INNOVATIVE AIRPORT VISUAL AIDS TO ENHANCE SITUATIONAL AWARENESS AND FLIGHT TRAINING FOR GENERAL AVIATION

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Runway incursions are a threat to runway safety and have been increasing in recent years. Incursions are categorized into three categories, pilot deviations (PD), operational incidents (OI), and vehicle pedestrian deviations (VPD). At general aviation airports, PDs are the most prevalent runway incursion type. Inadequate situational awareness is one of the human factors associated with PDs. Student pilots, pilots flying to an unfamiliar airport, ground operations personnel, and emergency planning and emergency responders can benefit from the use of visual aids that extend beyond an airport diagram or static Google Earth imagery. More robust visual aids can potentially increase situational awareness and reduce the risk of a runway incursion, and increase airfield familiarity through 360-degree photographs of the airfield facilities, including markings, signage, and intersecting taxiways/runways. This educational and informational tool has the ability to increase familiarity of airfield characteristics and increase safety.

Safety is the top priority in aviation, and runway safety is a critical aspect of aviation safety. According to the International Civil Aviation Organization (ICAO), runway safety related events account for more than half of all accidents, and 14% of fatal accidents (International Civil Aviation Organization, 2015). For this reason, runway safety is a high priority for all aviation stakeholders, and reducing runway incursions is one way to improve runway safety. Since October 2001 there have been 19,184 runway incursions at United States airports (Federal Aviation Administration, 2017b). 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 take-off of aircraft" (Federal Aviation Administration, 2017c). FAA categorizes incursions based on the cause, resulting in the following three incident types (Federal Aviation Administration, 2012):

- *Operational incident (OI):* runway incursion caused by air traffic controller (ATC) error that violates the required minimum separation between two or more aircraft or between an aircraft and an obstacle,
- *Pilot deviation (PD):* runway incursion caused by pilot error that violates any Federal Aviation Regulation, such as entry onto runway without permission, and
- *Vehicle/pedestrian deviation (V/PD):* runway incursion caused by unauthorized entry of vehicles or pedestrians onto the airport movement areas, such as ground vehicle entry onto runway without ATC authorization.

Incursions have been increasing in recent years. As a result of this increase, the FAA announced the Runway Incursion Mitigation (RIM) program in 2015. The purpose of RIM is to identify airport risk factors that might contribute to a runway incursion. Examples of risk factors consist of unclear taxiway markings, unclear airport signage, and complex airfield geometries, including unusual runway or taxiway layouts, and runway intersections. Through RIM, the FAA is focusing on reducing runway incursions by addressing risks at specific locations at the various airports, especially those that have a history of runway incursions (Federal Aviation Administration, 2016). While the FAA continues to be proactive in taking steps to reduce runway incursions through mitigation measures and airfield development projects that

reduce runway intersections, there are other potential opportunities to improve runway safety that would support the activities of the RIM program.

The proposed tool suggested in this research leverages technology to supplement and augment existing airfield diagrams and increase situational awareness for pilots and ground operations workers. Traditionally, airport diagrams (Figure 1) are used to familiarize pilots and other personnel with an airport's layout and geometry. While these diagrams meet basic needs and provide one frame of reference, they do not provide pilots and airport ground crews with a visual representation of the airport facilities, markings, signage, and intersecting taxiways/runways. Creating a more robust visual aid will fill this gap and potentially improve airport safety and pilot training.

Literature Review

Traditional airport diagrams reflect an aerial perspective and provide critical, but rudimentary information regarding how the runways, taxiways and terminal are oriented with respect to true north, and with respect to one another. Airport diagrams fill a critical need for pilots as they plan their trip and upon approach to an airport. Once on the ground, however, many pilots and ground vehicle operators would benefit from a more robust depiction of airport facilities. Specifically, one that is enhanced with actual photo images. The addition of visual references can be important to convey information, especially in complex environments such as airports where situational awareness is critical to safe operations.

Perhaps the need for enhanced tools is best evidenced by current runway incursion statistics. Since October 2001, there have been 6,288 runway incursions at general aviation (GA) airports, with a majority of these incursions classified as PD or V/PD (Figure 2) (Federal Aviation Administration, 2017b). Nearly two-thirds of GA incursions are a result of pilot error. Chang and Wong (2012), as well as Endsley and Garland (2000), identified a lack of situational awareness as one of the leading factors associated with pilot error. The proposed use of photo enhanced airfield diagram would be an appropriate intervention strategy to enhance situational awareness not only for pilots, but also for ground operators; together these two categories cause 96% of runway incursions.

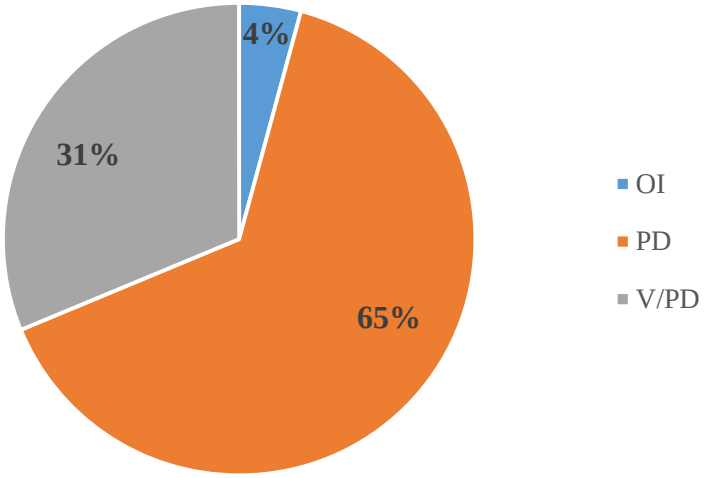

Figure 1. Classification of runway incursions at GA airports since October 2001 (Federal Aviation Administration, 2017b).

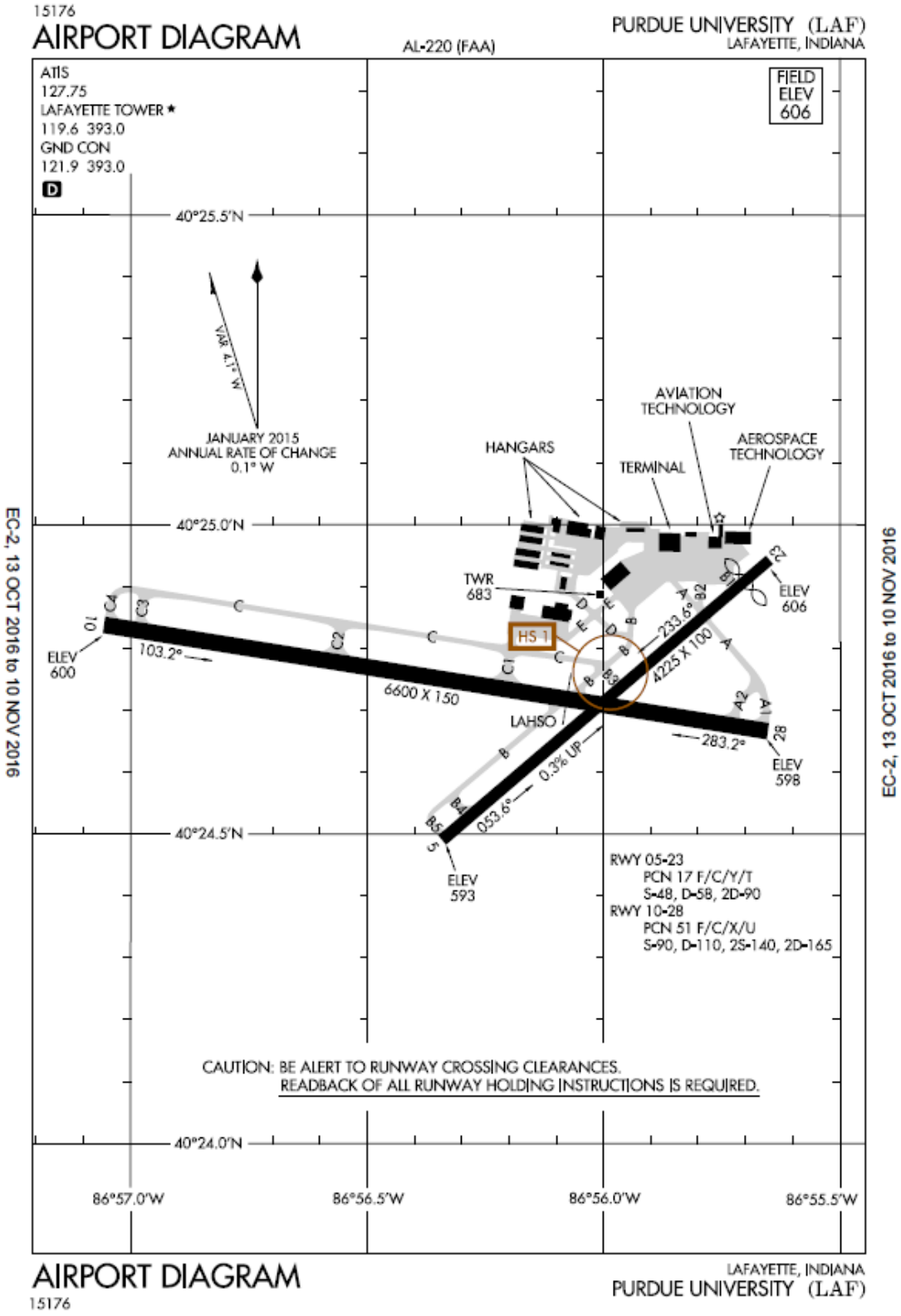

Figure 2. Airport diagram of Purdue University Airport (Federal Aviation Administration, 2017a).

Dublin International Airport was the first airport to address this need with the creation of a Google Street View perspective for their airfield. Vincent Harrison, Dublin Airport managing director, said, "these images will help the airport's Airside Safety Training department, as they will become an essential piece of the training suite in educating and familiarizing all airport employees" (Kennedy, 2016). The advent of virtual globe software, such as Google Street View, allows users to navigate and explore areas in three dimensions. This is very useful, as reported by Schultz, Kerski, and Patterson (2008), virtual globes can be used by educators to help students think spatially by investigating processes and places.

Other research has also demonstrated the value of this perspective. Oulasvirta, Estlander, and Nurminen (2009) compare 2D maps (similar to the traditional airport diagram) with 3D maps (similar to Google Street View), and state 3D imagery can provide realistic first-person perspective versus a use of flat symbolic illustrations to represent space. The information gathered through maps (2D) and actual navigation (analogous to Google Street View) is different. From a map, people acquire survey knowledge, from navigation people acquire procedural knowledge of the routes connecting diverse locations (Thorndyke & Hayes-Roth, 1982). The use of landmarks is often a key element in navigation (Raubal & Winter, 2002; Snowdon & Kray, 2009) and the integration of realistic visual cues to supplement existing airfield tools makes good sense.

Creating A More Robust Airport Visual Aid

Currently, through satellite images, a Google Earth view is available for airports, and is used by many GA pilots to provide additional information when landing at an unfamiliar airport. While the Google Earth view is helpful, it provides a top down perspective that is useful from the air (and similar to the perspective provided by the airport diagram), but less useful from the perspective of a taxiing pilot or a ground vehicle operator. Both Google Earth and the airport diagram lack the ability to convey important spatial cues, including airfield signs, markings, and views of intersecting taxiways and runways, as observed during taxiing and airfield operations. Through the use of emerging technologies, an improved and more robust visual aid can be created to allow an accurate representation of the sight picture pilots and operations personnel will encounter on the airfield.

This research explores the use of 360-degree photo enhanced airfield diagrams. Photo spheres, or 360-degree still photos, were taken of select locations on Purdue University's airport (KLAF). When paired with the airport diagram, the result is a more robust tool for training and for airport familiarization. Figure 3 shows how an airfield diagram can be enhanced with 360-degree photos. These photos can illustrate not only the upcoming pavement markings (both threshold markings and runway markings) and airfield signs, but also the upcoming intersection. Google Maps allows the photo spheres to be linked together to create a custom Street View, which is an application many users are familiar with from landside applications on city streets. Creation of an enhanced airport diagram allows for specific and unique areas of each airfield to be highlighted and emphasized to the wide variety of personnel that may need to operate on the ground.

Anticipated Uses and Benefits of the Enhanced Airport Diagram

This enhanced airport diagram could be utilized by many aviation stakeholders. In addition to pilots and ground operations personnel, airport managers, emergency planning and emergency response crews (including community partners who participate under a Memorandum of Agreement in an emergency) are some of the groups that could benefit from such a tool. Other users include student pilots, who can begin to orient themselves to the airport layout and airfield markings prior to beginning their flight training. Certified flight instructors (CFI) can walk a student through expected taxi procedures to provide virtual experience navigating an airfield for the first time; this virtual experience could allow student pilots to focus on aircraft operations rather than airfield orientation, especially in the beginning

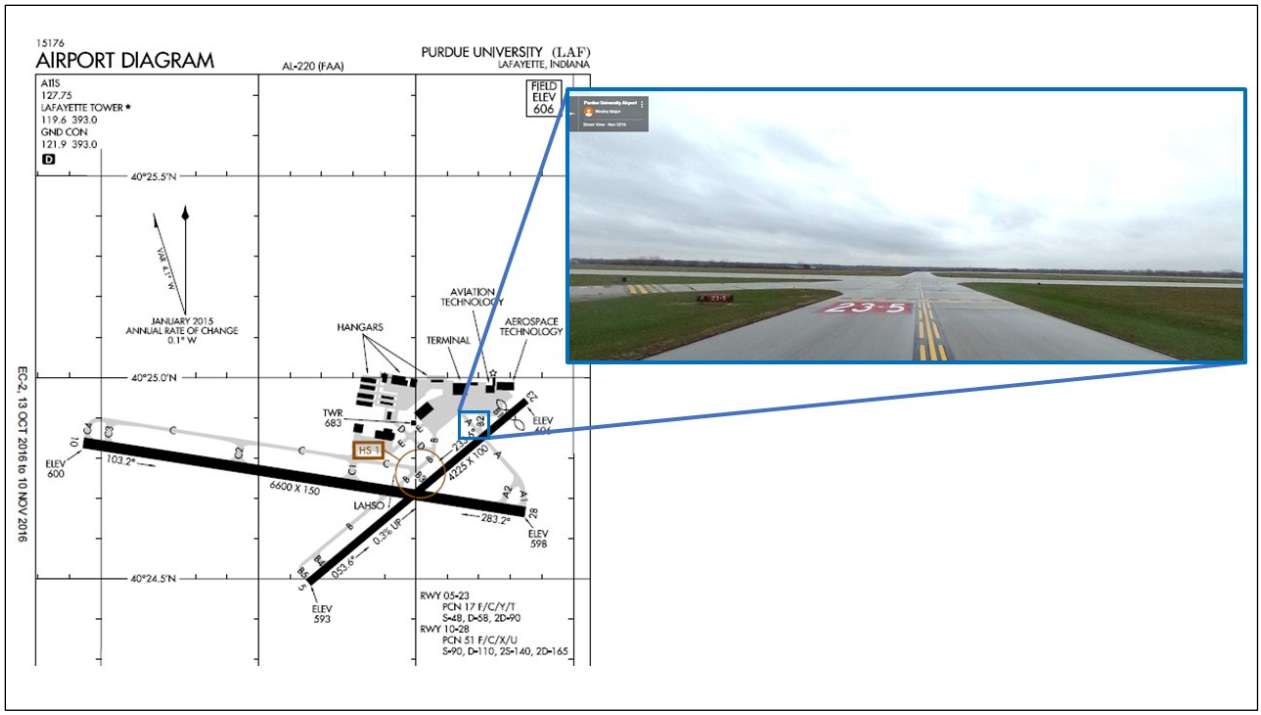

Figure 3. A 360-degree photo can provide an enhanced context for the airfield environment.

flight training. These are the kind of benefits that were substantiated by Schultz et al. (2008), in research that documented that virtual globes can be used to educate about the spatial environment. Similarly, pilots flying to an airport for the first time can familiarize themselves with the new environment and can incorporate the enhanced airport diagram into their pre-flight planning; familiarizing themselves with visual cues, and supporting the development of a movement plan, if desired. Ground personnel can also use this tool to train new team members on proper airfield navigation in a low risk environment. Emergency teams that do not normally operate on active airfields can utilize such a tool to maintain familiarity and support practice with airfield protocol. The enhanced airfield diagram would also be very useful as an aide during the table top exercises that are a required component for airport certification under Part 139. Perhaps most importantly, this tool can be used to illustrate hot spots and other potentially confusing areas on the airfield. Although airport diagrams label hot spots, they do not provide a strong visual context for hot spots. The use of the enhanced airport diagram, provides a means to examine airfield signage, runway markings, and other landmarks prior to experiencing them on the airfield.

Conclusion

Aviation safety is paramount, and the increase in runway incursions has prompted the FAA to created programs specifically to reduce incursions. This research sets forth a low cost method to familiarize airport users with the airfield, which will contribute to enhanced situational awareness and support a reduction in runway incursions. The traditional method of providing airfield information to aviation stakeholders via an airport diagram is useful, but a more modern version that incorporates photos is beneficial. A Google Street View style map of the airfield increases situational awareness, one of the risk factors identified by the RIM program, and results in a more robust visual aid, providing aviation stakeholders an accurate representation of the airfield procedures and conditions from a ground-based perspective, which has the potential to increasing safety and training efficiency.

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