The **Guairdian System**

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Executive Summary

Situational Awareness on the airfield is a factor of great concern for airport operators. Planned and regulated navigation of the runway and taxiways would reduce runway incursions and increase safety on the airfield. When a runway incursion occurs many operators are forced to shift focus from their current job in order to mitigate the situation until the runway or taxiway is clear for use. Therefore, reducing the number of incursions will increase the safety on the airfield for operators, pilots and passengers alike.

Working to create a system that would increase situational awareness, the team from Stevens Institute of Technology has devised a solution. The Guaidian system aims to increase operator awareness and thus proactively decrease the frequency of runway incursions. The system intends to do this by tracking a vehicle’s movement through the airfield. When the vehicle enters a zone they have not been given access to, the device will alert the worker to turn around before they cause a dangerous incursion. A need for this device was validated through studies of the operations at Newark Liberty International Airport (EWR). Here many maintenance vehicles and airfield operators drive on the taxiways daily and though training is required the airfield is still large and complex. The Guaidian system would create an additional safety precaution to watch the operators while they are carrying out their job.

The design for the Guaidian system has been fully conceived from a system architecture to a cost benefit model. Many current devices require large initial investment; however the Guaidian system was designed for low implementation costs. Implementation of the Guaidian System at airfields of all sizes will prove valuable to airfield operators by increasing the margin of safety across the industry.
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Acronyms

ASDE-X - Airport Surface Detection Equipment – Model X
ADS-B - Automatic Dependent Surveillance – Broadcast
BOS - Boston’s General Lawrence Logan International Airport
EWR – Newark Liberty International Airport
FAA - Federal Aviation Administration
PA – Port Authority of New York and New Jersey
1.0 Problem Statement and Background

The FAA has created a category in the Design Competition for Universities that brings attention to runway safety, runway incursions and runway excursions. Expanding situational awareness on the airfield is a top priority that would increase safety. New technologies provide many opportunities to create direct warning systems that would proactively alert air traffic controllers and workers before incursions occur at airports throughout the United States.

A runway incursion is any occurrence on the airfield involving the incorrect presence of an aircraft, person or vehicle on the protected area designated for the landing and takeoff of aircrafts. During the time from 2006 to 2011 the FAA reported 5,488 runway incursions. [6]

The fishbone diagram in figure 1 compiles the cause and effects behind the problem of runway incursions. Here, the problem is that 243,000 airfield incidents occur a year costing the airline industry $10billion. From that effect, the causes were broken down into 3 options: Airfield Congestion, Airfield Navigation and Volatility of the Airfield. Airfield Congestion is in reference to the number of vehicles using the airfield outside of the airplanes. These vehicles include the daily operations of the maintenance workers. Airfield Navigation deals with the complexity of airfields due to taxiways, runways and no movement zones. Much like a highway system, the airfield is complex in design due to its required functions. Finally, volatility of the airfield is two-fold. The first being that runways and taxiways will be closed at times for necessary maintenance; this is unavoidable but always forces a change in traffic flow. The other reason behind this cause is that the landing patterns of aircraft may change due to the weather. When landing patterns change the traffic on the taxiways shifts and as such the airfield operators need be alerted.
There are three types of incursions: Operational Errors, Pilot Deviations, and Vehicle/Pedestrian Deviation. These incursions are classified as: Category A-D with Category A being the highest risk of a collision and D the lowest risk[6]. Operational Errors are actions of an Air Traffic Controller that violates FAA regulations. These regulations include, but are not limited to, specifying the minimum safety distance between 2 aircrafts and defining protocol for clearing an aircraft for takeoff or landing. The next type of incursion, Pilot Deviations, occurs when a pilot crosses a runway without first receiving clearance from the Air Traffic Controller. The third and final incursion is Vehicle and Pedestrian Deviation. This occurs when pedestrians or vehicles cross any portion of the airfield without clearance from the Air Traffic Controller. (See Appendix J.1 for complete table) Runway incursions result in delays, runway closings and even fatal accidents. The table in Appendix J.3 shows the amount of incursions fluctuating from
2008 - 2012. A majority of incursions are a result of Pilot Deviations and Vehicle/Pedestrian Deviation.

1.1 Current Technology: Airfield Signage

Signs on the airfield convey 2 parts of information: where you are currently located, and where you are heading. Signs like the one produced below in figure 2 are built upright alongside runways and taxiways in the airfield. The black square indicates current location on taxiway W. The red square with a white 11 indicates that runway 11 is to the right and you will be approaching a crossover. These signs are present to help operators know their location and to navigate through the field. They do not help with planned navigation, nor do they quickly inform operators of potential danger. The signs are stationary and unable to change in response to a closed runway or taxiway. Airfield operators cannot rely on the signs to warn them of danger and to proactively stop them from a runway incursion.

In addition to the upright signs, there are also signs on the ground when an operator is moving from a taxiway to a runway. These signs look like the red one in figure 3. This is a thermoplastic decal that is heated up to secure it to the taxiway surface. Using the sign as a reference, this would indicate that the threshold for runway 22R-4L is in front of the operator. These signs, though more costly than paint, require much less maintenance when applied to the taxiways.

In addition to the 2 types of signs previously mentioned there are markers along runways that indicate the remaining length. This indication gives pilots a reference to gauge their
landing/take off parameters. There also are standardized line types to differentiate borders of a runway, taxiway and no movement zone. These are yellow and painted on the pavement of each of the airfield locations. A more detailed description of each of the runway signs/markings may be found in Appendix J.2.

1.2 Current Technology: ASDE-X

Workers in the Air Traffic Control tower are given tools to alert them to potential dangers on the runway and in the airspace. Most commonly, this assistance is found in the form of a radar system called the Airport Surface Detection Equipment – Model X (ASDE-X). The ASDE-X equipment has an intended two-fold purpose; the first being to increase situational awareness within the Air Traffic Control tower and the second being to reduce the impact of inclement weather.

The ASDE-X system is a tool used by the Air Traffic Control tower. The controllers are able to use it to identify potential hazards. Technology within the system works to project paths of airplanes and will notify the controller if these paths will intersect. The ASDE-X offers a preemptive high level view of traffic threats, but it does not have the ability to relay directly to the operators on the ground. It is a proactive system that aids the tower in identifying potential threats which is helpful in its own right. As determined through visits to the Air Traffic Control Tower (See notes in Appendix H.1) the operators already have an efficient system to organize the large scale responsibility they handle every day. The ASDE-X gathers and interprets a wealth of information, but it then relies on the controllers to distribute the data rather than proactively informing the operators. Additional literary research was conducted regarding this technology and can be found in section 3.0 below.
2.0 Interaction with Airport Operators and Industry Experts

Research into the Runway Safety Design Challenge was separated into two sectors: The FAA through contacts at the Air Traffic Control tower, and the Port Authority of New York and New Jersey. The initial meeting at Newark Airport was meant to acquaint the team with airfield operations. Subsequent visits were more focused on solution capabilities and expected impacts for the airport and airline industry.

2.1 FAA: Airport Air Traffic Control

Research regarding the FAA was conducted at the Air Traffic Control Tower at Newark Liberty International Airport. Robert Lehmann, Supporting Manager at the tower, was the team’s initial contact. He was able to answer high level questions and narrow the initial scope of the project. Robert was also able to provide clearance for a tour of the Newark Tower with Traffic Management Coordinator, Erik Carney. The initial meeting at EWR was very informational as Erik explained the procedure and protocols of his job. Each morning Erik Carney consults with New York TRACON, The New York Air Route Traffic Control Center and United Airlines (the primary airline of EWR). During these telecons, each participant aids in discussion relating to optimizing the daily Airport Arrival Rate (AAR) in response to weather, traffic on the airfields and traffic in the air. Erik was very serious in communicating that delays at one airport would impact others both nationally and abroad. For this reason, Erik explained, there are many reasons for defined procedures so each air industry employee, whether in the tower, on the airfield, or in an airplane knows their exact job expectations. Most specifically, Erik discussed the protocol for movement on the airfield.

Once the controller clears the plane for landing they need to watch and help to navigate it through the airfield and towards the gate. Erik explained the dangers of Runway Incursions from
the Tower’s point of view. The controllers do a visual sweep of the runway before they clear an aircraft for landing or take off. Their main focus is other aircraft on the airfield, not the maintenance vehicles. For this reason, when maintenance vehicles deviate from specific areas it takes the controllers attention from navigating aircraft through runway and taxiways. This is a dangerous distraction and one that happens an uncomfortable number of times per day.

Approaching FAA personnel at Newark Liberty International’s tower, proved helpful in understanding the local area and how the airport operates. To provide a comparison with another commercial airfield, not controlled by the Port Authority, the team looked at Boston’s General Lawrence Logan International Airport (BOS). Reaching out to Brendan Reilly, the Operations Manager in the FAA control tower at BOS, some of the same questions resulted in different answers. BOS is more complicated, with more than twice the number of runways and two fire departments on the airfield. Brendan explained the development of BOS’s runways and talked about the lack of congestion when compared to any of the New York area airfields, partially because BOS is the only commercial airfield within 13 Nautical Miles. Then Brendan talked about how the ground traffic at BOS between the seven runways and the five terminals, must always be well choreographed in order to prevent collisions and congestion on the narrow taxiways leading into the terminal area. Looking at maps of the complex runway and terminal configuration for BOS the need for a feedback system is readily apparent.

2.2 Port Authority of New York and New Jersey

Following the research of the FAA processes involved in airport operations, the focus of investigation turned to the operations on the ground. In the greater New York area all commercial airfields are controlled by the Port Authority of New York and New Jersey (PA). The PA therefore oversees all construction, maintenance, and general operations of non-aircraft vehicles
on the airfield. George Martinez is in charge of supervising all training of workers that conduct daily operations on the airfield, such as Aircraft Rescue and Firefighting (ARFF), construction, snow removal and maintenance crews. George explained the process required to maintain the airfield and its general operation (see meeting notes in Appendix H.2). After explaining his role and basic operations around the entire airfield, George took the Stevens team out to the airfield in a Port Authority vehicle to see the operating processes in action. He showed the team safety features such as the Engineering Material Arresting System (EMAS) and the de-icing facilities. George then explained how a system to provide active location feedback and restricted area information would benefit his employees when they are working on the airfield. During a normal day there are projects all over the airfield, some standard like surveying to make sure the airfield markings remain up to code, and some more specialized like repainting enhanced centerlines with reflective beads. George then parked the truck and allowed the team to observe the operations from a central vantage point proving how much happens on a daily basis to keep the airport operating.

Further communications with George proved that Newark had started looking into implementing a system to improve operator awareness on the airfield, similar to the Guairdian system. This system is called the Automatic Dependant Surveillance – Broadcast (ADS-B) and works in conjunction with the previously implemented ASDE-X. Looking at their proposed system, George provided technical information about the purposed ADS-B system and validated the system requirements and functionality for the Guairdian System. George proved to be a
valuable resource answering questions and providing technical information about Newark while also supporting the efforts to validate the Guairdian system.

3.0 Summary of Literature Review

Airfield Operation is a complex system of many components. Amidst all the interaction the FAA’s mission statement holds true as a basis for all decisions [1]. Acting for safety and efficiency of the aerospace system will drive the project’s design and implementation. Further information regarding airfield operation was gleaned from the Port Authority’s Document on Airport Rules and Regulations [20]. In order for the airfield to function properly individual roles need to be specified and implemented. In this document every aspect of the airfield from planes, to vehicles is given an expected standard regarding their functionality. Section 6.0 was of particular interest to the group because this section outlines vehicle specifications. These are the specifications that any system implemented on to the airfield will have to abide by. Specifications regarding speed of vehicles, restricted zones and vehicle driver training are all preventative systems to reduce runway incursions. A new system will have to supplement these existing precautions and not overwrite them. It is important to understand the current measures already in place on the airfield to ensure that a new system to reduce runway incursions does not result in integration issues elsewhere.

The most current technology at airports that is used to combat runway incursions is the ASDE-X Radar system. The ASDE-X increases situational awareness by identifying possible collisions/dangers both on the ground and in the air. The system compiles information from surface movement radar, multilateration sensors, automatic dependant surveillance-broadcast sensors, terminal automation system and aircraft transponders to record locations of vehicles on and above the airfield[4]. It then tracks the movement of each object through use of the ASDE-X
Safety Logic and provides projected paths of travel. Should these projected paths intersect, or even pass too close, the ASDE-X system will recognize the potential for collision and alert the Air Traffic Controller.

Reduction of the impact of inclement weather is necessary because early morning fog and low clouds greatly reduce visibility from the tower. Low-visibility conditions such as rain and fog would not affect the ASDE-X as much as it would affect a controller’s visible range of sight.

Thirty airports are currently using the ASDE-X system, EWR being one of the thirty. This system has yet to be implemented at every airport due to its high cost and new technology. ASDE-X implementation requires complex infrastructure additions. In an audit performed by the U.S. Department of Transportation it was reported that the estimated cost for completion of the ASDE-X initiative was $549,800,000[5]. In addition to cost estimates, ASDE-X implementation at airports does not yet have a solidified time estimate. The ASDE-X Implementation is a large scale project that requires a large amount of contract negotiation and regulation. Due to the incumbent amount of paperwork this project is not yet agile enough for widespread, timely implementation. Research of the ASDE-X system provided an in-depth understanding of the current operations on the airfield.

**4.0 Problem Solving Approach**

There is a high demand for a location based feedback device that fits the needs of large commercial airports as well as small local airports. In order to satisfy both market segments, the device needs to be reliable and affordable. It will also need to be highly accurate as to fit the FAA’s mission of improved safety on the airfield.

As written in the FAA’s mission statement the two most important values are safety and efficiency. Any and all potential solutions need to abide by these rules and values in order to be...
considered by the FAA and implemented by the Port Authority. Through research of the current situation, with a specific focus on runway incursions, the following three criteria for a solution were created:

**Acceptance Criteria**

1. Reduce number of incursions on the runways and taxiways by 30% in the first 3 years.
2. Reduce time between potential runway incursion identification and notification to operator.
3. Minimize implementation and maintenance costs of the system by 50%

The identified acceptance criteria narrowed the scope of this project to a location based feedback device. The potential for this solution would be to reduce the number of incursions by proactively notifying airfield operators when they are approaching a location they do not have clearance for.

Through brainstorming, research and evaluation, four possible solutions were proposed to the runway incursion scope. Each of these ideas was tested against a set of metrics designed to highlight important customer requirements and functionality expectations. The metrics and corresponding explanations are:

1. **Location Accuracy:** How accurate, in distance, is the actual location from the detected location?
2. **Clearance Personalization:** How easy is it to program a multitude of clearance locations?
3. **Time to transfer information:** How quickly is data transferred and information is output?
4. **Infrastructure additions:** Will there need to be additional infrastructure implementations in order for the system to function properly?
5. **Overall Implementation Cost:** Will there be high costs associated with implementation?
6. Maintenance cost: Will there be high maintenance costs associated with the upkeep of the system?

7. Handheld size: Will the handheld device be an appropriate size and weight to transport around the airfield?

Each proposed solution was rated in accordance with these metrics to identify strengths and weaknesses in the design. Once the ratings were compiled a clear design was chosen for further implementation.

4.1 Concept Development

The four identified solutions are Radio Frequency Identification, Global Position System, Scanner Technology and Transponders. Each of these solutions was chosen based on functionality. Through research into each solution brief descriptions are provided.

Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a wireless non-contact system that utilizes radio-frequency electromagnetic fields to transfer data from a tagged object. RFID is most beneficial for tracking and location identification purposes. Recently, Boeing has introduced RFID-Based Parts Tracking which has developed a maintenance system for aircraft parts [7]. Through this, the team decided that there are opportunities of using RFID chips not only for maintenance systems but also to help regulate activity on the airfield and decrease runway incursions. RFID chips would be added to every vehicle and worker badges. On a daily basis, the FAA control tower will grant authorization to vehicles and worker badges to meet necessary maintenance needs. If a worker or vehicle enters an unauthorized area, data will be transmitted from the RFID which will trigger an alert to go off, notifying the worker or vehicle that they have entered an unauthorized area, and
that they must immediately leave. This concept does not eliminate the use of ASDE-X, nor does it require its use.

**Global Positioning System (GPS)**

Global Positioning System is a navigational tool that reports location of devices with the use of satellites. Currently there are twenty-four deployed satellites that are monitored by the United States government, but anyone worldwide with a GPS receiver can harness these capabilities [11]. The receiver must make contact with at least four GPS satellites which send signals to the device. The device then compares the time it took to receive the signals and the distance between the device and satellite to calculate the receiver’s exact location. GPS’s are highly accurate and reliable as they can receive signals through materials such as plastic and glass. In addition, weather has no effect on this system [12]. The cost of GPS on the user is fairly inexpensive, as the technology is standard in devices such as automobiles, cell phones, watches and handheld GPSs. There are minimal maintenance costs or downtime required for GPS, only requiring occasional updates to the software.

**Scanner Technology (Scan Tech)**

A barcode scanner is an electronic device for reading printed barcodes. It consists of a light source, a lens and a light sensor translating optical impulses into electrical ones. Barcode scanners also contain decoder circuitry. This analyzes the barcode's image data provided by the sensor and sends the content to the scanner's output port [13]. If barcode scanners were affixed to the bottom of personnel vehicles and barcodes were painted on the ground at specific areas, workers could be notified when they have entered a restricted area. As soon as the scanner reads a restricted barcode an alarm can be sent to the worker in that vehicle. Scanners can be set to clearance levels to read specific barcodes that are restricted to certain individuals.
Transponders:

The transponders used are a key component of the ASDE-X system and are already required in every vehicle on the airfield at an airport where the ASDE-X is implemented. The current ASDE-X architecture consists of five components: Multilateration, Surface Movement Radar, Automatic Dependent Surveillance – Broadcast (ADS-B) transponder, Multi-Sensor Data Processing, and Tower Displays [8]. The Transponders are highly reliable, accurate and will prevent extended down time with minimal maintenance cost. Most aircraft have transponders but the expense for the rest of the system will be preventative for smaller airports with limited resource. These particular transponders are real time information processors designed to receive and transmit information; therefore, information about clearances will be easy to share with each transponder user.

4.2 Pugh Matrix

A Pugh matrix is a decision making tool used to rate characteristics of alternative solutions and to compare each of these solutions against the others. Positives or negatives are assigned to each characteristic, which are added together at the end to find a total net value. The concept with the highest net value is the concept that best fits the criteria of the ideal solution.

![Figure 5 Pugh Decision Matrix](image-url)
Chosen Solution, GPS

Analysis of the Pugh Matrix shows the Global Positioning System as the best fit for the required functionality. GPS scored the highest total net value of the alternative proposed solutions. Two categories GPS did not excel in were location accuracy and clearance personalization. GPS uses coordinates which can be harder to track, decrease accuracy and would provide a location range rather than binary yes/no. GPS scored positives for costs as it requires minimal new infrastructure to implement and handheld size because technology has been refined to handheld devices.

Originally designed for the Department of Defense the Global Positioning System is a high level tracking system that calculates position based on time signatures. Using a series of satellites, set into precise orbit, the GPS signal is derived from time coded pulses that can be read by a receiver. The receiver is programmed to triangulate its exact position by calculating the distance to each satellite through measuring the time codes.

The GPS system is comprised of three segments: the user interface or receiver unit, the satellite system and the series of maintenance relay stations.

Receiver:

Each receiver is different based on the manufacturer, functionality, user interface and user segment. According to GARMIN, within every device there is a basic signal receiver to read the 1575.42 MHz signal, a processor to triangulate the global position, and antennas to receive the electromagnetic signal. These receivers allow land, sea, or airborne operators to receive the GPS satellite broadcasts and compute their precise position, velocity and time.
Satellites:

At any given time based on the satellite replacement cycle between twenty four and twenty eight [16] satellites are orbiting the earth at a distance of 10,900 Nautical miles (≈12,500 miles) [15]. Each satellite weighs around 2,000 lbs, is 17ft wide, carries a 50 watt transmitter and has a life expectancy of around 10 years. The entire system orbits the earth twice daily, traveling at 7,000 miles per hour.

Relay Stations:

Five relay stations around the globe collect position and distance data from all satellites in sight of the station. The information collected is sent to the master control station in Colorado Springs where it is compiled into updates for each satellite. The updates are meant to maintain the system by keeping satellites in proper orbit, maintaining spacing between satellites and sending updated timing information to the transmitters [15].

4.3 Context Diagram

Figure 6: Context Diagram

The purple box of the high level context diagram in figured 6 depicts the proposed GPS concept, referred to as the Guardian system. The system consists of 2 parts: the handheld (as operated by the Airfield Operator) and the Safety Database. These two parts are in constant communication with each other in order to verify the operator’s location. The handheld requests
and receives its location from the GPS satellite. This location is then passed along to the safety
database which is maintained by the Port Authority and the FAA. In this database, a personalized
list of clearance locations would be recorded. These clearances are a range of
longitudinal/latitudinal coordinates that the operator is cleared to be in. The database cross-
references the handheld’s location with the list of available clearances. It then provides feedback
to the handheld regarding whether it is located in a space it has clearance for, or not.

5.0 Technical Aspects Addressed

The Guairdian system is designed to provide feedback to operators on the airfield. This
feedback is achieved through two alert functionalities. The first is a map overlay to show the
runways and taxiways the operator is cleared to drive on. The second alert function is an audible
alarm that will inform the operator that they are about to cross into an unauthorized zone. These
zones will be set by the airfield operations manager depending on the operator’s project and
training on the airfield.

The system will consist of 2 components: the first is the handheld device. This device will
be on the airfield with the operator. It will have a GPS locator to identify the location of the
operator at all times. This location information will be sent to the other component of the system
is the software database. This database interfaces with the airfield operations manager and
provides the functionality of setting clearances. To further identify the functionality of these
components many aspects had to be addressed.

5.1 System Functionality

The Guairdian System consists of the handheld device and the software. The handheld
device and software shall perform individual functionalities and interact with one another in order
to make the Guairdian System successful. The concept of the system’s functionality is defined and explained thoroughly below.

<table>
<thead>
<tr>
<th>Guairdian System Functionality</th>
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<tbody>
<tr>
<td><strong>Handheld</strong></td>
</tr>
<tr>
<td>Display Visual Location</td>
</tr>
<tr>
<td>Alert Worker</td>
</tr>
<tr>
<td>Interact with GPS</td>
</tr>
<tr>
<td>Interact with Software Database</td>
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</tbody>
</table>

**Handheld:**

The operator on the airfield will use the handheld device. The device shall be easy to carry around, and the display screen easy to view. The handheld’s overall purpose is to increase situational awareness for the airfield worker by allowing them to view their current location in regards to restricted areas. In order for the handheld to be successful it must perform the four defined functionalities.

**Display Visual Location**

This function of the handheld is important because the user on the airfield shall be able to see their current location in regards to clearance and restricted zones. The display will be similar to current automobile GPS systems and can be found reproduced in figure 7. The user will be displayed as an arrow, facing the direction they are moving towards. The arrow shall be overlaid
on a schematic map of the airfield. The map of the airfield will also contain transparent color coordinated areas. These color-coordinated areas will either be green, representing a safe or clearance area for the user, or red for an area that the user is not granted clearance for.

**Alert Worker**

This function will send an audible alert to the user. The audible alert system will be triggered through the handheld device and will be similar to how current automobile GPS systems alert the user of direction instructions. For example, if the user on the airfield approaches a restricted area within a defined distance, the handheld unit will send an audible alert warning the user that they are approaching a restricted area.

**Interact with GPS**

The system will continuously track its location based on the information it receives from the GPS satellites. Based on the GPS location the handheld receives it will be able to display visual location for the operator as well as decide whether an alert is necessary.

**Interact with software database**

This function will allow the handheld device to interface with the software database. The handheld device should accept inputs from the software database controlled by the Port Authority and/or FAA in order to successfully display clearance and restricted areas on the handheld device. This function will enable the handheld device to know whether an alert is necessary.

**Software:**

The administrators of the FAA and Port Authority will use the software to create clearances and restricted areas as well as monitor all vehicles on the airfield. The software will also include a database system to save all changes made. Previously used clearances and
restrictions may be reused if no changes are needed. In order for the software to be successful, it must be able to perform the four defined functionalities.

**Store Clearance Data**

This function will store the data created by the Port Authority and/or FAA. This shall allow the ease of daily use of the system. For example, a baggage handler would have daily clearance on the no movement zone as well as daily restrictions on runways and taxiways.

**Display Visual Airfield Movements**

This function will allow the Port Authority and FAA to view all the movement on the airfield. The display shall be similar to current GPS tracking on an iPhone map. It will contain several dots that represent activity on the airfield. A green dot will be displayed when an airfield worker is in a clearance zone. A yellow dot will be displayed when an airfield worker is approaching a restricted area. A red dot will be displayed if there is no GPS track on that specific handheld device.

**Accept Inputs from Port Authority and/or FAA**

This function of the software database shall allow the Port Authority and/or FAA to create restriction areas. Creating restriction areas will be similar to creating a geofence on the Garmin GTU10 device (explained further in section 5.4). The user from the Port Authority and/or FAA will set and edit boundaries on their computer through geofences. For example, runway 4L and 4R are currently closed down for maintenance. In order to grant clearance, the Port Authority manager would remove the geofence around 4L and 4R to those assigned to the runway maintenance.
Interact with Handheld Device

This function shall allow the software database to interface with the handheld device. The software database will send all the inputs from the Port Authority and/or FAA to the designated handheld device. This shall allow the handheld device to accept and display restricted and clearance areas.

5.2 Software Database and Handheld Interaction:

The handheld will be interacting with the database to cross reference its location with the set of granted clearances. This interaction is extremely time sensitive because the operator will need to be notified with enough time to safely react and change the course of their vehicle. To determine the interaction time necessary the heat chart was calculated in figure 8. The chart produces the distance a vehicle would travel (in feet) depending on its speed and the time of notification. The green boxes represent a distance that is less than 262 feet, the average width of commercial runways. The yellow box represents a distance less than 899 feet, the width of the widest runway at the Edwards Air Force Base in California. The color chart demonstrated that alert response times need to be nearly instantaneous (less than five seconds) to properly alert the operator before they drive across the runway.
To achieve the necessary response time the Guardian handheld functionality needed to be tested to determine if the database of clearances should be stored on the device or in a separate location. An onboard database would allow for quicker response time because the device would not have to communicate with an outside source before providing feedback. However, this software on the handheld would increase the complexity and raise the individual price. An external database has the potential to increase response time, but would also allow the handheld to simply be a transmitter and therefore require less costly onboard technology.

An onboard database system has similar functionality to a Garmin nüvi 1450LMT device. This device provides proactive instructions to alert the driver of a turn coming up. These alerts fall into the time response restriction of less than 5 seconds to notify the airfield operator with enough time to react. External Database testing was conducted to validate assumptions of a longer response time. The Garmin GTU 10 is a location tracking device that syncs with an online database of “geo fences” to help to create clearance zones. The device is constantly sending its location to the database which cross references it with the set clearances. If the device is in a

![Figure 8: Speed VS Response time model](image)

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restricted zone the database then notifies the device which blinks 4 times to identify the operator. When tested, the GTU 10 took 45 seconds to alert the operator that they had passed into a restricted zone (Test results in appendix K). According to figure 8, the operator would be well across the runway by the time this notification arrived. The testing concluded that only an onboard database supports the necessary functionality of the Guairdian handheld device. The notifications are much quicker which allows for a more accurate warning system and increased safety on the airfield.

The safety database will be created on the airfield operations manager’s computer and loaded on to each of the handheld devices. Once on the airfield, the handheld will receive its location via the GPS satellites and internally crossreference it against the database. If it is in a restricted zone the handheld will be able to alert the operator immediately.

5.3 Internal System Interactions

The following sequence diagrams show the internal system interactions to allow the user or system to complete a certain task. It shows a better understanding of the concept of the Guairdian System. The tasks shown in the following figures include the FAA and Port Authority creating clearances and restricted areas on the software, monitoring the entire airfield movement, the airfield worker being able to view their current location, and the handheld sending a notification to the airfield worker when they are approaching a restricted area.
For creating clearances and restricted areas, the FAA or Port Authority administrator would select to pull up the airfield map on the software. The Guairdian System software will then retrieve the most up to date map from the satellite. The administrator would then select the unique user’s handheld device they wish to change. The software will retrieve any stored information from its database and display it to the administrator. Restricted areas can then be created or edited. The software will then save the information into the database and send the information to the specific handheld device.
The FAA and Port Authority will have the opportunity to monitor the entire airfield movement through a map that shows all active handheld devices and their location on the airfield. The administrator would request the Active Airfield Option from the software, which will then request the Satellite for all handheld positions. The location will then be given to the GPS and to the software, enabling the display on the Active Airfield Map.

The airfield worker shall also have the capability of viewing their current location at all times. When the airfield worker turns on the display, the handheld will request its location from the satellites while simultaneously loading the boundary information from the software database. The information received by the handheld will be displayed on an overlaid colored map.
The handheld must send notifications to an airfield worker when they come to a defined close distance to a restricted area. The handheld will request the location from Satellites while simultaneously communicating with the software to cross-reference its location and restriction areas. If a worker comes close to a restricted area an audible notification will trigger from the handheld. This will warn the airfield worker to take caution in order to avoid causing an incursion.
5.4 External Interface Interactions

The Use Case Diagram shows the interactions of the Guairdian System. The Guairdian system consists of two components: the software and the handheld device. The FAA, Port Authority, Satellite and the Database interact with the software. The Airfield Operators and Satellite interact with the handheld device. The FAA and Port Authority interact with the system by creating clearances and restricted areas as well as monitoring the entire airfield movement. Satellites interact with the system in order to ensure that airfield maps are up to date. The software has a built in database, which stores modifications of both clearances and airfield
infrastructure. The software and the handheld device interact with each other allowing information to be transferred.

5.5 System Architecture

The GPS system is comprised of two sets of internal components; the software database and the network of handheld devices. For each of the handheld devices a Port Authority Controller will be able to assign clearance locations based on the expected duties of the airfield operator. The Port Authority Controller would select the set of taxiways the operator would need for their day’s work. The database will contain the latitude and longitude coordinates of each Runway/Taxiway boundary. With this information the selected clearance locations, and associated coordinates, will be compiled into a list associated with the certain handheld device.

The runway/taxiway clearance decisions would be compiled in an overlay for the map of the GPS. This overlay would read the selected clear locations and shade them in green, the remaining locations would be deemed unclear by the database and as such would be shaded in

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Figure 14: Functional Architecture

The GPS system is comprised of two sets of internal components; the software database and the network of handheld devices. For each of the handheld devices a Port Authority Controller will be able to assign clearance locations based on the expected duties of the airfield operator. The Port Authority Controller would select the set of taxiways the operator would need for their day’s work. The database will contain the latitude and longitude coordinates of each Runway/Taxiway boundary. With this information the selected clearance locations, and associated coordinates, will be compiled into a list associated with the certain handheld device.

The runway/taxiway clearance decisions would be compiled in an overlay for the map of the GPS. This overlay would read the selected clear locations and shade them in green, the remaining locations would be deemed unclear by the database and as such would be shaded in
red. This overlay map would be sent to the GPS to implement on the screen. The map would lay over the current map of the airfield and thus show the operator their expected boundaries for the day.

When the operator is in the airfield, their device will be communicating with both the database and the GPS locater. The device will send a location request for the GPS system. In response to this the GPS will triangulate the location of the device and send an accurate location back. The device will cross reference the handheld’s location with the set of allowable clearances assigned earlier that day. If the location is within the cleared range, the database would send an “OK” message to the handheld therefore confirming to the operator that they are in a safe place. If the given location is not found on the clearance list, the database would produce a “Not OK” response. This would trigger the handheld device to alert the operator that they had strayed from their given path and must return to a cleared area promptly.

5.6 Concept Assessment

Functionality of the Guairdian system was tested using two GPS devices: a Garmin nüvi 1450LMT and the Garmin GTU10. As stated earlier, the Garmin nüvi 1450 LMT outlines the functionality of the Guairdian handheld. The four main functionalities (display visual locations, alert worker, interact with GPS and interact with Software Database) were proven via this device. The Garmin nüvi 1450 LMT is a common automobile GPS system with functions such as turn-by-turn directions. The turn-by-turn directions feature notifies the driver of the next step they need to take in their direction. This shall be similar to the Guairdian system when the user is notified that they are approaching a restricted area. With the Garmin nüvi 1450 LMT, the user can also see their location on a map and the direction they are moving towards. This is the same feature that the Guairdian System will provide to the user when they are on the airfield.
The GTU10 has the ability to create clearance zones and provide feedback when the zones are breached. Therefore, this device is used to prove the functionalities of the Guairdian’s clearance zone features. With the GTU10, a user is able to set up a maximum of 10 geofences per device. This is similar to the Guairdian’s functionality, besides the limit on the number of geofences created. Geofences will represent restricted areas on the airfield. These geofences can be made into any shape, providing they have at least 3 sides. When a GTU10 device enters or exits a geofence a notification is sent to the user. This notification capability, combined with the turn-by-turn approach functionality of the Garmin Nuvi 1450LMT will allow the Guairdian device to warn the operator when they are approaching a restricted area. Testing the functionalities of the system proves that the technology does exist in separate forms, such as the Garmin nüvi 1450LMT and the Garmin GTU10.

6.0 Safety Risk Assessment

From the Safety Risk Management and National Airspace System diagram (see Appendix G.3), the Guairdian system will include new safety procedures. In order to ensure its success, the FAA and Port Authority must be able to demonstrate how to use the device to the airfield workers as well as create emergency protocols. The diagram was also used to perform risk assessment and mitigation. The Risk Table in Appendix G.4 shows a comparison and ranking of each identified risk to the system. It addresses issues such as security, device mishandling, theft, and communication problems. These risks and associated effects are explained and analyzed in further detail. There is also an analysis of the likelihood of each situation happening and the severity of the impact if it does happen. It is also explained how each situation will be mitigated. The cost for each mitigation strategy is then proposed.
After performing this analysis, the risks were ranked depending on the highest expected value being the one that poses the most threat. The two risks with the highest expected value are Security Breach and Communication Disruption. Both risks have a high impact on affecting safety on the airfield, and it is necessary to focus on how to mitigate these risks. Communication Disruption is the risk most pertinent since the likelihood of it taking place depends on Satellite performance. If a disruption occurs, it is possible that devices would not perform properly and cause confusion on the airfield. In order to mitigate this risk, the FAA and Port Authority must be able to implement emergency protocols when this situation arises. These protocols include, but are not limited to, immediate clearing of the airfield, stop all traffic or manual navigation. All airfield workers operating with the handheld device must be trained to perform proper emergency protocols.

Security Breach poses a large threat due to its impact on safety. If an unauthorized user accesses and grants clearances through the software it can cause incursions due to unauthorized actions on the airfield. Creating and requiring a unique administrator password for changing clearances and restrictions can easily mitigate the risk. There shall also be a log system that records all the actions made in the system along with the user who made them.

The next risk is Misuse of Device, which poses the highest probability. In order to eliminate the hassle of replacing devices, airfield workers must be properly trained from the start on how to handle the device. With the proper training along with emergency protocols, this risk can easily be mitigated and ensure that if it does arise, it does not pose safety problems to the airfield worker. The last risk is Device Theft, which has the lowest expected value since it is the least likely to happen and the impact is low. In order to mitigate this risk, every device will be assigned to a unique user and documented into the system. This allows administrators to monitor
device movement and ensure that it is within the airfield. The defenses-in-depth design philosophy shows the gaps defined by the risks that can lead to an incursion.

7.0 Project Analysis & Impacts

Guairdian System would be beneficial when examining the potential impact on the airfield and the safety of its operators. To further support the sustainability of the system it is important to look at economic viability and examine the potential costs for the system implementation.

7.1 Airport Impact

Direct impact on airfield operations will vary based on classification of the specific airport. At a Class I commercial hub airport with an ASDE-X system such as EWR, BOS, and 28 other Class I airports the Guairdian system would supplement the equipment already in use to provide an additional layer of protection for the safety areas. For the rest of the 389 Class I airports the Guairdian system will show the location of every vehicle on the airfield to serve as an alternative to installing an ADS-B system. In the case of EWR, the system would be installed on all Port Authority vehicles, airline service vehicles, and all airfield operational vehicles. Tracking each of the hundreds of vehicles that operate daily on the airfield will allow operators to mitigate their own airfield navigation while still being overseen by the operations managers (both on the ground and in the tower). At smaller airfields, especially those locations loosing Air Traffic control towers, the Guairdian System has a larger job of being the first line of defense for preventing vehicles from deviating into safety areas where they may be at risk of causing collisions. Preventing vehicle operators from veering onto occupied pavement or restricted areas on the airfield the system will prevent unnecessary delays caused by safety checks of runways and
aircraft after an issue is detected. In line with the FAA safety regulations the Guairdian System seeks to prevent operator deviation and runway incursions.

According to conversations with air traffic controllers when an incursion occurs the minimum down time is at least five minutes. The purposed Guairdian System provides an active feedback system that helps prevent these incursions and the resulting down time. By providing an active monitoring system, the goal of the Guairdian System aligns with the FAA’s directive to safely regulate all civil aviation.

7.2 Economic impact

To prove the Guairdian System is economically viable valued projections were entered into a Spreadsheet Engineering Economics Model (SEEM). The SEEM excel sheet (screen shots can be found in Appendix G.4) was created by Hans Lang and Donald Marino who were professors of cost estimation, accounting and engineering economy classes at Stevens Institute of Technology. The outcome of creating the Guairdian System is not to generate a profit, but to analyze information and determine if the project is economically feasible compared to current options.

The calculated cost for each Guairdian System handheld is estimated to be $250. Analysis behind this cost can be found in appendix G.4. For presentation purposes, the team assumed airports will contract out the research and development (programming) of the system, but will purchase the handhelds and software from said contractor.

The project life of the Guairdian System is predicted to take seven years to reach the five-hundred United States commercial airports. In the first year it will be implemented in ten airports. From then on it will be implemented in forty and fifty airports in the second and third
year, and then one-hundred airports per year until all five-hundred airports have it in use. On average each airport will purchase 2,000 units that will be given to workers to carry or place in vehicles. Selling each handheld unit at $250 will generate an annual revenue of $5,000,000 in the first year (Appendix G.4, revenue tab). The selling price is predicted to decrease over the years however, the number of units increases so total revenue increases as well. The Guairdian software and databases will be included in the purchase of the handheld units, so there is no extra revenue collected from software installation.

The Guairdian System will break even, and earn back expenses after the third year on the market (Appendix G.4, Breakeven tab). The system will continue generating a profit, and at the end of seven years the net income after taxes is estimated at $4,649,057 (Appendix G.4, income tab). Not only is the Guairdian System proven economically to be profitable and viable, but the cost for airports is significantly cheaper than the current competing ADS-B system. The hardware of the ADS-B is $5,800 per unit, according to George Martinez from the Port Authority at EWR, totaling $11,600,000 for two-thousand vehicles, while the Guairdian System would only total $500,000 for the same number of units. The implementation of the Guairdian System is economically logical and feasible for commercial airports.

8.0 Implementation process

As with any airfield-wide system the Guairdian system will involve a complicated implementation process involving development, equipment, and training for users of the system. During the initial implementation process it is important to look at the long term sustainability of the system.

8.1 Deployment

To prepare for deployment of the Guairdian system each airfield will need to examine its
current infrastructure for feasibility. The location of runways, physical infrastructure and restricted areas need to be integrated into one map. This all-inclusive map will be loaded on to the devices and into the software database. Deployment of the system involves setting up the communication network between each of the handhelds and with a centrally located database. If the system reliability is suffering due to the location of the airfield, a local global position transmitter may be erected to transmit an additional time stamp. This addition would increase the accuracy of triangulating the movement of vehicles on the field.

The existing Global Positioning System infrastructure, external to the airports, will make the Guairdian system possible. Most of the physical infrastructure for the Guairdian system is already in place due to existing the GPS system and will therefore not be the responsibility of the airfield to maintain. Only the local system would need to be purchased and implemented at each airfield minimizing the infrastructure cost and maintenance issues.

Employees that will be on the airfield will have to be trained on how the Guairdian System operates. Demonstrating capabilities and displaying reliability of the system can be done in a workshop setting that would take minimal time and man hours away from airfield operations. In addition to the implementation workshop, training manuals as well as troubleshooting guides can explain functionality and system components to personnel.

8.2 Support and Maintainability

Ongoing support of the Guairdian system is meant to simplify the implementation process and make maintenance easier in order to benefit the Airport Owners and the system users. In the deployment of the Guairdian system, the easiest way to gather the needed equipment would be to create a partnership with an existing GPS company such as Garmin. Such a company would be able to guide the use of equipment to meet system requirements and assist in the facilitation of
initial database programming. Following the initial system deployment, the system will need to be
maintained and be able to receive updates remotely. The users however, will only need to ensure
that there is power to the system and that the signal is not able to be manipulated by outside users.

9.0 Conclusion

Implementation of the Guairdian System at airports will increase operator awareness.
Moving around the airfield and crossing paths with commercial aircraft leads to potential
collisions which can result in fatalities. Over the course of the 2012 fiscal year 1150 runway
incursions occurred in the United States, 199 of those were vehicle and pedestrian deviation onto
restricted surfaces. Each incident halts airport operations until a team can investigate causes and
determine safety for future flights. This Guairdian System is an affordable way for airports to
increase situational awareness on the airfield without highly disrupting current operations.

Following the mission statement of the FAA, this system aims to make the airfield safer
for workers, pilots and passengers alike. The more information accessible to operators means the
more aware they are of their surroundings. It only takes one wrong turn to cause an incursion and
put many lives at risk. The Guairdian System is designed to not only eliminate that risk, but
proactively prevent situations where dangerous incursions may occur.
Appendix A - Contact Information.

**Students:**

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Professor – School of Systems & Enterprises  
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**FAA Contacts:**

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(973) 565-5045  
erik.carney@faa.gov

**Robert Lehmann**  
Support Manager, Newark Tower  
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robert.lehmann@faa.gov

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**George Martinez**  
Deputy Chief of Operations  
Port Authority NY & NJ  
Newark Liberty Int'l Airport  
973-961-6020  
ggmartin@panynj.gov
Appendix B - Description of Stevens Institute of Technology.

Stevens Institute of Technology was founded in 1870 due to a generous grant for Edwin A. Stevens. Located on Castle Point in Hoboken, NJ this Institute has grown from the legacy of the Stevens Family; a group of self trained engineers heavily involved with innovations from the railroads to steam engines. From its inception, Stevens has remained at the forefront of engineering and technology whether it be the first meeting of the American Society of Mechanical Engineers to currently being home to three National Research Centers of Excellence.

With 32 Undergraduate Majors offered, Stevens Institute of Technology provides a wide range of Engineering and Science options to their students. These 32 majors span across 3 schools (The How School of Technology Management, The Schaefer School of Engineering and the School of Systems and Enterprises) and 1 college (The college of Arts and Letters). All four entities find home amidst the academic buildings on the southern end of campus. Stevens prides itself in the coordination between these schools being that students are encouraged to earn minors outside their major’s school of study.

Stevens Institute is currently home to 2,040 undergraduates as well as 3,220 graduates. These students participate in over 70 on campus organizations from professional societies to ethnic organizations and even Greek life. There are 26 Division III varsity sports that compete in Empire 8 competitions along the east coast. Student Life on Stevens Campus is an ever evolving and constantly growing aspect of the school’s appeal.

The Stevens Institute of Technology team members have each enjoyed their 4 years in the Engineering Management program at Stevens. This Design Competition is a positive capstone with which they can proudly showcase their prestigious Stevens education.
Appendix C – Non university Partners.

Federal Aviation Administration

The Federal Aviation Administration (FAA) an agency of the United States Department of Transportation under the jurisdiction of the United States Government. The FAA is headquartered in Washington, DC with regional offices located throughout the United States. According to the FAA mission statement and vision the main purpose of this agency is “…to provide the safest, most efficient aerospace system in the world,” and “…strive to reach the next level of safety, efficiency, environmental responsibility and global leadership. We are accountable to the American public and our stakeholders” (Federal Aviation Administration). The FAA sets the regulations and standards for the United States airspace. At Newark Liberty International Airport (EWR) the contact with the FAA is Erik Carney, the Traffic Management Coordinator in the air traffic control tower. Each morning Erik Carney consults with New York TRACON, The New York Air Route Traffic Control Center and United Airlines (the main airline of EWR). During these telecoms, each participant aids in discussion relating to optimizing the daily Airport Arrival Rate (AAR) in response to weather and traffic both on and off the ground.

Port Authority of New York and New Jersey

The Port Authority conceives, builds, operates and maintains transportation infrastructure such as tunnels, bridges, and airports in the New York and New Jersey area. The mission of the Port Authority is “To keep the region moving” (Port Authority) Newark International Airport is one of the five airports under Port Authority’s jurisdiction. George L. Martinez, Deputy Chief Operations Supervisor and Aeronautical Operations, is the contact to the PANYNJ at EWR.
George Martinez is in charge of supervising and approving training of all workers that conduct daily operations on the “no movement zone” such as Airport Rescue and Firefighting (ARFF), construction, snow removal and maintenance crews.
Appendix D - Faculty Sign Off

FAA Design Competition for Universities
Design Submission Form (Appendix D)

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

University: Stevens Institute of Technology

List other partnering universities if appropriate

Design Developed by: □ Individual Student □ Student Team

If Individual Student

Name ____________________________

Permanent Mailing Address ____________________________

Permanent Phone Number _______ Email __________________

If Student Team:

Student Team Lead: Adam Wing

Permanent Mailing Address: 11 Laurel Ave
Waltham MA 02453

Permanent Phone Number (781)-330-3448 Email awwingman@gmail.com

Competition Design Challenge Addressed:

Runway Safety/Runway Incursions/Runway Excursions Challenges

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 4/15/13

Name: Finiu HOLE

University/College: Stevens Inst. of Tech

Department(s): School of Systems & Enterprises

Street Address: Castle Point on Hudson

City: Hudson State: NJ Zip Code 07030

Telephone: 201-216-9388 Fax: 201-216-9641
Appendix E - Educational Experience Evaluation.

1. **Student Responses:**

Did the FAA Design Competition provide a meaningful learning experience for you? Why or why not?

There were two important lessons the team experienced throughout the process of the Competition, how to interact professionally with those in the workforce and the trial and tribulations that occur with being involved in a real life project. For some of the team members it was the first time that they were not just interacting and collaborating with other students or academic faculty but governmental workers. In classes projects are idealistic and theoretical, so essentially there are no major issues that arise with the scope or requirements of stakeholders. This project gave the team a lot of experience in how to handle and react to changes that occur mid project that can veer the original expectations and outcomes.

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

The biggest challenge the team faced undertaking the Competition was being able to find a well-defined problem to solve early on in the year. The team started out in the Competition under the Airport Management and Planning category, but it was not until meeting with FAA and PANYNJ representatives and receiving more insight that Runway Safety/Runway Incursion/Runway Excursion was ultimately chosen. After the group decided to focus on runway incursions it took an extended amount of time to narrow down the specific scope and solution. Without previous in-depth knowledge of the industry it was difficult to know exactly what specific problems were being faced by the FAA that were feasible to create a solution to.

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

Developing a scope and hypothesis for the project was the most difficult requirement for the team to achieve. The team first decided on a category that seemed interesting and fit within the skill sets that were available, and tried to identify a problem that fit within the
category. This process did not work well and set the teams progress back a significant amount of time because the team was limiting themselves to project ideas. The second approach that the team took was to meet with the FAA and PANYNJ representatives to find out problems they believed existed and were serious issues. From there, the team was able to identify a problem and later found it fit perfectly in the runway incursion category.

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

   The opportunity to interact with professionals working for the Federal Aviation Administration and Port Authority of New York & New Jersey provided a lot of useful insight into the industry. There were multiple moments that without being able to reach out to FAA or PANYNJ the project would come to a standstill, but because employees were always willing to assist in answering questions the project was able to proceed more efficiently. Only a certain amount of knowledge can be gained through research, and experiencing the day to day operations of the airfield and control tower first hand created a greater impact on the reality of the project.

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?**

   There were many experiences during the project that provided the team with skills and knowledge that will be valuable after graduation and entering the workforce. The team had to figure out how to successfully work with different types of personalities on the team itself, as well as outside sources such as students during bi-weekly reviews and professional consultants. At one point in everyone’s career they will be working on a team and must know how to handle and communicate amongst each other properly and efficiently. There is going to be a multitude of people providing opinions and beliefs and it is imperative to know how to evaluate the advice and criticism and apply what would truly be beneficial to apply to a project.
Advisor Responses:

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

The opportunity to work on a real-world challenge is very valuable. It requires the students to:

- really engage with the problem from the perspective of the FAA and other relevant stakeholders and potential vendors
- be exposed to real-world constraints – not only technical and economical, but also finding and accessing the right people, data and so on
- the realization that they are working on something that is of actual interest to several stakeholders

The competition aspect also adds beneficial experiences in the form of having to comply with the “customer’s” rules, guidelines and deadlines for a “proposal” as well as the potential for both significant monetary awards and prestige in case of a “successful bid”

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

Absolutely – the work fits well into the scope and context of a capstone Senior Design project in Engineering Management

3. What challenges did the students face and overcome?

Their main challenge was probably to find the right need/problem to solve that was of relevance, had a scope that was feasible, and matched their skill-set and interest.

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

Yes, for all the reasons given under 1.

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

No
Appendix F - Reference list 6


<table>
<thead>
<tr>
<th>Risk Mitigation Log</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium</strong></td>
</tr>
<tr>
<td><strong>Description</strong></td>
</tr>
<tr>
<td><strong>Score</strong></td>
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<tr>
<td><strong>Impact</strong></td>
</tr>
<tr>
<td><strong>Consequence</strong></td>
</tr>
<tr>
<td><strong>Likelihood</strong></td>
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<td><strong>Logical/Physical</strong></td>
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<tr>
<td><strong>Security</strong></td>
</tr>
<tr>
<td><strong>Mitigation Strategy</strong></td>
</tr>
<tr>
<td><strong>Event</strong></td>
</tr>
</tbody>
</table>
G.3 Risk Management Assessment Diagrams
G.4 Economic Impact Seed Model

For the analysis of economic viability, manufacturing and labor costs must be taken into account when producing a physical product. A single handheld Guairdian unit will take thirty minutes to produce, while four hundred and eighty hours of labor will be put into the development of the software. According to Salary.com (http://www1.salary.com/Professor-Computer-Science-Salary.html) on average a computer science engineer makes $85,000 per year ($49.50 per hour). The current minimum wage in New Jersey is $7.25, so this was put into the model on the expenses tab as the wage per hour of the workers needed to manufacture the handhelds. The model takes into account predicted wage increases over time so by the end of the seven year project the labor per hour is $8.66. Direct materials costs of the components of the handheld are also factored into annual variable costs and expenses. The parts list of an open GPS tracker was found at http://www.opengpstracker.org/build.html. The cost to produce one is $121.59. Taking into consideration these would be built in bulk the cost estimation is around $100.
Introduction tab:

Welcome to the Spreadsheet Engineering Economics Model (SEEM)

This spreadsheet package is designed to aid engineering students in the understanding of engineering economics and act as a powerful resource to aid in the selection process for capital projects.

This package will be presented in conjunction with E 355 lecture and lab at Stevens Institute of Technology. The material closely reflects the content of the text for the above mentioned curriculum, The Selection Process for Capital Projects, by Hans Lang and Donald Merino.

The major outputs of this package include an after-tax analysis of various cash flows to provide figures of merit such as Net Present Value (NPV), and Internal Rate of Return (IRR). The after-tax analysis is used to formulate pro-forma income statements and balance sheets for the first ten years of operations. Further benefit to the user is provided by a breakeven analysis and sensitivity analysis which reflects the affect on the figures of merit (FOMs) by percentage changes in baseline inputs.

The key objective in this package is to help the students understand the interconnectedness of the various economic exercises towards a comprehensive economic picture of a potential capital project to support a "go" or "no-go" decision at the managerial level.

The package begins with the user providing initial inputs that will aid in the baseline analysis. Color coded cells are used to aid in the ease of use of this package and to help the students follow the progression of the inputs and calculations toward the final analysis results. A legend is included below as a guide to to the cell coding.

Legend:
- User defined inputs.
- Information taken from initial user inputs
- Bottom line results, typically totals, etc.
- Information taken from previously calculated results
- Accumulated depreciation of multiple assets
- Reference Table information for MACRS rates
- Cells that should contain no value
## Revenue Tab:

![Revenue Tab Image]
# Breakeven Tab:

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Fixed Cost</th>
<th>Variable Cost per Unit</th>
<th>Sales per Unit</th>
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</thead>
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<tr>
<td>Direct Labor</td>
<td>$100</td>
<td>$30</td>
<td>100</td>
</tr>
<tr>
<td>Indirect Labor</td>
<td>$50</td>
<td>$20</td>
<td>100</td>
</tr>
<tr>
<td>Production Overhead</td>
<td>$150</td>
<td>$15</td>
<td>100</td>
</tr>
<tr>
<td>Sales Expense</td>
<td>$200</td>
<td>$30</td>
<td>100</td>
</tr>
<tr>
<td>Total Costs</td>
<td>$580</td>
<td>$90</td>
<td>100</td>
</tr>
</tbody>
</table>

**Breakeven Point:**

- Sales Volume: 100 units
- Sales Revenue: $3,000

**Operating Breakeven Analysis:**

- Contribution Margin: 30%
- Break-even Point: $1,000

**Graphical Representation:**

- Graph showing break-even point at $1,000 sales revenue.
Appendix H : Stakeholder Meetings

H.1: FAA meeting 10/22/2012
Air Traffic Control: Erik Carnie, Traffic Management
1400 operations/day (~1600 operations pre 9/11)
Tower is very visual, use radar but also visually spot planes as they come in
Delays are caused by:
  - AAR (Airport Arrival Rate), Sector Congestion, GDP, Weather, TFR
AAR: ~40 for EWR with 2 runways open
Daily Telecons with Traecon(sp?) and local airports (JFK, Laguardia) to determine landing conditions for the day
  - Airports will sit in on these to learn information and plan ahead
Information sent to the passengers:
  - Airlines will chose which flights to delay/cancel once they receive the schedule from the day from the ATC. They will prioritize important/business flights
  - Once the airport pushes back from the gate the airline can log the flight as “on time” even if it sits on the taxiway for awhile
  - Slot times to land flights are fought for between airline companies
Flyzone is set up like an upside down birthday cake (up until 1300 ft, air space is not heavily monitored)
  - 0-900ft : helicopters
  - 900-1100 : small plane
  - 1300 -2000 : Newark Controls
Wake Turbulence:
  - As a plane flies the current behind them can be modeled like horizontal tornadoes
  - If a separate plane gets caught in this it may/will lose control
  - 2nd plane should fly above 1st to avoid
    o This allows for VAP (Visual Approach) which means planes can fly closer together during approach and increase capacity
Process of ATC:
1) Flight Data Clearance
   - Flight plans/routes, System capacity, -Fixed balances
2) Ground Control
   - ASDX Radar, Taxiways
3) Tower/ Local
   - Arrival Departure
   - Runways
H.2 Port Authority Meeting 11/30/2012

Port Authority: George Martinez
Runways:
4R 22L: outbound and most landed space
~420,000 movements/year, at max capacity

New Runway Location:
1) Replace A-B plant
   - Problematic bc A-B plant is surrounded by cemeteries
2) Replace Turnpike
   - Troublesome bc planes would have to cross 2 runways to get to terminal
   - Could build a new accommodating terminal, but extra cost

Rehabilitation of current runway cost $11 million

End around taxi ways
- Extend Runway to go around the end of the other runway
- Used in ATL
- Extended runway is sunk into ground
- ‘cliff’ at the end of the shorter runway

Airport is running out of space
- Need 1000 feet of safety zone at the end of runway
- EMAS: shortens the need for a safety zone
  - Like Meringue, will sink if a plane moves on top of it
  - Will stop the plane
  - 1000ft safety zone = 6000ft EMAS
  - Created in 2008

EWR:
Class = 1 (based on what is needed to land, inspected yearly by the FAA)
Aircraft group 5
ARF E
Approach D

THERE IS NO TARMAC!
- Tarmac is a type of material, EWR does not use it

3 miles within EWR is monitored by the port
- Cranes in construction need to be lit at night and flagged during the day
- The port has the right to tell any construction to take it down

Runway Closures:
- The Port will close runways
- Closure greater than an hour will greatly affect AAR

ADS-B: Automatic Dependant SurveillanceBroadcast
- Costs approximately $5,800 - $6,000 per device
- Addition to ASDE-X system
Appendix J : Researched Resources

J.1 Runway Safety – Runway Incursions

<table>
<thead>
<tr>
<th>Operational Errors</th>
<th>Pilot Deviations</th>
<th>Vehicle/Pedestrian Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action of an Air Traffic Controller that results in: Less than required minimum separation between 2 or more aircraft, or between an aircraft and obstacles, (vehicles, equipment, personnel on runways) or Clearing an aircraft to take off or land on a closed runway</td>
<td>Action of a pilot that violates any Federal Aviation Regulation Example: a pilot crosses a runway without a clearance while enroute to an airport gate</td>
<td>Pedestrians or vehicles entering any portion of the airport movement areas (runways/taxiways) without authorization from air traffic control</td>
</tr>
</tbody>
</table>

Runway Incursion Severity

<table>
<thead>
<tr>
<th>Available Reaction Time</th>
<th>Evasive of Corrective Action</th>
<th>Environmental Conditions</th>
<th>Speed of Aircraft and/or Vehicle</th>
<th>Proximity of Aircraft and/or Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Increasing Severity

<table>
<thead>
<tr>
<th>Category D</th>
<th>Category C</th>
<th>Category B</th>
<th>Category A</th>
<th>Accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident that meets the definition of runway incursion such as incorrect presence of a single vehicle/person/aircraft on the protected area of a surface designated for the landing and take-off of aircraft but with no immediate safety consequences.</td>
<td>An incident characterized by ample time and/or distance to avoid a collision.</td>
<td>An incident in which separation decreases and there is a significant potential for collision, which may result in a time critical corrective/evasive response to avoid a collision.</td>
<td>A serious incident in which a collision was narrowly avoided.</td>
<td>An incursion that resulted in a collision</td>
</tr>
</tbody>
</table>
J.2. Airfield Markings

Chart retrieved from:

<table>
<thead>
<tr>
<th>EXAMPLE</th>
<th>TYPE OF SIGN</th>
<th>PURPOSE</th>
<th>LOCATION/CONVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 - 22</td>
<td>Mandatory: Hold position for taxiway/runway intersection.</td>
<td>Denotes entrance to runway from a taxiway.</td>
<td>Located L side of taxiway within 10 feet of hold position markings.</td>
</tr>
<tr>
<td>22 - 4</td>
<td>Mandatory: Holding position for runway/runway intersection.</td>
<td>Denotes intersecting runway.</td>
<td>Located L side of runway prior to intersection. &amp; R side if runway more than 150 wide, used as taxiway, or has &quot;tandem &amp; hold short&quot; ops.</td>
</tr>
<tr>
<td>4 - APCH</td>
<td>Mandatory: Holding position for runway approach area.</td>
<td>Denotes area to be protected for aircraft approaching or departing runway.</td>
<td>Located on taxiways crossing thru runway approach areas where an aircraft would enter an RSA or apch departure airspace.</td>
</tr>
<tr>
<td>ILS</td>
<td>Mandatory: Holding position for ILS critical area.</td>
<td>Denotes area to be protected for an ILS signal or approach airspace.</td>
<td>Located on taxiways where the taxiways enter the NAVAID critical area or where aircraft on taxiway would violate ILS apch airspace (including POFZ).</td>
</tr>
<tr>
<td></td>
<td>Mandatory: No entry.</td>
<td>Denotes aircraft entry is prohibited.</td>
<td>Located on paved areas that aircraft should not enter.</td>
</tr>
<tr>
<td></td>
<td>Taxiway Location.</td>
<td>Identifies taxiway on which the aircraft is located.</td>
<td>Located along taxiway by itself, as part of an array of taxiway direction signs, or combined with a runway/taxiway hold sign.</td>
</tr>
<tr>
<td>22</td>
<td>Runway Location.</td>
<td>Identifies the runway on which the aircraft is located.</td>
<td>Normally located where the proximity of two ways to one another could cause confusion.</td>
</tr>
<tr>
<td></td>
<td>Runway Safety Area/OFZ and Runway Approach Area Boundary.</td>
<td>Identifies exit boundary for an RSA/OFZ or runway approach.</td>
<td>Located on taxiways on back side of certain runway taxiway holding position signs or runway approach area signs.</td>
</tr>
<tr>
<td>ILS Critical Area/POFZ Boundary.</td>
<td>Identifies ILS critical area exit boundary.</td>
<td>Located on taxiways on back side of ILS critical area signs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Direction: Taxiway.</td>
<td>Defines designation/direction of intersecting taxiway(s).</td>
<td>Located on L side, prior to intersection, with an array L to R in clockwise manner.</td>
</tr>
<tr>
<td>J</td>
<td>Runway Exit.</td>
<td>Defines designation/direction of exit taxiways from the way.</td>
<td>Located on same side of runway as exit, prior to exit.</td>
</tr>
<tr>
<td>L</td>
<td>Outbound Destination.</td>
<td>Defines directions to take-off runway(s).</td>
<td>Located on taxi routes to runway(s). Never coalesced or combined with other signs.</td>
</tr>
<tr>
<td>22</td>
<td>Inbound Destination.</td>
<td>Defines directions to airport destinations for arriving aircraft.</td>
<td>Located on taxi routes to airport destinations. Never coalesced or combined with other types of signs.</td>
</tr>
<tr>
<td></td>
<td>Information.</td>
<td>Provides procedural or other specialized information.</td>
<td>Located along taxi routes or aircraft parking/loading areas. May not be lighted.</td>
</tr>
<tr>
<td></td>
<td>Taxiway Ending Marker.</td>
<td>Indicate taxiway does not continue beyond intersection.</td>
<td>Installed at taxiway end or far side of intersection, if visual cues are inadequate.</td>
</tr>
</tbody>
</table>

**Additional Markings**

<table>
<thead>
<tr>
<th>EXAMPLE</th>
<th>TYPE OF MARKING</th>
<th>PURPOSE</th>
<th>LOCATION/CONVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Position.</td>
<td>Denotes entrance to runway from a taxiway.</td>
<td>Located across centerline within 10 feet of hold sign on taxiways and on certain runways.</td>
<td></td>
</tr>
<tr>
<td>ILS Critical Area/POFZ Boundary.</td>
<td>Denotes entrance to area to be protected for an ILS signal or approach airspace.</td>
<td>Located on taxiways where the taxiways enter the NAFAID critical area or where aircraft on taxiway would violate ILS apch airspace (including POFZ).</td>
<td></td>
</tr>
<tr>
<td>Taxiway/Taxiway Holding Position.</td>
<td>Denotes location on taxiway or apron where aircraft hold short of another taxiway.</td>
<td>Used at ATCPs airports where needed to hold traffic at a holding point. Installed provides wing clearance.</td>
<td></td>
</tr>
<tr>
<td>Non-Movement Area Boundary.</td>
<td>Delimitates movement area under control of ATC, from non-movement area.</td>
<td>Located on boundary between movement and non-movement area. Located to ensure wing clearance for non-movement area.</td>
<td></td>
</tr>
<tr>
<td>Taxiway Edge.</td>
<td>Denotes edge of usable, full strength taxiway.</td>
<td>Located along edge where contiguos shoulder or other paved surface NOT intended for use by aircraft.</td>
<td></td>
</tr>
<tr>
<td>Dashed Taxiway Edge.</td>
<td>Denotes taxiway edge where adjoining pavement is usable.</td>
<td>Located along edge where contiguos paved surface or apron is intended for use by aircraft.</td>
<td></td>
</tr>
<tr>
<td>Enhanced Taxiway Centerline.</td>
<td>Provides visual cue to help identify location of hold position.</td>
<td>Taxiway centerlines are extended 150 prior to a taxiway holding position marking.</td>
<td></td>
</tr>
<tr>
<td>Surface Painted Taxiway Direction.</td>
<td>Defines direction/direction of intersecting taxiway(s).</td>
<td>Located L side for turns to left. R side for turns to right. Installed prior to intersection.</td>
<td></td>
</tr>
<tr>
<td>Surface Painted Taxiway Location.</td>
<td>Identifies taxiway on which the aircraft is located.</td>
<td>Located R side. Can be installed on L side if combined with surface painted hold sign.</td>
<td></td>
</tr>
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J.3 Runway Incursion Statistics

Runway Incursions by quarter

Data Retrieved from:


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Note: 2013-Quarter 2 does not contain data for the month of March

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Note: Year 2013 only contains data for the month of January and February
Appendix K: Testing Results

Testing of the GTU 10 was conducted on Stevens Campus. Geofences were set up prior to the testing’s start. Next, the group drove around campus on a predicted route and recorded the time between crossing the boundary and notification receipt. These results were used in the determination of a necessary on-board database.

<table>
<thead>
<tr>
<th>Geofence</th>
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<th>Exit Time</th>
<th>Notification Time</th>
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<tbody>
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<td>-</td>
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<tr>
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<td>11:45:00</td>
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<td>-</td>
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<td>11:50</td>
<td>-</td>
</tr>
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<td>-</td>
</tr>
<tr>
<td></td>
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</tr>
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<td>11:53</td>
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</tr>
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<td>-</td>
</tr>
<tr>
<td></td>
<td>11:58</td>
<td></td>
<td>-</td>
</tr>
<tr>
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<td>-</td>
</tr>
<tr>
<td>Lib</td>
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Averaging the notification times results in a mean response time of 45 seconds.

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<tr>
<td>BC</td>
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<td>45 sec.</td>
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<tr>
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<td></td>
<td>12:32</td>
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</tr>
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<td>X</td>
<td>12:32</td>
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<td></td>
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<tr>
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