new touchscreen monitor. As for the vehicles, the system is designed to be easily installed into visiting vehicles and would be very similar to installing a GPS holder on the vehicle and plugging it into a power source.

In terms of use, the VIPS would be designed to be as user friendly as possible so that its use is easy to learn. This is why the system would have an interface similar to that of Google Maps, a platform that is very familiar to most people. Also this system requires very little maintenance over time. The only updates that would be necessary would be to include changes to the airports such as eventual expansions to the airport or the inclusion of more GPS units.

VIPS allows the ATC to easily keep track of large numbers of ground vehicles and allows vehicles to better navigate confusing airports. As a result, the system is geared more towards larger airports with towers as most smaller airports do not have enough ground vehicles or a complex enough airport layout for such a system to be necessary. However, it still offers interesting possibilities towards smaller airports. An example would include the event that weather reduces visibility or in the event of new or temporary drivers who may not be used to airport regulations. VIPS would help reinforce certain rules such as hold shorts and forces drivers to use proper protocol. Also, since smaller airports often do not have a tower, the VIPS could still provide small airports with the ability to track vehicles without actually seeing them. It would also compliment new systems such as remote air traffic control towers as the GPS data can be accessed both on site and via the Internet.

c. Financial Analysis

Item	Description	Quantity	Cost
Garmin Drive™ 50LM	The GPS unit which is a basic unit made by a trusted company includes vehicle mount.	1 per vehicle	$149.99
3M C4667PW 46" LED LCD Touchscreen Monitor - 16:9 - 12 ms	Large touchscreen to be used by controllers in tower.	1 per airport	$3,763.01
Map graphic design	Design created for each airport to be uploaded on to the GPS.	1 per airport	$100

Figure 8 – Cost analysis for VIPS.

The VIPS is an extremely cost effective system, as seen from the data in Figure 8. The project's main cost consists of the price of the hardware. We estimate that in an average small airport there is an average of 25 vehicles in need of a GPS unit at once, whereas a large airport may have up to one thousand. Therefore, the implementation of our system could cost between $7,600 and $160,000. Although this startup cost may seem large, it is a lot less than many of the currently proposed solutions. For instance, the solution that was planned to be implemented into numerous airports, known as the ASDE-X would cost around $16 Million per airport [20]. Therefore, the implementation of this system could save millions of dollars. This explains why our system is a worthwhile investment.

VIII. Summary and Conclusion

The FAA has set its goals regarding airport safety and the expectation is that they will be met by 2025. In order to improve the overall efficiency of the airport, it is necessary to address the safety concerns. Although the FAA has certain methods in place in order to provide airport safety, there are some methods that are able to provide the same amount of safety, if not more. Along with potentially increasing an airports safety, the development of new methods will improve the efficiency of the airport. Additionally, these new methods can also help meet the FAA's goals as mentioned in *Destination 2025*.

Ground vehicle communication with the control tower has a high risk for runway incursions to occur due to miscommunication or unclear instructions, decreasing the overall safety of the airport. Currently, many airports use the same system for communication between the ground vehicle and the control tower, repeating what each other say in order to reduce the risk of incursion. However, since error is still able to occur very easily, the development of additional systems will help reduce the risk of runway incursions by reiterating what the ground vehicle is requesting, and then reiterating the response of the control tower. The students at Binghamton University - State University of New York have created a vehicle location awareness system to help decrease the likeliness of runway incursions. The way the system works is similar to GPS technology in that the main display is a satellite map of the airport, with labels for each road and runway. This display is to be placed in the air traffic control tower as well as ground the vehicles with access to movement areas. The vehicle display shows the map with labels, locations of intersections and locations of hotspots. The control tower display shows everything on the vehicle display, as well as the location of each vehicle. This system is designed to promote airport safety by increasing vehicle location awareness. By addressing one of the most important values in aviation, this solution will allow the FAA to further its goal to “advance aviation safety worldwide.”

Appendix A: List of Complete Contact Information

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Appendix B: Description of Binghamton University

Figure 9 – Binghamton University.

Binghamton University (BU, pictured in Figure 9), originally called Triple Cities college, was founded in 1946 as a satellite location of Syracuse University. It was created in an attempt to create educational opportunities for soldiers returning home from World War II. In 1950, it was renamed Harpur College and officially joined the network of the State Universities of New York. The school moved to its current location at 4400 Vestal Parkway East in Vestal, NY in 1961 and finally became the State University of New York at Binghamton in 1965. Binghamton University has been the school's informal name since 1992 [21].

The University has roughly 13,000 undergraduate and 3,000 graduate students with a student to faculty ratio of 20:1 [22]. There are six schools within BU (College of Community and Public Affairs, Decker School of Nursing, Graduate School, Harpur College of Arts and Sciences, School of Management and Thomas J. Watson School of Engineering and Applied Science) with a seventh set to open soon (School of Pharmacy and Pharmaceutical Sciences) [21].

In 2015, Forbes ranked Binghamton University as the 154th best college in America, the 72nd in the Northeast. As a research institute, Binghamton boasts a rank of 73rd [22]. The University was also listed as the 37th best public school and the 89th best national university by US News [23]. With a 43% admittance rate [22] and 90.8% student retention rate from Freshman to Sophomore year, Binghamton University is listed as one of the premier public universities in the Northeast [21].

Appendix C: Description of Non-University Partners

a. Greater Binghamton Airport, Johnson City, New York

The Greater Binghamton Airport is a local airport in the Binghamton area that offers non-stop airline flights to three locations, including Philadelphia, Newark, and Detroit on three airlines Delta, American, and United Airlines [24]. The Greater Binghamton Airport is in a prime location, offering access to many large cities in the Northeast including Boston, Washington, D.C., New York City, etc. With so much local aviation history at this airport, there is a lot of education to experience, available incentives, and a business friendly environment [25]. In addition to commercial air service, the Greater Binghamton Airport offers private, corporate, and charter flights, with a Fixed Base Operator and U.S. Customs and Border Control to provide many different services for all types of aviation [26]. The current Commissioner of Aviation at the Greater Binghamton Airport is David Hickling, and he, along with other airport staff, made themselves available to answer questions in relation to the project during the Binghamton team's trip to the airport.

b. McFarland Johnson

McFarland Johnson is a 100 percent employee-owned engineering consulting firm that has multiple branches throughout the east coast, with its corporate headquarters located in Binghamton, New York [27]. Founded in 1964, McFarland Johnson's mission is to "be recognized as a progressive company comprised of innovative employee-owners working together as a team in a fun learning environment, who are dedicated to achieving our goals while improving our communities, our families and ourselves [28]." This company has worked on hundreds of projects for a variety of airports ranging from large commercial airports to small general aviation facilities [29]. Their services offered include grant writing, environmental services, aviation planning, and geographic information system (GIS) capabilities [30]. In addition, Jared Moore, who works at McFarland Johnson, visited the team at Binghamton University and made himself available to answer questions about the project and explain how he works with the Greater Binghamton Airport.

c. Federal Aviation Administration (FAA)

The FAA is mainly responsible for all safety involved in aviation. The duties of the FAA include regulating civil aviation, developing programs to control aircraft noise, regulating commercial space transportation, and most important for this specific project, developing and operating a system of air traffic control and navigation for both civil and military aircrafts [31]. The Air Traffic Organization (ATO) at the FAA is responsible for providing safe air navigation to over thirty million miles of airspace, which represents more than 17% of the world's airspace. Right now, the U.S air traffic system is experiencing its safest period ever, as the Safety Management System can often identify risks before there's even a problem [32]. During the team's trip to the airport, Jeremy Polhamus and Bill Peterson, who both work for the FAA and deal with air traffic control on a daily basis, made themselves available to answer questions about the project.

Appendix E. Evaluation of Educational Experience

Student Evaluation

1. Did the ACRP provide a meaningful learning experience for you? Why or why not?

The ACRP design competition provided a meaningful learning experience because it gave us the opportunity to use the information learned in class and give it a real-world application, which is rare for undergraduates. There were few set deadlines which meant each team member had to be more self- aware in terms of time management and finishing assignments. Each member improved his/her time management skills. In addition, being able to participate in a national competition during freshman year, many of us feel, is a unique experience we feel will be able to help us in the future. The traditional classroom has students learning in a lecture setting or doing labs while this competition taught our team to take an idea and develop it from start to finish.

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

Initially, the main concern for the team was the lack of prior knowledge on the topic and on airports in general. None of our members had previously done extensive research on the dynamics of air travel and therefore the phrasings and terminology relating to the aspects of our project were difficult to understand. Before we could begin brainstorming, our team had to do weeks of research. Our biggest challenge was trying to find a project idea that both included our original ideas and the accommodation of the airport controllers. The air traffic control operators showed reluctance to our initial proposal, so we had to revise. Our Design team had to revisit their proposal and generate a number of revisions before we could move forward. Each proposal was reviewed by our team leader and discussed with the Safety and Risk Assessment Team.

Satisfying the project requirements while appeasing the controllers was a difficult and unforeseen complication that our team overcame.

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

In November of 2015, the project leader hypothesized thirteen possible project concepts for our team to accomplish. These were each compared to the FAA's safety goals in order to determine which current issues needed to be addressed. These ideas were forwarded to our Professors, and then narrowed to five ideas, which were then voted on by the student team at the start of the Spring 2016 semester.

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

Participation by industry in the project was absolutely a key part of this project. Without industry interaction, our team would not have known exactly which type of solution would be preferred. This information was invaluable because it made us tailor our solution to be favorable to both large airports and small airports.

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

This project enhanced the team's research skills. We evaluate sources and figure out what data is meaningful to our project. The whole process was successful in teaching us the skills and knowledge to pursue other research. We practiced teamwork and team building, both of which are useful skills that are favorable in the workforce.

Faculty Response

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

The ACRP Design Competition provides an ideal opportunity for students to complete real world tasks in an academic setting. Experiential learning is a critical element in the overall academic experience, which is not usually incorporated into the freshman/sophomore curriculum. The students started with an idea and had to develop, revise, and research it from start to finish. They could also see their work. It is a very applicable topic that can be used in airports across the country, from small-scale, local airports such as the Southern Tier Airport to widely used, large-scale terminals such as LaGuardia or JFK.

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

All of the students on the team are undergraduates, with most in their freshman or sophomore year of college. As a result, many of these students have had limited opportunities to work in a team setting. This competition brought students together into teams and taught them to communicate and work together effectively in order to submit documents and meet deadlines. The aggressive schedule pushed them to develop and refine their time management skills. This is a key element of the learning experience and one that they will be able to utilize beyond the classroom and into their careers. As a result, the experience was appropriate and effective.

3. What challenges did the students face and overcome?

The students faced and overcame numerous challenges throughout the development of their proposal. This is not something usually asked of underclassmen and therefore not covered in regular courses. The challenges the students faced were overcome through teamwork and the dedication of the project leader. These leaders set a tempo from the first day that ensured all team members understood their role and took those roles seriously. The leader checked in with each member frequently to ensure progress was made and that all documents to create the overall proposal were completed in a cohesive manner.

The competition deadline has also provided additional challenges which our students have overcome. Again, the project leader was tasked with delegating all assignments among the team members. The entire class was well aware that all students would need to perform at their highest levels to ensure completion of the proposal in advance of the deadline and to ensure that the entire team would not suffer due to a missed deadline. This interdependency proved a valuable learning experience.

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

We would highly recommend this competition to future faculty members and students. The project's real-world application and the competitiveness on a national level are difficult to simulate in a traditional classroom, which is why this experience is so valuable. The students were held up to certain standards and requirements which they had to fulfill by a strict deadline, which promoted teamwork and self-monitoring. This competition served a vehicle to teach the teams how to work together, which is a highly valuable skill in the workforce.

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

Considering the rapidly changing industry, the ACRP should modify the competition prompts to keep them relevant. Historically, the ACRP/FAA has diligently been updating project prompts to including topics such as climate change and land use. The competition should continue to review their prompts and modify them as needed to applicable to current issues.

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