Inspector Drover

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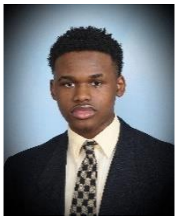

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HAMPTON UNIVERSITY

INSPECTOR DROVER

FAA Challenge
Smart Airport Student Competition

Objective and Description of Effort:

- The objective of our project is to create a safe and more efficient way to conduct runway inspections by using drone and rover technology to conduct autonomous inspections

Technical Approach:

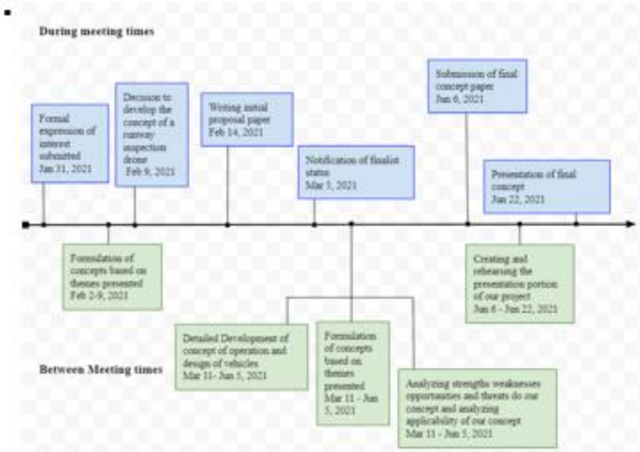
- Discovered the need for autonomous innovation to speed up runway inspection and quick FOD removal

Image:

Key Findings/ Potential Benefits:

- Discovered that the need for runway inspection documentation improvement.
- Discovered safe autonomous runway inspection methods.
- Standardized runway inspection methods through different airports across the nation.
- Create the initial relationship between drone and rover operation in aviation.

Schedule:



Cost: $282,000 Per Unit

2 Executive Summary

The aviation industry is the safest mode of transportation today. Because of our well-trained pilots, talented mechanics, and amazing airport operation managers, they ensure that the aviation industry is withheld to its prize safety standard every day. One problem the industry constantly faces is Foreign Objects Debris (FOD) that appear on runways all over the world. FOD is defined by the FAA as “any object, live or not, located in an inappropriate location in the airport environment that can injure airport or air carrier personnel and damage aircraft.” This leads to pilots having to watch out for debris, airport managers taking valuable time to search for the debris, and airline operators having to pay millions to billions of dollars each year for aircraft repair that has been affected by FOD, which also leaves valuable aircraft inoperable for aa extended duration of time.

Composed of mainly student pilots, the team in the Hampton University Aviation Department wanted to discover ways to make flying safer for themselves and others around them. The team has discovered and experienced on their own that FOD is a constant issue that pilots face. The research team quickly investigated ways to help mitigate the dangers and delays that come with FOD. This is where the concept of “Inspector Drover” came to fruition.

Airport operators are currently tasked to inspect runways each day and multiple times a day. The quality of these checks may vary between different airports, and at times, the demand of the job may lead to a less-than-thorough inspection. The current method of runway inspections involves closing a runway down for an extended period and reopening after the completion of the inspection. This could take several minutes to an hour at larger airports to complete a full and thorough inspection and may still consist of human error.

Inspector Drover was created with the main mission to expedite the inspection process safely and efficiently. Using a drone and rover partnership, whenever there is a time and need for a runway inspection, the rover will autonomously dispatch to the runway and deploy the onboard drone. The drone and rover would then quickly examine the runway in its entirety, including approximate safety areas, taxiways, and runway lighting. If the drone detects any FOD, it will signal the FOD’s exact location to the rover where the rover would then swiftly remove the object. The drone and rover will also collect and store data throughout inspections to help airport managers monitor runway conditions over long periods. Once the rover and drone finish their mission, the pair will rejoin each other and return to their designated resting areas to be ready for their next use.

The goal of this project is to bring innovative uses for unmanned aerial and ground systems to airports around the country. We acknowledge there are current companies that are developing UAS solutions to help make airport inspections easier. The UAS has current limitations of not being able to collect any FOD or properly measure and potential deterioration to the runway. Therefore, the innovation of the rover and upgrade of current software will further help the FAA improve safety regulations, make airports safer, and save airlines millions in potential repair costs.

3 Table of Contents

4 Problem Statement and Background

In the field of aviation, landing and taxiway surfaces are one of the most essential parts of the swift and efficient operation of an airport. Whether they are small, private airfields or large airport hubs with multiple runways, the proper care, and maintenance of these surfaces is of the utmost importance when it comes to keeping people both on the ground and in the air safe. Some of the biggest threats that aircraft face during normal operations are Foreign Object Debris (FOD), diminished runway lighting, and runways in poor condition. The airport operators are tasked continuously to inspect runway conditions to ensure these problems do not arise and look after the people who are flying in the skies.

FOD can come from almost anything and can be found anywhere, but it poses a heightened level of danger when it is located on runways and taxiways. While aircraft engines can withstand trace amountsof debris being pulled into the engine, even small amounts of debris can cause massive damage to the aircraft engine that, at the very least, could be extremely costly and at most incredibly dangerous. The average cost of a single-engine repair could be from $8,000 to $15,000. The single repair for a commercial jet engine could cost from hundreds of thousands to millions

Boeing reports that FOD costs the Aviation industry roughly 4 billion dollars a year in damages, but even more dangerous is the possibility of a serious incident as a result of FOD. One example of an aircraft accident that was caused directly by FOD was the Air France Flight 459 accident that took place on July 25, 2000. The Air France Concorde's right-wing engine inhaled a piece of metal debris during the initial takeoff, bringing the plane down shortly after and killing 113 people, and costing over 125 million dollars in damages.

Another area concerning runway safety is the inadequate runway lighting during low visibility and night operations. Improperly lighted runways and taxiways can result in an aircraft landing on incorrect surfaces and/or aircraft taxiing off approved surfaces. A lack of runway lighting also carries strict penalties, such as temporarily shutting down the active runways to take valuable time to go out and repair the problem.

The condition of the landing surface is also important to consider when discussing runway safety. Cracked and uneven pavement can cause unexpected movements on an aircraft's takeoff or landing roll which could lead to the aircraft being damaged or involved in a runway excursion event. For this reason, airport managers inspect the runway condition multiple times a day and are also tasked with inspecting the runway safety area which encompasses the area around the touchdown surface, typically 250 feet in either direction from the centerline.

To prevent runway-related incidents, airport managers currently carry out this routine runway and taxiway ins and light inspections, carefully looking for FOD typically in a vehicle and picking it up. The number of inspections varies from different sizes of the airports, but it typically involves an airport operations manager getting into a vehicle and manually drive up and down the runway to inspect for any problems. The issue that managers face is the massive amount of space they must cover,as runways can sometimes be over two miles long, all while staying clear of aircraft operations. The process is time-consuming and requires large amounts of coordination with ATC and flightcrews and may even cause delays if not planned accordingly.

Each of these issues should be recorded and reported properly. Airports have a variety of recording devices, but typically to report an issue concerning surface irregularities requires measurements with a traditional ruler and photographing the inconsistency with a camera. This process takes an extended amount of time and requires the operator agent to step out of the safety of the vehicle and onto an active runway which adds another level of risk to the job of an airport ops individuals.

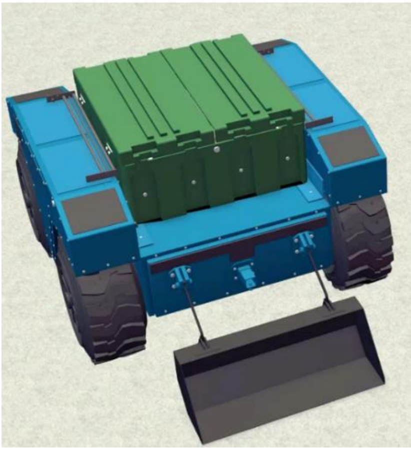
Any of the issues presented above can result in noncompliance with FAA standards which will result in runway closure. Unplanned runway closure causes a slew of financial and schedule-related nightmares not only for the airport but also the surrounding airports and air carriers attempting to use the field. Even worse than runway closure is airport certificate revocation. For these and so many more reasons, airport operation officials work hard to keep their touchdown surfaces safe and functional.

5 Project Description

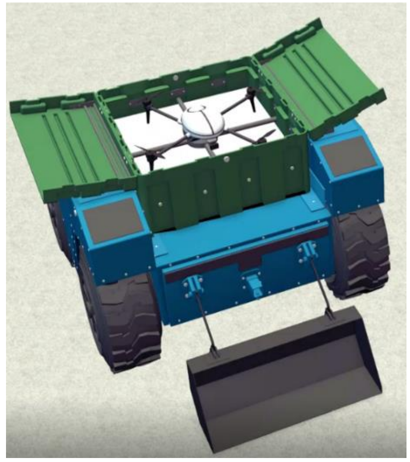
5.1 Design Overview

The Inspector Drover project idea includes an Unmanned Aerial Vehicle (UAV) drone and a rover combination. The primary mission of Inspector Drover must be to inspect runway conditions and autonomously remove and FOD. This combination helps improve the research and technology that the FAA and other companies are conducting to inspect runways with drones. Current methods may include a remote-controlled drone flying down a runway and highlighting an FOD on the runway. Inspector Drover aims to take this a step further by adding an unmanned ground rover to autonomously remove these objects, instead the need of an operations manager to take time and go out to remove it themselves.

5.2 Concept



(a) Fully Rendered Rover with Box Closed



(b) Fully Rendered Rover with Box Open

Figure 1: Inspector Drover Design Concept

5.2.1 Concept of Rover Design

The rover design was the innovative and primary focus of the overall team. Our design criteria were to create a rover with safety as its priority. It was important to include numerous safety features inside of the rover so that it would make the experience efficient for everyone. We finalized on a design that was not only reliable but modular to incorporate future upgrades and designs creations on the needed bases for different airports

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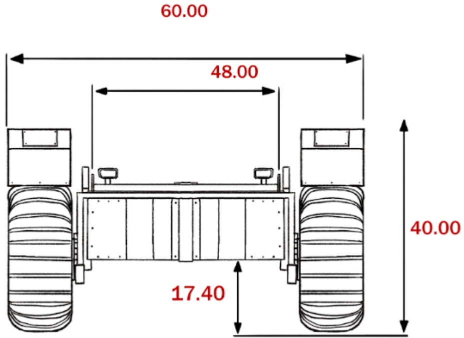


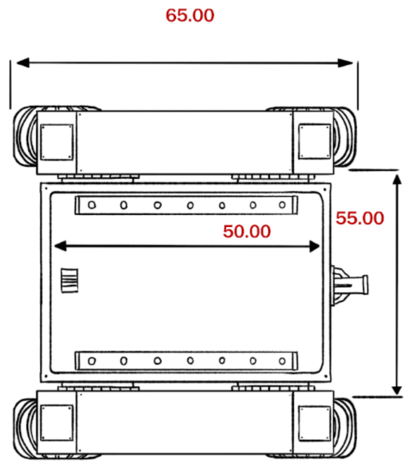


Figure 2: Mockup design of the Rover. *Measurement in inches*

We first wanted to make sure that our rover design was large enough to see and fit the description of the mission. We started with a 110-amp hour Lithium-Ion battery. This is important because it will allow the rover to power all its systems efficiently with a nominal run time estimated at 3 hours. We wanted to make sure this number exceeded numerous rover operation passes in case of emergencies or human error by forgetting to recharge the device. We chose the dimensions of 60 x 40 x 65 In to have the rover large enough to be seen easily hundreds of feet away. This would also allow for the rover to carry four 24” Argo tires to operate on any terrain and in any weather terrain, these wheels are also easy to carry, fill, or replace in case there are any incidents during operations.

The rover must also have a high maximum speed. This was important to incorporate in case of an aircraft needing to conduct an emergency landing on the runway during the inspection, the rover must be able to clear the runway. The engineering team decided that for safe operations, the rover must clear an average full runway length, 2 miles, in 3 minutes. This would require that the rover have a maximum speed of 40 miles per hour and a 3-5 horsepower DC electric motor on each wheel would help facilitate this requirement. This would also allow for all-wheel drive, which would help the rover overcome any terrain and rotating the appropriate wheels faster than others to help maneuverability and turn radius.

The internals of the rover consists of numerous technologies that will help the rover achieve its mission. The first item planned to be incorporated inside the rover was an ADS Transponder. This was important for aircraft and Air Traffic Controllers, ATC, to identify and see where the rover is always at. ATC must be able to clear and help direct the rover to its initial inspection point and know where to stop the rover and direct it off the runway at any point in time. The rover will also carry an internal Nvidia Nano computer that will help the rover think and process all the information between itself and the drone. GPS and gyroscope devices will be implemented in the center of the rover for accurate position and directional processing to assist in autonomous operations. The rover will also include 1080P cameras all around to record and monitor the rover’s activity. If there are any issues, an operations manager would be able to manually control the rover from a first-person view perspective.

One final important implementation of the rover was the inclusion of the rail system that is seated on top of the rover. This would allow the modular approach to customizing the rover for the specific mission needed. In this research, the team has focused on the drone-in-a-box solution that would be mounted on top of the rover for runway inspections, see more in 5.2.2. This could be replaced with a loudspeaker solution to operate where ATC may need birds or other wildlife mitigation. The rover could also be equipped with high-powered LIDAR and camera sensors to help safety inspectors conduct thorough and highly accurate runway inspections. There is plenty of room to grow with the rover design.

Our research team has collaborated with the company Clearpath Robotics to create an invoice for the creation of a rover that would meet our minimum specification. From the invoice, we recommend that airports invest in the total base package, computer package, software package, and spare parts to ensure that the rover could be used in perfect condition in any weather.

PDF A sample invoice from Clearpath can be found here

5.2.2 Concept of Drone Design

Our research team has acknowledged that there are current research and technologies on drones conducting runway inspections. One of the areas of improvement in the technology readily available is efficiency. Companies would require operation managers to be fully trained in drone operation, go out on the runway and set up the drone, then retrieve and dismantle the drone once the operation is finished. All this could take valuable time and questions if it would be just as efficient and time-costly for a person to just manually inspect the runway in a vehicle.

The Inspector Drover team has then decided to go with a drone-in-a-box solution. This would ease setup cause because the drone will be charged and ready for operations from its box housing. We discovered that the box would still need to be carried from the airport, where it is stored, to the runway each time it is ready for use. We have decided to partner with Icaros Incorporated, based in Manassas, Virginia. Icaros is a company that focuses and specializes in Drone-in-a-box solutions. The use of their advance and readily available technology would allow a dedicated and professional company to be able to support and provide appropriate maintenance.

PDF A sample invoice from Icaros Inc. can be found here

The invoice includes the SAMS Falcon drone. This drone can fly upwards of 45 minutes, top speed of 65 mph, and the endurance to be flown in all weather including rain, snow, and fog. These specifications are important for our mission so that in case of emergencies, the drone will also be able to appropriately get out of the way. The drone must also be able to conduct inspections through any weather type so that the efficiency could continue. The invoice also includes the appropriate ground station/ box. This all-weather ready box will be installed on top of our rover and shield the drone from any outside weather conditions or damages it may otherwise face. The box would also serve as the recharge station for the drone so that it may be able to always reside inside the rover. The drone also includes the appropriate cameras that would have object tracking, increased zoom, thermal resolution, and gimble. This allows not only easy FOD detection on the runway but a multitude of operations like easy wildlife detection with the thermal resolution or accurate runway and building safety inspection.

Figure 3: Rendered design of the Drone-in-a-box system

The invoice also includes optional accessories that airports have the options to consider. The design team recommends that every airport includes the Power Guard option to allow the rover to recharge the drone multiple times. The airports also have an option to buy spare Falcon drones and spare parts that includes easy-to-swap motors, propellers, and batteries that all tend to deteriorate or fail. The design team calculated that it would be best for airports to invest in the full package including the optional accessories. Airports should have these accessories for any unplanned circumstances and ready to swap components than the whole Inspector Drover being offline for an extended period while an airport waits for a replacement.

5.3 Concept of Operation

5.3.1 Concept of Rover Operations

The engineering and design team has planned an efficient method for the rover during FOD inspections. The rover will be housed in an adequate parking space that is easily accessible for charging or repairs next to the runway. When it is due time for a runway inspection, the operations manager will coordinate with ATC to start the autonomous process from their office. The rover will power on and proceed under the direction given by ATC to the active runway. The rover will stop before all movement areas. The rover will not continue until given clearance by ATC and the operations manager approved the rover to continue operations.

The rover will then proceed to open the center end of the runway and commence the inspection protocol. The rover will open the drone-in-a-box solution and then deploy the drone. Once the drone is in the air and commences its sweep, the rover will follow behind the drone down the edge of the runway. When the drone signals to the rover that it detects FOD, the rover will receive an accurate GPS location of the debris and move from the edge of the runway to the FOD’s current location. The rover will then drive up and scoop the debris in its front arms. Once the rover has scooped the debris, it will return to the edge of the runway and continue the FOD inspection will the drone and repeat the pickup process if needed.

Once the inspection is complete, the rover will return to the center of the runway and the drone will land back onto the box solution. Once the drone has returned and secured, the rover will promptly exit the movement area onto the taxiway. ATC will then give ground clearance for the rover to return to its parking spot and the operations manager will approve the rover for this action. The rover will then continue and stop at its designated spot and signal to the operations manager if the scoop needs to be cleared, batteries need to be recharged, or any other maintenance issues that needed to be addressed before the next inspection.

5.3.2 Concept of Drone Operations

The concept of drone operations will be similar to the rover operations. The drone will be sitting inside the box on the rover until it is time for it to deploy. When the rover opens the box, the drone will then raise to approximately 50 feet above ground level. Once the drone has calibrated itself in the air and the cameras are ready to use, the drone will move down the runway centerline. This is the best position for the drone to examine and record all parts of the runway. The drone will use its onboard cameras and object trackers to scan for any FOD.

Once the drone has detected and debris, it will calculate from its height and GPS location in conjunction with the camera angle to determine the exact location. The drone will then send this information to the rover and stay and watch the removal of the debris. Once the debris has been picked up, the drone will continue the inspection protocol and repeat the removal process as needed.

Once finished, the drone will fly and return to the box system on top of the rover. Once secured inside the box, the drone will signal to the rover to close the box and the rover will return to its designated spot. If the box needs to be recharged, or a propeller needs to be replaced, the drone will signal to the operations manager to conduct the appropriate maintenance.

5.3.3 Concept of User Operation

When a scheduled runway inspection is due or at ATC's request, the operations manager will coordinate with ATC on which runway needs to be inspected. ATC will then tell the operations manager the route that the rover should take. The operations manager will program from the office what route that the rover will take and send the commands to the rover. Once the rover has commenced its operations, the operations manager will monitor all actions from the rover through the live feed camera. ATC will also be in constant communications with the operations manager in case the rover needs to change directions or abort the mission.

In the event the robot pauses for any movement areas, ATC will give the clearance to the operations manager, and they will send the signal to the rover to continue. The rover will deploy the drone and the operations manager will now be able to monitor the drone and rover feed simultaneously. The operations manager will watch as the duo completes its mission. If needed or any problems occur, the operations manager can switch control of the rover and/or drone from autonomous to manual controls and the manager will be able to fully control the systems.

When the inspection is complete and the rover has returned to its designated spot, the operations manager must run through a checklist to make sure the rover will be ready for the next inspection. This checklist will include collecting and recording any FOD the rover has picked up, making sure the batteries for the rover and drone are fully charged up, and inspect if there are any damages on the vehicle.

5.4 Expected Potential

We believe that the Inspector Drover system will become widely used in airports of all sizes and varying climates across the national airspace system. In its base form, it can greatly increase the speed, quality, and uniformity of runway inspections done, which increases both efficiency and safety. The most important improvement to runway inspections it will bring is by removing the inspector from the active runway. This keeps airport officials off the runway and away from any potential danger.

When looking at potential additions to the platform and missions the system could take on in the future, the possibilities are endless. With the ability to add attachments to both the drone and the rover, any number of tools could be added to increase the system's capability. Attachments could be created to carry out missions such as ASOS/AWOS maintenance and testing, lawn care, Localizer, and Glideslope testing, light replacement/repairs, wildlife control, runway icing stop tests, HAZMAT cleanup, runway groove hydro blasting, and many more missions. The concept rover could also be redesigned to be larger and thus capable of picking up large degrees of FOD or help carry items across the airport. It could even be designed to inspect a non-standard surface such as grass, sand, packed snow, or ice.

5.5 Risk Assessment

5.5.1 The importance of risk mitigation

Risk mitigation is extremely important in aviation and is possibly what aviation is known for. Therefore, it is equally important to consider the different risks that may affect our desired goals. Risk mitigation must be looked at and thoroughly thought of, or the Inspector Drover concept will be just as effective as the FOD on the runway. Consequently, the engineering team has created a list of possible risks has been created and based on a severity level between “1-5” with 1 being the least severe and 5 being the most severe. The severity rating is considering multiple factors such as the potential damage done to the drone and/or rover, the potential damage is done to aircraft around operations, the time it would take to fix/negate an issue, and more. The list also comes along with potential solutions and possible causes to said risks.

Click here for the list of possible risks.

SWOT Analysis

Strengths	**Weaknesses**
• Shorten inspection time, • Increase inspection accuracy, • Allow inspection to be shared virtually	• Communication between drone/air traffic controller • Frequent repair/upkeep
Opportunities	**Threats**
• To expand and grow to different missions • To be used globally • Expansion outside aviation	• Loss of control over Inspector Drover • Collision between Inspector Drover and aircraft

Figure 4: SWOT analysis

5.5.2 Physical Risks

With the combination of both a rover and drone, there is a physical risk that could arise between the two systems themselves. The drone has the same number of physical risks that could arise with everyday drone operations. The risks of parts from the drone flying off like propellers or camera systems would always be a possibility. It is important to always make sure that the drone is thoroughly inspected after each operation to prevent that risk. Other physical risks may include the rover accidentally hitting something or someone. It is vital for an operations manager to always monitor the rover's position and ensuring that an event like this does not happen and potentially minimize the physical risks associate with the rover.

The physical risks do not stop with Inspector Drover and people on the ground. The rover or drone could leave behind material that would become FOD and damage aircraft that were around the system. On rare occasions, the drone and rover could also be subject to wildlife attacks. It is important to monitor for these events to make sure our system is not hurting the ecosystem around us.

5.5.3 Social Risks

The risk of pilots interfering with Inspector Drover is not inconceivable. With any new technology, pilots must be trained and aware of current systems that would be taking place at the airport. This would help pilots understand what may be going on when Inspector Drover is in operation and how to avoid the system or deal with any problems that may arise. Pilots may be unaware during taxiway or pushback operations to avoid Inspector Drover completely. The social risks of Inspector Drover are high because any small incident that may occur, could cause massive damages to an aircraft and damage the airport, airline, or Inspector Drover's brand. It is important to always check and ensure that Inspector Drover is functioning as safe as it could be

5.5.4 Cyber Risks

There are minimal cyber risks involved with Inspector Drover. The engineering team has developed numerous ways to help mitigate the risk for outside attacks. The first area of consideration would be in the software. The software for Inspector Drover will automatically check before each autonomous run if there were any significant deviations from the software's original plan. If Inspector Drover detects that an original file is missing or significantly modified, the rover will not start, and the software will ask for the operations manager to review the systems software for a complete reset. Another vulnerability would be the override manual control of the drone and/or rover. To help mitigate this from happening and causing millions of dollars in damages or the hazardous risk of numerous lives, the operations manager has an automatic kill switch that will send a special signal to the drone and rover to shut off completely once it is pressed. This will prevent the cyber-attack from happening any further and the operations manager could identify and fix the appropriate backdoor event.

6 Research

The following portion of our paper is a detailed explanation of our research of current airport runway inspection methods used to develop our project. It first details the methods of research and how the group decided to pursue information. It then details the subjective and objective data in written and graphical format. It finally details the determinations made by the group over several meetings after studying and receiving the data.

6.1 Research Methods

We divided our research into three portions. We did personal research to get a better understanding of runway inspections, studied the FAA regulations, and familiarized ourselves with the part 139 airport certification requirements. We reached out to a couple of airports to interview the airport officials to ask various questions about how they carry out runway inspections and how our rover and drone companionship can help improve runway inspections and where it could potentially cause problems. The data information we have gathered so far has helped us develop a more precise perspective on how we plan to use our product. We expanded our interviews with more operation officials at several other airports. Our goal was to start interviewing small airports and work our way to airports with larger airspace in different locations across the nation to get a wide variety of responses and opinions. After each interview, we sent out surveys to each airport official to get objective information to help create charts, graphs, etc.

6.2 Data Collected

We reached out to many different airports to try and receive data from each one to get a consensus of what the majority needed. While doing so we also were seeing what we can do to accommodate different airports with their different needs. We had 4 airports respond which were KPNE, KRDU, KSEA, and KDEN. Through our questionnaire, we found a lot of good information that helped us finalize and make some key decisions.

In our questionnaire, we had 17 questions ranging from “What concerns do you commonly (on most inspections) face when inspecting the surface of the runway” to “How long does your average runway inspection take in minutes?”.

This is what our research has shown us. When it comes to the most common concern that affects runways, the consensus was FOD. However, pavement, markings, lighting, signs, safety areas, obstructions, and wildlife hazards were also mentioned. Another concern was having sufficient time to perform thorough inspections without disrupting the aircraft traffic. With FOD being a common concern, we wanted to know what some of the challenges and concerns were with looking for FOD on a runway inspection. Most of the responses said seeing the FOD was the main concern when performing a runway inspection. KSEA stated that they have sensors to help detect FOD but none of the other airports seemed to have that technology. We also asked how big the

FOD usually was and they all said less than 3"x3"x3" (could fit in a coffee mug). The main material the FOD was made of was plastic with metal as the second most common material as one of the graphs shown.

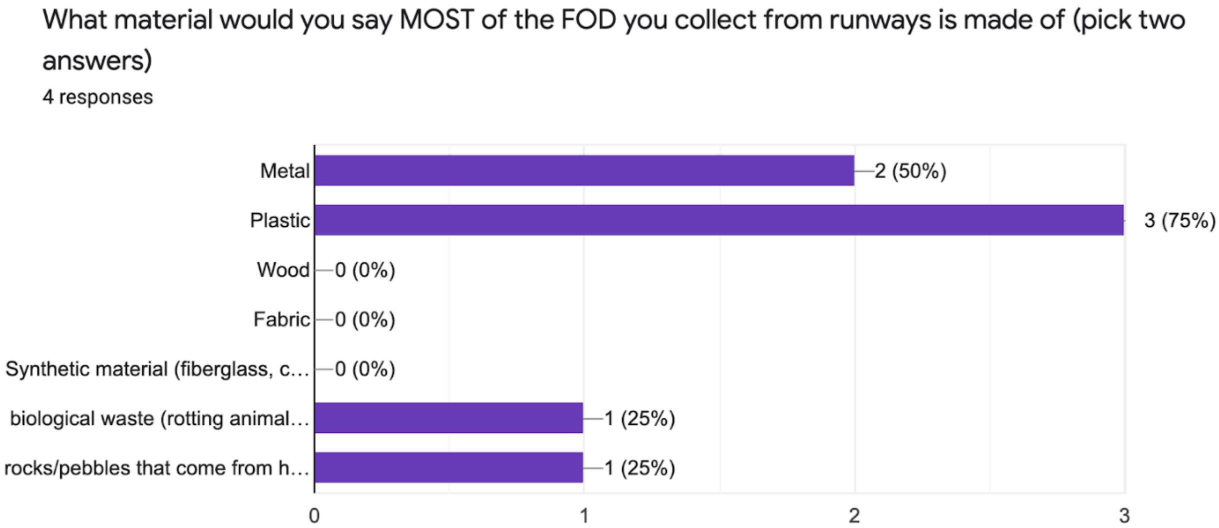


Figure 5: Graph of the different materials that are collected

All the airports usually performed 3 to 5 runway inspections throughout the day that lasted anywhere between 10 to 30 minutes depending on what time of the day it is and what type of inspection they are performing. On these inspections, we were also curious not only about the FOD but the runways themselves. The most common irregularity for the runways was faded markings at 50% with cracks and spalls being at 25%.

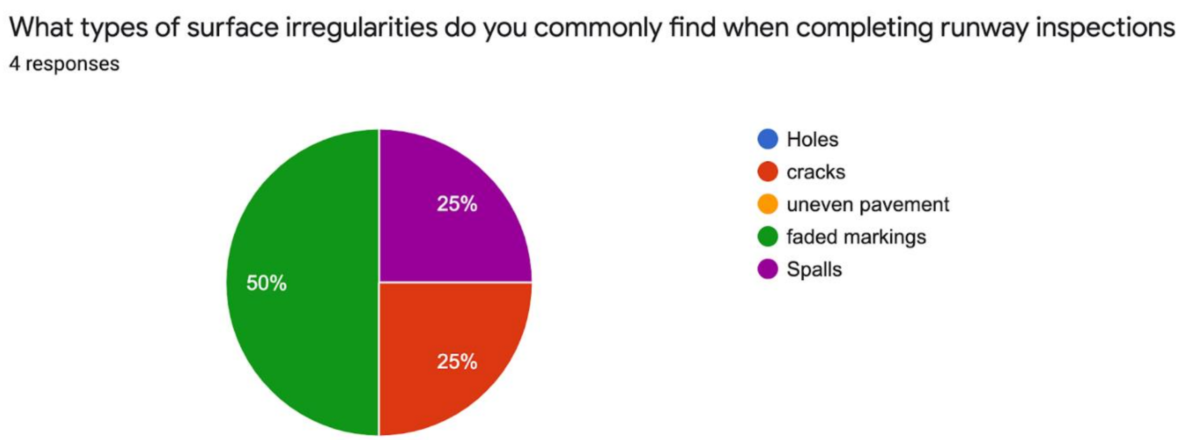


Figure 6: Graph of surface irregularities

Our final concerns dealt with some problems they face when getting from their operations center out to the runway sight and data documentation. When it came to the problems they faced, the most common answer the managers had to deal with was the high amount of air traffic coming in and out of the airport and trying to fit in an inspection. One problem that KRDU faces is that their Airport Operations Center is located outside of the airport operations area itself, so they do not have direct access to or direct visibility of the field.

Once the airports have performed their runway inspections, we wanted to know how and where they keep and document their inspections. 50% of the airports used Veoci while the others used either Microsoft Office products such as word or excel, or, a safety inspection form.

6.3 Data Determinations

Based on the data collected by the research team, the collective group was able to determine that the best focus was to focus on FOD collection as the main mission of Inspector Drover. This was determined due to the nature of FOD itself. As explained by several officials, FOD is typically blown around and can be hard to locate as it might change location in between the time it was reported, and the time airport operations officials can get to the runway to collect it. All operation officials reported FOD was typically less than 3”x3”x3” thus making locating small objects even harder. This differs from surface irregularities in the sense that cracks, holes, and other pavement and runway issues are not mobile. FOD collection is an extremely important component of proper runway care as neglecting this duty or missing a minute detail could lead to extensive aircraft damage or cause a harmful accident.

The research group determined that to collect FOD, a system would be devised where a drone flying overhead the runway would identify pieces of debris and a rover following close behind on the runway would quickly move to the spot and collect the FOD. After the inspection, the rover will then return to the airport operator and the operations official will collect and dispose of the FOD as they see fit. The operator can also hold onto the FOD if for some reason it is deemed it needs to be retained for documentation purposes.

While FOD collection was determined to be our main goal for this project, it was discovered that our drone and rover combination could be used in several different ways. This has allowed us to be more open on the design so that others may take this research and develop their drone and rover combination to solve any problems they may have globally.

Runway surface inspections were seen as an important secondary task, and it was decided that the use of some extra technology would be sufficient to accomplish this goal.
The engineering team determined the drone might require several different cameras so that it can locate and document both FOD and Surface irregularities. This would allow the drone to capture high-quality images of FOD and surface irregularities such as cracks, bumps or spalling, and allow

the airport managers to record and keep this documentation on a dedicated hard drive in their office for future use. The drone will also be able to withstand weather hindrances and be rugged enough to carry out its mission in less-than-ideal conditions.

It was decided the rover could be equipped with a gyroscopic system to determine the levelness of the runway surface and detect any large holes or cracks. To collect FOD that is found on the runway the rover will possess a scoop and the drone-in-a-box system to carry out that task. To complete numerous other tasks, the team decided to give the rover the ability to become fully modular and carry several other attachments and systems that could be added to the system to widen the range of its mission. Other attachments discussed were grove cleaning mechanisms, mowing tools, localizer, and glideslope testing systems, and wildlife removal/prevention systems.

7 Conclusion

Using the group created parameters the group was able to create a clearer and stronger concept to improve upon the current airport operations. A residual result of our research was that we discovered throughout the process that our concept is something that would be welcomed at several airports and had strong applicability at airports. With that in mind, it was decided to continue on our current path with the target goals of the drone rover system defined.

7.1 Impact Statement

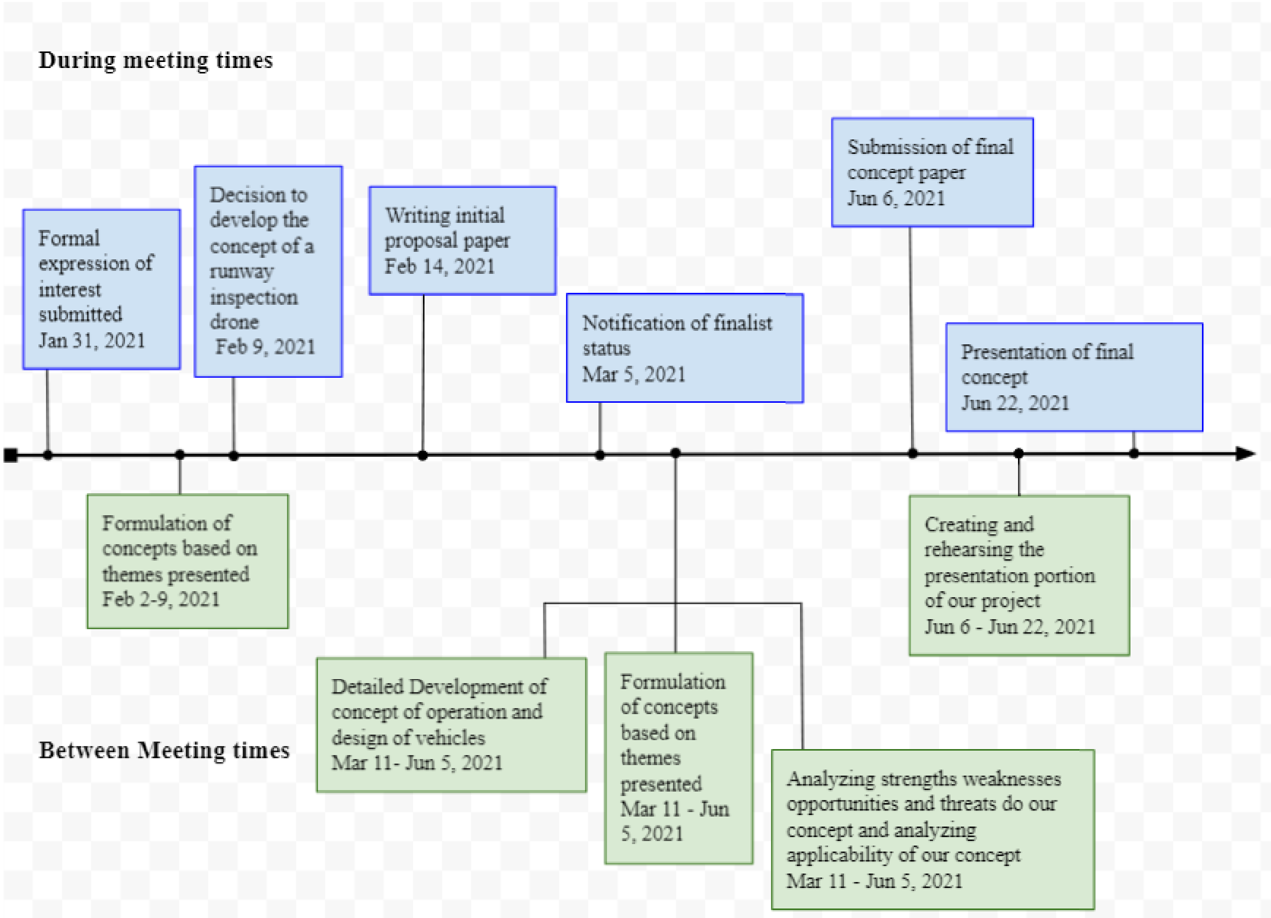
There are two key components to the aviation industry that makes them successful, safe,and efficient. With our new autonomous aerial drone and land rover drone technologies, we willbe able to cut the cost of FOD damage tremendously and speed up the inspection process. FOD has a major impact on airports such as damaging aircraft engines, cutting aircraft tires, items lodged within aircraft mechanisms, preventing smooth operation, and unfortunately causing injury to people. The result of these damages costs the aerospace industry $4 billion a year. Our Innovation intends to guarantee significant savings on these damages accumulated by FOD. The drone application intends to cut the cost by over 85% annually, saving airlines hundreds of thousands of dollars.
Our application will foster efficient foresight for maintenance and improvement of buildings, maintenance of aircraft, promote easier and more efficient staff training, reduce the pressure on staff, increase the number of daily inspections, and other profitable benefits to the airfield. Everything that FOD negatively impacts we plan to reduce by a large margin. According to aviation safety records, aviation is the safest means of transportation. Our drones will be able to diagnose potential threats to ensure the safety of the airfield while also decreasing fatalities.
Our application will greatly benefit airlines and airports' economic impact such as airport profit, aeronautical and non-aeronautical charges, single/dual/hybrid, and public-private partnerships (PPP). Our application will follow all guidelines presented by the ICAO's airport Economics manual. The importance of the manual is to guide individuals responsible for airport management to improve the cost-effectiveness and efficiency of the development ofan airport. Ultimately, we

will follow all regulations to operate unmanned aircraft to promote safety and efficiency to the aerospace industry.

8 Technical Demonstration

Due to current travel restrictions and COVID-19 protocols, our team will be using numerous virtual demonstrations to help and guide others to understand our concept. The team will be showcasing ideas with the main video demonstration, created with Adobe Premiere. The main video will showcase a prerecorded digital video of the drone and rover operating in ideal conditions, different 3D AutoCAD renders to help viewers visualize the systems and sketches that helped us create Inspector Drover. All of the technical demonstration materials will be showcased in the video file and presented on June 22, 2021.

9 Project Timeline



10 Budget

Using the invoices between the two industry partners, Clearpath robotics and Icaros Inc., we were able to create an appropriate cost budget of what one system of Inspector Drover would cost. Using the tagged invoice from Clearpath, the rover will include the Base Package of $102,160, Computer Package of $10,711, Software Package of $30,950, and a Spare Part Package of $6,050. The total of the rover will be estimated at around $149,871.

Using the recent invoice from Icaros Inc., the cost for the drone-in-a-box will include a total of $78,948. We recommend that airports also invest in the optional accessories package that adds up to $53,171. The total cost of the drone-in-box system will be $132,119. The combined total and estimate for the Inspector Drover system will be $282,000 will at the appropriate modification per pair.

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