Tracking and Monitoring Technologies to Support Airport Construction Safety

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Abstract. This paper discusses how advanced tracking and monitoring technologies can be used to increase safety for construction activities at airports. Airport construction is a significant infrastructure sector and in 2020 the Airport Improvement Program funded $300 million for airport projects in the United States. This includes funding for pavement reconstruction, airfield upgrades to meet current standards (e.g., wider runways), the construction of new terminal facilities, and additional capacity (e.g., new runways). The airfield environment presents special hazards for constructors, including proximity to active aircraft operations, and the requirement to comply with many additional rules such as those required by Federal Aviation Administration (FAA) and the Transportation Security Agency (TSA); many of these rules are required to ensure safety and security. Airport construction activities require close oversight, additional inspections by airport operations personnel, and stringent rules regarding access and operation in different areas of the airfield. Access and operating requirements affect both construction workers and construction equipment, and there are often different rules for different areas at the airport. One of the most restricted areas on an airport is the runway. Access to the runway and the safety area around a runway requires explicit permission from Air Traffic Control (ATC). If a vehicle or pedestrian (or aircraft) crosses the boundary without permission, it is considered a runway incursion. A runway incursion could cause a major incident at the airport and could result in injuries and fatalities. Runway incursion events are recorded by the FAA and represent a serious safety violation for the airport. Runway incursions and the technology to prevent incursions are discussed as an example that illustrates the need for and benefits of accurate monitoring of construction equipment and personnel. Technologies that may be used to enhance tracking and support situational awareness are present to illustrate the possible ways that enhanced monitoring can be used at an airport. Solutions may include the use of advanced technologies such as real-time vehicle location sensors, which may be combined with robust electronic maps to enhance safety for construction equipment and personnel location in the airfield environment. A discussion of opportunities and challenges of these systems is detailed.

1. Introduction

Airport construction is a large sector and growth in this sector will continue since airport construction supports the movement of both passenger and cargo. U.S. airports expected an average of $22 billion dollars of construction projects each year from 2019 through 2023 [1]. Future funding is expected to
remain strong, and in the coming years from 2021 to 2025, the U.S. National Plan for Integrated Airport Systems (NPIAS) identifies $34.3 billion dollars for airport projects related to reconstruction, standards, safety and capacity (2020) [2]. Airfield construction is critical to our aviation system, however, it can create operational challenges since airport construction is typically undertaken while aeronautical activities continue. This can create challenges for both constructors and airport users.

Different areas of the airport have different restrictions for use, and the runway is an area with the most restrictions. At airports with an air traffic control, all airport users must have permission to enter the runway or the safety area around the runway. If any vehicle, pedestrian or aircraft enters this area without permission, it is considered a runway incursion. Runway incursions are a major concern for airports due to the safety threat, and because the occurrence of a runway incursion implies a “near miss”. The official definition of a runway incursion is provided by FAA 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” [3]. Although there are many other operating constraints at an airport, examination of runway incursions provides a good case study to illustrate the operational constraints at an airport, which presents unique constraints, rules and regulations for constructors. This paper presents data on runway incursions when there is airport construction activities underway and then explores new technology that constructors and airports can employ to help reduce runway incursions during construction activities.

2. Background

Airfield construction is an important activity but it also introduces a number of operational and safety considerations. Airport construction affects many airport users, including pilots for airlines and general aviation aircraft (these are smaller airplanes used by individuals and businesses), air traffic controllers (ATC), personnel who ensure the safety of the runway and airports (often called airport operations personnel), airport tenants such as aircraft maintenance facilities and fixed base operators (FBOs), and emergency response personnel, called aircraft rescue and fire fighting (ARFF) personnel at airports. Not all airport construction activities have the same impact, and characteristics such as the number of construction workers, the kind of project, the project duration, the construction material and equipment, and the location of the construction project on the airfield may all affect the impact of the construction project on airport activities. In many cases, the construction project has defined stages and phasing throughout the duration of the project. Some characteristics such as material storage location, access points, and construction site boundaries may change throughout the project, which will have an impact on the airport operations, as well as safety, security [4] and cost. There is relatively little published research regarding airport construction on an active airfield, although some of the issues that have been mentioned in the literature include security escort requirements, night work, short closures, segmenting of work, provision of barricades and fencing, maintaining operational surfaces free of FOD (Foreign Object Debris), maintaining operational surface zoning requirements, protecting workers from jet blast, the need for flexibility to adapt to changing circumstances, unusual weather and labor disputes [5]. The limited research regarding the safety of airport construction is in sharp contrast to research in other transportation infrastructure sectors, such as the roadway sector, where there have been extensive studies related to work zones, including the associated costs, risks, and accident characteristics (e.g.[6 - 9]).

3. Data Pertaining to Runway Incursions During Construction

One metric for the impact of airside construction activities is the incidence and cause of runway incursions during airport construction [10]. FAA publishes runway incursion data in the Runway Incursion Database. Examination of data from the last two decades indicates there were 612 runway incursions that had “construction” in the narrative (for the years from 2001 to 2020). Details about these
runway incursions are shown in Figure 1. There are three primary causes for runway incursions: either a pilot makes an error, called a pilot deviation (PD), air traffic control makes an error, which is called an operational error (OE) or a pedestrian or the driver of a vehicle makes an error (VPD). For construction events, 46% are vehicle or pedestrian deviations (VPD), 33% are operation error (OE, caused by ATC) and 20% are pilot deviation (PD). VPD and OE are much more likely for events with “construction” in the narrative than for all runway incursion events, which are dominated by pilot deviations (60%). This suggests that there may be a need to provide better tracking of people and vehicles, which includes construction workers and construction equipment, when there is an active construction project at the airport. There may also be a need to provide additional support for air traffic controllers. One way to meet both these goals may be to provide better tracking of construction personnel and equipment, with the potential to make this information available to ATC.

Figure 2. provides information regarding the severity of runway incursions and Figure 3 provides definitions of these severities. FAA ranks runway incursions from severity A (most severe) to severity D (least severe). Fortunately, severe runway incursions (A and B) are very unusual event and represent less than 2% of all construction runway incursions. Most runway incursions pose no risk of collision, with 15% Type C and 32% Type D incursions. Approximately half of the construction runway incursions did not have a designated severity. A further breakdown of VPD, OE, and PD next to the definitions are shown in Figure 3. Vehicle or pedestrian deviation for type C and D are the most prevalent. Of the 612 construction runway incursions, 266 indicated a vehicle and 32 indicated a pedestrian (in the aircraft flight code columns); this suggests that vehicles may be a greater concern than pedestrians during airfield construction activities.

Figure 1. Distribution of Incident Type for Runway Incursions from 2001 to 2020.
4. Advanced technology to prevent runway incursions

To prevent runway incursions there are a number of technologies that can track and monitor people and vehicles in the airport construction environment. These technologies can be programmed to provide an alert when the vehicle and/or person is approaching and/or in proximity the proximity of an area that is restricted and/or has special operating rules. Technologies in both the construction and aviation sectors are being used for these types of purposes and offer solutions to airport construction issues such as runway incursions. While many of these technologies in both construction and aviation share common technology platforms the use, accuracy, robustness and applicability to the issue of runway incursions varies. In addition to the capability and applicability of the systems, the systems have to operate under FAA and airport operators’ rules and regulations and not interfere with plane and airport location and communication systems. In this section some potential technologies and systems used in both the construction sector and aviation sector are presented that could be applied to prevent runway incursions.

4.1. Construction Technologies to Prevent Runway Incursions

Construction companies have utilized many off the shelf commercially available systems to track people and equipment and with recent technology advances in tracking has become more feasible and economical. Tracking in construction is often used to support increased productivity and monitor safety issues. Initial productivity studies were done with data generated from the job jobsite and analysed later. As technologies have improved these systems have become real-time and are able to provide alerts to construction supervisors and safety personnel for safety issues and real-time production information.

4.1.1. GPS Positioning. Constructors have utilized low cost commercially available Global Positioning System (GPS) equipment to identify and track equipment activity [11]. GPS locations coupled with accurate mapping have the ability to provide real-time location and detect the proximity to airport protected surfaces to reduce the risk of a runway incursion. Location tracking could also be used on construction personnel similar to equipment. The real time data could be used to alert equipment operators, construction personal, and/or airport officials of a potential runway incursions and take appropriate action. GPS has the advantage over many other system because it is receiving signals from satellites and cell phone towers (Assisted GPS) and not sending or generating a signal. The generation of additional signals could interfere with plane and airport operations and would require additional FAA and airport approval.
| Severity | Description                                                                 | n  |
|----------|-----------------------------------------------------------------------------|----|
| **A**    | A serious incident in which a collision was narrowly avoided.               | 4  |
| **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. | 5  |
| **C**    | An incident characterized by ample time and/or distance to avoid a collision. | 94 |
| **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. | 197|

Figure 3. Severity Definitions [3] and Breakdown by Severity Type

4.1.2. UWB Positioning. Ultra Wideband (UWB) systems have also been utilized to provide real-time location information for construction workers and equipment. UWB systems use multiple receivers to triangulate a position [12]. The system consists of a central processing unit, receivers, UWB tags for the equipment and workers and a reference location. UWB could be used to detect a
worker or equipment leaving the construction site and getting close to or entering a protected surface in real-time. While UWB has been used for indoor tracking at airports in Beijing and Estonia [13-14], setting up a UWB system in the runway area may be an issue because of signal interference with airport and airplane cockpit instrumentation. UWB is advancing quickly such as the development of the 5G cellular network however electromagnetic interference with aircraft systems is still a concern [15].

4.1.3. Multiple systems positioning (Wi-Fi, RFID, GPS and Bluetooth). Commercial systems have been developed that use Wi-Fi along with other signals such as RFID (Radio Frequency Identification), GPS, and Bluetooth to accurately determine positions. Commercially available tracking systems such as Aeroscout [16] have developed systems based on Wi-Fi positioning that also use RFID and Bluetooth signals to triangulate a position. These systems could be used on their own but increased accuracy is provided with multiple systems. These systems have been used in airport environments such as in Davis-Monthan Air Force base [17] and Munich Airport [18].

4.2. Aviation Technologies to Prevent Runway Incursions

The airport environment is focused on safety and have for years been developing systems to keep airplanes safe and to keep the air and ground operation running smoothly including the prevention of runway incursions. To ensure the safety of the airport environment and prevent runway incursions, air traffic controllers track and monitor the location of the planes. In the airport environment, planes are monitored by a transponder that is known as ADS-B. ADS-B provides information to air traffic control with information on the identity of the plane, location, speed, altitude and additional data [19]. At some airports, an ADS-B system is also used for tracking ground vehicles; this and other systems to prevent runway incursions are currently being used in the airport environment and may have applicability to construction activities.

4.2.1. ADS-B out squitter. ADS-B out squitters are also known as ADS-B squitters, squitters, or Vehicle Movement Area Transmitters (V-MAT or VMAT)]. ADS-B out squitters can be used in the airport environment on ground vehicles, and this is the same kind of ADS-B transponder that is used on aircraft [20]. The ADS-B out squitter identifies the vehicle, and provides speed, similar to the information provided by ADS-B equipped aircraft. FAA limits the number of ground vehicles that use ADS-B out squitters, and the ADS-B system is used to support airport ground surveillance by ATC and is connected to the Airport Surface Detection System. The 35 largest airports have ASDE-X, which is the Airport Surface Detection Equipment - Model X; a newer version of this is ASSC, Airport Surface Surveillance Capability (ASSC) which has been installed at seven airports and provides enhanced capabilities in all kinds of weather to improve situational awareness and surface surveillance. Both systems use radar, multilateration, and satellite technologies to track the surface movements of aircraft and ground vehicles on the airfield and translate this information to a visual overlay of the airfield map that provides the real-time locations [21].

A primary goal of this technology is to prevent runway collisions and reduce critical Category A and B runway incursions by alerting ATC to any hazardous movements [22]. These systems also may reduce surface delays and improve situational awareness. However, the ADS-B systems for ground vehicles are expensive, require FAA approval, are geared for use by airport vehicles, and allow only a limited number of vehicles to use ADS-B squitters at the airport. Even if airports obtained permission to use ADS-B squitters for constructor equipment, it is very expensive and there are other more cost-effective solutions. Furthermore, the system is not set-up to track personnel in the airfield environment, only equipment. Another consideration is that since the system is intended for aircraft and a limited number of airport vehicles, the additional signals from construction system may overwhelm the system capacity cause confusion for air traffic controllers and pilots using cockpit displays. To use ADS-B squitters, both the airport authority and the FAA would need to approve and authorize the use of this equipment for monitoring construction activities.
4.2.2. Fleet Online Airside. Fleet Online Airside is used for tracking and location of ramp equipment and was developed by AdaptaliftGSE [23]. The system uses sensors to identify the current position and track each piece of airport ground vehicles equipped with a transponder. The software provides driver verification, vehicle control and monitoring, geofencing, safety overrides, and supports mobile communications. The geofencing aspects of the system would be useful for the construction process to ensure vehicles do not stray outside of their designated areas. Also, since the system is currently being used in the airport environment it has gone through the scrutiny of airport operations and would require less approval process to be used in the airfield environment. One drawback is it is set up for vehicles and not for workers.

4.2.3. Runway Incursion Warning System (RIWS). Similar to the GPS systems noted in the construction section, there are commercially available systems that combine the GPS signal with up to date airport GIS mapping information such as arriving and departing planes along with NOTAMs (Notice to Airmen, a safety alert system for the airport). These specialised systems, such as [24], provide on-screen airport information and can notify drivers of vehicles when there is a potential for a runway incursion.

5. Discussion
Technology in the construction industry for tracking equipment and people has become feasible and economical. Many commercial systems could be used to help avoid runway incursions by alerting equipment operators or personnel that they are going into an unauthorized location. Systems that use available signals such as GPS and cell phone towers signals to provide location information would be immediately applicable in the airport environment because they are only receiving signals and do not require additional systems to send out a signal.

The use of a Building Information Modelling (BIM) in construction that provides construction locations with specific coordinate details provides supporting information for GPS location systems and other location devices. Information from a BIM Model can be used to plan areas for construction along with acceptable and restricted movement areas and pathways.

Other proposed systems such as a local UWB system for highly accurate location detection would be difficult to use in airport construction environment because of concerns with signal interference and the process to get a system approved. However, as cellular companies begin to develop 5G UWB networks, these systems could be used in the airport environment as long as the signal is available. Accuracy is reported to be 10 meters in urban environments [25] which would make it feasible for both equipment and workers to have the technology available in their smart phone or other device.

Tracking and monitoring technology in the aviation industry is very advanced and there are many systems to support tracking. Aviation has been more focused on equipment (planes and ground equipment) and most of the systems are equipment based and do not support the tracking and location of individuals. While the software and hardware are available to allow construction equipment to be incorporated into the system, the addition of construction equipment would be a burden to the ATC and may not be allowed. The systems also tend to be expensive and may require extensive periods working in the airport environment or multiple jobs to make the equipment cost effective.

One requirement that is creating change in the ADS-B manufacturing industry is that all small planes [26] as of 2020 are required to have ADS-B system. This has created a bigger market for ADS-B systems and the cost has reduced. Also, there is discussion that drones (aka Unmanned Aircraft Systems (UAS)) also should be equipped with an ADS-B type transponders [27]. Because of the increase in number of signals the airport may receive there are also changes being made to the transponders that may only provide a signal when they are near an aircraft or close to a runway/airport (site UAS). These recent movements may make it feasible in the future for construction equipment to be equipped with a ADS-B transponder to provide better monitoring of the airport environment.
There are also a significant number of systems in aviation that work similar to the construction industry location and tracking systems. Since these systems are already used in the airport environment they could be easily employed for construction activities. Constructors may also want to consider these types of devices since airport operation and the FAA are more familiar with their operation.

6. Conclusion

Airport construction during active airport operations requires an additional level of safety and monitoring of equipment and personnel to ensure the safety of both the planes and construction personnel. Runway incursions due to construction are significant concern and advanced technologies are available to help prevent runway incursions. Both the construction industry and airport industry have technologies available to help reduce the number of construction runway incursion events. Many of these systems are immediately applicable to help reduce the potential for injuries and fatalities of an airport incident.

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