Terminal Surveillance of Aircraft Ground Operations Using GPS

The global positioning system plays a key role in a multimodal technology approach to creating a safer environment for aircraft operations on the ground.

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The successful control of ground operations at large-terminal airports depends on precise communication between ground traffic controllers and the crew of the transiting aircraft. Multiple surface operations of aircraft, service and emergency vehicles — especially occurring in low-visibility conditions such as fog, precipitation, low light or darkness — may set the stage for potential traffic conflicts and incident occurrence. Visual cues such as runway and taxiway markings, lights and distance markers assist the movement of aircraft and ground vehicles. Charts denoting position and standard taxi clearances are also available to the crew in transit. Nevertheless, there is a need for the use of surveillance initiatives incorporating the latest technological advances to augment pilot-controller communication and visualization for the necessary separation of multiple aircraft and other ground vehicles.

According to the Federal Aviation Administration (FAA), a runway incursion can be defined as any "occurrence at an airport involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." Runway incursions are made up of pilot deviations, operational errors and vehicle or pedestrian deviations. Although these incursions are mainly unintentional, they are violations that happen on an average of more than two hundred times each year. Runway incursions have steadily increased from 186 in 1993 to 319 in 1997. The runway incursion rate per 100,000 airport operations was 0.30 in 1993 and has risen sharply and steadily to 0.50 in 1997.

In the past, these runway incursions have resulted in multiple fatalities. The worst aircraft accident in history occurred on March 27, 1977, in Tenerife, Canary Islands. It involved a Pan Am Boeing 747 aircraft and a KLM Boeing 747 aircraft. The death toll was 583. Both aircraft were on the active runway, with the Pan Am plane taxiing and the KLM plane taking off. Poor communication, loss of positional awareness, poor judgment and low visibility led to the collision. Since then, 100 persons died in Madrid, Spain, when two Spanish airliners collided in 1983 on a runway. Two Northwest airliners, a Boeing 727 and a DC9, collided in Detroit in 1990. An Eastern Boeing 727 and a Beechcraft 100 collided in Atlanta, Georgia, in 1990. A US Air Boeing 737 and a Skywest Fairchild Metroliner collided in Los Angeles, California, in 1991. More recently, a TWA MD80 and a Cessna collided in St. Louis, Missouri, in 1994. In 1996, in Quincy, Illinois, a United Express Beechcraft 1900C and a King Air A90 collided.

Given the demands on our air transportation system, it may be inevitable that these incursions will increase unless intervention is performed. On April 14, 1998, then Vice President Albert Gore, Transportation Secretary Rodney Slater, and FAA Adminstrator Jane Garvey announced a comprehensive plan to review the causes of aviation accidents and adopted an agenda to reduce fatal accidents by at least five-fold. This initiative, called "Safer Skies," focused on six major areas including runway incursions. The use of new technologies (such as airport surface detection equipment and an airport movement area safety system) were adopted along with a continued education program designed to help the aviation community reduce the number of runway incursions — the goal of the FAA's Runway Incursion Reduction Program. The project developed technical and operational specifications, then proceeded through developmental testing into full-scale development.

Using the Global Positioning System

Currently, standards for required navigation performance (RNP) are being studied and developed by the International Civil Aviation Organization's (ICAO) All Weather Operations Panel (AWOP) for advanced surface movement guidance and control systems (A-SMGCS). With the advent of the global positioning system (GPS) and its future modifications, there exists the potential to improve the situational awareness of both the controller in the tower and the crew managing the aircraft.

GPS technology utilizes twenty-four satellites at an 11,000-mile orbit around the earth. These satellites transmit signals to receivers below. By calculating the time delay between transmissions of the signals from the satellite to the receiver, the distance to the satellite can be measured. When signals from at least four satellites are received, a receiver can determine its longitude, latitude, altitude and time. Two-dimensional accuracy of approximately 300 feet is achieved 95 percent of the time on or near the earth's surface.

As the development of the GPS in the United States and global navigation satellite systems (GNSSs) worldwide progress, the required parameters of integrity, continuity, accuracy and availability of these systems will be assured. Under development in the United States, the wide area augmentation system (WAAS) and the local area augmentation system (LAAS) will soon play a key role in managing airport ground operations using differential GPS solutions (DGPSs). WAAS became operational for FAA visual flight rules (VFR) in the United States in August 2000.

Some difficulty exists in obtaining GPS accuracy due to atmospheric and terrain errors inherent in the reception of satellite transmissions. However, selective availability (SA) — the intentional degradation of the GPS signal by the U.S. Department of Defense (DOD), which affects the use of the system for precise flight and ground control operations — has been discontinued since the spring of 2000 by order of the U.S. President, thereby lessening intrusions on GPS accuracy.

The WAAS is an enhancement to the current GPS protocol. WAAS is a network of precisely surveyed ground stations positioned across the United States (including Alaska, Hawaii and Puerto Rico) to collect satellite data. With this information, satellite signal errors are measured at ground stations and transmitted to broadcast geostationary communication satellites. The correction signal is transmitted at the GPS L1 frequency to user ground and aircraft receivers. Primarily used for Category I precision approaches, missed approaches and departure guidance for airports throughout the National Airspace System, it will not provide the accuracy for precise position reporting for taxiing aircraft.

The LAAS, when completed, will be able, through precisely placed differential GPS transmitters in the terminal environment, to provide complete navigation capability for all phases of flight (including Category II and III precision approaches). LAAS will also provide the sole means of navigation capability down to the surface within a 30-mile radius. Differential GPS solutions that can be performed with the commissioning of LAAS will assure accuracy for terminal ground guidance and control.

Surveillance Initiatives

Some of the technological advances available today for improved ground control include:

- airport surface detection equipment (ASDE-3): a primary radar for locating surface traffic and providing a visual display to the controller;
- airport movement area safety system (AMASS): logic software, which provides runway incursion detection with alert and tracking capabilities;
- airport surface detection equipment (ASDE-X): a low-cost marine X-band radar, providing runway incursion detection and alert capabilities;
- airport surface target identification system (ATIDS): a location and identification system using automatic dependent surveillance broadcast (ADS-B) and multilateration or triangulation with mode-S transponders;
- forward-looking infrared radar (FLIR): provides a depiction of an aircraft's infrared signature via a visual display; and,
- inductive loop technology: a surface detection technology prototype that classifies, tracks and records ground activity.

All 34 highest activity U.S. airports now use ASDE-3; the next 25 highest activity U.S. airports will use low-cost ASDE-X and will include Phoenix, Orlando, Honolulu and Oakland. AMASS is planned to be operational in all 34 highest activity airports; airports in San Francisco and Detroit are now using AMASS.

Integrated Surface Movement Technologies

Conducted during the summer of 1997, tests were performed using a Boeing 757-200 research aircraft in ground control operations at Atlanta's Hartsfield International Airport. Research data were collected during roll-out after landing, turning off the landing runway, and inbound and outbound taxi operations. These tests were a follow-up to trials conducted at the FAA Technical Center in Atlantic City, New Jersey, during the summer of 1995.

Equipment in the test aircraft included a heads-up display (HUD) that presents a computer-generated holographic-like display of the runway and taxiways, a cockpit panel mounted liquid crystal display (LCD) for visualization of the airport environment as well as other transiting aircraft, a pilot input device (PID) to control the LCD, a VHF data link between the Mode-S transponder equipped Boeing 757 aircraft and the ground controller for the transmission and reception of printed data and instructions, and, finally, a precise position reporting system integrating a differential GPS and an inertial reference unit (IRU).

The ground-based system included ASDE-3 radar, ATIDS with AMASS components, a flight plan unit (FPU) to correlate existing radar data and air traffic information, a DGPS ground station for signal correction, a controller interface (CI) converting voice messages to digital format for transmission and display in the aircraft cockpit on the LCD. Approximately 23 hours of data from audio, video and digital messages were collected for analysis.

Results & Comments

Preliminary results support the use of these integrated technologies in improving safety and efficiency in airport terminal environments. When the data are completely analyzed a clearer understanding of how these systems integrate for the control and routing of aircraft on the terminal airport surface will emerge.

ADS-B receiver signal reception in the aircraft ground operations area for each of the five receivers used was approximately 60 percent. There was a 98 percent probability of receiving accurate signal updates within 0.95 seconds. Multilateration position updates of the 757-200 test aircraft were obtained for 78.8 percent of the Mode S transponder transmissions. Errors were caused by system failures due to lack of synchronization, system inefficiencies (timing errors) and interference with the signals due to airport structures.

It is clear that these technologies are currently available to assist with the ground control of aircraft in the terminal environment. However, at present, their use needs augmentation with non-cooperative surveillance initiatives for improved system accuracy, redundancy and for the location of vehicles not using these technologies.

Pilots felt an increase in situational awareness, an increase in confidence during taxiing operations and an increase in speed of movement. Controllers felt that an LCD at the controller's position similar to the pilot's equipment in the test aircraft would enhance situational awareness. Concern was raised about the accuracy of the voice recognition system implemented in the study, especially with regard to how it would respond during periods of extreme voice inflection.

Conclusions

The feasibility of a multimodal use of technology to improve situational awareness, safety and efficiency in the terminal airport environment during aircraft ground operations is affirmed by this study. In addition, the use of the GPS is clearly established as a vital means to achieving current and future navigation needs.

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