2018-2019 ACRP UNIVERSITY DESIGN COMPETITION

IoT in the Cockpit: Intelligent Runway Status Indication System (IRSIS)

April 2019

Design Challenge Addressed: Runway Safety/Runway Incursions/Runway Excursions

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IoT in the Cockpit: IRSIS

1. Executive Summary

According to the records from the Aviation Safety Reporting System, runway incursions demonstrates a dramatic increasing trend since 2001 (NASA, 2019). Solutions have been developed and implemented to mitigate the risk of runway incursions, however current solutions are cost prohibitive, and mostly limited to international hub airports with adequate resources. General Aviation (GA) and non-hub commercial airports lack affordable and practical preventive solutions to runway incursions. In that case, development of alternative low cost and effective strategies is critical for resource constraint airport operators to mitigate runway incursion risk in routine operations. Leveraging the emerging intelligent transportation technologies and existing aviation technology, such as the Internet of Things (IoT), Geo-fencing, Automatic Dependent Surveillance-Broadcast (ADS-B), and Differential Global Positioning System (D-GPS), this project proposes an Intelligent Runway Status Indication System (IRSIS) to provide an automatic three-dimensional (3-D) runway incursion prevention strategy. The IRSIS is designed to monitor surface traffic movements as well as airborne traffic statues, detect potential risk of runway incursions, and communicate with pilots, air traffic controllers, and ground crew with warning information in a real-time manner to prevent runway incursions.

The background of the team includes professional pilot, aviation administration, and emergency management. Team members also have front-line experience as private pilots, and former members of the Delta Go Team. Engaged industry professionals have significant experience as pilots, air traffic controllers, air traffic management subject matter experts, airport managers, and airlines managers. In addition, professors with aviation safety and engineering provided professional inputs for the competition design as well. This project was started in the January of 2019 and completed in the April of 2019.

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3. Background and Problem Statement

Runway incursion is one of the top safety concerns that involves pilots, air traffic control (ATC), and ground operations (FAA, 2012). In the United States, approximately three runway incursions occur each day at towered airports (FAA, 2012). Runway incursions resulting in collisions have the potential to cause severe damage to both people and property. The FAA adopted the definition of runway incursions from the International Civil Aviation Organization (ICAO) 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" (ICAO, 2007). Scenarios, such as bad weather, low visibility, construction, airport unfamiliarity, time of day, distractions, fatigue, and miscommunications with ATC, add greatly to the challenge of surface navigation that can lead to significant damage and fatalities.

According to the FAA, approximately 65% of runway incursions are caused by pilots (FAA, 2012). Majority of those can be further attributed to GA pilots. The insights from ten years of detailed investigation have led to three major factors contributing to runway incursions: failure to comply with ATC, lack of airport of familiarity, and nonconformance with standard operating procedures. Those factors outline the difficulty of effective communication between ATC and pilots, as well as the uncertainty that pilots often face as it relates to runway status.

Airport movement areas are in need of increased monitoring with ground vehicles and personnel being vulnerable and potential risk to runway incursions. The Airport movement areas are defined as the runways, taxiways, and other areas of an airport that aircraft use for taxiing, takeoff, and landing (exclusive of loading ramps and parking areas) under the control of an air traffic control tower (ACRP, 2014). There are a diversity of activities occurring in critical and safety-sensitive airport movement areas. Monitoring all entities in airport movement areas can provide additional situational awareness and runway status accuracy. There are a number of variables that must be monitored, such as (ACRP, 2014):

- Aircraft fleet (size, diversity, evolution)
- Airline/aircraft operator flight schedules
- Airfield size/configuration
- On-airport facility locations
- Time of day that activities occur
- Size/type/location of construction projects
- Weather/visibility

Understanding the potential benefits of implementing best practices for working at airports is expected to help increase overall operation safety. The Next Generation Air Transportation System (NextGen) refers to the federal programs (predominantly airspace, air traffic, or avionics related) that are designed to modernize the National Airspace System (NAS) (ACRP, 2016). This initiative aims to inform airport operators about some of these programs and how the enabling practices, data, and technologies resulting from them will affect airports and change how they operate. Taking advantage of data from emerging ground-based and space-based communications, navigation, and surveillance technologies; and integrating data streams from multiple agencies and sources increase situational awareness and seamless global operations for all appropriate users of the system (ACRP, 2016). Airports are vital in achieving the goals of these NextGen systems, yet the costs make implementation a challenge for most operators.

The IRSIS design is an intelligent 3-D runway status detection and communication system that provides pilot, ATC, and ground operation personnel additional insight to other parties. Leveraging technologies currently in place, such as the Internet of Things (IoT), geo-fencing, ADS-B and D-GPS navigation, the IRSIS is designed to be a low-cost and adaptive solution for all types of airports to increase the overall situational awareness and mitigate runway incursion risk. The principle of IRSIS is to provide a multilateral system that can alert both pilot and ground-based operators of current airport runway status. By predefining geo-location-based boundaries for airport critical areas, such as a runway, runway intersections, and airport hotspots, objects entering and exiting those critical areas will automatically trigger IRSIS alert to other vehicles that might enter the occupied areas. Furthermore, IRSIS offers an intuitive human machine interface in the cockpit to provide runway alerts directly to the pilot to eliminate potential distraction and adverse environmental factors. Based on the interaction with industry and academia professionals, a system with the cost, functionalities, and features that IRSIS offers is highly desired by pilots, ATC, and airport operators. In addition to principle of design, an example of system implementation, safety risk analysis, cost-benefit assessment, and potential impact are presented in this report.

4. Literature Review

Runway incursion is one of the biggest concerns for airport surface operation safety due to the high frequency and potential significant severity. The Aviation Safety Reporting System shows 267 reported runway incursions, as of February 13, 2019 (NASA, 2019). Nearly 84% of runway incursions were reported as a result of human factors such as communication breakdown, confusion, and situational awareness (NASA, 2019). Additionally, weather conditions resulting in haze/smoke, rain, snow, fog, or cloudy conditions can further aggravate circumstances for involved aviation activities. The impact of those factors can be seen in the Tenerife accident, where two B-747 aircraft collided taking the lives of 583 people (Weick, 1990). The cause was a breakdown in communication, dense fog, and loss of situational awareness (Weick, 1990). Another instance occurred in the August of 2006 when Comair flight 5191 crashed after attempting to take off from the wrong runway, killing 49 of the 50 people on board (NTSB, 2007). Those situations highlight the importance of widely implementing more effective strategies to further mitigate the risk from human and environmental factors.

There have been a variety of research conducted by different stakeholders on runway incursion prevention strategies, such as airport surface traffic surveillance technology and runway incursion detection algorithms. Those strategies are based on protecting measures against causes of a runway incursion such as operational error, operational deviation, pilot deviation and vehicle/pedestrian deviation (Keller, 2003). Previous studies concluded that runway incursion avoidance was primarily based on the improvement of situational awareness. Systems such as ADS-B, Runway Status Lights (RWSL), and the Advanced-Surface Movement Guidance and Control System (A-SMGCS) provide effective solutions to enhance route awareness and traffic position awareness of both ATC and pilots (Schoenfeld, 2012). However, runway incursions are still occurring at an increasing rate. The National Transportation Safety Board (NTSB) stated that, "A direct in-cockpit warning of a probable collision or of a takeoff attempt on the wrong runway can give pilots advance notice of these dangers (NTSB, n.d., 2007). The NTSB statement pointed out the importance and possibilities of appropriate in-cockpit warning technologies in runway incursion prevention.

4.1 Current Runway Incursions Prevention Systems

A number of runway incursion avoidance strategies have been approved and encouraged by the FAA. Most notably, the Airport Surface Detection System - Model X (ASDE-X), the Runway Status Light System, and A-SMGCS are examples of successful runway incursion technologies. Most current studies indicate that the addition of the Internet of Things (IoT) within the airport environment leverage emerging technologies to provide information to the participants involved (ACRP, 2018). The goal is to enhance situational awareness by integrating advanced technologies in airport operations, but it still faces many challenges towards implementation. High cost of installation and operation, system reliability and accuracy are two of the most prominent examples of challenges for airport operators when considering implementation of new technology. The Automatic Dependent Surveillance – Broadcast (ADS-B) is a satellite-based surveillance technology being deployed throughout the National Airspace System as a core component of the Next Generation Air Transportation System (FAA, 2016). The implementation of ADS-B provides pilots and air traffic controllers of better situational awareness of the operation environment. In addition, ADS-B shifts aircraft separation and air traffic control from ground-based radar to satellite-derived positions. ADS-B Out determines the GPS position of aircraft and broadcasts the position along with additional information about the aircraft to nearby ADS-B In capable devices used by ATC and other pilots (Collins, 2018). The ADS-B Out signal is transmitted to other ADS-B In capable aircraft either directly or relayed by ground stations, to enable pilot to maintain self-separation with increased situational awareness. An aircraft equipped with ADS-B In can also display Flight Information Service - Broadcast (FIS-B) weather and other traffic advisory information on the cockpit displays or wirelessly on a tablet. Pilots and ATC can access local traffic information from the Traffic Information Services (TIS). The effectiveness of this technology relies on the setup of tracking devices at the airport and aircraft onboard systems. ADS-B incorporates surveillance technology for tracking aircraft and provides free traffic, weather and flight information as well as messaging including position, altitude, and speed. Traffic Information Service Broadcast (TIS-B) is a service that transmits relevant traffic position information to ADS-B In equipped aircraft within the coverage of ADS-B services (Mozdzanowska, 2007). As ADS-B Out continues to be equipped to most aircraft in the U.S. by January 2020, better quality and applications of ADS-B services are expected to further improve flight safety (14 Code of Federal Regulations, Part 91.225, 2001; Part 91.227, 2014). The benefits of equipping aircraft with ADS-B can vary aside from enhancing situational awareness. According to the Aircraft Owners and Pilots Association (AOPA), it can also allow more efficient search and rescue using ADS-B's GPS-based surveillance to provide more accurate information about an aircraft's last reported position (AOPA, 2015). The possibility comes from the capability that ADS-B Out broadcasts flight data approximately once every second, compared to a ground-based radar sweep rate of 3-15 seconds. ADS-B can also provide more efficient spacing and optimal IFR routing without radar coverage, including the Gulf of Mexico, mountainous regions of Colorado, and lower altitudes in some parts of Alaska (AOPA, 2015).

Despite numerous benefits of ADS-B, cost remains prohibitive for successful nationwide implementation. Aviation operators, especially General Aviation operators with resource constraints, find it difficult to meet the requirement of ADS-B Out equipage. Another limitation of ADS-B is the potential vulnerability to disruption from outside entities. Experts claim that ADS-B (and GPS in general) is vulnerable to system infrastructure attacks such as hackers or GPS jamming (Houston, 2017). Additionally, since ADS-B is reliant on the Global Navigation Satellite System (GNSS), common satellite errors such as timing errors and satellite weather errors can impact the normal functioning of ADS-B (The Research Institute of China Technology Group Corporation, 2017).

ASDE-X utilizes a combination of Surface Movement Radar (SMR), Multilateration and ADS-B to provide highly accurate traffic position information and intuitive human machine interface (HMI) to ATC. The integration of different positioning systems enables ASDE-X to provide good resolution, service coverage, and accuracy of position information. The purpose of this technology is to reduce Category A and B runway incursions. Category A defines a serious incident in which a collision was narrowly avoided. Category B is 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 (FAA, 2015a). The introduction of ASDE-X provides detailed data on aircraft movements on the airport surface, which is essential to prevent such incidents or accidents. Different positioning systems track all aircraft on the airport surface by collecting and fusing data from a variety of sensors, enabling ASDE-X to track both non-transponders equipped and transponder equipped vehicles and aircraft on the airport movement area.

The ASDE-X equipment gathers position data from aircraft and vehicles and alerts ATC of potential conflicts and safety concerns. Alert information could be presented to ATC outlining aircraft or vehicle’s position and identity. The ASDE-X provides one second position reports on each track of data to the airport map, which can greatly enhance the situational awareness of controllers (FAA, 2014). It's particularly beneficial to offsetting issues of poor visibility at night or due to adverse weather conditions. The ASDE-X reports consist of two main types of messages that come in the XML data distribution format: system track reports and status reports. Status reports contains the information about the components of the ASDE-X, whereas system track reports provide information regarding the vehicle being tracked. However, the estimated cost of an ASDE-X installation is $44.11 million (FAA, 2007).

The RWSL is another fully automatic advisory system for runway incursion prevention (FAA, 2018b). RWSL automatically sets the runway entrance lights and takeoff hold lights in accordance with current state of occupancy of the runway in use. The effectiveness of RWSL relies on the positioning sensors being used, which determine the reaction time of lighting. The RWSL utilizes traffic data from the ASDE-X as the primary input (FAA, 2018b). Currently, there are 20 airports with RWSL deployed in the U.S. (FAA, 2018b). Situations where taxiing aircraft or ground vehicles get in the way of another aircraft that are landing or taking off, are currently the biggest threat to aviation safety. With many runway incidents being caused by pilot error, providing pilots of additional warning information aside from ATC could potentially prevent runway incursion related accidents. Runway status lights are designed to automatically interface with surface surveillance systems and other technologies to give pilots a quick and simple warning so that two aircraft do not attempt to cross a runway at the same period of time. The use of RWSL at the Dallas Fort-Worth (DFW) International Airport have demonstrated to be an effective strategy to decrease runway incursions by 70% (Conkey, 2008).

RWSL is designed to be compatible with existing procedures without interfering with airport operations. The essential attributes for RWSL are as follows (FAA, 2008):

- Provides timely warnings of potential conflicts
- Automatically provides information without human input
- Acts independently and does not interfere ATC operations
- Indicates status only and does not issue ATC clearance
- Prompts pilots to notify the tower if a contradicting clearance has been issued

These attributes highlight the benefits of RWSL and how RWSL works to mitigate the risk of runway incursion. Despite those benefits, RWSL still has many limitations for wide implementation. One of the biggest roadblocks being presented to a nationwide rollout of RWSL is managing cost overruns, in addition to possible delays and false alerts. Even with the success from the initial implementation of RWSL, DFW is undergoing further upgrades costing millions of dollars (Russell, 2017). FAA recognizes the need to expedite technologies that could improve situational awareness of cockpit crew to further reduce the probability of runway incursions (FAA, 2012). An easier and cost effective strategy to enable cockpit technology to alert pilots if aircraft are on the wrong runway or taxiway is expected to be a practical and effective solution for runway incursion prevention.

4.2 Implementation of NextGen Systems

The FAA is currently leading the modernization of the National Air Transportation System, in an effort known as NextGen. NextGen seeks to increase the safety, efficiency, capacity, predictability, and resiliency of aviation activities in the U.S. It encompasses the combining of innovative technologies, capabilities, and procedures that improve how we fly from departure to arrival. This transformation is one of the most ambitious infrastructure projects in U.S. history, with the rollout of ongoing improvements starting in 2007 until all major components are in place by 2025 (FAA, 2018a). NextGen has opened the door to various new opportunities to leverage these technologies at an almost unlimited capacity.

The Internet of Things (IoT) is an innovation that greatly extends the applications of internet into physical devices. IoT is defined as the infrastructure that enables advanced services by interconnecting physical and virtual things based on existing and evolving interoperable information and communication technologies (ACRP, 2016). The wave of connectivity goes beyond laptops and smartphones, towards connected wearables, vehicles, and smart cities. Industries such as healthcare, transportation and manufacturing are taking advantage of how IoT devices connect interactions between multiple devices, allowing greater access to specific data. In a survey conducted by Texas A&M Transportation Institute and Deloitte Consulting, LLP, 76% of respondents using IoT indicated that they used IoT for efficiency optimization, compared with 58% for the purpose of customer experience differentiation, and 35% for new revenue (Deloitte, 2017). The value in IoT is how it enables physical objects to see, hear, think, and perform jobs by having them share information and coordinate decisions.

The term connected airport refers to a wide variety of IoT technologies and applications deployed at airports that utilize similar loop method to communicate. Enabling data-driven and collaborative decision making is how IoT creates value in business. Table 1 showcases the fundamental components involved in this process. The smart technologies of today can be described by a multitude of terms such as: wearables connected devices and ubiquitous computing. While these technologies are not entirely the same, they share several similar components. IoT requires physical objects that are instrumented to collect data about their location, state, or other activities. In order to efficiently retrieve the data from the physical objects, connectivity is required. This allows a pathway to transfer data from all sensors and devices within the entire IoT system. The final component is analysis, which provides information that can lead to an appropriate conclusion or response.

Table 1

Fundamental components of IoT (ACRP, 2016)

Physical Object	The things themselves, such as a person, luggage, or boarding pass
Instrumentation	A smart component: sensor or other data collection system
Connectivity	A network-based device facilitating the interconnection between an object, its environment, and data management system.
Analytics	Actionable information gained from the analysis of data created

IoT also allows the introduction to additional systems that can further increase airport operations and safety. Geo-fencing enables a remote monitoring of geographic areas surrounded by a virtual fence (Geo-fence), and automatic detections when tracked mobile objects enter or exit the specified areas (Zimbelman, Keefe, Strand, Kolden, & Wempe, 2017). With the accuracy of Geo-fence alerts affected by the Global Navigation Satellite System (GNSS) errors and angle of approach, Geo-fencing for occupational safety is appropriate for general situational awareness. Utilizing a predefined Geo-fencing boundary allows the location of an object to be consistently monitored within the designated area. By gathering and transmitting the coordinates of monitored objects, Geo-fencing technology can automatically determine whether the object enters or exits the predefined geo-fenced area. Implementation of Geo-fencing technology with the support of IoT in the airport environment could drastically increase awareness of all equipment, personnel and passengers operating within the determined airport perimeter.

The current applications of IoT at airports focused on improving traveler information systems, passenger traffic monitoring, baggage handling systems, and facilities management. Airports have only begun to touch the surface of what IoT can achieve. Despite these various benefits, there still remain many barriers to implementation for IoT. Two significant barriers pertaining to IoT in physical buildings are the large capacities of storage required for the magnitude of data gathered by IoT, and the inherent privacy risk associated with monitoring individual movements of people (ACRP, 2018).

4.3 Regulation, Operating Procedures and Training

To further improve runway incursion prevention, new regulations and requirements have been specified by the FAA and ICAO. Primarily dedicated to ensuring the accuracy and reliability of technology, relevant technical requirements define the minimal performance of the system for determining the position, orientation, speed and identification of the vehicles at the airport. The effectiveness of systems such as ASDE-X depend on operators' equipage and operating cooperative surveillance capabilities (i.e., altitude reporting transponders). Nationwide, airports with ASDE-X report an average of twenty non-compliance transponder events per day (FAA, 2018b). The regulations implemented by the FAA are geared towards standardizing technological systems at all airports. After January 1, 2020, unless otherwise authorized by ATC, no person may operate an aircraft in Class A airspace unless the aircraft has equipment installed that meets the performance requirements in TSO-C166b (FAA, 2018a). The rules apply to all aircrafts in that airspace, including foreign registered aircrafts. Through pilot training, general aviation seminars, NTSB reports and updated training procedures; runway incursions prevention strategies are expected to continually become more effective.

The FAA has issued new regulations related to new emerging aviation safety. Nearly 475 people are killed each year in what NTSB classifies as preventable incidents (American Society of Safety Engineers, 2013). Following the plane crash in San Francisco, CA, on July 6, 2013, the FAA issued increased pilot requirements for first officers who fly for U.S. passenger and cargo airlines. This new rule required first officers (commonly called copilots) to hold an Airline Transport Pilot (ATP) certificate, requiring 1,500 hours of flight time. The past regulation only required 250 hours of flight time for a commercial pilot certificate. In addition, several other new training requirements: first officers must be trained and tested for the specific type of airplane they will be flying; and pilots must have a minimum of 1,000 flight hours as a copilot before being promoted to a captain position (American Society of Safety Engineers, 2013). The FAA has continually recognized that these fatal incidents are most often attributed to human error and that proper training of both pilots and ATC will reduce these occurrences.

The recent fatal plane crash of Ethiopian Airlines Flight 302 on March 10, 2019 has opened the door to resurfacing concerns of the safety of aviation. This is the second fatal crash involving a Boeing 737 Max 8 in only five months. While a final conclusion of the cause may take time to determine, experts have speculated that a new automated system meant to prevent "aerodynamic stalls" —which occur when a plane isn't producing enough lift and are addressed by pointing its nose down—may have sent the plane into a dive after detecting a stall where none existed. As a result, many national regulators have grounded the aircraft, causing Boeing $12.7 billion lose in market value (Fitzpatrick, Hennigan, 2019). While the FAA insisted that the plane was safe, many passengers became uneasy about its use. This has led to new concerns on how these innovative systems are implemented and regulated within aviation. In this case, well developed and conducted training on this aircraft model as well assist new automated system may have allowed the pilots to avoid these devastating events. Integrating new systems within the training requirements for both pilots and ATC is essential for safety and security of the national airspace and aviation operations.

As the FAA has implemented gradually increasing regulatory requirements for security, environment protection, operational safety, and health standards on U.S. airports, there have been added costs to airport capital and operating expenses. For non-hub airports with limited staff and financial resources, there has become a growing concern about how they will fulfill their compliance responsibilities. Airports with lower passenger enplanements and freight throughput have a limited ability to raise revenues or make significant cuts to cover the costs of new requirements. These resource constrained airports struggle to absorb the expense of compliance as budgets are already stretched thin by operating costs and capital expenditures. Only limited funding is provided by government agencies for new regulatory initiatives, while costs attributed to ongoing compliance remain unfunded (ACRP, 2013). For the ability of all airports to improve safety and productivity, other low-cost innovative solutions must be considered to meet the costs of expanding requirements, especially for median and small size airports.

5. Problem Solving Approach

5.1 System Principle

The limitations of current runway incursion avoidance strategies along with the rapid development of emerging new technologies and implementation of the NextGen components have made the development of an affordable and effective runway incursion prevention system possible by mingling multidisciplinary assets. In this project, the Intelligent Runway Status Indication System (IRSIS) considers the threats from airport surface traffic as well as airborne traffic, especially inbound aircraft on the final approach, and was designed to overcome the challenges in current runway incursion avoidance. The IRSIS primarily consists of 1) aircraft warning device in the cockpit of aircraft and ground vehicles, 2) runway threshold warning light, 3) ATC surveillance and traffic Geo-fencing interface, and 4) a server computer. The IRSIS collects and fuses both surface and airborne traffic position data from portable IoT positioning devices installed on the aircraft and ground vehicles and ADS-B Out. The runway threshold warning light alerts inbound traffic on final approach when the landing runway is occupied by other traffic. The server computer of IRSIS tracks the traffic movements to determine the status of runway occupancy and communicate with aircraft/ground vehicle warning device and runway threshold warning light accordingly to provide pilots and ground operators a simple and intuitive warning. Meanwhile, the Graphic User Interface (GUI) with Geo-fence features installed at control tower or airport operation center provides ATC or airport operators real-time runway status information. The architecture of IRSIS is shown in *Figure 1* and *Figure 2*.

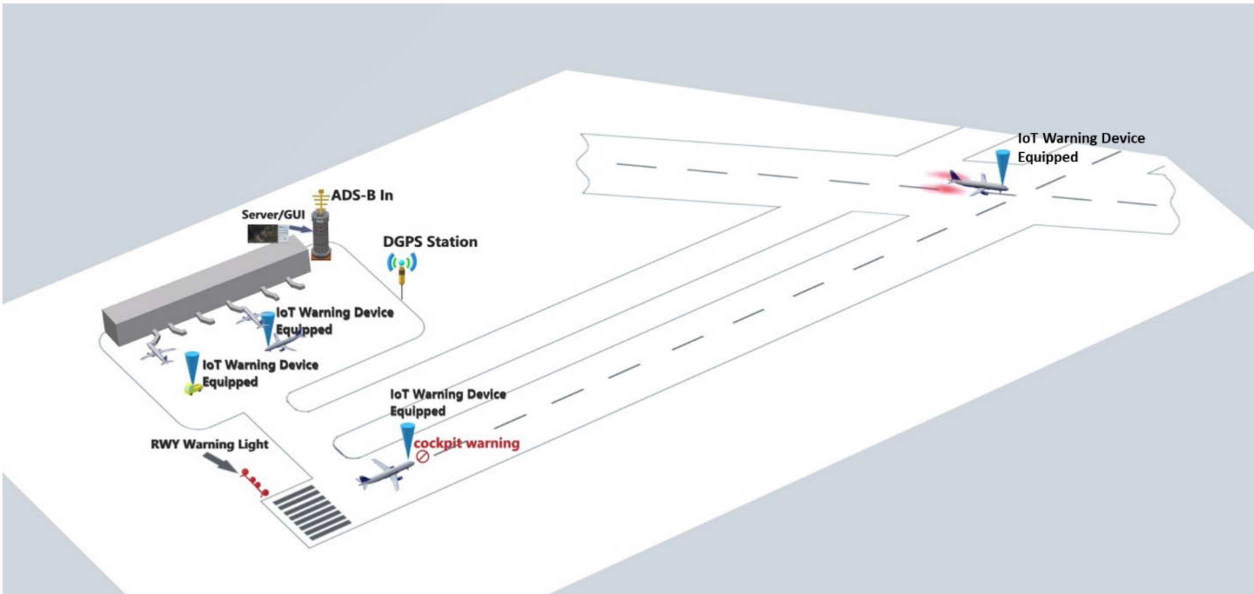

Figure 1. Overview of IRSIS architecture

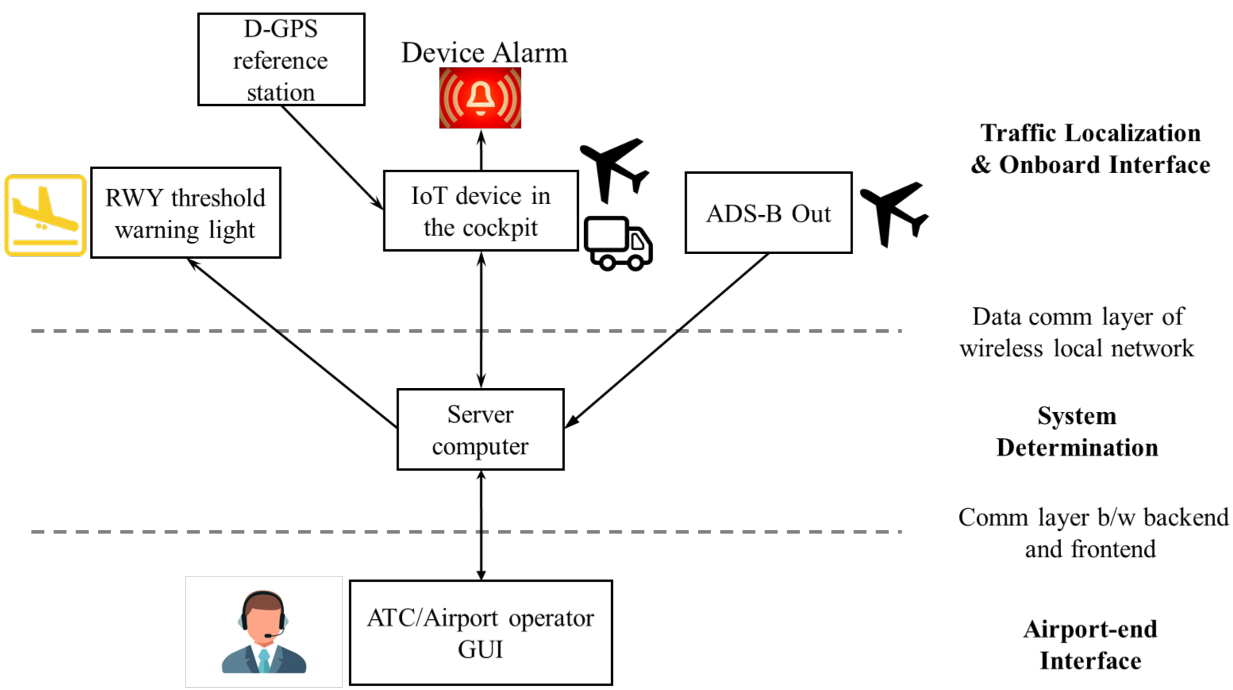

Figure 2. Schematic of IRSIS architecture

High accurate and reliable traffic localization is foundation of runway incursion prevention systems. The IRSIS relies on D-GPS and ADS-B Out as for surface and airborne traffic positioning. A D-GPS reference station will be installed at airport coupled with mobile GPS modules imbedded on IoT device in the cockpit and ground vehicle provide to provide real-time kinematic (RTK) positioning service within centimeter-level accuracy. Considering the working range of D-GPS and limitations for airborne traffic positioning, ADS-B Out is used as the secondary position data source for airborne traffic positioning. A set of runway threshold warning light will be installed to provide additional warning to inbound traffic on final approach if the landing runway is occupied. A server computer processes all traffic position information to determine the runway status, and communicates with IoT devices and runway threshold warning light to trigger runway incursion warning. A GUI with Geo-fencing features at the ATC or airport operation center will share and display the intuitive and real-time traffic and runway status for controllers and airport operators. An IoT data link will provide a communication layer between server computer and IoT devices and runway threshold warning light. ADS-B In capable receiver will be used to receive and process ADS-B Out capable airborne traffic for position information. Traditional internet based or local landline will provide a communication layer between server computer and frontend GUI at ATC or airport operation center.

In general, the working process of IRSIS includes four steps for a corresponding list of functions, shown as *Figure 3*.

1) The initialization of IRSIS include the server computer, aircraft and ground vehicle IoT warning devices, runway warning light, D-GPS station, and ADS-B In ground station.

2) Geo-fenced areas predefined according to the airport environmental features, those areas include but are not limited to runways in use, intersections, airport hotspots, and three-dimensional final approach areas for each runway.

3) ADS-B In station and D-GPS feedback real-time traffic position information to server. Traffic position information include active ground vehicles, ground aircraft, as well as airborne aircraft in the Final.

4) The server computer tracks real-time traffic positions and detect occupancy of Geo-fenced areas. If runway occupancy is detected, server computer will send warning information to all associated traffic and runway warning light through the deployed IoT warning devices. In addition, a GUI near ATC with display of all traffic positions will assist ATC for surveillance and further confirmation of traffic conflict.

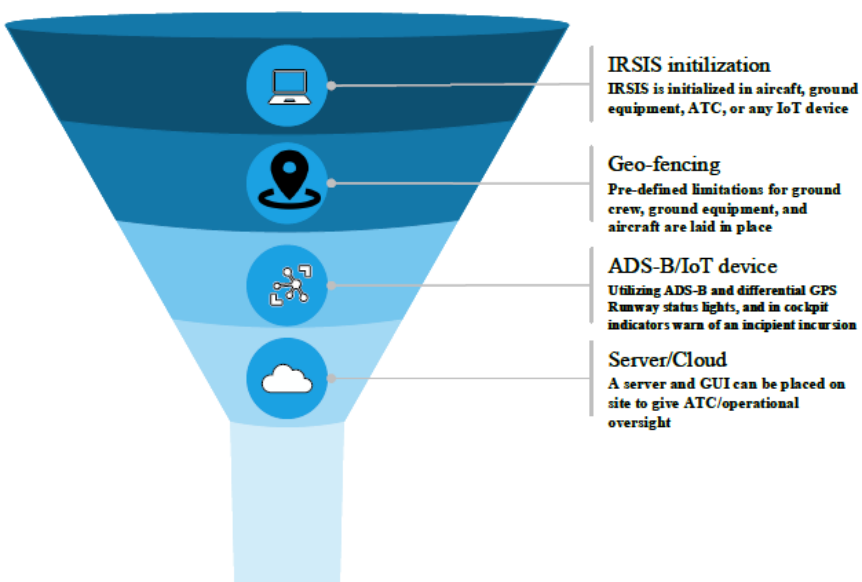

Figure 3. Working process of IRSIS

The IRSIS applies modular design, and there are three major principles underlying the system operations:

1) The integration of ADS-B and differential GPS for low-cost real-time positioning of surface and airborne traffic in airport vicinity with high accuracy;

2) Leveraging the IoT to provide a reliable, low energy consumption, and adaptive local network for data communication between server computer and mobile warning devices;

3) Utilizing Geo-fencing technology to provide customizable perimeters for runway incursion prevention in all types of airport environment. Along with GUI that displays traffic real-time positions, ATC and airport operators benefit from intuitive runway status information for enhanced situational awareness.

5.2 System Design

Principle 1: The integration of ADS-B and differential GPS for low-cost real-time positioning of surface and airborne traffic in airport vicinity with high accuracy.

Localization of traffic is one of the primary technical challenges for most runway incursion prevention systems. Instead of relying on expensive surface surveillance radar, the IRSIS integrates ADS-B and differential GPS as airport traffic positioning strategy. By deploying a differential GPS station and portable IoT mobile warning devices on aircraft and ground vehicles, all IoT warning device equipped traffic are able to have centimeter level high accurate GPS service. The real-time position information will be transmitted to server computer through local network built on the IoT devices for real-time surveillance. In addition, to extend the envelope of system capability, airborne traffic, especially aircraft on final approach, with tendency to infringe occupied runway is protected in IRSIS by integrating ADS-B as secondary position data source.

ADS-B Out capable aircraft broadcasts its position information at 1090 MHz or 978 MHz. With a dual-band ADS-B receiver, aircraft airborne position information can be received and used by IRSIS when the inbound aircraft on final approach is not equipped with the IRSIS IoT warning device or out of the local IoT network coverage. When IRSIS is coupled with differential GPS and ADS-B, traffic both on the ground and airborne will be more reliably monitored and protected by IRSIS with two streams of position data, shown as *Figure 4*.

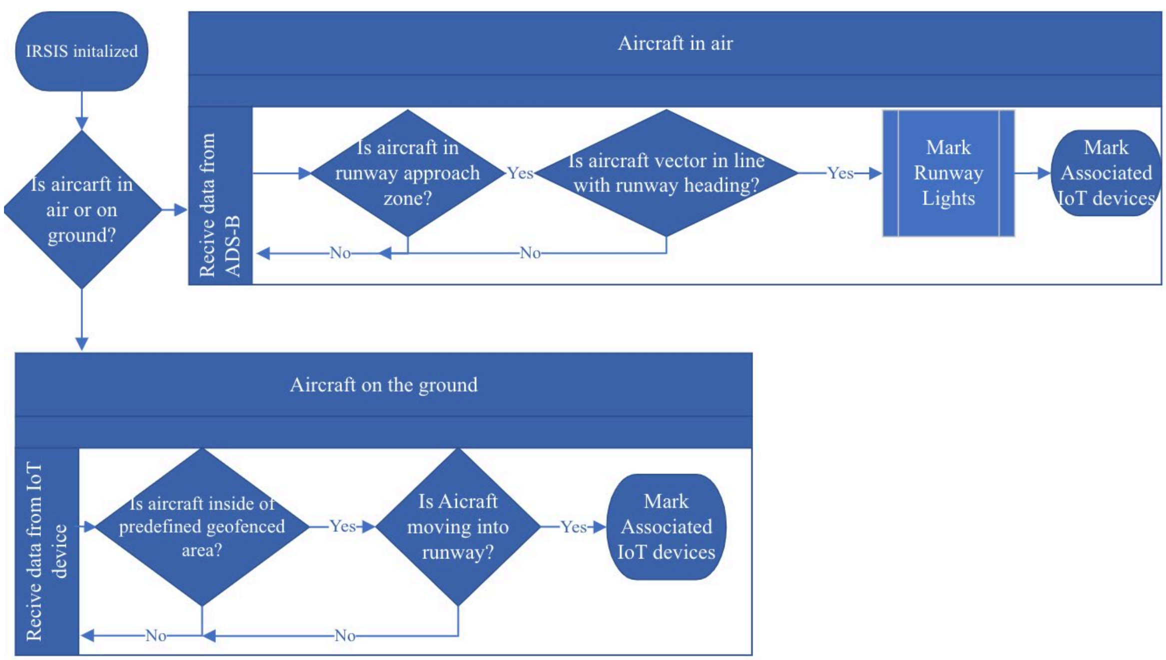

Figure 4. Data flow with integration of ADS-B and D-GPS

Principle 2: Leveraging the IoT to provide a reliable, low energy consumption, and adaptive local network for data communication between server computer and mobile warning devices.

Given the high cost of equipping ADS-B Out capable transponder on all ground vehicles, the IoT devices are leveraged as an affordable and low energy consumption alternative. Coupled with the differential GPS, centimeter level position information can be retrieved for traffic positioning. Wireless Mesh Network (WMN) works with a self-adaptive network routing protocol. Implementation of WMN on IoT device effectively strengthens the reliability and redundancy of local network. In that case, the WMN enables all components of IRSIS to operate seamlessly without a hardline connection and avoid the costs that may be incurred over a hardline installation. In addition, the modularity and scalability of IRSIS make it flexible for different airport operators under diverse operation environment and regulations. For example, with the implementation of 4^{th} or 5^{th} Generation cellular network covering the airside, the IRSIS could be deployed over existing network to avoid potential radio frequency interference. All of those functions could be achieved by fast development based on commercial off the shelf components with basic telecommunication and telemetry data process algorithms. The data flow between the IoT devices and server computer could be presented as Figure 5: 1) IoT devices receive GPS data from the differential GPS station; 2) IoT devices send the GPS data to the server computer, ADS-B signal will be used to extrapolate airborne traffic position; 3) if runway is occupied or Geo-fence is breached by traffic, server computer sends out warning signal to the associated IoT devices ; 4) IoT devices receive warning signal from server computer and present visual and audial warning to pilots or ground vehicle operators, in addition, runway warning light near the runway threshold provides flashing red warning light for the airborne aircraft on the final approach. In general, this real-time feedback close loop established on IoT technology is invaluable both in the cockpit and in the tower, or office.

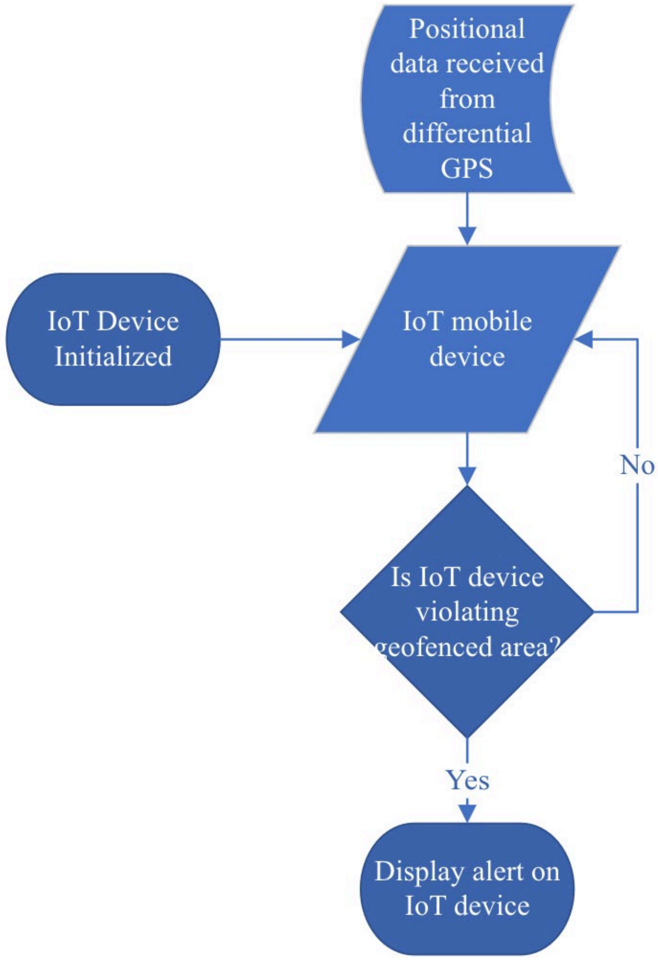

Figure 5. IoT device determination

Principle 3: Utilizing Geo-fencing technology to provide customizable perimeters for runway incursion prevention in all types of airport environment.

With either a hardwired or wireless mesh network, all traffic data can be monitored on the main server computer with a straightforward GUI for Geo-fence and runway status indication. Integrated with airport geospatial data, traffic information and runway status is intuitively projected on a simulated radar screen for ATC or airport operator. This feature enables IRSIS to be a flexible system to adapt different airport environment given the airport geographic information. Operators are allowed to delimit specific runways in use, airport hotspots, construction sites, or any desired protection areas at airport. In addition, the GUI displaying real-time traffic information will greatly improve the situational awareness of ATC and airport operators as well as collaborations with pilots.

5.3. System Implementation

Council Bluffs Municipal Airport in Iowa is a GA airport with two intersected runways at 18/36 and 14/32. Runway 18/36 has the capability to accept 60,000-pound aircraft. The airport design leads to potential runway incursions at multiple locations in addition to potential land and hold short operations.

The illustration as *Figure 6* is the proposed monitoring area for IRSIS. Yellow areas are the predefined Geo-fenced space for the incoming airborne traffic on final approach of each runway. Red areas are the runway incursion zones for ground traffic. Blue areas are the predefined Geo-fenced areas limiting ground personnel and equipment without prior authorization. Table 2 describes the major components for IRSIS implementation.

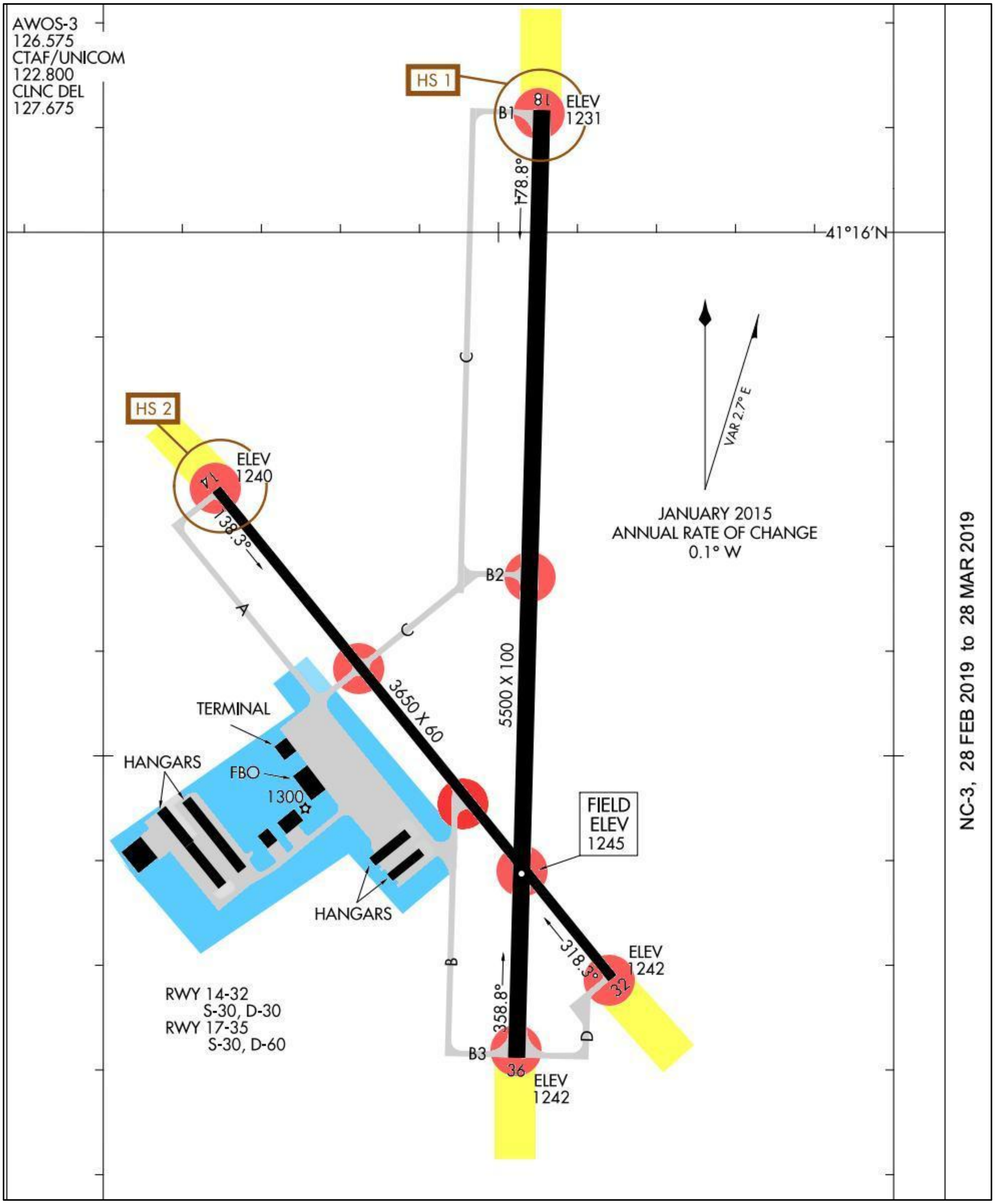

Figure 6. IRSIS implementation at Council Bluffs Airport

Table 2

Components for IRSIS implementation

Item	Specs	QTY	MSRP
Server/GUI	PowerEdge T330 Tower Server, Intel Xeon E3-1230 v6 Quad-Core 3.5GHz 8MB, 32GB DDR4 RAM, 8TB	1	$1,999.00
ADS-B In receiver	PingStation dual band (978MHz and 1090MHz), networkable ADS-B receiver	1	$1,750.00
Wireless mesh network	Horizon 900 MHz, 72 Mbps, Ethernet and Serial Wireless Radios	6	$9,000
Ground Equipment location device	Horizon 900 MHz, 72 Mbps, Ethernet and Serial Wireless Radio with GPS enabled. Custom warning module utilizing off the shelf-solution such as Kunbus RevPi Core 3	3	$3,000
Aircraft warning device	Custom warning module utilizing off the shelf-solution such as Kunbus RevPi Core 3 integrated with ADS-B unit	30	$12,000
Runway warning lights	low power led clear X signals located at all VASI/PAPI locations.	4	$10,000
Differential GPS unit	Trimble NetR9 GNSS Reference Receiver	1	$25,500.00

With the implementation of IRSIS, Council Bluffs Municipal Airport allows pilots and airport operators to have better situational awareness in 13 potential incursion zones. This system is completely automatic, requires no additional full-time staff, and can be operated and maintained at the end user level. Utilization of the 900MHz band for IoT device data communication violates no FCC regulations, and is safe to use on the airfield.

6. Safety Risk Assessment

Conducting an overall risk assessment is a necessary step for any innovation designed to be applied at this scale. The most basic tool for quantifying risk is the matrix provided by the FAA Advisory Circular (FAA, 2007). Table 3 is a modified version of this matrix, implemented with a scoring system. After determining level of risk and severity, the overall degree of risk can be calculated from the product of the two resulting in the final risk score. This risk score is then classified as low, medium, high, or unacceptable as seen in Table 4.

Table 3

Predictive risk matrix (FAA, 2007)

Severity	**Insignificant** damage to property, equipment or minor injury	**Non-reportable** injury, minor loss of process or slight damage to property	**Reportable Injury** moderate loss of process or limited damage to property	**Major injury,** single fatality, critical loss of process or damage to property	**Multiple fatalities,** catastrophic loss of business
Probability	(1)	(2)	(3)	(4)	(5)
Improbable (1)	1	2	3	4	5
Remote (2)	2	4	6	8	10
Occasional (3)	3	6	9	12	15
Probable (4)	4	8	12	16	20

Table 4

Risk Categories (FAA, 2007)

Unacceptable Risk (16-20)
High Risk (11-15)
Medium Risk (5-10)
Low Risk (0-4)

Table 5

Risk Assessment

#	Risk Description	Impact Severity	Risk Probability	Risk Score (Impact x Probability)	Mitigation Plan
1	Data link break down	1	1	1	Software engineers troubleshoot the system
2	Failure to prevent unauthorized access to ground vehicles/personnel	1	2	2	Technicians regular maintenance Regular ground crew training
3	Damage to sensor from weather	1	3	3	Ensure weatherproof design of sensors
4	Algorithm malfunction	4	1	4	Software engineers troubleshoot the system
5	Cyber Vulnerabilities to ADS-B; IoT	5	1	5	Encryption
6	GPS/Radio GPS/Radio Navigation Satellite Service Failure	5	1	5	Software engineers troubleshoot the system. Regular recalibration
7	Server Disruption	3	2	6	Backup Servers (on or off-site)
8	Data Saving Failure	3	2	6	Weekly maintenance/ Redundant Array of Independent Disks
9	Power Outage	4	2	8	Backup Power Source (i.e. generator)
10	Human errors (poor maintenance, incorrect operations, etc.)	3	3	9	Regular training and maintenance

Based on the assumption that Risk = Impact × Probability, Table 5 is a detailed risk assessment outlining risk description, impact, probability, risk score, and possible solutions for mitigation. The IRSIS is designed to create a built-in redundancy that would reduce the severity of human errors, but the system is still vulnerable to the risks associated with technological malfunctions. Scenarios such as GPS tracking system error, sensor damage, and algorithm malfunction are relatively low risky for overall runway operation safety given this system is a decision-making aid technology while the final decisions are up to the pilots and ATC. The worst risk scenario remains human errors: Pilots or ATC who ignore the IRSIS system warning can increase risk probability. Human and technological risks could be mitigated by improving system design and implementing proper training of both pilots and controllers. After implementing IRSIS, the severity of hazard impact is expected to be decreased with no risk measuring as high or unacceptable.

7. Cost Benefit Analysis

7.1 Cost Assessment

The cost benefit analysis of the proposed system is vital to understanding the feasibility of IRSIS implementation. The cost analysis of the system includes initial installation/implementation cost and operational/maintenance cost. The cost analysis is based on the quote for the implementation at Council Bluffs Municipal Airport. For each stage, the cost analysis includes labor (specialists and labor) and material (equipment, device and parts) cost, as shown in Table 6.

Table 6

Cost analysis of IRSIS implementation

Cost Analysis of IRSIS for Council bluffs						
Labor		Material		Operational		Total
Type	Cost	Type	Cost	Type	Cost	
System Installation and Initial Training (1 Month)						
Specialist Labor	1 FTE at $35 per hour 4 weeks	IRIS equipment cost	$50,000 (as quoted MSRP)	At the discretion of the purchaser 1 FTE recommended for training	$20 an hour	$66,000
General Labor	3 FTE at $15 per hour 4 weeks					
System operation and maintenance (annual cost)						
No additional FTE's recommended for operations						$4,000
Specialist Labor	1 FTE at $35 per hour 2 weeks					
General Labor	1 FTE at $15 per hour 2 weeks					
FTE= full time equivalent This table was inspired by ACRP Resource Video (Byers, 2016).						

The estimated installation one-time cost $66,000 is the capital expense and total annual operational cost for Council Bluffs Municipal Airport for the quoted IRSIS system is $4,000. The average cost of hull damage of general aviation equipment, occurring due to a runway incursion, is $105,911. For a full breakdown of the complete general aviation aircraft hull damage is included in Table 7.

Table 7

Hull damage of GA aircraft

Aircraft Category	Certification	Col. 1 Average of Hull Value	Col. 2 Average of Hull Damage	Col. 3 Damage/ Value
Piston engine airplanes, 1-3 seats	Part 23	$33,201	$9,624	29%
Piston engine airplanes, 4-9 seats one-engine	Part 23	$59,768	$12,065	20%
Piston engine airplanes, 4-9 seats multi-engine	Part 23	$125,372	$30,008	24%
Piston engine airplanes, 10 or more seats	Part 23	$87,330	$9,151	10%
Turboprop airplanes, 1-9 seats one-engine	Part 23	$714,179	$145,546	20%
Turboprop airplanes, 1-9 seats multi-engine	Part 23	$675,523	$137,668	20%
Turboprop airplanes, 10-19 seats	Part 23	$1,068,640	$7,845	1%
Turboprop airplanes, 20 or more seats	Part 25	$1,903,301	$387,884	20%
Turbojet/turbofan airplanes, <= 12,500 lbs.	Part 23/25	$1,840,114	$375,007	20%
Turbojet/turbofan airplanes, > 12,500 lbs. and <= 65,000 lbs.	Part 25	$5,144,237	$1,059,169	21%
Turbojet/turbofan airplanes, > 65,000 lbs.	Part 25	$17,006,419	$1,038,907	6%
Rotorcraft piston <= 6,000 lbs.	Part 27	$206,934	$42,172	20%
Rotorcraft turbine <= 6,000 lbs.	Part 27	$1,185,951	$241,691	20%
Rotorcraft piston > 6,000 lbs.	Part 29	NA	NA	NA
Rotorcraft turbine > 6,000 lbs.	Part 29	$3,321,674	$676,942	20%
Other		NA	NA	NA
Experimental		NA	NA	NA
Light Sport		NA	NA	NA
All Aircraft		**$519,695**	**$105,911**	**20%**

Figure 6 Estimated Market Values of General Aviation Aircraft (FAA, 2015b)

Category A runway incursion is defined as a serious incident in which a collision was narrowly avoided (FAA, 2018b). The probability of a Category A runway incursion at Council Bluffs is relatively low at .00002157% [P(A)= 46,349 operations without incursions /46,350 (FAA 5010) operations total=.00002157%]. The statistical chance of runway incursion is small, the statistical value of human life must be considered as it is in section 7.2.

7.2 Benefit Assessment

The statistic value of life is valued at $9.6 million (Moran, 2016) or 137 times the amount of the cost of an IRSIS system. A below IRIS amortization chart illustrates the cost benefit point occurring in 2030. This chart was constructed using the installation cost of IRIS, the annual maintenance and labor allotted in Table 7, and past incursions and damage related accidents related to situational awareness. It should be noted that past performance is not a guarantee of future results. The amortization of IRSIS may occur at a higher, or lower rate than illustrated.

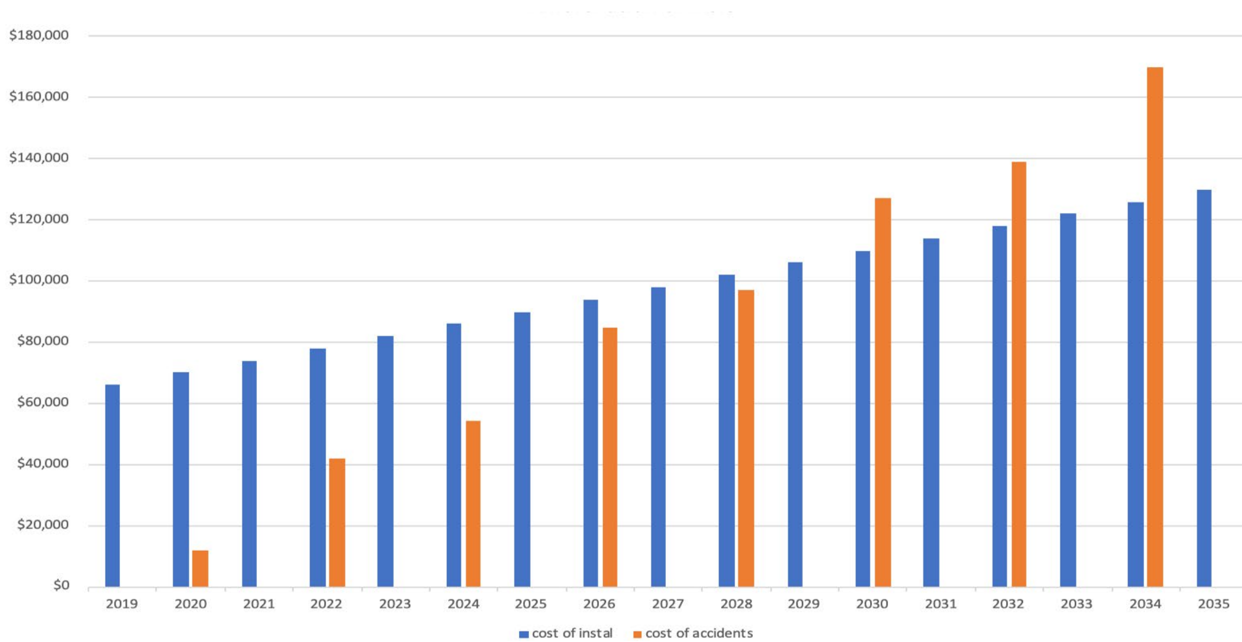

Figure 7. IRSIS amortization

8. Industry Interaction

Runway incursions are a common occurrence caused by many factors. Speaking with industry experts with backgrounds in professional flight, air traffic control, aviation safety, airport operations, and engineering helps outline where IRSIS fits into the current airport environment and operation challenges. Interviews were conducted with the following individuals:

1. Former U.S. Air Force Colonel Pilot Officer:

   Skip Bailey

2. Omaha Eppley Airfield (OMA) and Millard Airport (MLA) Operations Manager:

   Matthew Aubry, C.M.

3. Former FAA ATC manager, ATM subject matter consultant for ICAO and EUROCONTORL:

   Louis Rosgen

4. Station supervisor for Alaska Airlines at Oakland International Airport:

   Dawn Betz

5. Omaha Eppley Airfield and Millard airport Operations Supervisor:

   Pat Dankof

6.. Omaha Eppley Airfield and Millard airport Operations Supervisor:

   Denis Mencia

Mr. Skip Bailey has 25 years of service in the Air Force with extensive global operation experience in the KC-135, EC-135, KC-10, and E-4B. According to Mr. Bailey, airports generally have a similar layout across the world, however small differences can create catastrophic problems. Some European airports will label parallel taxiways as the “inner” and “outer” taxiway, whereas the United States label each in a different phonetic alphabet letter. This could cause confusion for an American pilot flying into a European airport. Another difference is some airports, depending on the airport layout, a single ATC tower may not be able to see every spot on the surface. In that case, it requires controllers to be located at different locations on the ground working on different radio frequencies. While taxing, the aircraft may be required to stop at one point and switch frequencies to talk to a different ground controller at a different section. A distracted or inexperienced pilot may have difficulty in following this special taxi procedure and enter the following segment of taxi or runway without ATC permission.

Bailey further expanded on these differences across airports internationally. Many airports have parallel runways in different sizes. The smaller runway appears like a taxiway to a large aircraft, causing aircraft to taxi across smaller runway as a taxi. Bailey stated, “Training cannot solve all these issues. Some sort of system, whether it's lights, better signage, or an audible warning, maybe in a headset, when you get close to an intersection, or close to a runway could be very helpful.”.

In the interview with Mr. Louis Rosgen, he referred to his vast knowledge of runway incursion prevention systems to speak to the challenges of implementation. He stated, “Using current technologies are expensive and very few airports can afford it, the aviation community needs a simple, accurate, low cost system. It could be an alert system with a flashing light installed in the cockpit that lets you know when it's safe to land or enter the runway environment.” The current largest issue for airport surface operation is the loss of situational awareness, which stresses the importance of a new system that incorporates ground traffic for situational awareness enhancement. Most issues are caused by loss of situational awareness and not following instructions.

In speaking with Matthew Aubry, he expressed interest in IRSIS. Eppley airfield (KOMA) relies on training and enforcement for the prevention of runway incursions. The airfield currently exceeds the guidelines set forth in the FAA Part 139. Eppley airfield has in-pavement runway guard lights. Aurby felt that these extra measures could further increase situational awareness on the airfield. Aubry further expressed that IRSIS would be a fantastic resource to keep track of ground equipment as well as aircraft in irregular operations. The geographical location of KOMA leads to advection fog, which at times limits a runway visual range of less than 1,000 feet. In addition, during snow removal and runway deicing, vehicles may not be visible from the control tower or the operations command center. Low visibility not only result in disorientation of ground vehicles but also potential confusion for ATC and surface operation employees on duty. Aubry outlined cost as a potential issue stating that "there is a concern that traction may not be gained until it is either an FAA mandate or if the costs for installation is low. A low cost and automatic system that would not require any additional personnel would greatly facilitate the implementation of IRSIS at airports.

Dawn Betz felt that the runway incursions were the responsibilities of the pilot and air traffic control. Being a station supervisor, she has the responsibility of taking care of the aircraft when it is in the gate. She believes that Oakland International Airport does a good job of training for runway incursions and insuring comprehension is paid to the line markings as signage present. Dawn however was very interested in the Geo-fencing capability of IRSIS and was extremely interested in the possibility of a handheld device capable of giving situational awareness to her and her superiors.

Pat Dankof and Dennis Mencia both mirrored Mr. Aubrys responses. They felt that the additional lighting they had in place was sufficient to help increase situational awareness regarding runway incursions. However, if a cost-effective solution was available, they felt it would be invaluable during irregular operations. Dennis Mencia is in charge of the Surface Movement Guidance and Control System guidelines for Eppley airfield. Dennis felt that his planning would be greatly enhanced by a system such as IRSIS and went on to say that irregular operations would potentially look much more like standard operations if the IRSIS system were to be implemented.

9. Potential Impact of Design

The IRSIS is designed to mitigate the risk of aircraft runway incursions. The primary purpose of this design project is to improve safety, the proposed system also has operational impacts, economic impacts, environmental impacts on airports, communities and other related people or areas in terms of aviation sustainability.

The operational impact of IRSIS is clear. It is an automated system that requires no additional operational overhead. This simultaneously improves situational awareness while maintaining transparency in relation to current systems and infrastructure. In our industry interactions there was a strong desire to have 1) An economical system 2) A flexible system that can work through the multiple infrastructures that may be in place on the airfield 3) Have little to no additional labor cost. IRSIS meets all this goal, making a positive impact.

With a one-time cost approaching $100,000 and an annual cost estimate to be less than $5,000 it would require just one avoided airframe damage to amortize the cost of an IRSIS install. This low install price, coupled with a very low ongoing maintenance cost, should attract all forms of airfields. With no additional full time equivalent needed to administrate, it can even operate within the current bounds of staffing.

Admittedly, IRSIS doesn't directly benefit the environment. However, if you dovetail in the fact that any aircraft damage comes with fluid leakage and cleanup. The hazards of releasing these toxic compounds are reduced by the increase of situational awareness induced by IRSIS. It is possible that carbon emissions can be reduced to enhanced traffic flow. However, this claim is outside the scope of this document.

10. Conclusion

The Intelligent Runway Status Indication System (IRSIS) was designed in this project to address the ACRP challenges from "Runway Safety/Runway Incursions/Runway Excursions". The IRSIS includes mobile IoT devices for pilot and vehicle operators with direct warning system to alert pilots and vehicle operators for approaching of occupied runway. A GUI with Geo-fencing features provides air traffic controllers and airport operators warning about unauthorized use of runway with intuitive situational awareness. In addition, a runway threshold warning light in the IRSIS enhance airport visual aids for approach aircraft with the function of occupied runway warning.

IRSIS offers a low cost, automatic, user friendly, and adaptive runway incursion prevention solution for airports with different sizes and operational characteristics. The situational awareness enhancement and decision-making aid services of IRSIS have only been offered by very costly systems such as ASDE-X and RWSL which equal up to 600 times more than the cost of this project design. The IRSIS is expected to significantly benefit median and small size airports with affordable investment for advanced runway incursion prevention technology that only a handful international hub airports own. The design of IRSIS is supported by current FAA requirements such as ADS-B Out and is further adapted to achieve the NextGen initiative established in 2003 (ACRP, 2014). The benefits offered by this design aid the current efforts put forth by the FAA, ATC, airport operators and pilots to increase the flow and accuracy of information. By introducing IRSIS to the industry, the design team is hoping that runway incursions could be proactively prevented at all airports with affordable innovative technology.

Appendix A: List of Complete Contact Information

Faculty Advisor:

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Students:

Team comprises of two undergraduate students and one graduate student. Graduate student has a degree in Emergency Management and working towards a Master of Public Administration. Undergraduate students are working on Bachelor of Science degrees in Aviation with a concentration in Unmanned Aircraft Systems and Airport Management.

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Alexander Nguyen
University of Nebraska Omaha, Aviation Institute
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Appendix B: Description of the University

About the University of Nebraska Omaha (from www.unomaha.edu):

Founded in 1908, the University of Nebraska Omaha (UNO) is Nebraska's metropolitan university – a university with strong academic values and significant relationships with our community that transforms and improves life. UNO is dedicated to the city and state in our name. As a good neighbor, for more than a century, we actively engage in the teaching, research, service, culture, and economy of the region and strengthen the quality of life in Omaha.

As both the University of Nebraska's metropolitan university campus and a Carnegie Doctoral Research institution, we address real issues, providing relevant learning opportunities that uniquely prepare our graduates as professionals and active members of their community. The University of Nebraska at Omaha (UNO) transforms and improves the quality of life locally, nationally, and globally.

About the Aviation Institute (from www.unomaha.edu):

The Aviation Institute of UNO has the vision to lead collegiate aviation in ways that measurably enhance the lives of our students and others we serve through our instructional, research, and service programs.

The mission of the Aviation Institute is to:

- Provides an environment where students are supported and challenged as they develop the skills, knowledge, and experiences that prepare them for personally and professionally rewarding careers in aviation and transportation.

- Conduct research that enhances the safety, security, efficiency, reliability, and sustainability of aviation and transportation services; and improves mobility and quality of life for the citizens of the State of Nebraska.
- Engage the community through partnerships and other collaborative initiatives that improve the lives of the citizens of the State of Nebraska and others through innovative education, training, research, and service projects.
- Maintain the highest standards of integrity and transparency in the conduct of the Institute's business and the management and stewardship of its resources.

Appendix C: Description of Non-University Partners Involved in the Project

Not applicable

Airport Cooperative Research Program
University Design Competition for Addressing Airport Needs
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 University of Nebraska at Omaha

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: Joseph Harris

Permanent Mailing Address 9251 Cady Ave. Apt #9, Omaha, NE 68134

Permanent Phone Number 402-213-2892 Email josephharris@unomaha.edu

Competition Design Challenge Addressed:

Runway Safety/Runway Incursions/Runway Excursions: Expanding situational awareness of pilots and ground operators on the airfield.

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 Chenyu Huang Date 04/23/2019

Name Chenyu Huang

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Department(s) Aviation Institute

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City Omaha State NE ZIP code 68182-0508

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Appendix E: Evaluation of the Educational Experience Provided by the Project

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airports Needs provide a meaningful learning experience for you? Why or why not?

The learning experience provided by this competition was exponential. The design competition provided a learning experience that could not be experienced in the classroom. The competition required us to step out and brainstorm not only answers but questions that answer the overarching topic. It allowed us students to see the many variables that must be considered when addressing these needs. Whether its costs restrictions, training requirements, FAA regulation, there are many stakeholders who are affected. The area of research we undertook (runway incursions) was a very widely approached subject. We were given the opportunity to distil this very wide idea into something we feel is practical for a real-world environment. An opportunity such as this does not arrive often.

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

Scheduling was a major issue; setting timely deadlines and setting times to coordinate as a group was a challenge. Furthermore, gathering an understanding of all the components involved in the many different systems for airport operations, may have been the greatest challenge. Each individual of the team had differing areas of expertise, so devising the best strategy to compete in the competition required much time. It took many meetings as a team and with our advisor and to ensure everyone had the same understanding. It’s very much another thing gestate that statement into a practical and feasible idea.

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

It required multiple group sessions to discuss our potential pool of ideas. The initial process for developing IRSIS consisted of outlining current airport needs as it relates to Runway Incursions. With NextGen components such as ADS-B becoming requirements, devising a strategy to easily integrate these systems into low-cost solutions for long-standing aviation issues seemed necessary.

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

The industry interaction provided insight on areas we had not considered, while also confirming issues in the industry that our design was intended to mitigate. Interacting with industry experts allows students to understand the potential benefits, consequences and concerns that can only be determined based off practical experience. Although this is only a competition, students who wish to become high-level decision-makers must understand that different stakeholders have differing challenges that must be considered. Discussions with knowledgeable individuals on different subject matters allowed the group to be able to contextualize how a system such as IRSIS would work based on our limited knowledge experience. It was especially rewarding when the picture became clear to industry experts and they began to see its benefits. Also, having insight from multiple perspective in the industry such as airport operations and ATC, was very helpful.

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?

The skills of time management and research were thrown on us in a safe environment, providing us room to fail while still succeeding. The project overall has been a learning experience in every aspect from the design of our system on the technical side to the writing of the report and gathering of information. The technical knowledge gained from this process was immense. Many of the potential applications for these applications can be used for a variety of industries to improve safety, security and overall operational efficiency. Gaining this perspective will present new opportunities for the group in the future to maximize the use of these growing technical innovations. This was one of the few industry research projects some members of the team were able to participate on. This project filled in multiple gaps in knowledge, not only from research design, but to what the market needs to bring a product to market. That experience alone is invaluable.

Faculty

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

   The ACRP University Design Competition provides students a great opportunity to apply theoretical knowledge to explore solutions to aviation challenges in the real world. By participating this project-based education, students learned more about the actual demands and challenges from the industry, worked as a team to analyze the requirements of proposal and address technical challenges, explored and developed practical strategies. It tremendously supplements the traditional classroom education to better develop student abilities, such as self-study, team work, interdisciplinary knowledge applications, and project management.

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

Yes. The ACRP design competition was integrated in a one-semester course on the topic of Aviation Safety. Students are highly motivated and understand the value of this project. The course level and context is appropriate.

3. What challenges did the students face and overcome?

The student team shares a strong passion on aviation safety with diverse background and working experience, including two undergraduate students major in professional pilot and aviation management, and one graduate student major in emergency management. Two undergraduate students have different working experience and concentrations though both are major in aviation. The gap of domain knowledge and previous project experience result in communication challenges and project management issues within the team. Project coordination took a while, but this multidisciplinary team demonstrated great advantages when team members developed into a team. The team performed very effectively to educate each other and contribute to the project by sharing personal expertise and experience. The team intensively studied airport operation regulations, causal factors of runway incursions, and existing challenges by reviewing literature and interviewing industry experts. In addition, they all overcame the lack of knowledge about the current runway incursion prevention systems, the operation principles of Internet of Things (IoT) and Geo-fencing. By overcoming above challenges, students are better prepared for future teamwork environment and the use of interdisciplinary advantages.

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

   I would keep use this completion in the future. Students are highly motivated and inspired by the real-world challenges listed in the ACRP competition guideline. The interaction with industry experts significantly inspired students and broadened their view outside of university.

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

   The ACRP competition is usually integrated as course project or independent study, because of resource constraints, many innovative designs cannot be developed into prototype. Follow-up funding opportunities for further development of promising designs would be helpful to transform the value of successful designs into applications.

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