Airport Cooperative Research Program

University Design Competition for Addressing Airport Needs

Challenge I: Airport Operation and Maintenance

Option C: Innovative approaches to address wildlife issues at airports including bird strikes

Title of Design: MINI HFSS (High Frequency Sound Systems)

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Executive Summary

Wildlife-aircraft interactions are a costly and painstaking issue that has caused immense detriment in the past to certain wildlife (mainly bird) populations, human populations, and airplane security. The student team in question wanted to build upon current solutions with a new, innovative product that would take into account costs surrounding bird strikes, bird safety, and most importantly, human safety, by targeting keen bird senses. The team started the research phase by looking for stories revolving around bird strikes, research articles on bird senses, current solutions, and costs that bird strikes regularly cause airlines. We then went through an extensive problem-solving approach consisting of brainstorming, concept selection, rapid prototyping, and a combined decision-making process. After this was completed, we found that one main solution stood out to the team, so we progressed forward with our final solution concept for mini high-frequency sound systems (HFSS). When working on our final solution prototypes, we conducted tests to see if the hypothesized frequency range of 6-9kHz would actually affect birds, and also, we designed each speaker so that the shape will maximize the radius at which the noise travels. While working on the final prototypes, the team completed a cost-benefit analysis with the help of expert advice. This analysis calculated the Net Present Value for the next ten years, assuming a 2.1% inflation rate; from this, we came to find there would be a payback period of just under three years and the project would realize a positive NPV after year zero. Finally, we conducted a risk assessment in order to determine any potential hazards that our selected prototype could house in the future, while looking at actions we could take to mitigate the more dangerous risks. We took these concerns into consideration when conducting all final prototypes, models, and analyses.

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Problem Statement and Background

The team of undergraduates chose Airport Operation and Maintenance as their challenge, within which the topic of “Innovative approaches to address wildlife issues at airports including bird strikes” was chosen. To us, this topic meant that we would be finding an innovative way to reduce the number of wildlife strikes, and the team chose to focus on bird strikes because we found through research that they are the primary cause of plane damage, amounting to approximately $155 million USD annually (Anderson et al., 2015). This number stood out to our team as being a huge cost for what seems like such a small thing, and so, we wanted to propose a feasible solution to the problem. Some current solutions around airfields include the use of sonic cannons, lasers, falconry, and possibly killing the birds. Our team decided that we did not want to cause harm to birds, so we opted for a solution that would instead target the senses of birds. After some preliminary research, the team reached out to Sandy Liu, a sound mitigation engineer with the FAA, to gain some insight into how we could better focus our project. As a result of this interaction, the team came up with the following Point of View (POV) statement: “Team 2 heard from Sandy Liu, an aircraft noise mitigation engineer at the Federal Aviation Administration. We were surprised to learn that sound is a powerful tool that has potentially not been utilized to its full potential in airfields. Sound may therefore be a useful way to mitigate property damage due to bird strikes, as long as human and bird safety is ensured. It would be game-changing if we could come up with a technical solution that targets multiple bird senses to reduce bird strikes.” This POV statement guided our research and design processes to ensure that our solution would be acceptable to any potential client or stakeholder.

Literature Review

We started our research efforts by trying to pinpoint how often bird strikes really occur, in order to answer the question, *what is the real-world significance of our project*? We ran into problems in this arena because many bird strikes are unaccounted for. However, while looking at past studies of bird strikes, our team came across one of the most historic landing stories of all time: The Miracle on the Hudson. While a plane was in the air over the Hudson River, it struck a flock of geese and subsequently, lost all engine power. The aircraft was forced to land in the Hudson River and evacuate the cabin members (Greenspan, 2015). After the team read more about this story, we realized that this was in fact an important issue that could have a positive effect on both human and animal life, with an innovative solution.

In reviewing literature with regards to our issue, we found many interesting findings. First, the team read into current solutions that are already in the field of mitigating bird strikes around airports. Presently, solutions exist such as sound cannons, scarecrow-like decals, and robotic falcons, which are essentially drones that look like predatory birds and they chase other birds away from airfields (Rosenberg, 2017). Another solution we found was controlled falconry (Rosenberg, 2017). A falcon was brought in by a handler in this situation to scare off smaller birds and waterfowl. One negative aspect of this solution is that sometimes birds, which are meant to be saved from strikes, actually become prey to a live falcon.

As we continued in the research process, the team looked into the capital effect on aircrafts that were caused by bird strikes. According to Elsevier, airlines are forced to spend approximately $155 million dollars annually in repairs to airplanes struck by birds (Anderson et al., 2015). This sum could be highly valuable elsewhere if a highly-focused solution were in place.

While contemplating the solution of using sound around an airfield to fend off birds, we had to see at which frequencies birds reacted. We found that birds do not like being in areas with sound emitted around 6kHz-9kHz because this is a frequency range at which birds can communicate, and not having the ability to communicate with other birds frightens them away (Beason, 2004). After determining this information, it was important for us to see whether or not humans were affected by this frequency of noise, as we took into account the long-term effects of this noise on people in close contact with airfields. We concluded that this frequency range was outside of the normal hearing range of human beings, and additionally, most people working on runways would likely be wearing protective headgear in an effort to protect their hearing ability from the loud engines of aircrafts.

Problem Solving Approach

As we moved into the problem-solving portion of the design process, we first held a team brainstorming session, using the Field Guide to Human-Centered Design for direction (IDEO, 2015). We spent a couple of minutes each coming up with as many ideas as we could, no matter how nonsensical they seemed (see Fig. 1 for a visual of the brainstorming process). After this brief brainstorming session concluded, we worked as a team in order to group them into four categories: focus on the environment, cost of damage, cost of time, and airport efficiency.

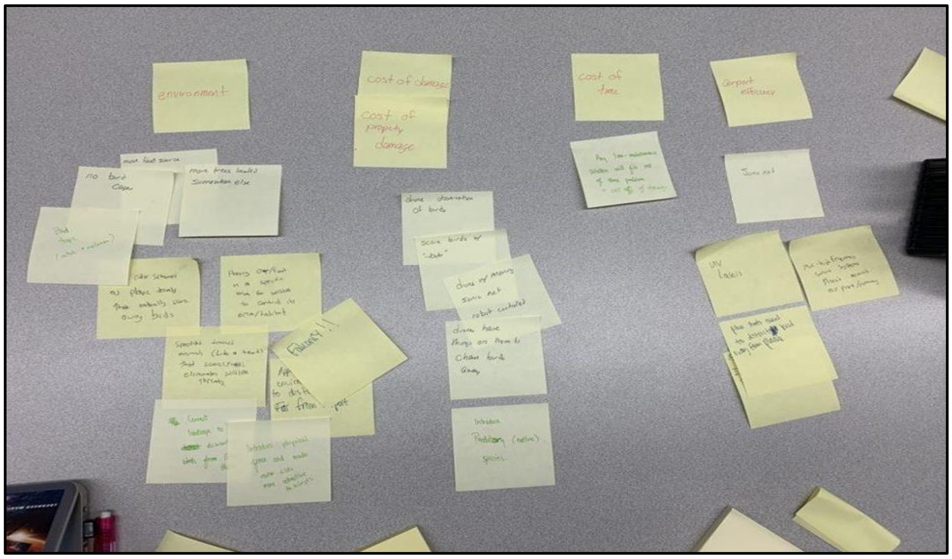

Figure 1. Brainstorming Process

Before the rapid prototyping phase, we created a concept selection matrix in which we discussed criteria that we thought was most important for our product. After we determined six pieces of criteria to move forward with, we determined whether or not the idea we were ranking met the selection criteria. If it met the selection criteria, we rewarded the concept with a number one. If it did not meet the criteria, the cell in excel was left blank. After we ranked five brainstorming ideas, the total was looked at, and we then chose to move forward with the three top-ranked concepts into the rapid prototyping stage. These concepts included a drone with a sonic net, stationary mini high-frequency sound systems, and stickers or decals meant to frighten away smaller birds. The concept selection matrix our team utilized can be viewed in Fig. 2.

	Concepts				
	Drone with sonic net	**Mini-high frequency sound systems**	**Sticker/Decal**	**UV lasers**	**Appealing bird-friendly environment**
Selection Criteria					
Environmentally friendly	1	1	1		1
Cost			1		
Low maintence time	1		1		
Feasibility	1	1	1	1	1
Originality		1		1	
Ease of Implementation		1	1		
Total	3	4	5	2	2
Continue?	Yes	Yes	Yes	No	No

Figure 2. Concept Selection Matrix

After the brainstorming session and concept selection processes were complete, the team continued forward with a rapid prototyping phase. This consisted of models, diagrams, and storyboards designed to illustrate how each solution would work. Due to COVID-19 restrictions, we went through the rapid prototyping process within our homes, so we were limited with what we were able to construct. More information regarding the prototypes is included in the *Prototyping and Design Process* section. When we finished first phase rapid prototyping for the three concepts, we then reached out to our alumnus contact (Kartik Singhal) in order to obtain feedback with regard to our initial designs. After constructive feedback was obtained, we moved forward into second phase prototyping of two designs, the drone with a sonic net attached and the plane with the sticker decals. After prototyping was completed on the three concepts pulled from the concept selection matrix, a weighted decision matrix was the next step for our team.

As the weighted decision matrix was created, we again thought of proper criteria to rank our three prototypes upon. These criteria included: being environmentally friendly, having a low average cost, having a low maintenance time, realizing a high effectiveness, feasible implementation into an airport, and stakeholder preference for our proposed solutions. Weights were then selected as a team in regard to what we thought was most crucial for our product. Effectiveness was deemed most important, followed by low cost and ease of airport implementation, low maintenance time, and finally, stakeholder input and environmental impact. Then, each individual team member went through and rated the three prototypes as we thought were appropriate. Figure 3 shows the weighted decision matrix completed by each team member. Our ratings were based on a one to five scale, and then a weighted score was calculated by multiplying the weight of the selection criteria by the rating given to the prototype. After the weighted score was calculated, each individual score was added up and put into a total score row which was able to be compared across prototypes. After this was done for all three prototypes, we compared our total scores and found that our individual judgements were largely the same. From this process, we were able to hone in on one prototype, mini high-frequency sound systems, to move forward with into our final tests and design process.

		Concepts					
Josh		Drone with sonic net		Mini-high frequency sound systems		Sticker/Decal	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Environmentally friendly	3	3	9	4	12	5	15
Low Average Cost	5	2	10	2	10	3	15
Cost of time (low maintenance time)	4	4	16	5	20	4	16
Effectiveness	6	4	24	4	24	2	12
Implementation into infrastructure	5	3	15	3	15	1	5
Stakeholder Feasibility	3	4	12	3	9	1	3
	Total Score		86		90		66
	Rank						
	Continue?						

		Concepts					
Adria		Drone with sonic net		Mini-high frequency sound systems		Sticker/Decal	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Environmentally friendly	3	4	12	4	12	5	15
Low Average Cost	5	2	10	3	15	4	20
Cost of time (low maintenance time)	4	2	8	3	12	4	16
Effectiveness	6	5	30	5	30	2	12
Implementation into infrastructure	5	2	10	3	15	1	5
Stakeholder Feasibility	3	3	9	4	12	1	3
	Total Score		79		96		71
	Rank						
	Continue?						

Corey		Drone with sonic net		Mini-high frequency sound systems		Sticker/Decal	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Environmentally friendly	3	3	9	4	12	5	15
Low Average Cost	5	2	10	3	15	5	25
Cost of time (low maintenance time)	4	2	8	2	8	2	8
Effectiveness	6	4	24	4	24	2	12
Implementation into infrastructure	5	3	15	3	15	2	10
Stakeholder Feasibility	3	2	6	4.5	13.5	1	3
	Total Score		72		87.5		73
	Rank						
	Continue?						

		Concepts					
Nisha		Drone with sonic net		Mini-high frequency sound systems		Sticker/Decal	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Environmentally friendly	3	4	12	4	12	5	15
Low Average Cost	5	3	15	4	20	5	25
Cost of time (low maintenance time)	4	2	8	5	20	4	16
Effectiveness	6	3	18	5	30	2	12
Implementation into infrastructure	5	3	15	4	20	4	20
Stakeholder Feasibility	3	3	9	5	15	4	12
	Total Score		77		117		100

Figure 3. Individual Decision Matrices

Safety and Risk Assessment

There are some inherent risks about this idea that will take place during installation and during operation. As seen by the risk assessment matrix in Figure 4, there are eight risks the team has come up with through research and brainstorming.

Severity Likelihood	No Safety Effect	Minor	Major	Hazardous	Catastrophic
Extremely Improbable			1		
Extremely Remote			5	4,7,8	
Remote		2		6	3
Probable					
Frequent					

Figure 4. Safety and Risk Assessment

The first risk (1) is electrocution. This could happen during installation but is very unlikely. Therefore, its likelihood is extremely improbable but its severity is major because it can cause harm to those installing it, pushing it into the green (safe) region. The second risk (2) is low effectiveness. This could happen while the systems are operating. The likelihood of this occurring is remote and the severity would be minor because there are multiple in place. Therefore, it has been placed in the green region. The third risk (3) is product malfunction. While unlikely, it could have catastrophic consequences if realized. This is therefore in the red (dangerous) region. To mitigate the risk, there will be an emergency battery system in place; this brings the risk into the yellow (moderate) region. Additionally, there will be a sensor inside of each system that alerts someone when it needs to be replaced or fixed. The fourth risk (4) is hearing damage. This refers to damage to humans and any nearby animals. According to our research, the frequencies that our systems run under are not harmful (Kecskes, 2016). Therefore, the likelihood of this happening is extremely small. However, if it is later found to be harmful, it could cause unknown damage, so it has been placed within the yellow region. The fifth risk (5) is unknown installation site conditions. This could be relevant during installation. The likelihood of this occurring is fairly small, yet possible, and the severity of occurrence would be major because there may be some setbacks due to the unknown topography. Therefore, it is in the green region. The sixth risk (6) is damage to the equipment during installation. This could also happen during installation. This is not too likely but it is possible for (hazardous) damage to occur, so it was originally placed in the red region. To reduce the likelihood of damaged equipment, there will be a routine site inspection before the equipment is installed. This then brings the severity to major, which is in the yellow region. The seventh risk (7) is frequency interruption with ATC/radio communication. The likelihood of this happening is extremely unlikely, according to our research (PHX International Airport, 2018). Additionally, the severity would be hazardous if it did happen, so it was placed in the yellow region. The eighth identified risk (8) is cyber-attack. The risk of a cyber-attack is extremely unlikely but would lead the system into a hazardous situation if frequencies are moved into the radio wave range, causing interference, if disabled, enabling bird strikes, or otherwise, if frequencies can be heard by humans (not dangerous, but complaint-worthy). Therefore, it is in the yellow region.

Prototyping and Design Process

After the team brainstormed and honed in on three different concepts, we went into the rapid prototyping process. The concepts that the team selected to continue with are as follows:

- **Drone(s) with a sonic net**
    - A sonic net is a high-pitched sound emitter that interrupts the communication between birds over a certain radius (Swaddle, Moseley, Hinders, & Smith, 2015). For example, it's a bit like being at a loud concert and not being able to hear the person right next to you. This sound-emitting device would be attached to a drone

and can be used to scare birds away from the surrounding area. It is meant to stay around tree level, so there should not be any problems for planes landing and taking off.

- **Mini high-frequency sound systems**
  - Small sound-emitting speakers, as specified in the sonic net description, would be stationary, lining the entirety of the runway of an airport to keep birds away from an airfield. These systems will create a sonic net, thereby interrupting communication between birds. This frequency will not interrupt that of a radio tower and will not cause audible damage to humans nearby.
- **Plane Stickers/Decals**
  - Stickers or decals can either line the aircraft or the tree line of an airfield. They will either have the colors of flowers that are yellow, white, or black (colors that birds are instinctively afraid of) (Olesen, 2020), or they will make the plane look like a hawk (a predator of the bird). If placed directly on the wing of the plane, the stickers may scare birds away from the engine.

The team first researched different types of rapid prototypes to pursue and evaluated which types of prototyping would best represent each concept to a stakeholder. The team pursued first and second phase prototyping, and then ranked their concepts in order to figure out which to bring to final prototyping. During first phase prototyping, the team sought to pursue a storyboard for the drone with sonic net, a model for the mini high frequency sound systems, and a model for the plane with specific decals.

After first phase prototyping was complete, the team reached out to an ACRP expert contact and an alumnus contact for feedback on the initial prototyping. The feedback we obtained led us to make minor changes during the second phase of prototyping. We found that our storyboard for our drone with sonic net needed improvement, that we needed a storyboard for the plane with decal, and that we needed proof of concept for the mini high frequency sound systems. In order to prototype the proof of concept, we created a brief video showing how the systems would work. We used a real speaker at the designated frequency and played it outside for 1 hour, next to a bird feeder. Upon turning the speaker to the appropriate frequency, it scared away the birds and kept them out of the surrounding location.

After second phase prototyping was complete, the team reached out to the stakeholders again for feedback on the next set of prototypes. We then used this feedback within the decision matrix (referenced in *Problem Solving Approach)* to come up with a final concept to pursue in final prototyping. The concept that would be brought into the final prototyping phase was the mini high frequency sound systems. The final prototype and testing consisted of 3 methods of prototyping: (1) a proof of concept through the video, (2) a *SolidWorks* speaker assembly model of how one speaker in the system would look, and (3) a computer model of how the speaker systems would look and work together in an airport runway environment.

1. Proof of concept (video): The video used for this prototype was taken from second phase prototyping. The speaker played around a 9Hz frequency, successfully scaring away birds and keeping them out of the location. Upon being played, birds immediately flee the location and stay away. This shows us that our concept we are pursuing is feasible and our researched frequency of operation is correct.
2. *SolidWorks* speaker assembly: The following *SolidWorks* model is an accurate representation of how the speaker will look upon implementation (please see Figure 5). The top half sphere of the device will be visible above the ground. The sphere shape of

the device allows for sound to travel in all directions above the surface. The bottom half of the speaker will be located in the ground. With multiple models of this assembly being used, the sound frequencies from the speakers will overlap and cause interference with bird communications, therefore scaring them and keeping them out of the location.

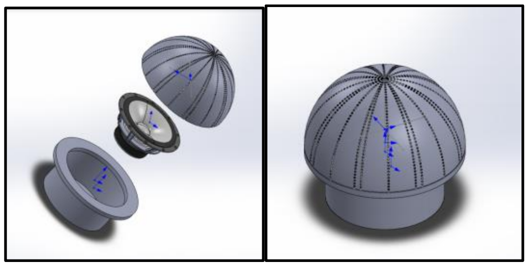

Figure 5. *SolidWorks* Singular Speaker System Model

3. System-runway integration model: The following mapping prototypes (Figures 6 and 7) show how the speaker system will be implemented on and along a runway. Due to the speaker's shape and size, the wavelengths of sound will continuously overlap and keep birds off the runway. As seen in both models, the sound from each speaker dies out radially, but is then overlapped with sound from a new speaker, making it so that there are no grey areas in the systems location of implementation. With many systems integrated into the runway, there will be no lack of frequency along runway areas, and there will be complete interference with bird communication along the runway environment.

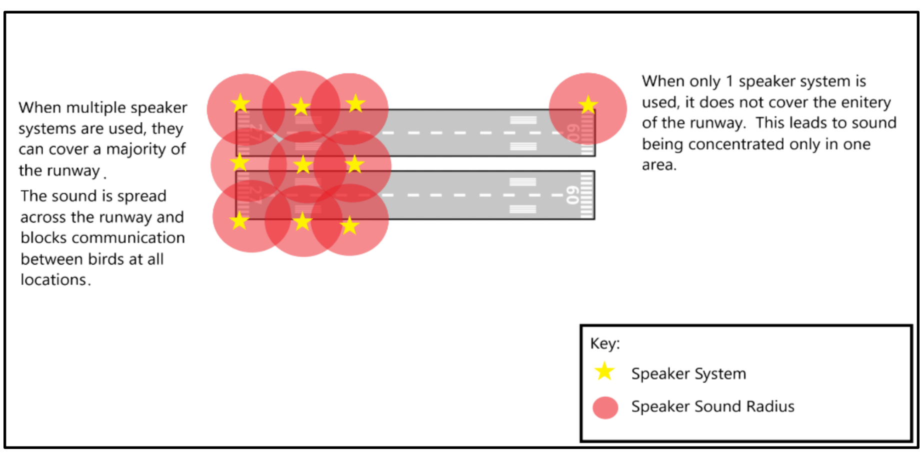

Figure 6. Description of Speaker System Overlap

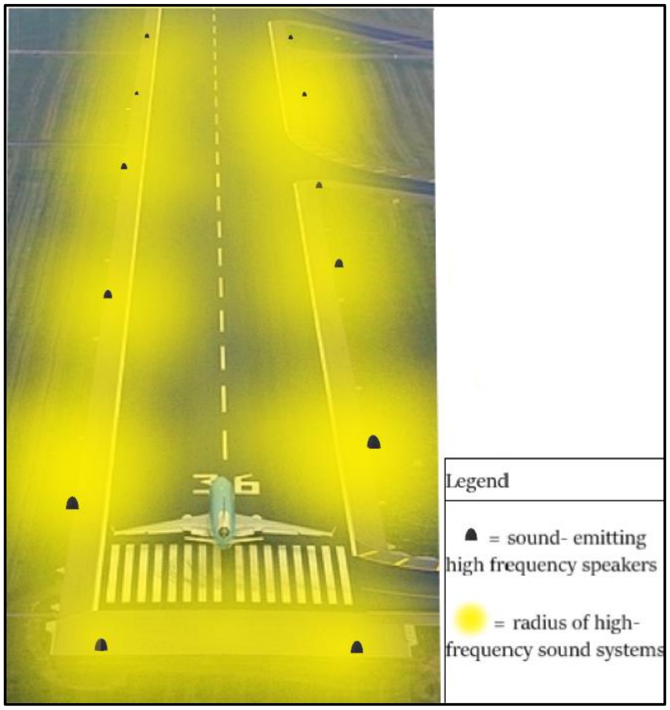

Figure 7. Example Placement of Speaker System on Runway

Interactions with Airport Operators and Industry Experts

This project would not have been possible without the input and advice of several industry experts. Throughout the concept selection and prototyping processes, the team kept in close contact with FAA Sound Mitigation Engineer, Mr. Sandy Liu. Sandy offered key advice about what he thought would work out, as well as his concerns, and this directed our research to ensure that we could address those concerns with a solution that would mitigate risk and encourage facile integration into any airport. He also helped our team develop a Point of View statement.

We owe a huge acknowledgement to Mr. Kartik Singhal, a Manufacturing Development Program Engineer with Cummins Aerospace (and a Penn State alumnus). Throughout all of our researching, planning, designing, and prototyping phases, Kartik gave pertinent and honest commentary on our proposed solutions and design process, he walked us through which prototyping tools would be most appropriate for a research proposal of this kind, and he provided us with feedback on our cost-benefit and risk analyses.

As mentioned in the financial analysis section, the cost-benefit and payback analysis was re-worked to create a more accurate end product, thanks to the expert advice of Jake Lovelace, a financial advisor and franchise owner, as well as Danielle Stauft, a Project Manager with Rosendin Electric, who has a background in airport construction.

Projected Impacts of Design

Financial Analysis

Once the team had decided upon pursuing mini high-frequency sound systems, we set to work on completing a cost-benefit analysis, which is pictured in Figure 8. This analysis shows annual costs per commercial airport in present-value USD, annual USD saved per commercial airport in present-value dollars, as well as a net present value stream up to 10 years into the future (only five of ten years are pictured in Fig. 8). Our calculations show a payback period of just under three years (see Fig. 9) with a positive NPV after year 0. For this analysis, costs were divided into three main categories: physical items, installation, and maintenance. An inflation rate of 2.1% was suggested by Jake Lovelace, a financial advisor and franchise owner, and the team acquired insight into installation times and labor rates with the help of Danielle Stauft, a Project Manager with Rosendin Electric. We were able to significantly cut installation costs by keeping the runway pavement intact and assuming that the speaker system wiring will run under ground, beside the pavement. Benefits for this system include costs that would be saved on average, annually, by mitigating bird strikes as much as possible. These include direct costs to repair aircrafts, fuel saved by reducing jettisoning or idling due to aircraft strikes, and human death or injury compensation.

Costs (per airfield)		per airport, annually		Considering 2.1% inflation rate:					
Category	Item	Total		0	1	2	3	4	5
Physical items	Wired speakers	$23,800.00							
	Weather protector (indivudal, per speaker system)	$1,700.00							
	Conduit/ cabling (13,000 ft of UF-B 14/2 outdoor wiring to avoid excavation)	$8,060.00							
	Electricity costs to run (per year)	$854.10	per year	$854.10	$872.04	$890.35	$909.05	$928.14	$947.63
Installation	Labor (10 electricians, 1 engineer, 3 PM, 3 flaggers) (quant: 18 days)	$10,400.00	per day (need 18 days)						
	Excavation (Tool rental + labor) (quant: 4 days)	$1,600.00	per day (need 4 days)						
Maintanence	Testing for effectiveness (labor cost- quantity in hours)	$1,200.00	per year	$1,200.00	$1,225.20	$1,250.93	$1,277.20	$1,304.02	$1,331.40
	Replacement of faulty materials	$7,500.00	per 5 years	$7,500.00	$7,657.50	$7,818.31	$7,982.49	$8,150.12	$8,321.28
		$228,360.00	Annual Costs per airport (PV):	$230,414.10	$2,097.24	$2,141.28	$2,186.24	$2,232.16	$10,600.31
Benefits				Considering 2.1% inflation rate:					
	Cost (at estimated ~78% reporting)	Unit	Capital saved, assuming a 75% reduction in strikes, annually, per airport	0	1	2	3	4	5
Mean direct aircraft repair costs	$158,573.00	per airport	$73,007.88	$73,007.88	$74,541.04	$76,106.40	$77,704.64	$79,336.44	$81,002.50
"Other" average costs (i.e. environmental destruction, fuel jettison/ burn/ idling, etc)	$25,036.00	per airport	$11,526.71	$11,526.71	$11,768.77	$12,015.92	$12,268.25	$12,525.88	$12,788.93
	Human wellbeing-related problems at 100% reporting		Capital saved, assuming a 75% reduction in strikes, annually, per airport						
Mean human death compensation	0.0005559	per airport, annually	$70.88	$70.88	$72.37	$73.89	$75.44	$77.02	$78.64
Mean human injury compensation	0.005565636123	per airport, annually	$709.62	$709.62	$724.52	$739.74	$755.27	$771.13	$787.32
			Annual USD saved per airport (PV)	$85,315.08	$87,106.70	$88,935.94	$90,803.60	$92,710.47	$94,657.39
			NPV	-$145,099.02	$85,009.46	$86,794.66	$88,617.35	$90,478.32	$84,057.08

Figure 8. Condensed Cost-Benefit Analysis

Payback period	Initial project cost	Annual project benefit
2.701	$230,414.10	$85,315.08

Figure 9. Payback Period Analysis

Many assumptions were made in order to get a more accurate model; these assumptions can be viewed in Figures 10 and 11. All assumptions were sourced from industry expert advice, HG Legal Resources Online, and the FAA (Capner, 2018; Dolbeer, Begier, Miller, Weller, & Anderson, 2018). To clarify, a 75% reduction in bird strike mitigation was estimated for this analysis. This was not done due to a lack of conviction in the proposed solution, but rather, to show that even a conservative effectiveness will result in a highly profitable investment.

Assumptions	
11,000 ft (3,400 m) runway	Speaker system install: 14 days install, 4 days excavation- no repaving
a speaker every 100 meters	Purchase annually: 10 speakers and 10 protectors - assume 10 faulty/ year
Want to maintain 80 dB minimum around airfield, assuming "free space"	*Year 0 includes upfront installation costs
2.1% inflation rate	*Years 5 and 10 cost significantly more because of replacement of faulty materials every 5 years
Electricity cost: $0.13/kWh at 750W	
As 100% bird strike mitigation is likely not feasible, estimate 75% bird strike mitigation	

Figure 10. Basic Cost-Benefit Analysis Assumptions

Labor cost Estimations: (source: Danielle Stauft)	Benefits estimations: (source: FAA, Wildlife Strikes...1990-2018)
Effectiveness tests (2 people) - $75/hour	Estimated 1,030 reported incidents per year
Excavation (3 people) - $1100/day	Estimated 78% incident/ damage reporting in 2018
PM team (3 people) - $90/hour	33 US human civilian deaths and 319 injuries in 29 years
Electricians (10 people) - $75/hour	FAA Study based on 2,047 US airports per airport
Certified engineer (1 person) - $100/hour	Average $170,000 per person in compensation for death/ injury (source: HG Legal Resources, *The Right to Compensation for Plane Crash Victims*)

Figure 11. Specific Labor Cost and Benefit Assumptions

Solution Findings

The team concluded that the implementation of the Mini HFSS would reduce the bird presence within the system radius by approximately 75% (Swaddle et al., 2015). This solution is effective in meeting ACRP goals of Design Challenge I: Airport Operation and Maintenance Challenges Option C: Innovative approaches to address wildlife issues at airports including bird strikes. The Mini HFSS solution addresses the damage costs of bird strikes that are applicable to civil, commercial, and military airfields and is highly affordable with a payback period of 3 years. To increase utility of the system, future analysis of the design could include looking into elevating the system so that the system's sound frequency disrupts bird communication at higher altitudes. With further analysis as such, the future reduction of bird presence could increase above 75%.

Appendix

A. Contact Information

- Student Contact Information:

  i. Joshua Chasen

  Nisha Labroo

  Adria Lewis

  Corey Watkins

  Faculty Contact information:

  i. Meg Handley, Paul Meister, or Mary Mastellar

B. Description of the Pennsylvania State University

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.

C. Description of Non-University Project Partners

- No university partners were involved in the project.

E. Evaluation of the educational experience provided by the project

Students

- 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?

  Yes, this experience offered our team an innovative opportunity to think more broadly as engineers, since we are all from different engineering backgrounds. This competition also taught us a great deal about leadership and project management; organization, delegation, planning, and research are only part of the process. Client satisfaction, feasibility, and expert advice are also crucial in completing an end product of value.

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

  Our team struggled with following the steps of a compartmentalized design process. In other words, we got so excited about coming up with a solution early on that we skimmed over the research for other, less feasible solutions. As a result, during the initial prototyping stage, we needed to divert some designated prototyping time to research in order to quell a significant concern brought up by expert feedback.

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

  The team observed the following structure, as requested by our faculty advisor:
  1. Frame the design challenge,
  2. Broadly research the option and identify stakeholders,
  3. Interview an industry expert to develop a point-of-view statement,
  4. Brainstorm potential solutions and create concepts,
  5. Select a concept to pursue,
  6. Prototype,
  7. Formalize and test hypothesis

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

  Industry participation was not only appropriate, meaningful, and useful, but it was absolutely crucial in coming up with a proposed solution that would integrate acceptably well into an airport system dynamic, have a reasonably accurate cost-benefit analysis, and have the support of industry stakeholders. Without these three things, none of the proposed solutions would be of value. Additionally, we are all students, and very few of us have had experience working in the realm of airports or aircraft management; integrating the experience of industry experts into our project helped create more a realistic and innovative solution.

- 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?
- All of our team members came onto this project with a different skill set, and therefore, we all learned something different. For instance, Nisha, a senior in energy engineering, learned a lot about the distinct needs of airport construction, which may come in handy as she joins the electrical contracting industry in September 2020. Adria, a sophomore in aerospace engineering, learned how she could directly impact her field of work and better protect animals from plane interactions. Joshua, a junior in mechanical engineering, learned how to lead a team in prototyping design. He also learned how to apply his design skill-set to developing a feasible solution in the aeronautical industry. Corey, a sophomore in industrial engineering, learned a good deal about project management in general, and he looks forward to putting this knowledge to use in future projects.

Faculty Perspective

- 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.

- 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.

- 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.

- Would you use this competition as an educational vehicle in the future? Why or why not? Are there changes to the competition that you would suggest for future years?

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

- Would you recommend any changes to the ACRP competition?

  No, we would not.

F. References

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