COVER PAGE

Title of Design: Runway Incursion Prevention Lighting System (“RIPLS”)

Design Challenge Addressed: Runway Safety/Runway Incursions

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Executive Summary

The Runway Incursion Prevention Lighting System (RIPLS) is a supplemental communication system primarily used by air traffic control (ATC) and pilots. It is designed with the intention of increasing situational awareness for all users of the system. Strengths of the RIPLS design include its redundancies, its strategic integration of technology and human/controller capabilities, and a user interface design that minimizes the potential for error and minimizes attentional demands on controllers. RIPLS is recommended for implementation at towered airports with the highest runway incursion rates at runway intersections that are deemed “hot spots.” RIPLS, in addition to current radio communications, differs from existing technologies in that it provides two-way visual communication between end-users. RIPLS was devised through a strategic research process that involved a comprehensive literature review, in-depth personal interviews with subject matter experts, and questionnaires used to gather stakeholder knowledge. Systems engineering tools and methods such as House of Quality, Stakeholder’s Analysis, Activity Diagrams, Safety Risk Management, and Human Systems Integration were used in the analysis of the problem and to devise the system requirements. RIPLS uses an in-pavement lighting system at hold short lines, controlled by ATC, to communicate safe entry for aircraft and ground vehicles across active runways. Many of the components are already in place and easily adaptable for the purposes of RIPLS. The financial costs to implement the system are offset by the low routine maintenance costs and the projected benefits of the system. RIPLS will give more control to ATC and will help to mitigate lapses in situational awareness by pilots and ground crews.

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1 Problem Statement and Background

The Federal Aviation Administration (FAA) defines a runway incursion as "any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and takeoff of aircraft" (FAA, 2009a, p. 4). Runway safety is the top priority for the FAA due to the rising increase in air traffic. Runway incursions may occur for a multitude of reasons. Many scenarios are common and can be categorized according to the nature of the incident. A recent report by the International Civil Aviation Organization (ICAO, 2007) describes some examples of these, which are as follows:

- An aircraft or vehicle crossing in front of a landing aircraft
- An aircraft or vehicle crossing in front of an aircraft taking off
- An aircraft or vehicle crossing the runway-holding position marking
- An aircraft or vehicle unsure of its position and inadvertently entering an active runway
- A breakdown in communications leading to failure to follow an air traffic control instruction
- An aircraft passing behind an aircraft or vehicle that has not vacated the runway

The Runway Incursion Prevention Lighting System (RIPLS) attempts to prevent each of these previous possible runway incursions from occurring. The FAA categorized runway incursions into four specific categories which are labeled "A" through "D", as listed in Table 1-1. These categories differ in terms of severity with category "A" being the closest to the occurrence of a collision, and "D" being the least likely to result in a collision. According to the FAA's 2009 Annual Runway Safety Report, in the fiscal years from 2005 to 2008, there were a total of 3,496 runway incursions reported and of those, 109 runway incursions were from categories "A" and "B" alone. Categories "A" and "B" are the most severe types of incursions and closest to resulting in an accident. The focus of RIPLS is to minimize and prevent situations like these from occurring.

Table 1-1

Runway Incursion Severity Classification

Category	Description
Accident	An incursion that resulted in a collision
A	A serious incident in which a collision was narrowly avoided
B	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
C	An incident characterized by ample time and/or distance to avoid a collision
D	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

Note. Adapted from "Annual Runway Safety Report" by the FAA (2009a, p. 6).

Another important aspect of classifying runway incursions is determining fault. The FAA uses three major types of fault classifications, which are the operational errors by air traffic controllers, pilot deviations from FAA regulations, and vehicle/pedestrian deviations. Over half of the reported runway incursions are pilot deviations.

1.1 Focus of Study: Towered Airports with Highest Runway Incursion Rates

From September 2008 to March 2009, 144 runway incursions were caused by aircraft taxiing beyond the hold short line of an active runway (FAA, 2009a). To reduce runway incursions caused by a pilot inadvertently taxiing past the hold short line, a type of incursion that can produce a disastrous accident, we propose RIPLS. The fault classifications that are the foci of RIPLS are ATC operational errors and pilot deviations. As listed in the ICAO Runway Safety Manual (2007), pilot deviations that may result in a runway incursion include unintended violations of ATC clearances inadequate situational awareness. Operational errors by ATC include forgetting information they receive and miscommunication with ground controllers, tower controllers, and pilots. More specifically, RIPLS will concentrate on deviation and errors at towered airports with the highest incursion rates in the United States, and towered airports that are most runway-incursion prone due to their design.

RIPLS is an ideal solution to the major problems identified in the FAA's National Runway Safety Plan (2009a). The plan emphasizes improvements in human factors as a means to increase runway safety and in particular, airport lighting and markings (p. 12).

RIPLS is a design developed by Human Factors Specialists to prevent the occurrence of runway incursions, increase safety, improve airport signage and communication, and increase the situational awareness of both pilots and air traffic controllers.

In subsequent sections we will look at existing technologies that share characteristics with our design, review literature pertaining to our design, briefly cover our interactions with subject matter experts, describe our analyses, define our design, present our risk analysis, and finally, analyze the overall impact of our design.

1.2 Existing Technology

Throughout its history, the FAA has sought to continuously improve runway safety. Many technologies have been developed over the past couple of decades with this goal in mind. Increasing situational awareness of both air traffic controllers and pilots has proven to be a central focus of technologies to reduce the number of runway incursions.

One of the technologies used for increasing controller situational awareness is the Air Surface Detection Equipment, Model X (ASDE-X), which is being deployed at thirty-five U.S. airports. ASDE-X allows ATC to detect potential runway incursions or conflicts using a visual display of traffic on the runways and taxiways (FAA, 2010). There was an earlier version of the system known as ASDE. The main difference between the two systems is that the ASDE-X is able to take current aircraft positions and predict if they could lead to possible incursions and then notify the controllers with all relevant data (FAA, 2010). Our system will complement ASDE-X. The visual display used in ASDE-X could be replaced by the switchboard or touchscreen control used in RIPLS. This would allow the controllers to have a visual display of the airfield that can control runway access.

A major influence on our design decision is the Runway Status Lighting (RWSL) system that is being used at Dallas/Fort Worth (DFW), Logan, San Diego, and Los Angeles airports (FAA, 2009c). The RWSL is a fully automated system that combines the data from approach radar, surface radar, transponder multilateration, and data processing safety logic (Rosenkrans, 2008). All the data is used to convey a runway's status to a pilot by indicating if a runway is occupied or not occupied. According to Eggert et al. (2006), the three types of lights include Runway Entrance Lights (RELs), Runway Intersection Lights (RILs), and Takeoff Hold Lights (THLs). The lights are installed in-pavement and when activated will always indicate that a pilot needs to stop. This is because the upcoming runway is in use. RELs signify to pilots that the runway is in use and it is not safe to cross or enter. THLs signify to pilots waiting to depart or preparing to land that someone has crossed onto the runway and it is unsafe to take off or land even if they have received clearance from the ATC. RILs indicate to pilots that an upcoming runway intersection is in use and it is unsafe to continue any further (Eggert et al., 2006). The RWSLs provide a visual cue to the pilots that give them some amount of warning indicating unsafe or occupied runways.

In order to evaluate the operational efficacy of the system, Eggert et al. (2006) evaluated the operations of each light individually with a goal of determining if the system was compatible with busy airports and acceptable to the users. Since the system is autonomous, the FAA deemed that only one false alarm per 2000 activations would be acceptable. According to Eggert et al. (2006), the RELs were tested at DFW for technical system performance. The performance was scored by three anomalies which were missed detection (MD), false activation (FA), and instance of interference (I). Upon surveying, the authors found that, “a total of 114 anomalies of all types were identified in the data encompassing 27,000 departure and landing operations and 36,000 runway crossings. Approximately 40% of the anomalies were classified as MD, 50% classified as FA, and 10% classified as I” (p. 140). In order to obtain operational feedback from the users of the system, surveys were given out and of the 220 returned, 92% felt that RELs would help reduce runway incursions and 88% recommended the system be implemented at other airports (Eggert et al., 2006). The goal of only one false alarm per 2,000 activations was not achieved. It would take 228,000 versus 63,000 activations for 114 false alarms to be acceptable.

The entire RSL system is far more complex, autonomous, and extensive than RIPLS. However, there are some general system traits that could be inferred from this system to the RIPLS. First, the systems’ primary similarity is that they use in-pavement lighting, which was found to be an effective way both to improve pilot situational awareness and to gain pilot attention. Secondly, both systems can increase pilot and controller runway awareness by being used in conjunction with ATC and pilot dialogue. The most prominent difference is that in RIPLS, the controller has direct control over runway hold lights, which he or she can use in conjunction verbally granting runway access to the pilots. The controller references the visual control and then switches the lights to green, while giving the pilot audible clearance to enter the runway. We view this visual display and verbal communication from the controllers to be a strength of the system as it adds to situational awareness for both the pilot and the controller. The autonomous RWSL only give visual indications to the pilot which could lead to controller errors and further runway incursions. The next section will summarize the printed resources that were used to help create the RIPLS design.

2 Summary of Literature

In the research and development phase of RIPLS, a multitude of resources were used to gather and synthesize information so the team could better understand the need for improving the safety of pilots, vehicle operators, and pedestrians. Our team researched a variety of resources including scholarly journals; FAA, NTSB, and NASA technical reports; and online resources that provided information that would be useful to the overall design and implementation of our project. This summary will briefly highlight the major points of the research that helped shape our system design.

The literature identified numerous incursions being reported at both commercial and general aviation airports. General aviation airports have a greater number of incursions (see Figure 2-1). As an example, according to a report about runway incursions at our local airport, Daytona International Airport (DAB), the airport experienced sixteen reported runway incursions from 2005 through 2008, three of which were Category A (ARSR, 2009).

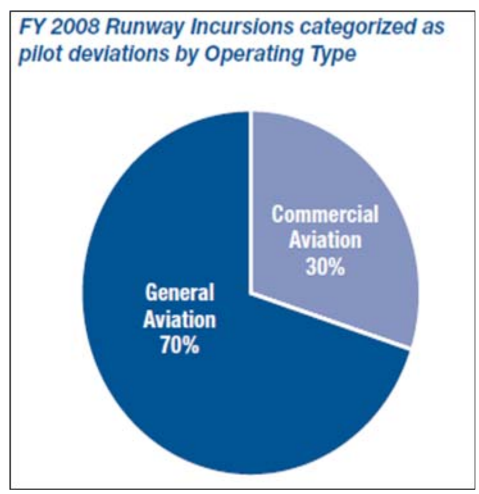


Figure 2-1. Runway incursions by type. (Adapted from ARSR, 2009)

As the RIPLS design evolved, the FAA Fact Sheet – *Airport Surface Detection Equipment, Model X (ASDE-X;* FAA, 2010), which outlines the implementation of ASDE-X, was integral in determining the major focus of our design team. The fact sheet stated the ASDE-X would enable ATC to detect potential runway conflicts by providing detailed coverage of movement on runways and taxiways and would be implemented at 35 towered-commercial airports by the end of 2010; one year earlier than expected. Also, the FAA has implemented the Automatic Dependent Surveillance-Broadcast (ADS-B), a satellite-based system that is used by United Parcel Service (UPS) at Louisville and Philadelphia airports. The team felt the technology would be cost-prohibitive for general aviation airports due to the subscription charges the FAA would be required to pay for the installation and maintenance of the nationwide ADS-B network (FAA, 2010). With this in mind, the team decided to develop a more cost-effective tool ATC could utilize to increase situational awareness for traffic crossing active runways, whether it is another airplane, a vehicle, or a pedestrian at both commercial and general aviation airports with minimal financial expenditure.

The FAA has issued new requirements for controllers to give explicit directions to pilots on specific routes to travel when crossing the airfield. In the past, controllers would instruct pilots to travel to a particular destination on the airfield. This could leave the pilot to determine the route he or she would travel from point of origin to the destination. With the new guidance from the FAA (Order JO7110.65) the controller is required to describe an exact route from the gate including all interim taxiways to the destination point on the airfield (FAA, 2009b). This new requirement would be enhanced by the use of RIPLS, as RIPLS would provide a visual cue indicating whether the active runway being approached is currently in use and whether the pilot has permission to cross.

As Mertz, Chatty, and Vinot (n.d.) reported in *The influence of design techniques on user interfaces: The DigiStrips experiment for air traffic control*, there are conflicting reports as to which type of human interface is better suited for ATC in their work environment. Mertz et al.

describe the strengths and weaknesses between touchscreens and the WIMP (Windows, Icons, Menus, and Pointing) interface. Our team reasoned that a protected avionics button-type device on a non-animated airport diagram, a virtual computer touchscreen, and the WIMP interface would be the three ATC interface options that give RIPLS flexibility in terms of preference and cost feasibility. The team reasoned that implementing an interface that features multiple sensory modes (e.g. tactile, kinetic, visual and auditory) should increase the situational awareness of the controllers during the process of moving vehicular traffic across active runways. Situational awareness should increase for the ground controller as a result of manually pushing the button for a particular intersection and receiving auditory feedback from the pilot, vehicle operator or pedestrian confirming their position at the correct intersection by acknowledging a RIPLS green light.

Based on the literature reviewed for this report, our team determined that by increasing the amount of sensory modes utilized by the controllers/pilots/vehicle operators, their situational awareness should improve and reduce runway incursions. The next section will describe our interactions with subject matter experts and how they helped shape the RIPLS design.

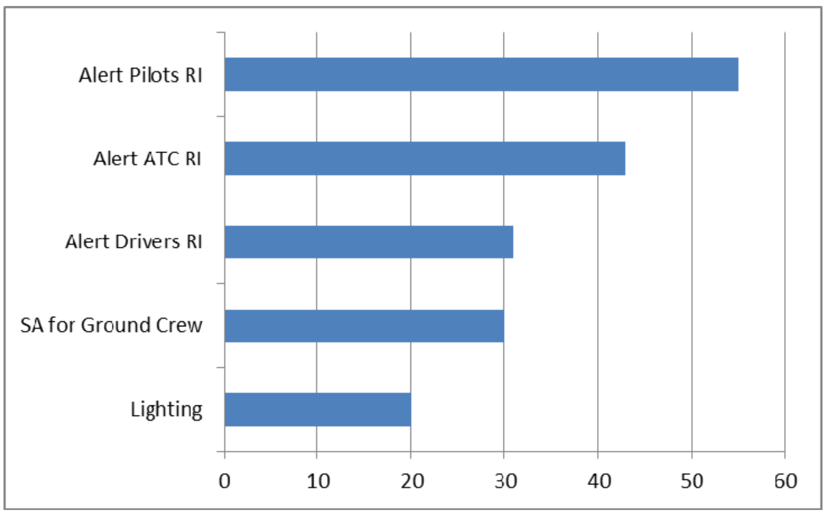
3 Interactions with Airport Operators and Industry Experts

In order to identify the biggest problem areas in airport management our team distributed surveys to thirteen SMEs including airport managers, airport operators, ATC, maintenance personnel, professors of human factors and systems, ATC instructors, and pilots. The SMEs we surveyed were asked to rate the importance of the following potential improvements:

- Warning system to alert pilots of a situation leading to a possible RI
- Warning system to alert controllers of a situation leading to a possible RI
- Warning system to alert airfield drivers of a situation leading to a possible RI

- Techniques to record, analyze, and display annotated spatial data for improved situational awareness of ground operations
- Methods for aircraft/runway interface that address issues caused by new energy efficient lighting not being visible to heat sensing, and/or enhanced flight vision systems

SMEs were asked to rank each issue on a scale of 1 to 5 (lowest to highest priority, respectively). Rankings were added together in order to determine the relative importance of each issue. Figure 3-1 illustrates the survey results.



According to the survey results, the three highest priority issues all seemed to involve an issue with warning ground traffic of a possible RI. The team held a number of brainstorming sessions to design an intuitive, visual communication system that would provide a warning to the pilot, ground operations, and feedback to the controller.

On October 10, 2010, we presented our basic idea to advanced student controller Brent Bowen. Bowen argued that controllers might be inclined to not use RIPLS if they did not see the benefit or if they felt it limited their control of the situation. The team feels it is imperative that RIPLS is easy to use and increases control of the airport environment and situational awareness.

On November 8, 2010 researchers sought out ATC instructor and veteran controller Marty Lauth. Lauth argued that the most significant differences between RIPLS and other similar systems are that, for the RIPLS design, combined verbal and visual cues jointly indicate that a runway is safe to cross and the controller is made aware if the lighting system is inoperative. Other advantages are that RIPLS is intuitive because red and green universally mean stop and go, and it increases situational awareness more so than similar systems because of the redundant feedback provided to both the ground controller and pilot.

A number of experts across a range of relevant domains were consulted to help us consider the many facets and potential effects of RIPLS. Refer to Table 3-1 for a list of SMEs consulted and a brief description of feedback given to the researchers. Included in Table 3-1 is a list of SMEs that are not identified. This is because they agreed to participate in a survey on potential aviation problem areas under the condition that the information they gave would not be traced back to them.

On November 15, 2010 researchers met with Marty Lauth and David Craven, an FAA tower controller, who provided a tour of the ATC Facility at DAB. Mr. Craven advised that it is incredibly important to have an interface that would require minimum "heads down" time for the ground controller operating RIPLS. It was also discovered that the logistics of installing RIPLS at each individual airport would differ significantly and no single installation procedure would work for all airports. RIPLS must be flexible and allow for multiple types of interfaces. These design provisions are addressed in section *5.1 Description of RIPLS Design*. The next section will describe the analysis tools we used to help construct and evaluate the RIPLS design.

Table 3-1

Interactions with Industry Experts

Name	Role in Aviation Community	Feedback Provided
Brent Bowen	ATC Student, Embry-Riddle Aeronautical University (ERAU)	Do not take control from the controller, minimize rush of confusion over selected hold short line; minimize time away from out-the-window view
David Craven	Air Traffic Controller, (FAA)	Advised that RIPLS should require very little “head down time”, installation factors
Marty Lauth	ATC Instructor, (ERAU)	Verbal and visual redundancy are key safety features, controller awareness of system’s operation status
Steven Taylor	Systems Specialist, (FAA)	Logistically, installation of RIPLS at each airport will be very different
Participant 1	Projects Engineering Coordinator, DAB	Identified RI warning system as most important issue on survey
Participant 2	Professional Pilot	Same as previous
Participant 3	Naval Aviator (ret), Instructor/Researcher	Same as previous
Participant 4	Facilities Engineer, DAB	Same as previous
Participant 5	Retired Pilot, Commercial Instructor, ERAU	Same as previous
Participant 6	Professor of Human Factors, ERAU	Same as previous
Participant 7	Operations Supervisor, (DAB)	Same as previous
Participant 8	Professor of Aviation, ERAU	Same as previous
Participant 9	Professor of Aeronautics, ERAU	Same as previous
Participant 10	Agent and Wildlife Expert, DAB	Same as previous
Participant 11	Simulation Expert, NextGen Research, ERAU	Same as previous

4 Problem Solving Approach

Our team chose the task of designing and developing a system to attempt to reduce runway incursions at FAA controlled airports. Due to constraints of time related to imminent deadlines our team decided to use a well-known rapid development strategy – Agile Software Development (ASD).

We initiated weekly meetings to devise, assess, and synthesize research and analysis work that was done on an individual basis throughout the week. We also established a system of communications that included e-mails, phone calls, and text messages. We found that ASD was instrumental in guiding and facilitating a smooth exchange of information and ideas. ASD is a method of development where team members tune and adjust their behavior with the goal of making the group's efforts more effective (Beck et al., 2001). The system's effectiveness was evident during the weekly meetings when one team member would manage the direction of the project as individual members presented their weekly research. These meetings would include discussions regarding design modifications, stakeholder analyses, feasibility studies, and risk management. The theme for the meetings, consistent with ASD, was that the needs of the customer were paramount. Those needs are to enhance the safe and efficient control of airport traffic. The team focused on developing a written proposal and stopped short of a working model because it was considered beyond the scope of the project.

4.1 Research and Analysis Process

Upon deciding on the FAA Competition's topic category "Runway Safety", our team spent a lot of time researching and brainstorming within that particular theme. Once the RIPLS concept was proposed, the first step of the development process was to implement a focused research strategy in lighting. We examined FAA regulations, studied existing technology, and looked at current ideas being proposed (but not yet implemented). In the initial phases of our design work, assessing questionnaire responses, conducting interviews with SMEs, and visiting our local airport and air traffic control tower helped us solidify our design concept. Although each member was assigned a different section of the report, everyone assisted in the collection and compilation of the data and information obtained. In these efforts, we designed a House of

Quality (HoQ), performed a stakeholder analysis, constructed activity diagrams, and explored and addressed Human Systems Integration (HSI) components. All of these contributions were necessary for transforming our research into concrete design solution specifications and each will be described in turn in the sections that follow.

4.1.1 House of Quality (HoQ) Analysis

Many systems developed solely by engineers, without the assistance of Human Factors Specialists and practitioners from related fields neglect an essential part of the overall system: the human. To implement system requirements most efficiently, engineers need to consider the expectations of the customers and users associated with the system throughout the design process. A helpful tool that transforms qualitative data into quantitative and testable requirements is a part of the iterative design process known as the HoQ.

The HoQ is a matrix that clearly defines the wants and needs of the customer and correlates them with the technical requirements of the system. This is an important part of the design process because it gives the customer a voice. Another important benefit of the HoQ is that it defines objectives and quantified goals for the system prior to development. If there are too many conflicts between customer needs and the engineering necessities, further evaluation, and possible compromises, must take place.

In order to clarify customer needs, the first step is accurately identifying the customer. Although the use of RIPLS is primarily for air traffic controllers and pilots, local airport management personnel and FAA representatives were interviewed as well for the development of the HoQ. Their experiences and insights were relevant for assessing the impact of RIPLS on the working environment within airports. Throughout the interview process, customers put emphasis on the following:

- The system shall have a user-centered design that will increase situational awareness
- The system shall be low cost
- The system shall comply with FAA regulations
- The system shall cause minimal airport construction
- The system shall not create additional task load for the operators
- The system shall not greatly impact the daily operations of the airport
- Training for the system shall not be too time-consuming or costly to implement
- The system shall require simple preventative maintenance

Upon obtaining the customer's wants, our team needed to determine the technical requirements for the system. Upon much research and deliberation, the RIPLS team decided that there are six high level design requirements which need the most attention. The six design requirements identified include:

- The system shall be accompanied with user manual and training guidelines for users and operators
- The system shall implement either a touchscreen or analog ATC interface
- The system shall only be installed at "hot spots" (i.e. areas with the highest traffic and incursion risks)
- The system design shall be as simple as possible
- The system software shall easily be maintained and updated
- The system hardware shall be integrated with current hardware installed at airports (e.g. wiring for tarmac lights)

From our team's perspective, these RIPLS engineering requirements are the most crucial necessities in creating the most useful system.

HoQ matrices differ depending upon the analyses being conducted. Our group incorporated five major components that were most applicable at this stage in the design process, as depicted in Figure 4-1 The five areas of focus are the customer requirements, technical requirements, an interrelationship matrix, technical correlation matrix, and the technical priorities section (Tapke, Muller, Johnson, & Sieck, n.d.). Prior to the completion of the HoQ, our group hypothesized the most important technical aspect of RIPLS would be to minimize construction at an active airport, since construction would interfere with the daily activity of an airport, and possibly interfere with routine airport operations. This is all true, however, in the HoQ we developed, as shown in Figure 4-1, it is apparent the most important design requirement is the interface design type.

According to the HoQ, the interface design type has the strongest relationship, i.e. correlates best with, the desires of the customer. This relationship is depicted by the “weighted importance” section located at the bottom of the HoQ. With an importance score of 55, it is by far the strongest relationship to the customer requirements. There are two choices for the type of interface that will be incorporated into the ATC tower: analog or touchscreen. The distinction between the two will be based on what the customer prefers for their specific ATC tower. A more detailed discussion of what is available to customers is in section *5.1 Description of RIPLS Design.*

In summary, the HoQ is a matrix that shows the correlation between customer wants and the design requirements, and graphically illustrates the significance of the desired outcomes to both parties. The RIPLS HoQ is clear about how to prioritize the design requirements based on correlations with customer needs. Determining the needs of the customer allowed the focus of our research to consider, and potentially satisfy, the goals of both the customers and engineers. The HoQ allowed our team to prioritize the engineering requirements according to the customer needs and, in turn, provided us with clear-cut goals for the development process.

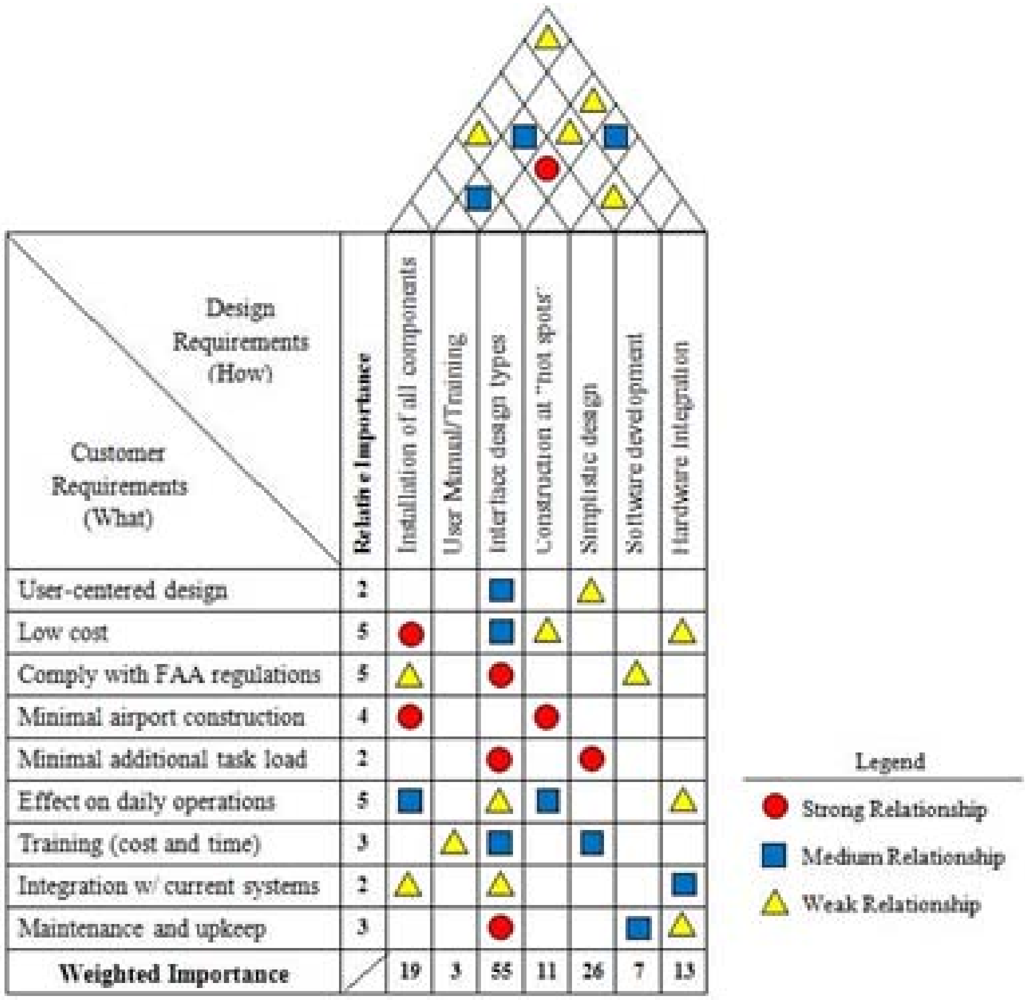


Figure 4-1. The House of Quality used to determine the customer and engineer needs for RIPLS

4.1.2 Stakeholder Analysis

The stakeholders involved with the implementation of the RIPLS ATC display are as follows:

- Federal Aviation Administration (FAA)
- National Transportation Safety Board (NTSB)
- Towered airports & operations
- Airport installation personnel (airport lighting technicians)
- Air traffic controllers
- Air traffic controllers unions

- Aviation training programs/centers/universities
- Aircraft Owners and Pilots Association (AOPA)
- Pilot Unions
- Airport maintenance personnel
- Airport lighting system suppliers (Cooper Crouse-Hinds, ADB Airfield Solutions, Honeywell, ATG Airports)

The stakeholders will have areas of involvement as well as influence on specific activities during the system's lifecycle. The team was able to interview potential stakeholders and therefore better understand the interests, influence, and impact of each. Information regarding the stakeholders' interests is depicted in Table 4-1 and Figure 4-2. This information is derived from stakeholder interviews and reviews of relevant literature.

Table 4-1 lists the stakeholders as well as the areas with which they all concerned. An asterisk after the stakeholder label in Table 4-1, Column 1, indicates information elicited from personal interviews from actual potential stakeholders. It is important to list and constantly review these depicted relationships between stakeholders and their interests so that no one is forgotten during the system development process.

Table 4-1.

Stakeholder Involvement Areas

	Areas of Involvement					
Stakeholders	***Legal and Regulations***	***Serviceability***	***Integration***	***Finance***	***Usability***	***Operational Changes***
FAA	✈	✈	✈	✈	✈	✈
NTSB	✈		✈		✈	✈
Airport Ops*	✈	✈	✈	✈	✈	✈
Installation	✈	✈	✈		✈	✈
Controllers*	✈	✈	✈		✈	✈
ATC Unions	✈	✈		✈	✈	
Pilots					✈	✈
Pilot Unions	✈				✈	✈
Maintenance*	✈	✈			✈	✈
Suppliers*	✈	✈	✈	✈	✈	✈

Note. The asterisk indicates information that was received during actual stakeholder interviews

If a stakeholder holds a higher influence, or is more impacted, it does not mean that the stakeholder controls all aspects of the project. It is best to understand each of their areas of influence or concern in order to best assess priorities. Figure 4-2 shows the relative extent to which each stakeholder may affect, or be affected by, the system. This information is based on stakeholder feedback. It is important to note that the placement of stakeholders in the influence-impact grid is approximate, and the relationships can change based on local and airport-specific regulations. This information is useful for determining legal, financial, social, operational, and practical limitations of the project.

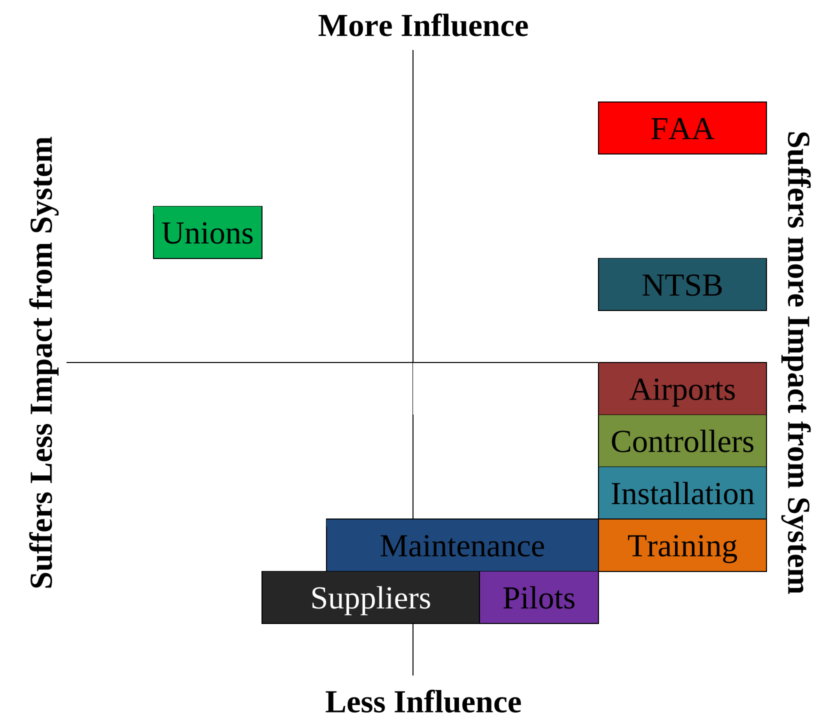


Figure 4-2. Stakeholder analysis grid

4.1.3 Activity Diagrams

The activity diagram in Figure 4-3 outlines the process that occurs when using RIPLS. There are two basic but different end scenarios outlined in the diagram. There is a scenario where the aircraft is in the correct position and there is one where the aircraft is not in the correct position. This is not to suggest that the two scenarios in Figure 4-3 are the only scenarios that would occur.

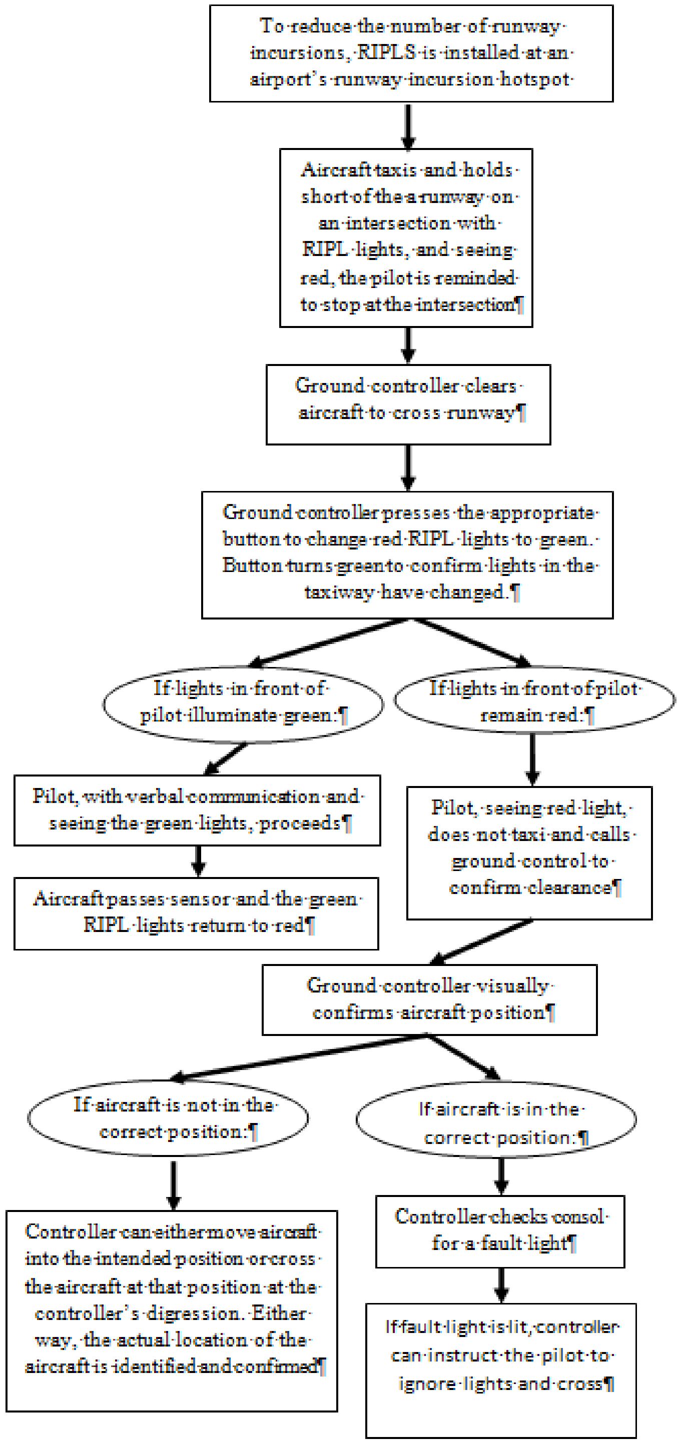


Figure 4-3. RIPLS SysML

The objective of the activity diagram is to create a visual representation of crucial activities that occur in the entirety of the course of action. These activities are written as text within a box and are connected to one another to show ways the activity may progress. The activity begins at the second box when an aircraft taxis and holds short of a runway as indicated by red lights. There are times when the activity takes two different paths and that is notated by two bold lines attached to what is called a fork node. At the first fork, the path on the left show the aircraft is at the appropriate runway and receives green lights and proceeds without problem. Ground control has given the pilot a taxi clearance to continue to the specified runway.

The right side is where a mix-up has occurred and either the pilot is at the wrong intersection or the ground controller has an incorrect idea of where the aircraft is. The pilot, having radio clearance but seeing the red light, will radio the ground controller to confirm clearance. At this point, the ground controller will visually confirm the position of the aircraft and take the appropriate action to guide the aircraft to where it needs to be.

The use case diagram below in Figure 4-4 outlines the use of RIPLS by the tower to achieve the goal of adding another “wall” of security to protect against runway incursions. This is a much simpler and cut down version of the activity diagram. The users or actors are the stick figures and a line connects the actors to a corresponding use case that is in an oval. This use case diagram is helpful because it illustrates the roles of pilots, ground controllers, and local controllers (tower) as they interact with RIPLS.

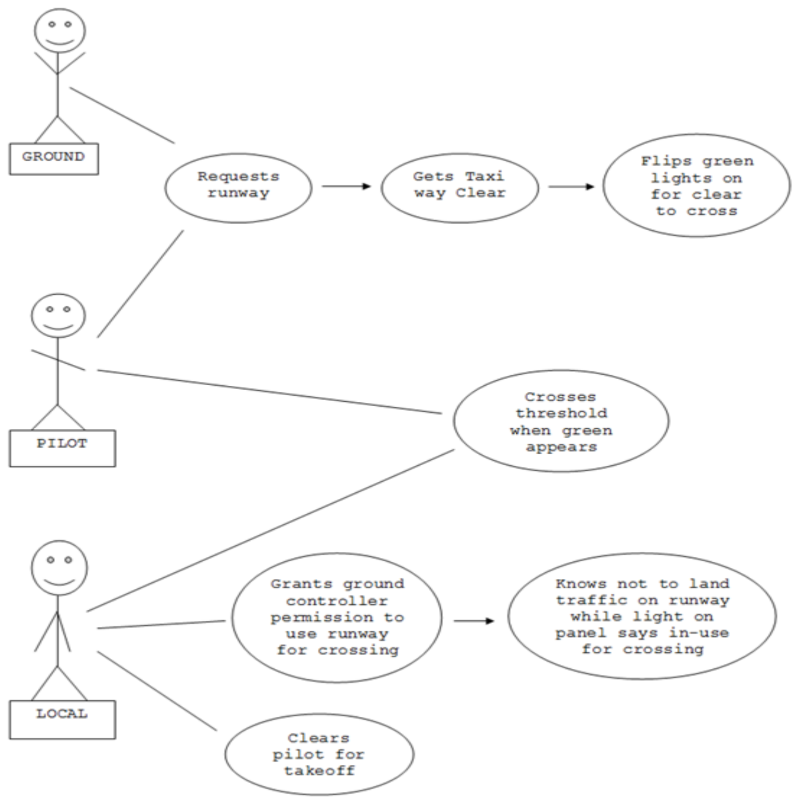


Figure 4-4. SysML diagram with actor roles

4.1.4 Human Systems Integration (HSI)

As part of our research method for RIPLS, we emphasized HSI while designing our system. HSI is an approach to system design that focuses on every human interaction with the system as a “critical system element” (Haskins et al., 2010, p. 326). Human capabilities and limitations are viewed as being just as important as system hardware and software. A full HSI analysis would include an analysis of all of the interactions that occur with all humans that come into contact with the system. This would include stakeholders, maintenance personnel, training personnel, and support professionals in addition to the main users such as ATC personnel and pilots. The following examples illustrate the HSI thought process needed to examine interactions between ATC personnel and RIPLS.

Brent Bowen (B.S., Air Traffic Management, Embry-Riddle Aeronautical University) identified a potential problem with our design: the ground controller is likely to make mistakes when identifying which hold short line they are giving a green light to on the RIPLS panel. In addition, they need to be able to quickly identify which hold short line they would like to control so that they can keep their main focus on the actual runway outside the tower window. Whether the panel is touchscreen or a basic switch board, we decided to arrange the switches so that they would be on a diagram of the airport. This display strategy is called pictorial realism. It is a method of displaying information as it is represented in the real world and it is also a form of ecological interface design. The aim and economical influence of this type of design in this particular situation is to reduce cognitive processing to the minimum level needed to complete the task (Vicente & Rasmussen, 1992). The display would give the ground and local controllers the ability to see where there is a green or red light as opposed to having a list of lights that do not relate in their orientation on the display to their actual orientation out on the air field. This design directly addresses Mr. Bowen's concerns by helping to clarify to controllers which hold short line he or she is giving clearance to and allowing the controller more attentional resources to devote to events occurring outside of the tower.

In addition, to ease the cognitive workload of the ATC personnel, the displays for both the local and ground controller would be sufficiently large to help the controller easily identify different intersections on the display. A further analysis of the size of the display would be needed to reduce the amount of ATC personnel workspace that is occupied by the display. We imagine that since the local controller has only light displays on their board and they do not have to actually press anything, their board would be smaller than the ground controllers'.

Limitations and capabilities of other professionals, such as maintenance personnel and training personnel, would have to be analyzed in the same fashion to determine how the system could be designed and implemented to make the interactions as effective as possible in any one area while maintaining quality in other areas. For example, if the RIPLS display board were too large, it would help ATC personnel find their intended hold short line but it would also detract from the available workspace.

5 Description of Technical Aspects and Risk Analysis

The previous section described research and analysis methods we used to devise RIPLS. The next section will provide a detailed description of the system, its components, and how the components will fit together. Also, a record of changes depicting the evolution of the design is presented. Then, a risk analysis will be presented based on the hazards identified by the changes that RIPLS will make to the National Airspace (NAS).

5.1 Description of the RIPLS Design

RIPLS is designed to increase situational awareness of both pilots and controllers at the runway incursion hot spots of airports. The new lighting system would consist of ten unidirectional high intensity inset lights, similar to the ATG L852S lights (Figure 5-1) currently used for other taxiway operations, per intersection. Each light would have the capacity to be illuminated red or green. The default color of the lights is red, with green selectable by the controller when needed. Figure 5-2 shows a top view of what the proposed light would look like. As shown, the light would only point toward the taxiway intersection in question, rather than an omni-directional light that would be visible from other locations, which could potentially cause confusion across the airport. These lights would be inset into the taxiway just prior to the hold short line, as seen in Figure 5-3. The red lights are illuminated in the top half of the image indicating that the approaching aircraft is not cleared to cross the runway. In the lower half of the image, the green lights are illuminated, indicating that the controller has verbally approved an aircraft to cross the runway and switched the lights to green.

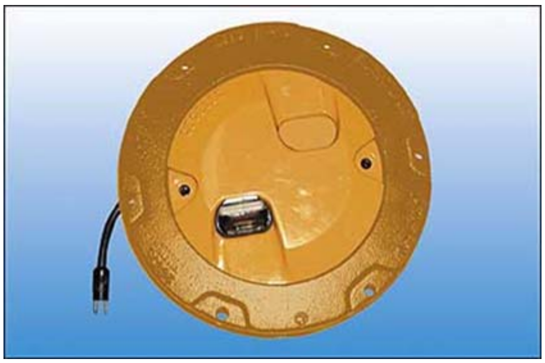


Figure 5-1. ATG L852S Unidirectional High Intensity Inset Light (adapted from www.flightlight.com)

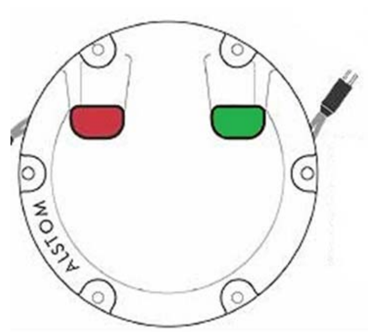


Figure 5-2. Proposed RIPLS light based upon ATG L852S (adapted from www.flightlight.com)

The system would also contain an Active Runway Configuration Button (ARCB) for each runway equipped with RIPLS. A controller would use the button to turn the system on for the runway, allowing for the system to turn off on runways that are not active and presently do not require permission to cross.

The system would also consist of a pair of sensors 100 feet beyond the hold short line. As an aircraft crosses the sensor, the lights would automatically turn from green back to red. This is to ensure that, should a second aircraft be waiting to cross the runway, the lights would illuminate before the second aircraft could potentially misinterpret the green lights.

Additionally, the system would have a fault-sensor circuit. If the lights do not agree with selected input, or the lights fail to properly illuminate, the fault-sensor circuit would illuminate and indicate to the ground controller that the system is not functioning properly. The fault sensor light would be on the control panel located beneath the ARCB buttons, as seen in Figure 5-4.

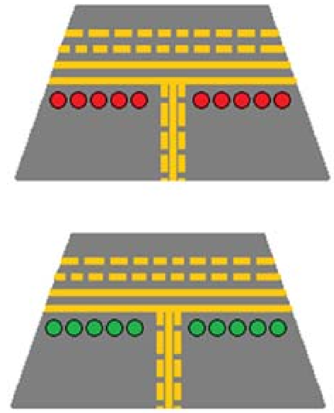


Figure 5-3. RIPLS lights indicating red (do not cross) and green (permission to cross)

As mentioned in previous sections, two different types of control systems have been proposed, analog and touchscreen. The simplest to install would be an analog panel. This control panel for would consist of an illuminated airport diagram with large buttons on each of the runway hot spots containing RIPLS. When the ARCB is selected for a particular runway, it will activate and illuminate in red the buttons corresponding to the intersections with RIPLS, as seen in Figure 5-4. When a ground controller clears an aircraft to cross a runway intersection equipped with RIPLS lighting, the controller would press the button for the corresponding intersection. The button would illuminate green to match the green RIPLS lights at that intersection as seen in Figure 5-5. After the aircraft passes the sensor that turns the RIPLS lights back to red, the button would return to red as well. Each of the buttons on this type of control panel would be high-rimmed button switches, to minimize the risk of an accidental button press which would display confusing information to pilots. The entire size of this panel would be sixteen inches wide by twelve inches tall, similar to the current airport lighting panel located in the DAB tower. The specific size of the panel would vary based upon the runway layout at each airport it was installed and the recommended optimal viewing size that would be obtained through analysis as mentioned in section *4.1.4 Human Systems Integration*.

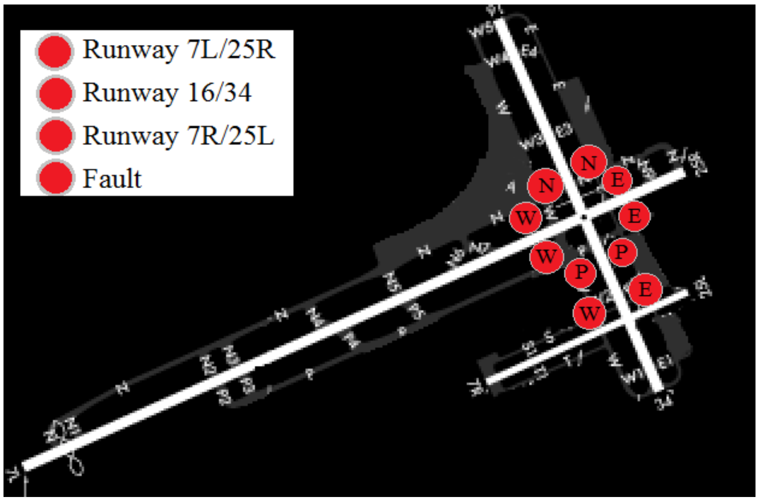


Figure 5-4. RIPLS control panel display default

Figure 5-5. RIPLS control panel, aircraft cleared to cross 16/34 at November

Alternatively, a touchscreen control panel could be used. The layout would be almost identical to an analog display. The individual RIPLS intersection buttons would only appear when the runway was activated, de-cluttering the display for the ground controller, and therefore, make it easier to select the appropriate intersection with less heads-down time. Another consideration for a touchscreen panel would be how it is mounted. Since the wiring of an analog display would not be necessary, a touchscreen control panel could be mounted vertically on an actuated arm, similar to an existing display of radar imagery in the DAB tower already. This would further decrease the heads-down time of the ground controller since he could just look to the side to see the display, rather than adjusting his entire point of view every time he looks back up. It would also help to improve functionality at airports that switch to a single ground and local controller at nights, so the RIPLS control panel could be moved to the local controller's station.

At airports with Instrument Landing System (ILS) hold short lines, RIPLS would be installed at ILS hold short lines as well as runway hold short lines for use during instrument conditions.

5.2 Record of Changes

As seen in Table 5-1, the RIPLS design evolved as we learned more about runway incursions and what the FAA has already implemented to decrease runway incursions. Originally, the team considered Department of Transportation (DOT) traffic lights similar to traffic lights used at intersections of streets. That idea quickly changed from above ground traffic lights to already available, FAA approved, in-ground lighting systems. The team briefly entertained the idea of having RIPLS guide the pilots from origin to destination on the airfield but felt that would be cost prohibitive and confusing to the ground traffic. As a secondary system, we added a display for the local controller to ensure all controllers were aware of which runways were clear for takeoff and landing operations and which ones were occupied by ground traffic operations. Our last major change to the original design was to incorporate sensors similar to garage door opener sensors. These sensors would indicate to the controllers when the crossing aircraft/vehicle had successfully cleared the active runway. As a result, RIPLS would automatically reset itself back to red lights.

Based on our research of published articles, studies and other literature during the initial phases of our project, our opinion is the RIPLS system would be a benefit to the overall aviation safety culture. Changes that were made contributed to the overall resilience of the RIPLS concept and its ability to integrate into and facilitate ground operations.

Table 5-1

Record of Changes

DATE	CHANGE	REASON
9 Sep 10	Lighting fixtures changed from gateways to runways to only at intersections of taxiways and runways	Discussion with expert Marty Lauth - having too many lights would be confusing on Tarmac.
16 Sep 10	Light fixtures changed from above ground to in ground fixtures. Utilize stop-bar lighting already in place at several commercial airports.	Reviewed ASDE-X Fact Sheet and airfield lighting requirements. Team felt existing technology would be recognized and utilized by pilots more than a new technology.
23 Sep 10	Touch screen idea changed to aviation-style push button	Reviewed: *The influence of design techniques on users interfaces: the DigiStrips experiment for air traffic control*
7 Oct 10	Added panel for local controller as a back-up system	Discussion of backup systems and physical locations of controllers in the DAB control tower with Marty Lauth.
18 Nov 10	Incorporated sensors on sides of runways to indicate to controllers the aircraft has cleared the runway. Sensors will automatically reset buttons/lights on controller's displays and reset RIPLS lighting at intersection back to red lights.	Final review of RIPLS system with team. Change was made to add final closure to RIPLS loop.

5.3 Safety and Risk Management

The RIPLS risk analysis was conducted in accordance with the FAA Air Traffic Organization Safety Management System Manual (SMSM). We began by performing a preliminary safety analysis and discovering that our system does affect the NAS and could introduce safety risk into the NAS. We conducted our subsequent risk analysis with the following hazard and risk definitions in mind from the SMSM:

- *Hazard*: any current or potential condition that can result in harm to people, property, or the environment
- *Risk*: The estimated severity and likelihood of the potential effect of a hazard

We also used a comprehensive method of identifying and analyzing hazards and risks as outlined by the SMSM. This analysis is illustrated in Figure 5-6. We elected to go as far as Phase 3, which involves analyzing risk with qualitative risk estimates in order to keep the project manageable. In the following section, we will begin with Phase 2 (Identify Hazards), as Phase 1 (Describe System) has been covered in section *5.1 Description of RIPLS Design*.

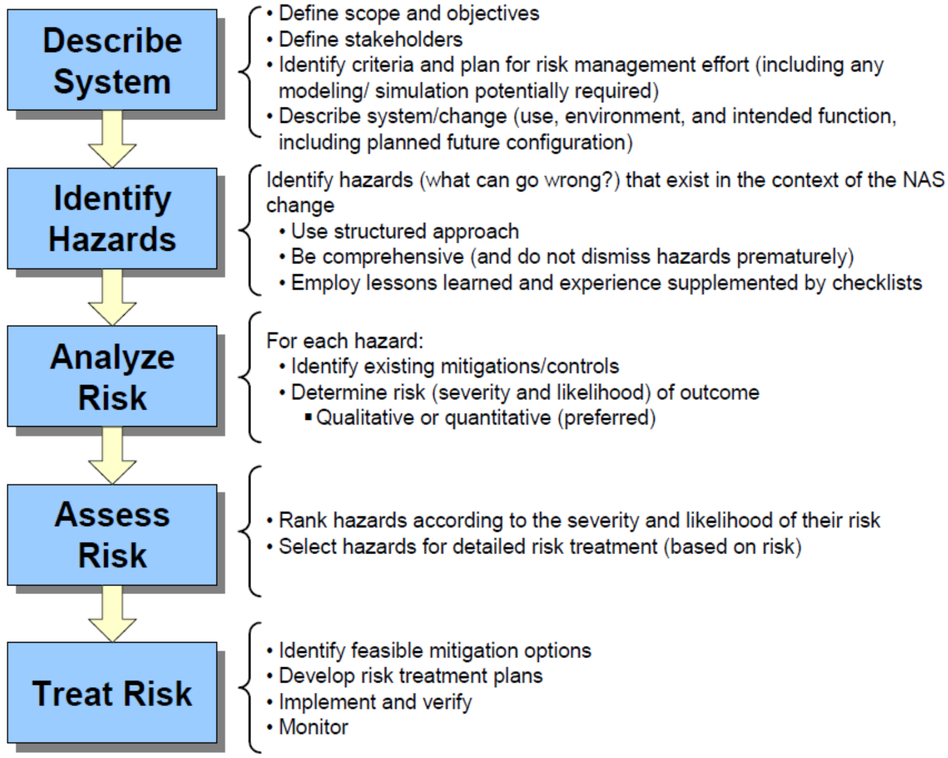


Figure 5-6. Safety Risk Management (SRM) Outline

5.3.1 Identify hazards

We identified general hazards that could present themselves at towered airports with the highest rates of runway incursions. Our hazards were identified by mainly talking with operational experts that are knowledgeable about air traffic control procedures. A list of subject matter experts can be found in Table 3-1 on page 15.

- **Environmental Hazards:** Weather conditions, particularly snow, pose visibility hazards for the RIPLS lighting system. The system uses LED in-ground lighting. LED lights do not emit enough heat to melt snow. This hazard gives rise to ambient risk, "defined as the risk caused by and created by the surrounding environment…" (Haskins et al., 2010, p. 214).

- **Human-System Interaction Hazards**: Human error on the part of the controller is a hazard. This can manifest itself in the event that a controller gives clearance for an airplane at a particular hold short line but uses RIPLS to give the go signal at a different hold short line. Human error on the part of the pilot is also a hazard in this category. This can manifest itself in the event that a pilot is mistakenly at a hold short line at which that he/she is not authorized to be present.
- **System-System Interaction Hazards**: Radio failure is a hazard that would affect our system and its effectiveness. This is because our system is meant to serve as a redundancy to radio clearance between air traffic control (ground and local) and pilots. If a radio failure were to occur, we would need a way to ensure that our system is one part of a two method system for giving runway crossing clearance.
- **System Acceptance Hazard**: Another possible hazard is non-acceptance of the system by air traffic controllers that are set in their ways. It has been identified by one of our SMEs that some ATC personnel are confident in their current method of performing their duties and may see a new system as an unnecessary addition and they may not use it.

5.3.2. Analyze risk.

With our general hazards outlined, the next step is to analyze the risk that accompanies these hazards. We first have to identify which existing controls are present to deal with each of the hazards. The following bullets will include the hazards, mitigations, and qualitative risk values. This information is also presented in an abbreviated form in Table 5-2 at the end of this section.

- **Environmental Hazard:** We chose in-ground lights so that they would be easily cleared in the event of snow. Plow machines at airports should be able to uncover lights, making them visible when the airport is deemed safe for operation. The worst effect this weather hazard could have is pilots and ATC relying on radio communications while the RIPLS lights are not visible. The risk that this hazard presents is more likely in northern airports than airports with more temperate climates. By SMSM likelihood definitions, this would be a frequent scenario, especially in winter months. At airports with more moderate climates, the likelihood is lessened to remote. The severity of the risk, however, is lessened to a minor rating since radio communications will still serve as the primary mode of communication.

- **Human-System Interaction Hazards:** RIPLS is designed so that a pilot would cross a runway after two events: 1.) He or she receives radio clearance and 2.) He or she receives visual confirmation via RIPLS lights. If a ground controller accidentally gave clearance to the wrong hold short line via RIPLS, the pilot that actually has clearance should question why his/her RIPLS light is still red. In the instance that another pilot is at the hold short line where RIPLS clearance was accidentally given, they should have no radio clearance and should question why he/she has RIPLS clearance.

This redundancy feature of RIPLS should also mitigate pilot error in the same fashion it corrects for ATC error. It is assumed that there might be instances where human error arises from both sides (i.e. ATC and pilot/vehicle operator). Thus if both of these hazards simultaneously occurred, the risk severity is estimated as either hazardous or catastrophic. RIPLS, however, is designed to reduce the likelihood of such an error. For a catastrophic risk to occur, a ground controller would have to give clearance to a pilot (referred to as pilot #1 for clarification) and select the wrong intersection for clearance on RIPLS. Pilot #1 would have to overlook the red RIPLS light and forge ahead. Another pilot (pilot #2) that received the erroneous green RIPLS light would have to cross an active runway without radio clearance. These conditions occurring without anyone radioing the mistakes are remote by the SMSM definition and this hazard should be selected for further analysis in order to select the proper risk mitigation technique.

- **Radio Failure Hazard:** In Section 2 of the FAA's *Air Traffic Organization Policy* (2008), it is outlined that radio failure is handled by using a light gun to give various clearances that would normally be given by radio. The light gun technology would be a replacement that RIPLS uses in the case that radio malfunctions occur or an aircraft does not have a radio. The severity for this hazard is minor and the occurrences are estimated to be remote.
- **System Acceptance Hazard:** To gain positive acceptance of RIPLS, involvement of ATC personnel in the evolution of the system might help make them an interested stakeholder in the system. From the standpoint of an ATC professional, if one of their own is helping to design a system with suggestions and it makes sense to them, then they should be more likely to use it. It is difficult to assign accurate risk severity and likelihood levels for this hazard without surveying the attitudes of seasoned ATC personnel. However, that would serve as a good method for gauging attitudes in order to assign risk values for this hazard.

Table 5-2

RIPLS Hazard/Risk Analysis

Risk	Mitigation		Risk Levels	
	Current	*Suggested*	*Likelihood*	*Severity*
Environmental Hazard (i.e. Snow)	Snow plows at airports	*No additional suggestions	Frequent - Remote	Minor
Human – System Interaction Hazards	Redundancy between radio communication and RIPLS	Further analysis needed	Remote	Catastrophic
Radio Failure Hazard	Light gun	*No additional suggestions	Remote	Minor
System Acceptance Hazard	None	ATC personnel involvement in evolution of RIPLS	Further analysis needed	Further analysis needed

Note. *No additional suggestions were made because the risk levels were deemed low given the current mitigations

6 Projected Impact of the Design

In this section, we focus on the impacts our proposed system design would have in terms of its potential to expand, the method of its implementation, and the projected amount of money it will cost and save.

6.1 Advancement/Commercial Potential

Runway incursions can occasionally happen even if controllers are completely alert. One major contributor is miscommunication between the control towers and the cockpits. Our design is intended to give towers another layer of control while minimizing the extra workload on the controller. It is also designed to give pilots a salient visual reference to supplement verbal commands from ATC.

With these basic functions in mind, our SMEs suggested that RIPLS first set up at ten towered airports with the highest nation-wide runway incursion rates. All intersections within the airports will be modified at the same time; this will maintain uniformity and minimize confusion.

Hopefully, once the system has become implemented, feedback from controllers and pilots will encourage its popularity.

However, we do realize that it may be unreasonable to rely on word of mouth for advancement of our system. One thing we can rely on is the similarity of our system with the RWSL system. As the FAA moves forward in its plans to test and implement RWSLs in airports around the country, this is an assurance that the infrastructure needed for RIPLS is already laid out. We would like to point out that the main difference, among others, between RIPLS and RWSL is the addition of green lights to the red lights to further confirm radio commands by air traffic control. Green lights have been implemented into the design for two reasons:

- Red and green are two colors used to regulate automotive traffic in the U.S.
- The green lights allow for easier identification of system failure. When all of the lights are off in the RIPLS configuration, a problem is definitely present. When all of the lights are off in the RWSL configuration, it may mean that the pilot is clear to cross or it may mean that the red lights are not working.

A couple of other advantages to RIPLS relative to RWSL are that most of the components are reinforced because they are in-ground and they can withstand assault from some of the most extreme natural and man-made disasters. Also, the design's simplicity should induce controllers and pilot comfort as it is designed to allow it to easily merge into current airport layouts and operations.

6.1.1 Deployment timeline and training plan.

A two-phase plan is required to deploy the RIPLS modification.

Phase One (1-3 months): Purchase, install, and test hardware. Intersecting portions of the runways will have to be stripped or drilled to accommodate new inset lighting fixtures and wiring. Red and green LED lights will then be installed in the implanted fixtures that will lie laterally across each intersection. Wiring may be routed to power sources along already formed electrical distribution pathways; otherwise new routes will need to be laid. Power to the lights will be controlled by analog or touchscreen switchboards located in the control towers. During assembly the lights and switchboards will need to be tested for effectiveness. Additions to aviation training will also begin to ensure pilot familiarity of the impending lighting system.

Phase Two (4-8 months): Intermittent on-site training will be provided to controllers. The RIPLS support team will prepare relay drills and staged scenarios to ensure the controllers' comfort with the system. During this time feedback will be collected and the system will be modified as needed to ensure a solid ergonomic foundation. Notices to Airmen (NOTAMs) will be issued.

6.2 Financial Analysis

We performed a financial analysis to help determine the projected economic impact that will result from RIPLS. As every investment takes away from Passenger Facility Charge (PFC) revenue, estimated costs for RIPLS implementation ought to be as reasonable as possible. According to SME interaction with the management crew at Daytona Beach International (DAB), $50,000 in cumulative benefits is conservative for a small airport like DAB. With that in mind, there are some equipment costs that can reasonably be calculated from online sources. The RIPLS project primarily requires three starting items, abbreviated below as “LCC” for lighting, cables, and control panels.

For inset lights, an airport such as our local Daytona Beach International (DAB) would require 10 lights per intersection, and 20 total for the two intersections available. The cost of one light as featured in Figure 5-1 and Figure 5-2 would likely range $150 each ("Flight light inc.," 2010). The cost for cables consists of 2 sets of 100-ft sensors for the hold short line in DAB and are estimated to be $85 per 100-ft ("Aerosonic corporation," 2010). Further, the other option of control displays ranges $350 for 11" LCD ("Aerosonic corporation," 2010). The costs of the LCC system for the two configurations are highlighted in Table 6-1 and produce a total estimated cost of $3,170.

Table 6-1

RIPLS Financial Analysis

Equipment	**Cost**	**Benefit**	**Net**
Inset Lights	$3,000		
Twin Cables	$170		
Control Panel	$350		
	Option A: Analog		
Total LCC	$3,170		
	Option B: Touch Screen		
	$3,350		
RIPLS Installation	$85,000		
Electric Billing	$2,000		
Operations Training	$5,000		
Average Maintenance	$25,000		
Approximate Unit Cost	$123,870		
Margin for Error	$12, 387		
1.8 Lives Saved/Year		$1,440,000	
0.68 Injuries Avoided/Year		$226,780	
6.6 Less Aircraft Damaged/Year		$231,000	
Cumulative Total	$169,000	$10,896,000	$10,727,000

Based on a strictly quantitative cost-benefit analysis, the net return on investment (ROI) would be positive if numbers for benefits are calculated based on a 20-year useful life and span. Though not calculated, a 7% discount rate is encouraged for inflation adjustments space. As RIPLS' proposal can serve both front-end or back-end capacities based on implementation strategies, Option A and Option B are presented. A cost savings model that incorporates intangible elements can be extracted from a recent HCI Cost-Benefit Analysis Model that was developed for NextGen and Single European Sky ATM Research (SESAR) development

(Sherry, 2006a, 2006b). For hardware, cost estimated is based on FAA investment values (GRA, 2007). This calculation is what an insurance specialist would embark on and can capture the intangible cost and benefits of RIPLS implementation. From a strictly financial perspective, with even the most conservative estimates, the system would break-even after approximately five years. The potential of one to two million dollars lost for an incursion is assumed. The basis of this latter estimate is from the Airport Districts Office (ADO) historical patterns and numerical data for Orlando.

With RIPLS implementation, the differential likelihood of 1:10 million chance risk of accident is migrated to approximately 1:20 chance million and costs are estimated as so. The benefits for the implementation of RIPLS were gleaned from estimation of the potential savings associated with prevention of USAir Flight 1493 and the disastrous effects, as it remains of the most well-known runway incursion (RI) accidents attributed to poor situational awareness among other factors. According to the National Transportation Safety Board (NTSB), Flight 1493 had 34 fatalities and 30 injuries with 13 serious and 17 minor (NTSB, October, 1991). Estimation of human life is $5.8 million, $333,500 for serious injury, and $35,000 for aircraft damage to repair aircraft (FAA, 2008; GRA, Inc., 2007). The initial costs of RIPLS implementation could as well be offset by combining its installation with routine runway resurfacing or some other ground maintenance that takes place at airports. Also, if the FAA were to support RIPLS implementation, individual airports may be subsidized to help them cover costs. The heart of RIPLS is risk reduction, which translates to cost savings over a 20-year useful life.

7 Conclusion

Runway incursions are the most significant threat to people and property while aircraft are on the ground. Our team, through a series of surveys and meetings with SMEs, established that many aviation experts from a variety of fields recognize a need to have a redundant system to communicate to any vehicle on airport taxiways that a runway is safe to enter. RIPLS will make the hold short line even more obvious to pilots by adding a row of imbedded lights in the surface of the taxiway. RIPLS will also provide a second layer of communication between the pilots and air traffic controllers. If pilots are given clearance to cross a runway but the lighting system does not switch to green, this will cause pilots verbally check through radio if they are in the right place. They will then communicate with the controller and establish a safe way to proceed to their destination, if they are indeed in the wrong location. RIPLS is a redundant safety measure, which will give more control to ATC and will help to mitigate lapses in situational awareness that may occur in pilots, ground crews, and ATC.

Appendix A: Contact Information

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Appendix B: Description of University

At Embry-Riddle Aeronautical University, what we do – and do best – is teach the science, practice, and business of the world of aviation and aerospace.

Since it was founded just 22 years after the Wright brothers' first flight, the University and its graduates have built an enviable record of achievement in every aspect of aviation and aerospace. The curriculum at Embry-Riddle covers the operation, engineering, research, manufacturing, marketing, and management of modern aircraft and the systems that support them. The university engages in extensive research and consulting that address the unique needs of aviation, aerospace, and related industries.

Residential campuses in Daytona Beach, Florida, and Prescott, Arizona, provide education in a traditional setting, while Embry-Riddle Worldwide provides instruction through more than 130 campuses in the United States, Europe, Canada, and the Middle East, and through online learning. All academic programs at Embry-Riddle are approved for veteran's educational benefits and are accompanied by personalized academic advancement.

ERAU prides itself for the diverse education its students receive. Academics at ERAU include aviation operations, meteorology, human factors psychology, systems engineering, software engineering, humanities, international relations, communication, mathematics, aerospace engineering, physics, business, and much more. The university community is additionally proud of the quality of the education obtained. Class size at both the Daytona Beach and Prescott, AZ campuses averages 24 students and the overall undergraduate student-faculty ratio at these campuses is 16 to 1. Low class sizes make possible the use of interactive and authentic approaches to learning, such as project-based learning approaches.

The university values community diversity and actively encourages diversity by means of programs aimed to support and provide education about minority groups, including ethnic minorities, gender-identity minorities, religious minorities, students with handicaps, and so forth. The ERAU Office of Diversity Initiatives was created by the current ERAU President, Dr. John P. Johnson, to help build a positive climate in which all students, faculty and employees are encouraged in their professional, social, and intellectual pursuits. Among its many efforts, the ERAU Office of Diversity Initiatives is involved in community outreach programs designed to foster interest in science, technology, engineering, and math among women and underrepresented groups in the K- 12 educational system. Pilot projects include a GEMS (Girls Exploring Math and Science) Camp during summer months and the introduction of an aviation/aerospace program for all 6th graders at Campbell Middle School in Daytona Beach. Both ERAU campuses participate in the Ronald McNair Scholars Program, a program that seeks to increase the number of Ph.D. degrees obtained by students from underrepresented segments of society.

Appendix C: Description of Non-University Partners

Not Applicable

Appendix E: Team Reflections

E-1 Dr. Kelly Neville

This team of nine students ran their project democratically. They did not appoint a leader, team members shared the floor during meetings, and team members' ideas were given equal consideration. This was a difficult team model for such a large team to execute because so much information and so many ideas were continuously being produced in parallel. This team model, while it facilitated a greater diversity of ideas and contributions, also produced a much higher workload than a more standard hierarchical structure.

Yet, the RIPLS team made this team structure work. They took the time to listen and evaluate the continuous flow of information and ideas and they made the (continuous) effort to work through it all and, as a group, to decide on which path(s) to take forward and what path adjustments to make.

I was impressed by the effort, maturity, and commitment that each member of the RIPLS team demonstrated. I think each gained a new respect for what a team can accomplish when everyone participates and for the variety of ways different people can contribute to and enrich a team effort and its products. The team members also learned about the difficulties and benefits of a democratic/flat team structure.

This team experienced at least one 'false start', where the design solution they were pursuing had to be abandoned. Through this challenge and the difficulty they faced in agreeing, as a group of nine, on the best focus for their efforts, they all remained positive, upbeat, and respectful of one another. If they did not previously appreciate the importance of remaining positive, respectful, and cohesive through such challenges (and clearly, some did), they gained this appreciation through this competition experience.

This team additionally did a fantastic job of tackling the challenge of learning about a domain that was new to almost all of them. For example, the team members sought feedback from many aviators and aviation personnel, arranged to tour the local air traffic control tower, and reached across the university to visit air traffic control courses. I was pleased with the appreciation they gained for the need to interact with and involve subject matter experts (SMEs) in their design work; and I was pleased with all they learned about airport operations.

This competition is a rite of passage of sorts. It turns insecure or timid students into confident students and emerging professionals who are ready to take on the next big challenge—either with a team or on their own. The competition also contributes to the development of bonds among our students. Embry-Riddle participants in last year's FAA competition teams have been taking classes as a team, conducting research projects as a team, and even going out into the workplace as a team! They continue to take advantage of the energy and rapport they developed while working on their competition project. I am already seeing this type of continued team energy with the RIPLS team and am looking forward to having almost all of them in my Memory and Cognition class this Spring semester.

E-2 Erik Schmidt

Working on this project has given me greater insight into the risks of aviation and a greater appreciation for the many "unsung heroes" that continue to keep the airport environment a relatively safe place. My favorite experience by far was being able to take a tour of the ATC tower. Everyone was incredibly friendly and surprisingly receptive to the idea of RIPLS. As soon as we mentioned what our project was about, the controllers told us story after story of how people seem to completely fail to recognize the hold short line and enter the runway when not authorized to. Thankfully, the vast majority of these mistakes do not end in tragedy. However, it was the goal of this team to reduce that risk of tragedy even further by providing greater visual stimuli to the people on the ground and an extra layer of control for the air traffic controllers.

E-3 Casey Smith

As a person with little background in systems engineering, this project was initially difficult for me. I did, however, learn a fortunate lesson: as intimidating as any endeavor may seem, things become much more clear and manageable as you advance forward. With a limited timeframe and several personal and peripheral factors taxing each member, our team was able to assume our respective roles and deliver each portion brilliantly. This experience taught us that things tend to come together if you remain focused and tenacious.

Each member was able to capitalize on his/her strengths as well as develop effective and creative ways to mitigate weaknesses. I believe the experience gave the team priceless real-world experience with systems engineering and project management. I am proud of the project that the group has put together. This is not just because the system belongs to my specific team, but because I admire the effort, ingenuity, sacrifice, and dedication that have been contributed. I am honored to have assisted in this process.

E-4 Nicholas Stapleton

While earning my pilots licenses and endorsements, I have seen and studied how runway incursions can cause devastation. Though my experience starting this project was primarily from a pilot’s standpoint, designing this system, reviewing the needs of other shareholders, and fully understanding the benefits and shortcomings of the current system have allowed me to have new insight into how safe aviation currently is, new technology that will make aviation safer now, and what we can still do to make aviation safer in the future. Working on this project has given me a fairly unique opportunity to potentially influence future safety of aviation in this country.

Thanks to the diverse background of our team members, we were able to balance each other's strengths, come up with unique ideas, and provide a design with few holes. Regardless of whether or not our system will ever be implemented, it has given us great insight into aviation safety that we will be able to apply in the future.

E-5 Tammy Strauss

Participating in the FAA Design Competition was an amazing experience. From the beginning, the spirit of being a participant and possibly submitting a proposal that could one day save the life of a pilot, passenger, or airport vehicle operator fueled my desire to learn as much as I could about the aviation safety culture.

I feel the biggest challenge our team had to overcome in the early stages of the process was the fear that there would be limited interactions due to the compressed timeline we were given. However, with so many of my team members being of the "electronic" generation I found I was kept well-informed through e-mails and instant messages. I would highly recommend the free flow of information via any electronic device for a small project situation like ours.

Our team utilized the weekly meetings afforded by our professor, Dr. Neville, to brainstorm ideas and ultimately select our competition topic – decreasing runway incursions. Our team had the opportunity to research several different ideas prior to making our final selection.

As the "old-timer" in the group, I originally felt overwhelmed by the youth and energy my teammates exhibited. As the team developed into a cohesive unit I learned that age was not a factor when we focused on the ultimate goal of winning the FAA Design Competition for Universities. I feel the experience has given me the confidence to further my education in the

Human Factors domain and has shown me that I can work with a wide-range of colleagues of varying ages and backgrounds.

E-6 Glenn Surpris

The FAA Design Competition provided a meaningful learning experience for me as a graduate student. It was the first time in my educational career that I had been exposed to and have had the privilege of working on such a serious and large project. My largest point of learning was about ATC procedures and the ATC personnel structure. More peripherally, I was able to learn about how to effectively coordinate between team members and how to format large documents efficiently. I feel like the skills I have acquired from working on this project would help me to be a better professional and a more valuable asset on a research team. Our biggest project challenge was finding a problem to solve. We were aiming for an airport management problem because we thought that it was a new problem that not many people have tackled before. After a couple of failed ideas, we decided to focus on runway incursions after speaking with subject matter experts (SMEs) that pointed out that there was still much to do in the area. This is where the idea for RIPLS originated. We are greatly appreciative to our SMEs for helping us develop our idea for RIPLS. They played a large role in helping us identify potential problems with our design and ways our design could help integrate with existing technology and ATC procedures.

E-7 Anna Vitalis

The FAA Design Competition provided a meaningful learning experience for me because I learned how problematic simple miscommunications can be amongst air traffic controllers and pilots, and how that increases the possibility of a runway incursion. One of the biggest challenges our team encountered in this competition was choosing a topic. We had a mixed group with different experiences on our team. Some were very familiar with the layout and technologies associated with typical airports and aircraft cockpits, while the others had less technical/aviation experience in their background. Collectively, however, our team was strong. The group consisted of subject matter experts (pilots, air traffic controllers, and aircraft maintenance personnel), experienced researchers, writers, and editors, all of which were crucial in the final product design. In the initial phases of our meetings, we came up with what seemed to be great ideas. However, after further research, we realized they were not. After many extensive brainstorming sessions, we finally found a topic that was both innovative and feasible, and something our team truly feels can prevent runway incursions from happening. From this experience, I learned that creating any design for the FAA is a very research-intensive project, requiring many interviews, literature reviews, and most importantly, teamwork. Overall, I feel we created a proposal that can save lives and save money, which is an essential part of any design.

E-8 Travis Wiltshire

This project, from the first day, seemed very daunting. It was clear to me from day one that there was a wealth of aviation information out there that I needed to know in order to fulfill my contributions to our team. I immediately started researching how planes, airports, and controllers all work together. I had to learn the system I was attempting to innovate upon. I quickly learned that even with a group of nine people it can still be a challenge to innovate. Communication was the first hurdle our group had to overcome. In our group meetings, everyone had some information to share or idea to suggest. In order for each team member to feel valued on the team, each person was given the full attention of their teammates during their turn to share their ideas. It was tremendously refreshing to have a team committed to carrying their own weight throughout the project. I was thoroughly pleased with the level of team cohesiveness on the FAA design competition.

From this project, I learned the basics of systems engineering. I believe this project was a valuable first step for learning to design systems later on in my career. It was incredible to see that the topics we learned in class could all be tied into the development process of our FAA design. Our group found some difficulty in assessing the problem area and picking a solution. After researching our first idea, we found that our solution may have been impractical. After we all decided upon the RIPLS design, the project flowed smoothly because there was much less confusion amongst team members. At that point, our team was all on the correct page and we began researching and writing our report contributions. I was assigned to discuss the existing technologies and projected impacts of the design. I learned from the writing process the value of input from team members to ensure that the ideas presented represent those of the team.

E-9 David Yacht

Participating in the FAA project was a fantastic experience. Together, we came up with a great solution to a problem that is plaguing our airports. We did this in a short amount of time and without funding. I am proud to say I worked with such an enthusiastic group of men and women with a myriad of backgrounds ranging from nursing and engineering to business and aircraft maintenance.

Being in the Navy, I am used to working as part of a team. In the Navy we would have many team building exercises to encourage trust and build moral. I feel that working on the RIPLS team has added an invaluable experience to my team participation experiences. Going forward into the Human Factors program and as a business professional, I can always use what I learned from this experience to enhance my learning for the future.

E-10 Zhengzhong Yu

The FAA Design Competition provided a meaningful experience because it offered me exposure to industry leaders and professionals in aviation that work at Embry-Riddle. While we work and study at the same school, it gave me the opportunity to branch out and see what my colleagues and peers are studying. Given my social science background, the experience helped develop my previously limited understanding of aviation and its challenges. The challenges we faced were mostly a function of resource availability and overall feasibility. Keeping these factors in mind, the team did its best to design for a problem that currently compromises aviation safety. Our efforts to find a solution were aided by trial-and-error and the experimental process was enjoyable as we slowly uncovered ways to make our design more innovative and successful. I had a great time interacting with our subject matter experts and each provided invaluable help. In my interactions with teammates and SMEs, I learned some humility and technical terminology that I would not otherwise encountered in my career.

Appendix F: References

Aerosonic corporation. (2010). Retrieved from http://www.aerosonic.com/index.html

Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., Martin, R.C., Mellor, S., Schwaber, K., Sutherland, J., & Thomas, D. (2001). *The Agile Manifesto.* Retrieved from http://agilemanifesto.org/principles.html

Eggert, J., Howes, B., Kuffner, M.,Wilhelmsen, H., & Bernays, D. (2006). Operational Evaluation of Runway Status Lights. [Electronic Version] *Lincoln Laboratory Journal, 16* (1), 123-146.

Federal Aviation Administration. (2007). *Fact sheet – nextgen.* Retrieved from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsid=8145

Federal Aviation Administration. (2008). *Aviation instructors handbook. (rev. ed. Rep. No. FAA-H-8083-9A)*, Washington, D.C.: U.S. Department of Transportation.

Federal Aviation Administration. (2009a). *Annual runway safety report.* Retrieved from http://www.faa.gov/airports/runway_safety/news/publications/media/Annual_Runway_Safety_Report_2009.pdf

Federal Aviation Administration. (2009b). *Fact sheet – runway safety*. Retrieved from www.faa.gov/news/fact_sheets/news_story.cfm?newsId=10166

Federal Aviation Administration. (2009c). *Fact sheet – runway status lights.* Retrieved from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=10255

Federal Aviation Administration. (2010). *Fact sheet - automatic dependent surveillance-broadcast (ADS-B).* Retrieved from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=7131

Federal Aviation Administration. (2010). *Fact sheet - airport surface detection equipment, model x (ASDE-X) fact sheet*. Retrieved from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=6296

Federal Aviation Administration, Air Traffic Organization. (2008). *Air traffic organization safety management system manual (Version 2.1).* Retrieved from http://atcvantage.com/docs/FAA_ATO_SMSM_v2-1_052008.pdf

Flight light inc. | airport runway lighting & obstruction lighting. (2010). Retrieved from http://www.flightlight.com

Fowler, M., & Scott, K. (n.d.). *Uml distilled (2nd ed.*). Addison-Wesley.

GRA, Incorporated. (2007). *Economic values for FAA investment and regulatory decisions, a guide*. Retrieved from http://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/050404%20Critical%20Values%20Dec%2031%20Report%2007Jan05.pdf

Haskins, C, Forsberg, K., Krueger, M., Walden, D., & Hamelin, R.D. (2010). *INCOSE Systems Engineering Handbook, version 3.2* (Report No. INCOSE-TP-2003-002-03.2). Retrieved from INCOSE website: SE Handbook 2010-0201 v3.2 Updated Final 8.5x11.pdf

International Civil Aviation Organization. (2007). *Manual on the prevention of runway incursions, 1st ed.* (Doc 9870 AN483). Quebec, Canada: ICAO. Retrieved from http://www.faa.gov/airports/runway_safety/publications/media/ICAO%20Runway%20Safety%20Manual.pdf

Kuchar, J., & Drumm, A. (2007). The Traffic Alert and Collision Avoidance System. *Lincoln Laboratory Journal, 16* (2), 277-296.

Management Sciences of Health. (2010). *Stakeholder analysis*. Retrieved from http://erc.msh.org/quality/ittools/itstkan.cfm

Mertz, C., Chatty, Stephane, C., Vinot, J. (n.d.). *The influence of design techniques on user interfaces: the DigiStrips experiment for air traffic control.* Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.77.4404&rep=rep1&type=pdf

Randazzo, J. & McCann, M. (2007, August). *Testing and evaluation methods of the runway status lights system*. Paper presented at the American Institute of Aeronautics and Astronautics Guidance, Navigation and Control Conference and Exhibit, Hilton Head, South Carolina. Abstract retrieved from http://acy.tc.faa.gov/cpat/docs/gncInvitedSessionsDir/AIAA-2007-6521-340.pdf

Roa, M. (2010). Model-based systems engineering. SysML tutorial handout.

Rosenkrans, W. (2008). Timing Is Everything. *Aerosafety world*, 46-50.

Sherry, L., Fennel, K., Feary, M., & Polson, P. (2006a). Analysis of ease-of-use and ease-of-learning of a modern flight management system. *Journal of aerospace computing, information, and communication, 3*, 177-186.

Sherry, L., Fennell, K., Feary, M., & Polson, P. (2006b). Human-computer interaction analysis of flight management system messages. *Journal of Aircraft, 43*(5).

Tapke, J., Muller, A., Johnson, G., Sieck, J., (n.d.). *House of quality: steps in understanding the house of quality*. Retrieved from http://www.public.iastate.edu/~vardeman/IE361/f01 mini/johnson.pdf

Thompson, R. (2010). *Stakeholder analysis winning support for your projects.* Retrieved from https://intranet.panda.org/documents/folder.cfm?uFolderID=60976

U.S. Department of Transportation, Federal Aviation Administration. (2010). *Air traffic organization policy*. Retrieved from http://www.faa.gov/air_traffic/publications/ATpubs/ATC/atc0302.html#atc0302.html.1

Vicente, K. & Rasmussen, J. (1992). Ecological interface design: theoretical foundations. *IEEE transactions on systems, man, and cybernetics*, *22*(4). Retrieved from http://ritter.ist.psu.edu/misc/dirk-files/Papers/HCI/Ecologicalinterfacedesign.pdf

World Wildlife Fund. (2005). *Cross-cutting tool stakeholder analysis*. Retrieved from https://intranet.panda.org/documents/folder.cfm?uFolderID=60976