AIRPORT SURFACE COLLISION WARNING SYSTEM IMPLEMENTATION

Joseph W. Ianniello, Raymond M. Kruczek

United Technologies Norden Systems, Inc.
P.O. Box 5300
Norwalk, Connecticut USA 06856
Phone: (203) 852-5000 FAX: (203) 852-7698

ABSTRACT

The Airport Movement Area Safety System (AMASS) is a ground traffic control advisory system. It tracks aircraft and other surface targets using data from two available sensors; the airport surface radar, and the terminal surveillance radar. The system stores an adaptive data base that defines the airport geography and traffic rules. AMASS algorithms use the airport configuration data base and aircraft track files to test for nearly one thousand hazards. AMASS issues audible warnings, and displays the location of the aircraft involved on existing monitors. This paper describes system operation, technology, and future enhancements. Preproduction system testing and validation at San Francisco International Airport (SFO) is also described.

AMASS is an outgrowth of Norden research and development. The preproduction program was funded by the United States Federal Aviation Association (FAA).

AIRPORT SURFACE TRAFFIC AUTOMATION OVERVIEW

Norden developed and demonstrated the Runway Incursion Monitoring (RIM) system on IR&D funding in 1990. The FAA's interest was heightened when three major airport surface accidents occurred in the United States between January 1990 and February 1991. Reference [1] describes these accidents. The AMASS program was funded by the FAA to complete the development of these concepts.

AMASS is a computer based system to help controllers manage traffic on airport surfaces. It can be installed without disrupting airport operations. The following are key system attributes:

a. AMASS does not require additional aircraft equipment. This eliminates the delays caused by equipment definition, development, and installation.

b. AMASS has minimum impact on airport operation during installation. Equipment is added in the equipment room of the control tower, not on airport surfaces. This is an important system attribute since adding equipment on airport surfaces involves large expenditures and disruptions to airport operations.

c. AMASS is a modular design that enables future enhancements and additional sensors. It can be upgraded to be compatible with other systems such as the Global Positioning Satellite (GPS) system.

d. AMASS allows custom installation at different airports and is capable of easy adaptation to changing airport configurations, both on a long range and daily basis.

Figure 1 is a simplified system block diagram. For the initial installation, two existing systems monitor traffic conditions — the Airport Surface Detection Equipment (ASDE-3) radar and the Automated Radar Terminal System (ARTS). ASDE-3 systems are being installed at 29 United States airports. Additional installations are planned. ASDE-3 images the airport surface and provides a complete map update once per second. ARTS is an existing FAA system. It provides data on aircraft being monitored by the Airport Surveillance Radar (ASR) which includes positional, status, and identification information of approaching aircraft. In addition, ARTS provides runway assignments for parallel approaches.

Programmable, high speed processors group sensor data into target clusters. They perform target filtering, detection, and compute target location, size, and velocity. These processors maintain track reports for each target.

A general purpose computer performs the airport configuration and adaptation functions, estimates future target positions, and tests for incursions.

The alert information provided by AMASS is both visual and audible. Visual alerts identify areas with potential incursions highlighted on existing controllers' displays. Audible alerts are voice messages that announce the incursion type and location. Alert processing is done in the programmable, high speed processors.

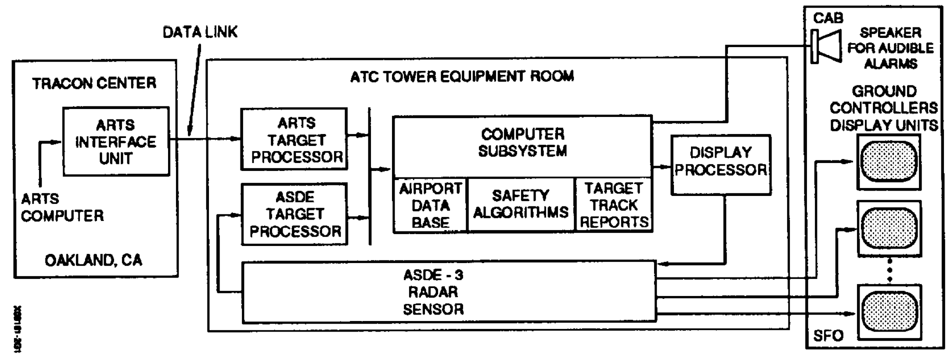

Figure 1. AMASS Overview

SUBSYSTEM OPERATION

Airport Surface Detection Equipment

Figure 2 is a simplified block diagram of the ASDE-3 system. ASDE provides a radar image overlaid on an airport configuration map on the monitors used by ground controllers. The major characteristics of the ADSE-3 system are:

a. The RF transmission is at Ku band. The transmitter has wide frequency agility and uses circular polarization. The high RF frequency results in a 0.25 degree beam width using a 5-meter antenna. This resolution provides fine imaging details that can enhance feature extraction in future implementations. The antenna is housed in an aerodynamically designed, heated rotodome. The rotodome sheds ice, rain, sleet, and snow. The circular polarization, frequency agility, and rotodome enhance the Ku-band performance in precipitation. The Federal Communications Commission (FCC) frequency allocation imposes Ku-band operation.

b. The antenna rotates at 60 revolutions per minute. The one-second update of the complete airport surface map maintains target tracks to the accuracy necessary to detect and project future positions.

c. The display subsystem provides a flexible graphics capability that:

1. Stores and displays the radar image
2. Stores and displays the airport configuration (runways, taxiways, buildings,etc.)
3. Mixes the radar image with the airport configuration
4. Provides independently controlled displays to observe different areas of the airport
5. Enables up to three windows on each display
6. Provides zoom, expand, and panning capabilities
7. Provides an external video port

AMASS uses the ASDE-3 display to identify the location of the alert and the aircraft involved. This information is superimposed on monitors through the external video port.

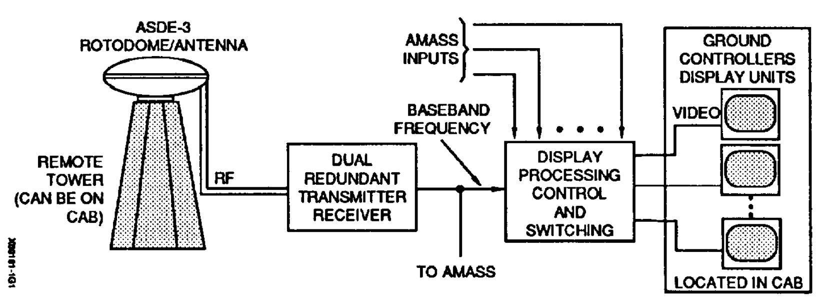

Figure 2. Simplified Block Diagram of the ASDE-3 System

AMASS was installed at SFO to verify its operation. The system elements described in the following sections are for the SFO installation.

Automated Radar Terminal System

The Automated Radar Terminal System (ARTS) computer used for SFO is at the Terminal Radar Approach Control Facility (TRACON) in Oakland, California. Reference [2] is an overview of the United States Air Traffic Control (ATC) system. The Airport Surveillance Radar (ASR) detects in-flight aircraft, both by primary radar returns and by interrogating the on-board beacon transponder. The transponder provides other aircraft flight information, such as altitude, aircraft identity, landing runway number, etc. AMASS equipment at the TRACON location has a listen-only interface with the ARTS computer and filters ARTS data to identify aircraft approaching the airport. A microwave data link transfers this data over a modem to the AMASS equipment at the airport. The ARTS processor shown in Figure 2 receives this data and formats track reports for AMASS correlation and safety logic processing.

Airport Movement Area Safety System

Figure 3 is a photograph of the AMASS equipment. The system installed at SFO monitors active airport areas — runways and taxiways. The ARTS data contains aircraft identification tags that can be affixed to landing aircraft symbols on ground controller displays. Future implementations will incorporate additional sensors to expand the area of coverage, enable all aircraft and vehicle identification, and automatically communicate with pilots.

Sensor Input Processing: The sensor input processing detects and correlates ASDE-3 and ARTS targets. The correlation function is performed from scan to scan of each sensor, and between sensors. The processing depends upon the particular sensor characteristics, but in general consists of the following:

a. Filtering operations to reject clutter and unwanted targets, and resolve ambiguous reports

b. Computations and logic to associate a given grouping of returns as a single target, and identify new targets

c. Operations to compute the centroid and extent of image groupings

d. Tracking algorithms to correlate targets from different reports of a single sensor.

The processed sensor information forms track reports containing target coordinates, size, identification, aircraft type, assigned runway, etc. These track reports are transferred to the computer subsystem.

Computer Subsystem: The computer subsystem performs safety logic processing, controls system operation, and manages the airport configuration data base. Reference [3] details all the tasks of the computer subsystem. This section describes the safety logic processing that detects and identifies hazardous situations.

For each target track report, the safety logic uses the target location, velocity, acceleration, and movement state to assess the traffic situation, and applies algorithms to detect incursions and rule violations. For example, assume an aircraft (Target A) is departing and a second aircraft (Target B) is on a taxiway approaching the runway as depicted in Figure 4. The safety logic must identify the situation, determine if they can simultaneously arrive within a safe window of the intersection, and issue the appropriate alert.

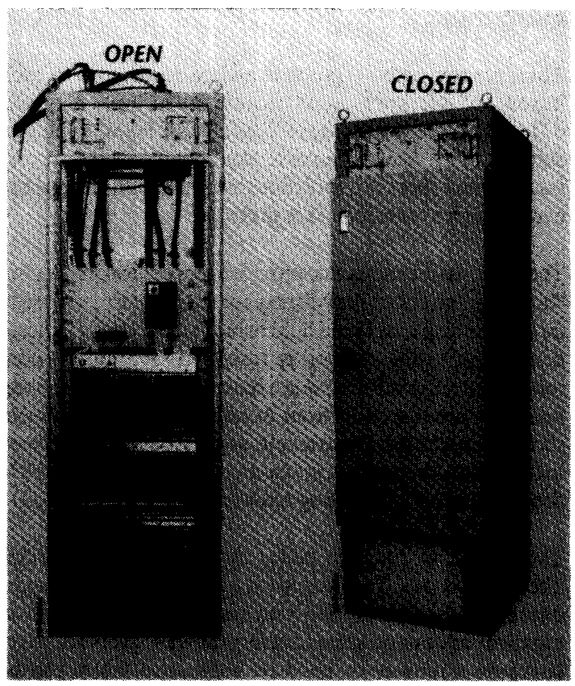

Figure 3. AMASS Cabinet

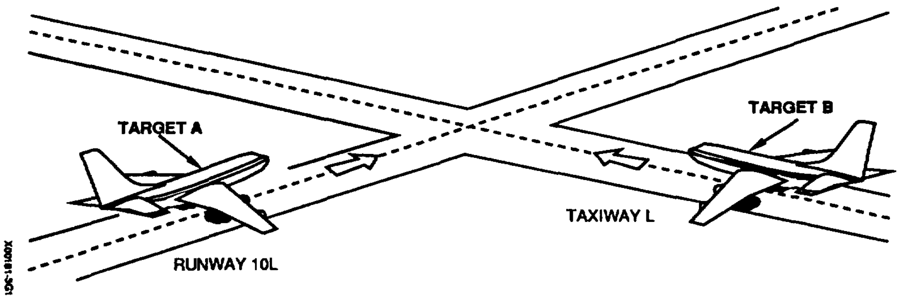

Figure 4. Crossing Runway Situation

The safety logic uses a geographic data base description of the airport and the target data in the track reports to identify and classify the positional situation of aircraft. For each situation, a table defines the algorithm appropriate to identify problems.

Each table depects two targets, A and B, in possible conflict with each other. The movement state (departure, departure abort, landing, taxi, arrival, stopped) of each target is determined along with its direction of travel along a surface. A subroutine declares either a "problem" or "no problem" at the table intersection of each pair of targets. This subroutine contains parameters that specify minimum separation distance and/or time, and estimates the location of each target after a specified time.

There are two cells — problem and no problem — at each movement state intersection because the software may take different actions depending on the situation. For example, the software may declare "no problem" but a caution may be issued when there are violations of separation parameters even though a collision is not probable.

The two classifications also provide a mechanism for placing "hold bars" on controllers displays or, in the future, a message on aircraft displays. Fixed hold bars at intersections indicate that access to the runway is restricted, and are a visual reminder to all controllers that a runway is occupied. Moving hold bars are placed in front of aircraft whose movement should be restricted. For example, a moving hold bar is placed in front of an aircraft in position-and-hold when an aircraft is departing on an intersecting runway.

There are four situation tables implemented in AMASS. These include: (1) Two targets on a runway, (2) Two targets on separate, but intersecting runways, (3) Two targets; one on a taxiway and one on an intersecting runway, and (4) A single target on a runway or taxiway. Additional tables can be added.

The safety logic processing is performed once every second.

TEST AND VALIDATION

Two formal testing programs have been used to validate AMASS performance.

Factory Demonstration

The first demonstration was a factory demonstration completed in October 1992 to validate the safety logic processing, the alarm generation, and the interface for adapting the airport configuration. Data recording and playback equipment captured aircraft movement scenarios at SFO. Test scenarios developed from these recorded tracks simulate single and two target test traffic situations, and exercise the safety logic. In addition, a synthetic target track is actuated by a computer "mouse." The mouse designates starting position, time, and direction to simulate real time-traffic situations. One hundred incursions were demonstrated to teams of air traffic controllers, program management personnel, MIT Lincoln Laboratory consultants, and MITRE Corporation consultants. The demonstration was considered a success.

Field Validation

The second test was a Field Validation at SFO employing an uncommissioned ASDE-3 and a commissioned ARTS installed at the TRACON center in Oakland, California. An Arts Interface Unit installed at Oakland used a modem to transfer data to SFO. The demonstration used live operational data but was off-line so as not to interfere with airport operations.

The testing at SFO was successful and AMASS production equipment fabrication is expected to begin in the near future.

EQUIPMENT FEATURES AND OPTIONS

The computer subsystems — in AMASS proper and in the ARTS Interface Unit located at the TRACON site — are rugged personal computers. Table 1 lists the specifications.

Table 1. Equipment Specifications

Component	AMASS Proper	ARTS Interface Unit
CPU	Intel 486 DX 25 MHz	Intel 486 DX 25 MHz
RAM	4 Mbytes	4 Mbytes
MASS STORAGE	80 Mbytes Fixed 210 Mbytes Removable	120 Mbytes Fixed
PERIPHERALS	Voice Processor Special Interface	Modem
LANGUAGE	WATCOM C/386	WATCOM C/386

TMS 320/40 Digital Signal Processors (DSPs) perform the input sensor, voice, and display processing.

A 6-foot, 19-inch cabinet (see Figure 3) houses the on-site AMASS equipment. The cabinet contains five 6- by 9-inch circuit card assemblies and an additional 2 display interface circuit cards for each ASDE-3 display processor (ASDE-3 can have a maximum of 8 display processors to support up to 24 controller display monitors). The digital technology is dual in-line packages. Nine thousand gate Field Programmable Gate Arrays perform many of the logic implementations.

ENHANCEMENTS

Norden is developing techniques to automatically identify aircraft and other airport vehicles. This will provide flight numbers on controller displays and accurate target size information in target track reports. Aircraft size information enables the detection of interference between two aircraft. Flight numbers attached to the aircraft radar video on the monitor help controllers identify aircraft quickly.

Reference [1] describes the use of runway lights to provide advisory information to pilots. AMASS could control these lights, however, Norden is developing a method to communicate directly with the aircraft display. This will be less costly and less disruptive to airport operations than installing runway lights.

AMASS presently monitors aircraft on runways and major taxiway intersections. It is compatible with future sensor enhancements to extend coverage beyond the movement area.

Radar as a sensor has the important advantage that it does not require any special equipment on the aircraft or other targets. The use of a sensor that requires equipment on aircraft and airport vehicles is more than a monetary burden. A system requiring active participation by targets cannot detect targets with failed responders, or targets that have no responders such as intruding vehicles and debris on airport surfaces. The radar sensor has the disadvantage that the returns are highly dependent on the reflectivity of the targets that can vary as a function of the aspect angle between the target and the radar antenna.

AMASS installed systems will probably incorporate at least two or more sensor types in the future to address these issues. Work is underway to integrate the AMASS concept into a complete solution for airport surface management. Interface to the aircraft Global Position System (GPS) will be an important future addition.

SUMMARY

This paper describes the AMASS concept and implementation. This system is a pioneering experiment into the application of electronic technology to ensure the safety of airport surface traffic. Also presented is a brief discussion of future improvements and enhancements to the system.

The lessons learned and results from testing the preproduction system at San Francisco International Airport indicate that AMASS is conceptually sound and the implementation will provide aid to airport ground controllers.

REFERENCES

[1] Ervin F. Lyons, *The Automation of Surface Traffic Lights to Improve Airport Safety*, New York: IEEE Systems Magazine, pages 14 to 20, March 1993.

[2] Tekla S. Perry, *Special Report: Air Traffic Control*, IEEE Spectrum, pages 22 to 36, February 1991.

[3] Marshall Watnick and Joseph W. Ianniello, *Airport Movement Area Safety System*, Proceedings of the 11th Digital Avionics Systems Conference, pages 549 to 552, October 1992.