2018-2019 Airport Cooperative Research Program Design Competition

Virtual Moving Map

Pennsylvania State University
Engineering Leadership Development Program

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3. Problem Statement

The design challenge the team chose to undertake was that of II.J, Methods for improving runway safety during airport construction and reconstruction. The problem statement for the team was developing new technology and methods of communication to reduce the number of incursion that occur during periods of construction. With that being said the team aimed to truly understand why this was such an issue. Through research it was established that $200 million was lost in 2016 due to incursions and the number of incursion has only continued to climb since then (*2016 Runway Accidents*, n.d.). Research also proved a direct correlation between construction and incursions. Lastly, research proved that the numbers of incursions have just continued to climb from 1561 in 2016 to 1834 in 2018 (*Runway Safety Statistics*, n.d.).

Research also showed that one of the biggest contributing factors of runway incursions is a breakdown in communication. Current communication methods that are in place to transfer information from air traffic control (ATC) to pilots comes in many forms, most of it non-verbal. There is the standard verbal communication through headsets from the tower to the plane. There is also various signs on the runway and runway lights which are powered by fibre optic cables. Marshalers also provide visual means of communication by using teams of workers and orange batons to guide the plane. These methods all have gaps as evidenced by the fact that incurisions still occur. There is talk of creating completely wireless airports to help improve communication as was tried by the Société Internationale de Télécommunications Aéronautiques (SITA) in the Dusseldorf International Airport in 2008 (Fischer, 2011). One of the primary challenges with an undertaking like this is the size of most airports. The team aims to focus more on continuing to streamline and improve communication between ATC and pilots giving pilots a better understanding of what is happening on the runway around them.

4. Research

In order to find a solution to the design challenge, we conducted both secondary research and research through contacting experts. We talked with experts in aviation construction management, communication, training, and technology; then, we researched the aforementioned factors and how they influence runway safety and incursions. We were amazed to realize that there is a direct correlation between runway incursions and airport construction due primarily to: human error, lack of training for construction workers, and difficulties with nonverbal communication. It would be game changing if we could help airports eliminate incursions from construction and improve the overall safety of airports for everyone involved.

4.1 Construction

The researching process began by looking into the different types of construction at airports and how they affect traffic on runways and taxiways. According to Gary Mitchell, common airport construction includes concrete slab replacements or asphalt patching and repairs or maintenance to taxiways and ramps. Some construction causes taxiways to be closed which results in the rerouting of traffic onto runways. Mitchell has also stated that if an active feature must be crossed, there is a station at the crossing that is in contact with tower and ground control. Furthermore, major demolition and reconstruction can cause a runway to be closed for months and sites are barricaded to prevent aircraft from going into the work zone. Safety is a top priority when it comes to airport construction. Mitchell has informed us that Notices to Airmen

(NOTAMs) are sent to notify people of construction, closures of taxiways and ramps, any changes in navigational aids.

At the Reno-Tahoe International airport in Nevada, an increase in incursions has been shown after a major taxiway renovation project in 2015. There were 18 total incursions in 2015, 11 of which were directly related to construction. To compare, there were just seven incursions in 2014 when there was not major construction. This construction has caused such a big problem that the airport has been attempting to inform pilots about it via newsletters and social media. The majority of the incursions occuring are from pilot error, as some of the pilots are not stopping behind the hold-short line without clearance from ATC (Hart, 2016). The data gathered from the Reno-Tahoe airport shows that there is a direct correlation between construction and incursions.

4.2 Communication

In 2018, approximately 62 percent of all incursions were caused by pilot deviation. (*Runway Incursion Totals*, 2018). A pilot deviation is when a pilot violates a Federal Aviation Regulation such as crossing a hold marking without clearance (Hart, 2016). Pilot confusion can cause pilot deviations when the pilot is unsure of where to go or what is happening at the airport around him or her. Further research noted that runway lighting is one of the primary channels of communication between pilots and air traffic control. These lights are powered via fibre-optic cables which can be damaged during periods of heightened activity. One proposed solution to this issue is to implement wirelessly controlled lighting as a backup system.

There is also the potential to make the entire airport wireless. All communication between airport personnel happens on a single radio platform. Dusseldorf International Airport had this system installed by SITA, the world's leading IT/telecom company for the airport industry. It allows for ATC to communicate directly with pilots in the cockpit and for the control of security personnel. Each authorized personnel member has a portable identification device that he or she can use to check in along patrol routes and gain access to certain areas. Access is programed an monitored to ensure that no one enters a secured area without proper clearance (Fisher, 2011). Incursions may occur when security personnel is not vigilant, therefore this communication system can resolve this issue.

4.3 Training

The levels of training for airport crews, pilots, and construction workers was researched. For airport crews, the training is extensive with many checklists and safety trainings completed to maintain knowledge of runway safety (*Runway and Taxiway Construction*, 2018). Pilot training is even more extensive because pilots need to know what to do when there is an obstruction on a runway or taxiway. The level of training for construction workers varies as some have more qualifications than others and it can depend on the airport according to Mr. Taft, Director of Airports at the Tri-Cities Airport in Washington. Some construction workers are trained in security and movement area, however, usually the leaders of the construction group has this training and are responsible for instructing the workers under them. Mitchell has stated that at pre-construction meetings and weekly meetings during the construction period, safety is always a big topic of discussion. Construction workers must either be badged or escorted. Workers with a badge go through specific trainings.

4.4 Technology

Before generating ideas for solutions to the problem, we investigated current technology systems in place at airports as well as the use of fiber optic cabling on runways. Some airports utilize runway surface detection technologies. The ASDE-X is a five component runway detection system consisting of: multilateration, surface movement radar, automatic dependent surveillance (ADS), multi-sensor data processing, and tower displays (SKYbrary Wiki. (n.d.)). AMASS is another system used that is a new iteration of ASDE-3 (Northrop Grumman's First AMASS System Commissioned at San Francisco International Airport. (n.d.)). This system provides aural alerts to ATC about potential incursions on ground and approach sensor systems. The aforementioned systems are primarily automated and are currently in place at high-traffic airports across the United States.

4.5 Contacting Stakeholders

Initial correspondence was established between the team and Dr. Jose Ruiz (professor of aviation at Southern Illinois University), Barry Bratton (associate at ADK Consulting), Gary Mitchell (Vice President, Airport and Pavement Technology), and Stewart Schreckengast (Lecturer, Purdue University). Both Ruiz and Bratton are experts in the field of runway safety and were very helpful in the early stages of our research. Mitchell and Schreckengast are experts in airport management systems. Through their experience they were able to validate some of our initial hypotheses that the human element is one of the primary causes of runway incursions. They helped connect construction projects to a rise in the number of incursions in airports. Additionally, they provided a bit of insight into the current methods of communication in airports and some of the standardization across the industry. All of this was crucial in establishing a solid base of knowledge for the team and getting us started of on the right foot.

Mitchell took a specific interest in our design problem, therefore we contacted him again after generating potential solutions, which is discussed in section 7.2.

5. Problem Solving Approach

The group chose a pretty general approach to solving this problem. With all of the information that had been collected through research the team developed some common themes and major insights. The team then began brainstorming various ways to address these insights. Once the team had generated and refined potential solutions a decision matrix was used to conduct a preliminary evaluation on the solutions. The decision matrix helped determine which solution met the needs the best and it helped identify which aspects of certain solutions were strongest. The final solution at the end of the problem solving process, in this instance the Virtual Moving Map, was then sent along for more in depth evaluation and refinement.

5.1 Concept Generation

The brainstorming process was a two week process. The first week involved identifying themes of our research from the two weeks prior of research. We did this by each writing five themes per person on the board and then as a group we went back through each person's list and highlighted ones that appeared more frequently. The major themes we decided upon were communication, construction, systems, and safety. Once we identified our themes, we then established insight statements for each theme. Some of the major insights that we later pursued were: "the break in communication between ground control and air traffic control can lead to safety hazards" and "a majority of runway incursions are due to human error such as lack of situational awareness or lack of attention." Both of those fell under the communication theme. The last major insight, this one coming from the construction theme, was: "There is a connection between high number of incursions and the presence of construction at the airport." After this we then as a team wrote "How Might We" statements out of every single insight. A "How Might We" statement is simply a way of phrasing the insight into a question or a problem. So for the major insights, we wrote: "How might we bridge the gap in communication between ground control and air traffic control?" for the first insight above, "How might we improve pilot situational awareness and attentiveness?" for the second of the insights above, and "How might we lower the number of incursions with the presence of construction at the airport?"

Having written these, it was then time to brainstorm solutions while keeping these insights and problem statements in mind. We used a method known as Group Sketching to brainstorm solutions. Group Sketching is a rather simple process, each team member takes an allotted amount of time to develop his or her own solution to the problem, then draw it and give a brief description so that it can be understood. We then each presented our solution to the group so that everyone had a general understanding of each. After this, the process included rotating our solutions to each team member. Every team member passed their solution to the next person and received one of his or her own. Then for the next allotted amount of time we each gave feedback, critiqued, and provided constructive criticism on the solution before passing and repeating the process until each solution was seen by every team member. After this we then shared our ideas with the feedback and then worked together to narrow our ideas down to just two solutions.

5.2. Potential Solutions

The Layered Construction Zone and Virtual Moving Map. The Layered Construction zone was a system that would involve sectioning the construction zone on the runway into roughly five sections or levels. Each construction worker then have to complete a series of classes and training in order to be granted a certificate for that level of training. He or she would already have an RFID badge that would now grant him or her access to a certain section of the construction zone. In order to access each layer or section, the worker would have to receive additional training and earn the certificate to be allowed into that area. Should a worker need something from a zone that he or she is not allowed into, he or she would either have to have someone else who does have access go obtain it, or have a worker who has access escort him or her into that layer so that he or she can obtain it. There will be RFID scanners that will be at each entrance to each zone. This solution addressed the construction insight and would eliminate a lot of confusion from the construction zone. Another insight not mentioned above was the high degree of variability in training amongst the construction workers. This solution would almost eliminate the problem this insight was addressing.

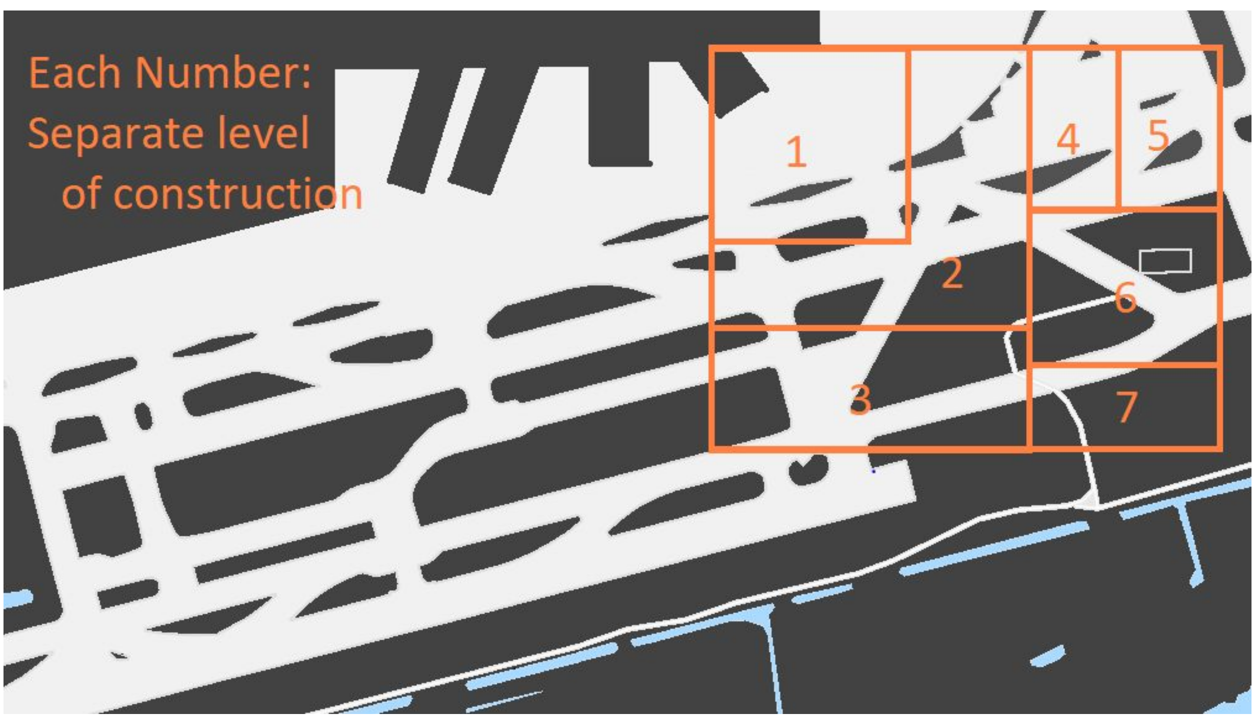

Figure 1. Layered Construction Zone Illustration. Each numbered section corresponds with a different level of construction that requires separate training and a corresponding certificate that will allow his or her badge to grant access.

The second solution was Virtual Moving Maps. This solution works very similarly to how a rear view camera works in cars. When parking or driving away from the parking spot, the camera is used. On the runway, when the plane is taking off or landing this virtual live map would be used. The map would show the entire tarmac and highlight all construction fences, construction workers, vehicles, planes, cranes, and other object in real time on a screen in the cockpit and in air traffic control. Each construction worker would again have an RFID badge, only this time there would be a GPS chip in the badge that would then connect to the Virtual Moving Map system and display the location of the worker on the virtual map. Each runway vehicle, plane, crane, and objects will all also have a GPS device placed inside them so that they as well show up on the map at all times. These badges have a 100m maximum range, so there will have to be sensors installed within the construction zone and within that radius. This map would be installed into the cockpit system so that it could be brought up on a pre-existing screen within the cockpit and then put away while the plane is in mid-flight. If that did not work, then it would likely be installed externally via a tablet that would be mounted somewhere in the cockpit.

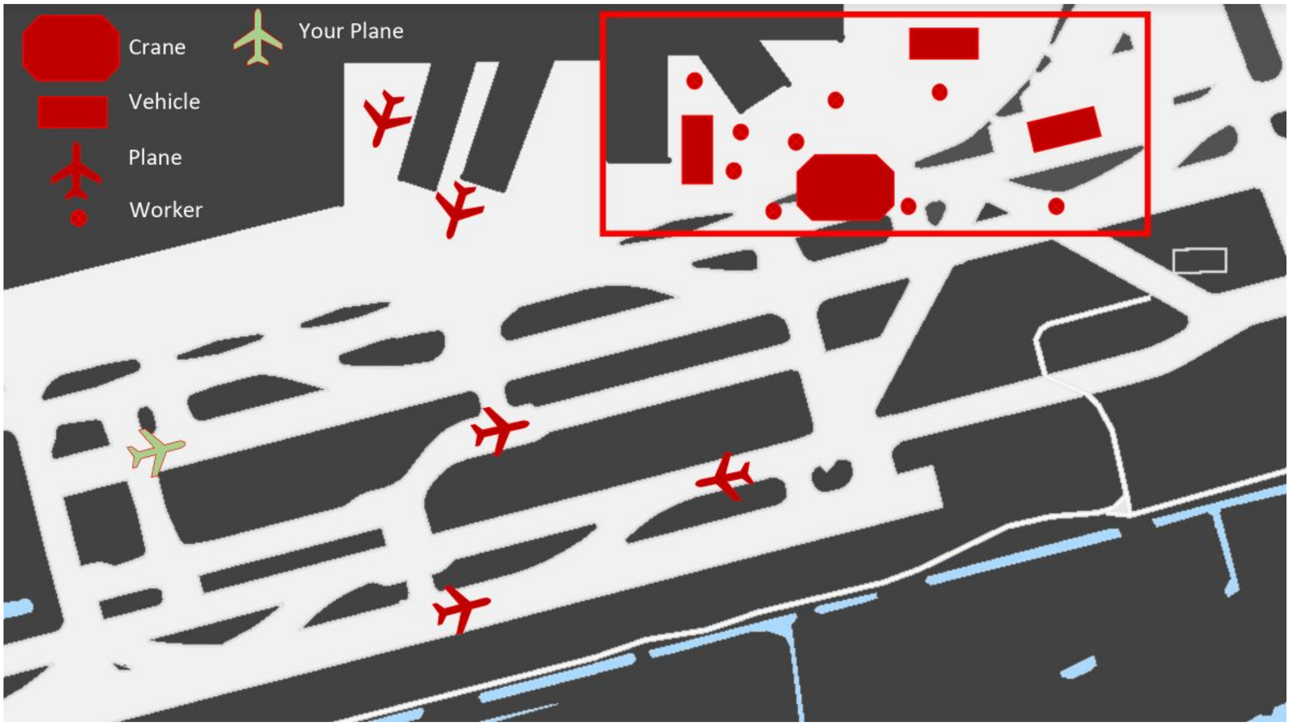

Figure 2. Virtual Moving Map that would be located in the cockpit of a plane. Map shows real time location of all workers, vehicles, and planes.

5.3 Concept Selection

Eight customer needs have been established in order to rate the ideas we generated. The affordability criterion refers to the cost associated with each potential solution. Cost is always a critical factor when evaluating a product; this was why we gave it such a high weighting. Ease of implementation refers to the relative ease that the customer will have when integrating the product into their existing system. In general; the easier the implementation, the more efficient and accepted the new system will be. It has a 10 percent weighting since it is not as critical as incursion reduction potential or affordability though. Incursion Reduction Potential refers to how much the given solution will reduce incursions after implementation. Given that our main objective is incursion reduction and increase in safety, this was an obvious choice for the highest weighted criterion. The Learning Curve/Training criterion refers to how difficult it is for the average employee to adapt to the implementation of this solution. High learning curve solutions are more prone to operators making mistakes during learning (and thus increasing incursions), so a mid to high weight was given to this category. Lead Time refers to how long it will take for full implementation of a solution. Most of our solutions have reasonably similar lead times and incursion reduction is more of a long term goal, therefore this was given the lowest weight of all criteria. Practicality refers to how feasible the solution is when it is implemented. We are trying to stop runway incursions which can be a difficult task, so a low wait was given to this criterion. Finally, Lifespan refers to how durable the solution is over time. A solution to a runway incursion problem must be able to withstand the test against time. Having to replace a solution to a problem like this would be very counterintuitive, so a mid weight was given to this category.

After completing the decision matrix to narrow down our ideas to just one, we decided to move forward with the Virtual Moving Map. We feel that this idea best delivers our customer needs and will most effectively reduce the number of incursions caused by not only construction, but also pilot deviation and communication barriers.

	Weight	Layered Construction Zone	Virtual Moving Map
Affordability	20%	0.8	0.6
Ease of Implementation	10%	0.3	0.25
Incursion Reduction Potential	35%	1.225	1.75
Learning Curve/Training	15%	0.3	0.6
Lead Time	5%	0.05	0.05
Practicality	5%	0.15	0.15
Lifespan	10%	0.4	0.5
Sum	100%	3.225	3.9

Figure 3. Concept Selection Decision Matrix. Solutions were evaluated on a scale from 1 to 5, with 5 being the best possible score and 1 being the worst possible; then that number was multiplied by the weight of each criteria.

6. Tests and Feedback

No formal tests were performed. If this design were to move forward we would need to submit the Virtual Moving Map technology to the FAA Technology Transfer. This is a program that the FAA provides for any proposed technology for any airport related issue. The program is fully funded by the FAA and involves the FAA performing extensive tests and research on the technology before it is then potentially implemented into planes or airports nationwide. We also planned on funding our own testing on it before submitting our solution to the FAA so that we could better the system and adjust it accordingly. In lieu of formal testing, we have presented our ideas to Penn State Alumni and ACRP contacts.

6.1 Feedback from Penn State Alumni

The Virtual Moving Map idea was presented to our Penn State Engineering Leadership Development Alumni. We pitched the Layered Construction zone idea to Kaylyn Rossi, (kmr5242@gmail.com). We originally thought about having the system be different for every airport to increase security but she explained to us how doing that will actually increase variability amongst airports which is a problem we were trying to address. So we adjusted our idea to a standard system that would be installed at every airport. Another important piece of feedback was that she thought it would a better idea for each construction worker to have a FOB instead of an RFID badge because they are much easier to program and reprogram should it be necessary. She also brought up the issue about a worker needing to enter an area he or she is not granted access to which is something we already addressed and she agreed that having an escort or someone else obtain it was the best method of fixing this problem. The last important thing was that knowing safety was our number one concern at all times, it is very important to have this solution be understood by everyone involved including the pilots, air traffic control, and each and every construction worker.

The Virtual Moving Map idea was pitched to Bill Finney, (wwfinney3@gmail.com). Bill provided some feedback about possible technologies to be used for transferring data from airplane to air traffic control and also provided feedback on methods of prototyping the solution. In particular, Bill mentioned that a visual demonstration on an iPad or equivalent with a physical model would work well to convey the idea. Kaylin Rossi also commented about this solution and brought up the problem of having an already preoccupied pilot being distracted by this virtual map while trying to perform the most difficult and important task of the flight, the landing and takeoff. Thus we decided that it would be best if the copilot handled the responsibility of monitoring the Virtual Moving Map.

6.2 Feedback from Industry Experts

We contacted Gary Mitchell, an expert in airport management systems, again after developing our solution. Mitchell thought the idea was brilliant and would be a very useful tool for pilots. According to Mitchell, there are no current technologies like this in place in airplanes or air traffic control. He agreed that having this tool will help the non-verbal communication issue between the pilots and the ground. The only criticism he provided was figuring out how to make this wireless technology work amongst so many other wireless systems already in place.

7. Safety Risk Assessment

		Severity				
	Probability	**Minimal (1)**	**Minor (2)**	**Major (3)**	**Hazardous (4)**	**Catastrophic (5)**
Likelihood	**Extremely Improbable (1)**					
	Extremely Remote (2)		E	B		
	Remote (3)			C,D		
	Probable (4)			A		
	Frequent (5)					

Figure 4. Safety Risk Assessment. A. Lag in technology (12); B. Vulnerabilities with GPS/RFID (6); C. Weather Issues (9); D. Workers not wearing badges (9); E. Distraction for Pilots (4)

Five major risk categories were identified for the Virtual Moving Map solution. Lag in technology is considered to be any instance in which the refresh rate of a map is behind reality such that there could be confusion about the location of planes or construction personnel. This could potentially be dangerous if a co-pilot or pilot is using a moving map solely for maneuvering the airplane without consideration of their surroundings. To address this, a risk transferral method is suggested. Pilots and co-pilots will be made aware that moving maps may not always be relaying up-to-the-second information, and to use it only as a secondary method of checking positioning information.

Vulnerabilities in GPS/RFID would refer to the possibility of unwanted parties accessing or GPS systems used within the system to position aircraft. The risk is assumed to be minimal since the positioning information one could obtain from the GPS positioning would be inferior to information one could gain from eye-witness observation. However, to mitigate this risk, GPS systems will only be activated upon landing so airplanes cannot be tracked mid-flight. Inclement weather can be a concern for some airplane tracking technologies like ASDE-X, and there is always the possibility of weather problems reducing the efficacy of GPS tracking systems. Transferring risk here seems to be the best option by again making pilots aware that during weather incidents reliability may suffer.

Workers not wearing badges could create problems with tracking them throughout the worksite or runway, so to mitigate this risk the RFID badges used to track construction personnel will be tied to their clock-in ID badges. This way, workers will be heavily dis-incentivized from removing their badges during operation hours.

Finally, distraction for pilots was a concern heard repeatedly through discussions with mentors about the design. To reduce the potential damage of a distracted pilot, the moving map will be primarily accessible to the co-pilot, who will then relay any relevant information to the pilot. Through the above mitigation strategies, the overall risks for such an implementation become lessened and appear to be quite low.

8. Evaluation

The Virtual Moving Map solution was evaluated for customer needs, costs, and benefits. Each of these three categories played a role in designing our solution. When it came to customer needs, we considered the needs mentioned above in section 5.2. These eight different categories helped us to make our decision before going forward in the design process. We ultimately decided that incursion reduction potential was the biggest factor which is what the Virtual Moving Map excels at. When it came to costs, like any other new technology, the programming of the software would likely be the highest cost and in this case it is no different. The technology also would cost a good amount because of the tablets needed should we install the software externally. Lastly, the benefits certainly played a major factor. Here is where the incursion reduction potential and benefits tie in. The benefits are essentially savings that the FAA does not have to account for. Our system would save incursions which would in turn save a significant amount of money that the FAA would otherwise have to spend to correct the problems and delays due to the incursions.

8.1 Evaluation of Customer Needs

The Virtual Moving Map solution was compared to the eight customer needs mentioned in section 5.2. In terms of affordability, the Virtual Moving Map is average. The Cost and Benefit Analyses in the following sections explain this further. The map is a bit difficult in terms of ease of implementation because the FAA will have to do lots of testings and it could take a while for it to be installed in every plane at an airport. However, this difficult implementation will pay off in the long run as the moving map has an extremely high incursion reduction potential. The training and learning curves involved are average, but again once the learning curve is overcome, there will be far less incursions. The lead time on creating the moving map is not long because experienced programmers should be able to create it in a relatively short period of time. In terms of practicality, we feel that the moving map is practical because similar gps technology is already in cars. The lifespan of this should be very long as it will be placed inside the cockpit so that weather and other factors should not influence its longevity. Overall, we feel that the Virtual Moving Map is an excellent solution to the problem at hand of incursions being caused by construction and pilot deviation.

8.2 Cost Analysis

Costs				
Category	**Item**	**Quantity**	**Price**	**Total**
Technology	Tablet	1 per plane (100 Planes)	$400	$40,000
	RFID Badges	1 per construction worker (100 per airport)	$0.36	$36
	RFID Scanner	Estimating 1 per acre Estimate 3 acre project	$645	$1,935
Labor	Programmer	4 programmers 30 day project 8 hours/day	$100/hour per programmer	$96,000
	Installer	2 installers per airplane 30 day project 8 hours/day	$15/hour per installer	$7,200
Testing	Independent Evaluation	1 Independent Engineering Firm in the Private Sector	$25,000	$25,000
Total				$170,171

Figure 5. Cost Analysis for 1 airport which is roughly estimated to be 100 planes.

Using a 100 airplane trial, upfront costs will be reasonably low. Since the moving map will only need to be designed for one airport and since the technology is quite similar to currently existings GPS systems, programming costs should be quite low and well within the budgeted ~$100,000. In addition to this, implementation of an additional screen can be cheaply done with a tablet system costing around $400 per airplane, or more cheaply done using existing screens in a cockpit and updating the software. RFID chips for construction personnel are very cheap, with the only major cost from that tracking coming from sensor towers, of which an estimated work site will have 3. In total, the upfront costs will be in the range of $200,000 with no annual maintenance required.

8.3 Benefit Analysis

Benefits	
Reduced Number of Incursions (5% reduction in incursions)	$180,000
Reduced Confusion for Airport Employees	$15,000
Reduction in Delayed Flights	$1,000
Total	$196,000

Figure 6. Benefit Analysis for 1 airport which is roughly estimated to be 100 planes.

The expected benefit of such a system, even with a very modest incursion reduction estimate of 5%, is an annual return also very close to $200,000. This number is calculated by taking the amount of money allocated for incursions in the 2016 fiscal year, which was $200 million (Safe-Runway GmbH), and scaling it to 100 airplanes vs the entire fleet, then calculating a 5% reduction. The Virtual Moving Map concept is particularly appealing as the costs are low and the benefits potentially significant, even at the 1 year mark post-implementation. The reasoning behind using a small scale implementation is in order to see the results on a small-less costly scale prior to rolling this out to the entire country. Starting small and essentially testing the effectiveness of the Virtual Moving Map system will then provide us and the FAA with enough data that will allow us to then better our solution and eventually install it across the rest of the country.

Appendix A: Contact Information

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Appendix B: University Description

Penn State University is an institution of higher education in Pennsylvania. It houses the college of engineering which includes numerous engineering degrees at both the undergraduate and graduate levels. The college of engineering supports an undergraduate minor in engineering leadership in which undergraduate engineers can build the non-technical skills to support the great technical skills they are developing through their engineering curriculum. The engineering leadership development program offers students classes in project management, leadership education and development, business basics, and cross cultural teaming. Students in the minor are dedicated to building these skills in addition to the technical work load required of their discipline's curriculum. The engineering leadership program also offers a graduate program in the form of a master of engineering and an online graduate certificate in Engineering Leadership and Innovation Management.

Appendix D: Sign-off Forms

Airport Cooperative Research Program

University Design Competition for Addressing Airport Needs

Design Submission Form (Appendix D)

University_______Pennsylvania State University_______________________________________

List other partnering universities if appropriate: _N/A___________________________________

Design Developed by: Individual Student ___ Student Team _X_

If individual student:

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Permanent Mailing Address

________N/A____

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Competition Design Challenge Addressed:

___II. I Methods for improving runway safety during airport construction and reconstruction___

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 ____________________ Date 2/5/19

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University/College Penn State University/ College of Engineering

Department(s) School of Engineering Design, Technology, and Professional Programs/ Engineering Leadership Development Program

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Appendix E: Educational Evaluation

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?

The ACRP University Design Competition was a great learning experience for us. It provided us all the opportunity to lead a team of engineers to accomplish a goal. It also gave us experience into the world of project management as well. Finally, the project also gave us a chance to apply some of the technical skills we have been learning in the classroom.

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

Some of the biggest challenges we faced was our lack of personal experience with the issue we were trying to solve. We overcame this with lots of research into different aspects of the problem and contacting professionals from various areas of the airport community. The knowledge and input of experts coupled with our individual research provided a base of understanding allowing us to better grasp and solve our design challenge.

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

We went through phases of a design process to develop our solution. To develop our hypothesis we first began by refining the problem statement and personalizing it into more of a mission statement for our team. We also turned that problem statement into a question as well and began our research phase where we set out trying to answer that question. As the research continued our understanding grew and our purpose became more clear. This resulted in the hypothesis that led us to our prototype.

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

Participation from industry professionals was instrumental in helping us develop our solution. None of the members of our team are a part of the aerospace industry and without the input and expertise of professionals we may never have been able to develop a proper understanding on the problem at had. They also proved to be a valuable way to get feedback on our ideas and they helped us refine our solutions as we progressed through the semester.

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?

This project provided us with leadership skills, management skills, presentation skills, and technical understanding. All of these helped make us better engineers and better professionals. The ACRP project provided us with valuable skills and knowledge that is going to make us better engineers both as students now and employees in the future.

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

Students in our leadership course are learning how to lead within the engineering context. This project provides an exceptional and organized experience for our engineering students to apply the knowledge and their personal leadership style as they lead their teams throughout the semester. The challenges provided mimic a real-world experience giving students an opportunity to practice both technical and non-technical problem-solving skills.

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

Yes, the learning experience was appropriate for the level of our students and fit within the context of our learning environment, per the note above.

3. What challenges did the students face and overcome?

Students faced some challenges getting in touch with experts and through that learned how important it is to talk with the "user" in order to come up with the best solution. Some students tried to jump ahead to the solution and not work through the design process to use all the information gathered in order to come up with a creative solution. They learned that user-centered research is important when coming up with solutions to challenges.

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

Yes. We plan to continue to use it based on the organization, the well thought out options for projects, the support, and the industry contacts.

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

If you could make some of the appendices an online form and allow for one submission of some of the appendices if a group is turning in multiple projects.

Appendix F: References

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