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NASA Runway Incursion Prevention System (RIPS) Dallas-Fort Worth Demonstration Performance Analysis

Rick Cassell, Carl Evers, Jeff Esche, and Benjamin Sleep
Rannoch Corporation, Alexandria, Virginia

June 2002

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EXECUTIVE SUMMARY

This report describes the test results of the runway incursion alerting systems recorded during the NASA Runway Incursion Prevention System (RIPS) testing at Dallas - Fort Worth International Airport (DFW) in October 2000. Both aircraft-based and ground-based runway incursion alerting were implemented and tested. The Runway Safety Monitor (RSM) and Runway Incursion Advisory and Alerting System (RIAAS) are aircraft-based runway incursion alerting systems. RSM was developed in-house by NASA. RIAAS was developed by Rannoch Corporation. The John A. Volpe National Transportation Systems Center (VTNSC) implemented the Ground-Based System (GBS). Prototype versions of RIAAS and RSM were installed on NASA's B757 aircraft (also called the Airborne Research Integrated Experiments System or ARIES).

The objectives of the RIPS flight test were [Ref. 1]:

Assess and validate the performance of Communications Navigation and Surveillance (CNS) infrastructure technologies and incursion alerting systems for preventing runway incursion accidents. Specific objectives were:

- Assess the performance of the airport surface infrastructure (data linked Surface Traffic Information Service – Broadcast (STIS-B) with runway incursion alerting) for providing sufficient situational awareness and warning to prevent runway incursion accidents.

- Assess the performance of aircraft-based runway incursion alerting systems for providing sufficient situational awareness and warning to prevent runway incursion accidents utilizing the following data sources:

  (a) STIS-B from airport surface infrastructure

  (b) Automatic Dependent Surveillance – Broadcast (ADS-B) aircraft to aircraft data link

Runway incursion scenarios were performed using the B757 and a ground vehicle. Some of the key performance measures analyzed include warning response times, missed detection performance, false alert generation, and surveillance latency.

The primary conclusion of this report is that the three types of approaches to generating runway incursion alerts in the cockpit demonstrated feasibility during the DFW RIPS testing. Out of the 47 test runs, RIAAS provided alerts on 44, RSM on 43, and GBS on 34. All of the missed alerts on RIAAS and RSM were a direct result of erroneous or missing traffic data. Most of the missed alerts for GBS were related to the original alerting criteria, which were changed part way through testing. Other missed GBS alerts were mostly due to the design of some specific scenarios where the GBS alerting criteria were not satisfied. In these instances the relative locations of the aircraft and test vehicle did not meet the GBS criteria for alert. RIAAS generated 2 false alerts during the testing, both the result of erroneous traffic data. RSM generated 4 false alerts, which were the result of the ownship-generated STIS-B traffic reports. GBS generated 9 false alerts during the testing, most of which were due to an apparent false ASDE-3 target located off the runway.

The testing showed that the pilot could safely take evasive action (i.e. go-around, rejected take off, stop taxi) when the alerts normally occurred on all three systems for the four incursion scenarios tested. However, for the scenarios involving violation of hold lines, the GBS alerts occurred significantly later than for the aircraft-based systems. In those two scenarios (1 and 3) the GBS alerts did not occur until the vehicle/aircraft was on the runway. The two aircraft-based systems alerted well before the vehicle and aircraft reached the runway.

Regarding the integration of the supporting airborne and ground systems, the test results indicate that the basic system architecture demonstrated at DFW will support both aircraft-based and ground-based incursion alerting. One conclusion, as expected, is that alert logic performance is very dependent on the performance of the traffic and ownship position information. This information must be reliable, timely and accurate to ensure optimum runway incursion alerting performance. The NASA B757 airborne systems demonstrated excellent performance with respect to ownship information. However, there were a number of issues identified regarding the generation and processing of traffic information using STIS-B and ADS-B. Missing or erroneous STIS-B and ADS-B data resulted in a number of missed, late, and false alerts. The prototype nature of the systems involved is believed to have played a significant role in the availability and integrity of the traffic data. One specific conclusion with regard to traffic information is that STIS-B information had significantly longer latency than did ADS-B. This translates directly into delayed alerting on targets using position reports from STIS-B. ADS-B position reports were also significantly more accurate than STIS-B.

RIAAS demonstrated a two-stage alerting concept, which includes a Traffic Alert and a higher priority Conflict Alert. The other two systems, RSM and GBS, provided a single conflict alert. The intent of the two stage alerting is to provide advanced warning to the pilot of a pending conflict. For most of the scenarios tested, the RIAAS two stage alerting worked as designed, providing time between the two alerts (as much as 10-20 seconds) for the pilot to determine the best course of action. Further simulation and testing is required to validate and optimize the two-stage alerting approach.

The testing demonstrated that aircraft-based alerting has several key advantages over ground-based alerts provided via data link, including:

- Shorter time delay between alert generation and annunciation of alerts to the flight crew.

- More timely alert generation. One reason for this is the capability to use ownship position data to accurately determine the ownship nose location. This provides a means to very accurately determine when ownship has violated a hold line on entering a runway. A similar computation can be made for the tail location to determine when an aircraft has failed to clear the hold line on exiting a runway.

- Ground infrastructure is not required when aircraft are equipped with ADS-B.

Aircraft-based alerts provided to the flight crew will in some cases occur in advance of ground-based alerts provided to ATC. For example, in the case where ownship violates the hold line, an aircraft-based alert can occur sooner than the ground-based alerts due to the ability to accurately determine nose position. There is a safety benefit to alerting the flight crew as soon as the aircraft has crossed the hold line. This may present an issue regarding the difference in timing for the two alerting systems. The compatibility of aircraft-based alerts reported to the flight crew and ground-based alerts reported to ATC needs further investigation.

Analysis of the test results yielded several recommendations regarding the supporting infrastructure and the alerting systems, including:

- Further development of ground and avionics systems should include enhancement of availability and integrity of ADS-B and STIS-B traffic information. The ground system should provide integrity monitoring of surveillance data prior to STIS-B transmission. STIS-B should transmit a parameter equivalent to the ADS-B Navigation Uncertainty (NUC). This will indicate the accuracy of the surveillance information. The latency in the STIS-B transmissions should also be minimized to reduce alert delays.

- A reference point correction for the ADS-B target should be performed. It is recommended that the ADS-B MASPS be amended to include a requirement that the reported position is referenced to a standard location on the aircraft. If the position is provided to a known location then the alerting systems can apply the correction to other critical aircraft points of reference (i.e., nose, tail).

- The ground system should provide STIS-B position reports that are corrected to a reference point, such as the nose or centroid of the aircraft. The ground system has knowledge of the surveillance sensor(s) used to determine the fused position. Each sensor can use a different reference point. For instance, ASDE-3 position is referenced to the target centroid and multilateration position is referenced to the transponder antenna(s) location. The avionics does not have the knowledge of which sensor is used to compute the ground system derived traffic reports.

- Aircraft-based incursion alerting systems should incorporate some level of integrity checking on traffic information to minimize missed and false alerts.

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1.0 INTRODUCTION

Airport surface incursions have been identified as one of the most significant safety hazards in civil aviation [1]. The Runway Incursion Prevention System (RIPS) is being developed by NASA in cooperation with the Federal Aviation Administration (FAA) to help address this problem. RIPS builds on the airport ground systems infrastructure put in place by the FAA. This ground infrastructure includes the following functions:

- Surface Surveillance – Provides surveillance of airport surface traffic.
- Ground-Based System (GBS) Alerting - Processes the traffic information to identify runway incursions and provide alerts for presentation to the Air Traffic Controllers or the flight crews.
- Surface Traffic Information Services – Broadcast (STIS-B) – Transmits surface surveillance traffic information to aircraft and ground vehicles.
- Local Area Augmentation System (LAAS) - Provides aircraft and ground vehicles with differential corrections to GPS navigation.
- Controller pilot data link – Provides ATC taxi instructions to the flight crew via a data link.

RIPS avionics supports enhanced safety by providing the flight crews with information regarding navigation, traffic movement, and runway incursions. This information is available on a Cockpit Display of Traffic Information (CDTI). Additionally, a Heads Up Display (HUD) provides navigation and traffic information directly to the pilot. Audible alerting is provided in conjunction with the display devices. Traffic information is obtained from the ground infrastructure via STIS-B, and can also be obtained directly from other aircraft via Automatic Dependent Surveillance – Broadcast (ADS-B).

This report describes the performance results of the runway incursion alerting systems recorded during the NASA Runway Incursion Prevention System (RIPS) testing at Dallas - Fort Worth International Airport (DFW) in October 2000. Both aircraft-based and ground-based runway incursion alerting systems were implemented and tested. Runway Safety Monitor (RSM) and Runway Incursion Advisory and Alerting System (RIAAS) are aircraft-based runway incursion alerting systems. RSM was developed in-house by NASA. RIAAS was developed by Rannoch Corporation. The John A. Volpe National Transportation Systems Center (VTNSC) developed the GBS. Prototype versions of RIAAS and RSM were installed on NASA's B757 aircraft, the Airborne Research Integrated Experiments System (ARIES).

The RIAAS and RSM systems provide runway incursion alerts directly to the flight crews. While the FAA is in the process of implementing ground-based alerting for Air Traffic Control (ATC) tower controllers, there is no operational system to alert pilots automatically at the onset of such conflicts. Ground-based alerts must be relayed by ATC, via voice communications, to the flight crew. The flight crew does not have the same level of situational awareness as ATC, because they lack the situational display of traffic information. The time delay associated with alert communication, combined with the lack of traffic information in the cockpit, limits the effectiveness of ground-based alerting implementations. Aircraft-based alerting can help minimize the risk of a runway incursion, in certain scenarios, through advanced traffic alerting prior to the occurrence of a runway incursion. In the event that a scenario develops into a runway incursion, conflict alerting provides the flight crew with timely information so that evasive action can be taken.

The objectives of the RIPS flight test were [Ref. 1]:

Assess and validate performance of Communications Navigation and Surveillance (CNS) infrastructure technologies and incursion alerting systems for preventing runway incursion accidents. Specific objectives were:

- Assess the performance of the airport surface infrastructure (data linked STIS-B with runway incursion alerting) for providing sufficient situational awareness and warning to prevent runway incursion accidents.

- Assess the performance of aircraft-based runway incursion alerting systems, utilizing STIS-B traffic data provided by the airport surface infrastructure and data provided by an ADS-B aircraft to aircraft data link, in providing sufficient situational awareness and warning to prevent runway incursion accidents.

Runway incursion scenarios were performed using the B757 and a ground vehicle. Some of the key performance measures analyzed include warning response times, missed detection performance, false alert generation and surveillance latency.

2.0 RIPS SYSTEM DESCRIPTION

The NASA Runway Incursion Prevention System consists of both avionics and ground systems elements [3]. The ground elements provide traffic information to the avionics elements. The avionics elements process this traffic information to provide runway incursion alerting. The avionics elements are also designed to support runway incursion alerting in the absence of the ground system elements using aircraft-to-aircraft surveillance provided by ADS-B.

2.1 Avionics Systems Architecture

Figure 1 shows the system architecture for the avionics installed on the B757 to support RIPS. A SGI Onyx served as the hardware platform for the RIAAS and RSM software. Runway incursion alerts were displayed on a HUD, a Navigation Display (ND), and an Electronic Moving Map (EMM), illustrated in Figure 2. A raster-style HUD supporting resolutions of up to 1280x959 was used. The HUD displayed the alert type and the distance and time to conflict in the event of an incursion alert. The EMM presented an ownship proximate view of the movement area and traffic information. Intruding traffic and its location were identified by highlighting that traffic's symbol. The color of the highlighted traffic symbol indicated the type of alert, yellow for Runway Traffic Alerts and red for Runway Conflict Alerts. The RIPS Audio Alert System was used to provide runway incursion alert annunciations in the cockpit. The system was comprised of a digital audio recorder/player and a speaker (part of the ARIES audio system). Runway Traffic Alerts were annunciated in the cockpit as "Runway Traffic, Runway Traffic." Runway

Conflict Alerts were annunciated as “Runway Conflict, Runway Conflict.” Textual forms of these messages were also displayed on the HUD and EMM.

Ownship position was provided by LAAS differentially corrected Global Positioning System (GPS) data and the Inertial Navigation System (INS) data. An INS/GPS blending technique was implemented to enhance position accuracy. This process involves filtering the DGPS (Differential GPS) position with the INS position to produce a blended solution.

Traffic information is obtained from both the 1090 MHz ADS-B and a STIS-B data link. A Universal Access Transceiver (UAT) data link was used to provide STIS-B data to the B757.

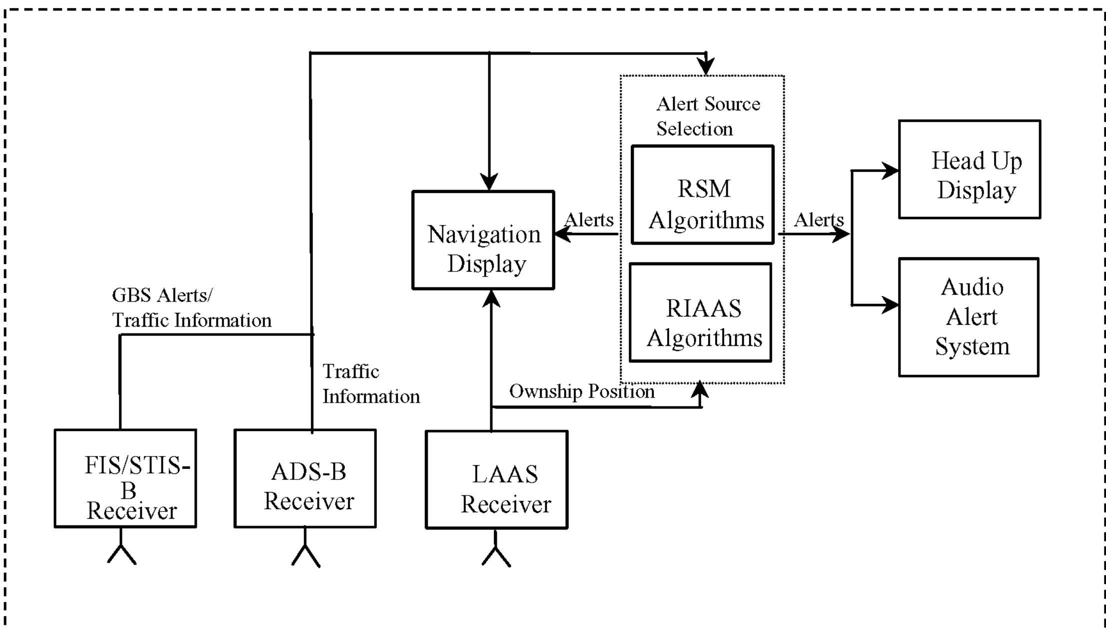

Figure 1. Avionics Systems Architecture

HUD Guidance | Electronic Moving Map

Figure 2. Alert Displays in ARIES B757

2.1.1 RIAAS Aircraft-Based Alerting

RIAAS is designed to monitor aircraft that are either on the airport surface, or are within the airport's arrival and departure zones [Ref. 2]. RIAAS initiates alert processing whenever the aircraft on which it is installed (ownship) enters a runway zone, which includes the runway, intersecting taxiways, arrival and departure zones associated with the runway. The system uses ADS-B and/or STIS-B to track other aircraft or ground vehicles (traffic) operating in ownship's runway zone. RIAAS is configured to issue alerts based on the states and proximity of traffic relative to ownship.

RIAAS is an aircraft-based safety alerting system designed to identify early conditions for runway incursions and provide aircraft pilots and ground vehicle operators sufficient time to avoid runway incursion conflicts and collisions when an alert is issued. The alerting logic is the core of the RIAAS algorithms. RIAAS also requires a method for annunciating the alerts. Alerts may be annunciated aurally and/or visually. A typical implementation would be to display alerts on a CDTI and provide aural alerts to draw the flight crew's attention to the incursion situation.

RIAAS is designed to handle over forty different runway incursion scenarios, as listed in Table 1. Parameters such as position, speed, acceleration, heading, distance to hold lines, distance to thresholds, distance to runway edge, closure rate and separation distance are measured for every vehicle operating in the vicinity of the runway being used. Calculations of each vehicle's dynamic state are compared against the alerting criteria, and an alert is issued if the criteria are

Table 1. RIAAS Alert State Pairs

Scenario Pair	Ownship State	Other Vehicle State	Conflict
1	Arrival	Taxi	Crossing
2	Arrival	Taxi	Tail Chase
3	Arrival	Taxi	Tail Lead
4	Arrival	Taxi	Head On
5	Taxi	Arrival	Crossing
6	Taxi	Arrival	Tail Chase
7	Taxi	Arrival	Tail Lead
8	Taxi	Arrival	Head On
9	Departure	Taxi	Crossing
10	Departure	Taxi	Tail Chase
11	Departure	Taxi	Tail Lead
12	Departure	Taxi	Head On
13	Taxi	Departure	Crossing
14	Taxi	Departure	Tail Chase
15	Taxi	Departure	Tail Lead
16	Taxi	Departure	Head On
17	Arrival	Departure	Crossing
18	Arrival	Departure	Tail Chase
19	Arrival	Departure	Tail Lead
20	Arrival	Departure	Head On
21	Departure	Arrival	Crossing
22	Departure	Arrival	Tail Chase
23	Departure	Arrival	Tail Lead
24	Departure	Arrival	Head On
25	Arrival	Arrival	Crossing
26	Arrival	Arrival	Tail Chase
27	Arrival	Arrival	Tail Lead
28	Arrival	Arrival	Head On
29	Departure	Departure	Crossing
30	Departure	Departure	Tail Chase
31	Departure	Departure	Tail Lead
32	Departure	Departure	Head On
33	Taxi	Taxi	Crossing
34	Taxi	Taxi	Tail Chase
35	Taxi	Taxi	Tail Lead
36	Taxi	Taxi	Head On
37	Arrival	Stopped	Head On
38	Departure	Stopped	Head On
39	Taxi	Stopped	Head On
40	Taxi	Stopped	Crossing
41	Stopped	Arrival	Head On
42	Stopped	Arrival	Tail Lead
43	Stopped	Departure	Head On
44	Stopped	Departure	Tail Lead
45	Stopped	Taxi	Head On
46	Stopped	Taxi	Crossing

met for one or more incursion scenarios. If multiple alert scenarios occur simultaneously, the one with the highest level of alert is used in determining which alert will be issued. Once corrective action has been taken and there is no longer a state of alert, the alerts are cleared from the display.

RIAAS provides two stages of alerting, analogous to TCAS. A Runway Traffic Alert (RTA) is generated when own aircraft is either projected to be involved in a runway incursion with other traffic or an incursion has occurred that does not yet require evasive action. A Runway Conflict Alert (RCA) is provided when an actual runway incursion has been detected, and there is potential for collision. An RCA indicates that the aircraft involved in the conflict needs to take evasive action to avoid the potential collision. RIAAS, as well as the other alerting systems, does not provide guidance information to the pilot for taking evasive action. The reason for this is that the number and complexity of the potential scenarios makes it difficult to correctly identify the proper evasive action to take in every situation. Information that is provided with each alert includes identification of the incurring aircraft (or vehicle), the runway associated with the aircraft, separation distance and time to conflict. Alerts can be displayed on a moving map display tailored to the airport surface. This display should provide enough information to the pilot to determine proper evasive action.

2.1.2 RSM Aircraft-Based Alerting

Runway Safety Monitor (RSM) is an alerting element provided by the Integrated Display System (IDS), a NASA developed experimental avionics display and data communications system for landing and surface operations [Ref. 3]. RSM is a single stage alerting system that provides Runway Conflict Alerts (RCAs). The system uses either STIS-B or ADS-B data as the source for traffic information. Selection of traffic source is done manually. The system uses a generic approach, which requires information on the location of the runways, but does not use information on the location of the taxiway hold lines. Runway incursion zones are monitored and established as follows:

Sides of zone: 220 feet from edge of runway

Ends of zone: 1.1 nm from runway threshold

Altitude of zone: 400 feet above airport surface

On initialization, RSM reads a configuration file and computes/stores coordinates for all runway incursion zones. The logic does not address taxi-only operations where both ownship and traffic are considered to be in a taxi state. The algorithm is divided into three main parts:

Part 1: Invoking RSM and determining when to start/stop/continue incursion monitoring (ownship inside any incursion zone?)

Part 2: Identifying and tracking all targets inside current runway incursion zone.

Part 3: Determining target/ownship states, testing for incursion alert conditions (Figure 3 State matrix) and setting or clearing alert data.

<table>
<tr><td>NO</td><td colspan="4">Check Operational State Conditions: Incursion YES/NO</td><td>YES</td></tr>
<tr><td></td><td></td><td>Target Taxi Or Not Moving</td><td>Target Land, T/O</td><td>Target Fly-thru</td><td></td></tr>
<tr><td></td><td>Ownship Taxi Or Not Moving</td><td>NO</td><td>YES if closing</td><td>NO</td><td></td></tr>
<tr><td></td><td>Ownship Land, T/O</td><td>YES if closing</td><td>YES if < min separation</td><td>YES if closing AND < min separation</td><td></td></tr>
<tr><td></td><td>Ownship Fly-thru</td><td>NO</td><td>YES if closing AND < min separation</td><td>NO</td><td></td></tr>
<tr><td></td><td colspan="2">No Incursions
Clear Alert Flags/Data</td><td colspan="2">INCURSION(s) Detected:
Set Alert Flags/Data</td><td></td></tr>
</table>

Figure 3. Runway Safety Monitor State Matrix

2.1.3 Ground-Based Alerting

The GBS safety logic utilized at DFW was a subset of the Airport Movement Area Safety System (AMASS) alerting logic used in the operational systems [Ref. 4]. The GBS is resident on the Surveillance Server. GBS analyzes traffic location and movement to identify runway incursion situations and other potential hazards. The GBS also provides generation of hold bar indications, which are transmitted and can be viewed on the cockpit display to indicate when it is unsafe to enter the runway. The GBS receives tracks three times per second from the Fusion Process of the Surveillance Server. Tracks are maintained in a database. At an interval of 1 second, this database is analyzed for potential hazards. When alerts or hold bars are generated, the information is sent to the aircraft via STIS-B. Safety Logic confines its analysis of alert situations to the active runways of the airport. Tracks are placed in a list of tracks associated with each runway. Tracks not on a runway or in an approach window are not processed. Tracks in each runway list are then assigned movement states (i.e., ARRIVAL, LANDING, STOP, TAXI, DEPARTURE, DEPARTURE_ABORT). For each of the runways, safety logic checks each track first to determine whether it qualifies as a one-track alert, and then compares it to all the other tracks in the runway list for the possibility of a two-track alert. One-track alerts include Arrival on a Closed Runway and Stop-Timeout. If a track is in the ARRIVAL state and is assigned to a closed runway, a Closed Runway alert is generated. A Stop-Timeout alert is generated when a target is in the STOP state on an active runway for a period that exceeds a user selectable timeout period. For analysis of two-track alerts, each track in a runway's list is compared to all the other tracks in the same list. Table 2 lists two-target alert situations for GBS. The Safety process is as follows:

1) Determine direction of each track as normal or opposite to the runway's designated direction.

2) Designate one track as Track A and the other as Track B.

3) Compute the separation distance between the two tracks.

4) Match the two tracks to an alert situation as identified in Table 2. (Note, dir = direction of movement, Mvmt. State = Movement State, N = Normal direction, O = Opposite direction)

2.2 RIPS Ground-Based System Architecture

The RIPS ground architecture, illustrated in Figure 4, includes the following elements:

1. Airport Surface Detection Equipment (ASDE-3) radar - Provides surveillance (position only) of aircraft or vehicles operating on the runway/taxiway area.
2. Airport Surface Target Identification System (ATIDS) - Provides surveillance (position and ID) of aircraft and ground vehicles equipped with 1090 MHz ADS-B, Mode-S transponders, and Mode A/C transponders.
3. Surveillance server - Provides the following:
    a) Tracking of ASDE-3 targets
    b) Data fusion of ATIDS target data with ASDE-3 track data to enhance situational awareness for Air Traffic Control (ATC) and flight crews with Cockpit Display of Traffic Information (CDTI)
    c) Ground-based Alerting safety logic to detect runway incursions and other conflicts.
4. Local Area Augmentation System (LAAS) DGPS ground station - Provides differential corrections for navigation and surveillance.
5. Surface Traffic Information Services – Broadcast (STIS-B)/ Flight Information Services – Broadcast (FIS-B) digital data link system - Provides the following to data link equipped aircraft:
    a) Digital transmission of traffic information
    b) Runway hold bar information
    c) Ground generated alerts.
6. Automated Radar Tracking System (ARTS) - Provides ASR-9 radar position/ID of airborne aircraft near the airport.

Table 2. GBS Alert Situations for Two Target Alerts

SITUATION				ALERT INFORMATION
TRACK A		TRACK B		
dir	Mvmt. State	dir	Mvmt. State	
N	DEPARTURE	O/N	STOP	(Track A ID) AND (Track B ID), (Runway ID), DEP, OCCUPIED RUNWAY
O	DEPARTURE	O/N	STOP	(Track A ID) AND (Track B ID), (Runway ID), OPPOSITE DIRECTION DEP
N	LANDING	O/N	STOP	(Track A ID) AND (Track B ID), (Runway ID), LDG, OCCUPIED RWY
O	LANDING	O/N	STOP	(Track A ID) AND (Track B ID), (Runway ID), OPPOSITE DIRECTION LDG, OCCUPIED RWY
N	DEPARTURE	O	DEPARTURE	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON DEPS
N	DEPARTURE	O	LANDING	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON TRAFFIC
N	LANDING	O	DEPARTURE	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON TRAFFIC
N	ARRIVAL	N	DEPARTURE	(Track A ID) AND (Track B ID), (Runway ID), ARR, OCCUPIED RWY
N	ARRIVAL	O	DEPARTURE	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON TRAFFIC
N	ARRIVAL	O	LANDING	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON TRAFFIC
N	ARRIVAL	N	TAXI	(Track A ID) AND (Track B ID), (Runway ID), ARR, OCCUPIED RWY
N	ARRIVAL	O	TAXI	(Track A ID) AND (Track B ID), (Runway ID), HEAD-ON TRAFFIC
N	ARRIVAL	O/N	STOP	(Track A ID) AND (Track B ID), (Runway ID), ARR, OCCUPIED RWY

2.2.1 Multilateration

Multilateration and target identification was accomplished with an ATIDS system. ATIDS is based on Secondary Surveillance Radar (SSR) technology and is an enhancement to current airport primary surveillance equipment, which at DFW is ASDE-3/Surveillance Server. ATIDS augments the ASDE-3/Surveillance Server surveillance with aircraft identification and surveillance to fill in coverage gaps of the ASDE-3 radar. ATIDS is a multilateration system that receives SSR transmissions from aircraft and triangulates, or multilaterates, from several receiver locations to pinpoint the location of an SSR transponder. The system is designed to operate in conjunction with aircraft equipped with Mode A/C and Mode S transponders.

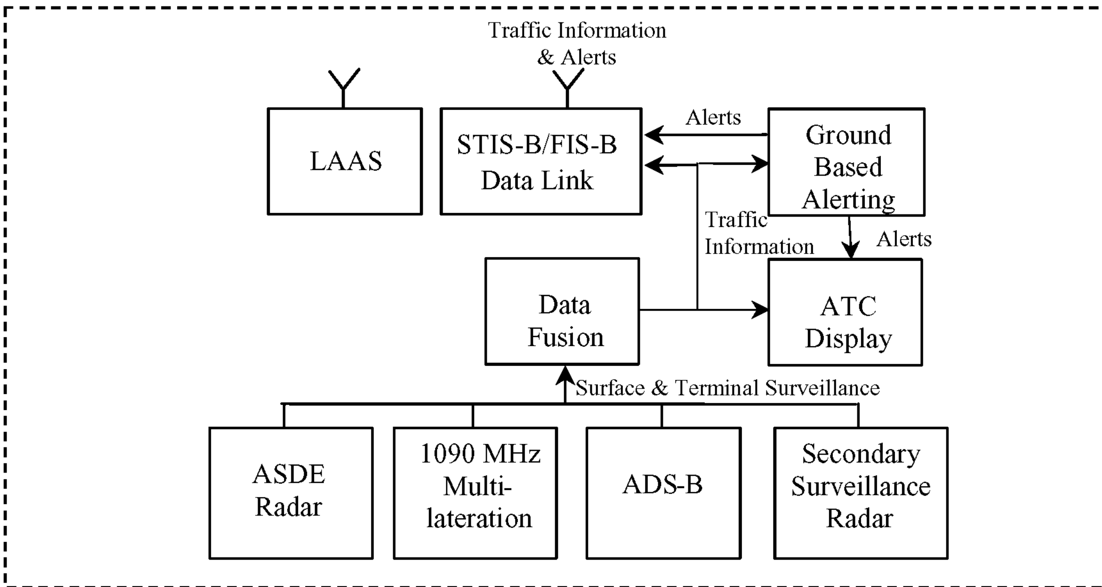

Figure 4. RIPS Ground System Architecture

2.2.2 ASDE-3 Radar

The ASDE-3 is a Ku band primary radar used for airport movement area surveillance. It is intended to provide controllers with enhanced visibility of airport surface traffic in low visibility conditions, thereby increasing safety and reducing runway incursions. It uses an antenna rotating once per second, resulting in a target update at the same rate. The ASDE-3 provides surveillance of aircraft and vehicles operating on runways and taxiways that are in direct line of site to the radar. Non-movement areas such as grass and ramp areas are intentionally filtered out. The ASDE-3 installed at DFW is a commissioned production unit installed on top of the air traffic control tower.

2.2.3 Surveillance Server

The Surveillance Server is a prototype system that takes radar return inputs from the ASDE-3 and digitizes them. It then determines the centroid and extent information of the airport surface targets. The Surveillance Server fuses data from the following sources:

- ARTS arrival database information
- ASDE-3/Surveillance Server target track information
- ATIDS 1090 MHz ADS-B target information, and
- ATIDS 1090 MHz multilateration target information

The resulting fused surveillance data is output to a controller interface and to a datalink manager to be transmitted to the NASA B757 via STIS-B. Using this digitized data, the Surveillance Server can track aircraft and vehicles on the airport surface and provide automatic warnings of conflicts and runway incursions.

2.2.4 Automatic Dependent Surveillance Broadcast (ADS-B)

ADS-B is a function on an aircraft that periodically broadcasts the aircraft state vector (position and velocity) [4]. Air traffic control can receive the state vector reports to accurately display traffic identity and position. Other aircraft can receive the information for use in collision avoidance and CDTI applications.

ADS-B, as implemented in the RIPS tests, consisted of a Collins GPS receiver and Mode S extended squitter transponder installed on the NASA B757 as well as on a ground vehicle. Differential GPS corrections were obtained from LAAS. Position was calculated 5 times per second and the most recently computed position was transmitted nominally twice per second. Two different ADS-B messages were transmitted, depending on whether the aircraft was airborne or on the airport surface. The airborne ADS-B message includes type code (information on airborne or surface message and precision category of the data), surveillance status, turn indicator (turning or not turning), altitude (either barometric or GNSS derived), and encoded latitude and longitude (17 bits). The surface ADS-B message includes type code (same as airborne), ground speed, track angle and encoded latitude and longitude. ADS-B transmissions alternate between the top and bottom mount antennas when airborne. ADS-B transmissions are only radiated from a top mount antenna when the aircraft is on the ground. In the RIPS test vehicle at DFW two antennas were used to broadcast transmissions, alternating at half second intervals.

2.2.5 STIS-B/FIS-B Data Link

STIS-B and FIS-B are uplinked to the B757 via a UAT data link. Traffic information is updated once per second. FIS-B transmitted data includes ground-based alerts and hold bar indications. UAT operates in the L band and accordingly requires line-of-sight between the ground-based and aircraft-based transceivers.

3.0 DATA COLLECTION AND ANALYSIS METHODOLOGY

3.1 Test Scenarios

A complete description of the tests can be found in the NASA test plan [Ref. 1]. All RIPS testing was performed at Dallas - Fort Worth International Airport, at night, and under good visibility conditions. Four RIPS scenarios were tested as illustrated in Figures 5 through 8. In each scenario, the NASA B757 was involved in an incursion with a ground test vehicle.

<u>RIPS Scenario 1 – Arrival (NASA B757)/Taxi (Test vehicle)</u>

Scenario 1 is illustrated in Figure 5. The captain positioned the aircraft for intercept of the runway localizer 7-10 nautical miles from the runway. A coupled approach was flown to 100 feet altitude. The test vehicle began crossing the hold line on a taxiway near the runway threshold when the B757 was approximately 2000 m from the runway threshold. A few moments later an RTA was issued (for the RIAAS algorithm only). This is an advisory warning and the subject pilot was not required to take evasive action. As the aircraft approached the threshold, an RCA was issued for all three systems. The timing of each RCA was system-dependent. At this time the captain initiated a go-around maneuver following standard operational practices. If no alerts were received before the aircraft reached 150 ft AGL, the captain automatically initiated a go-around maneuver. After the RCA was issued, the test vehicle crossed over the runway. In some cases the pilot elected to initiate the go-around following the RTA.

<u>Scenario 2 – Departure (NASA B757)/Taxi (Test vehicle)</u>

Scenario 2 is illustrated in Figure 6. The captain taxied the B757 into position on the departure runway and held. Once the aircraft began its take off roll, the test vehicle crossed the hold line. The test vehicle was located at least 3000 m from the aircraft's take off hold position. An RTA was issued (RIAAS algorithm only). This is an advisory warning and the subject pilot was not required to take evasive action. An RCA was issued as soon as an incursion had occurred or was eminent. The RCA occurred before the aircraft reached V1 (maximum allowable rejected take off speed). At this time, the captain rejected the take off by stopping on the runway. After the RCA was issued, the test vehicle immediately crossed over the runway. In some cases due to the timing of the scenario, only an RCA was annunciated, skipping the intermediate RTA.

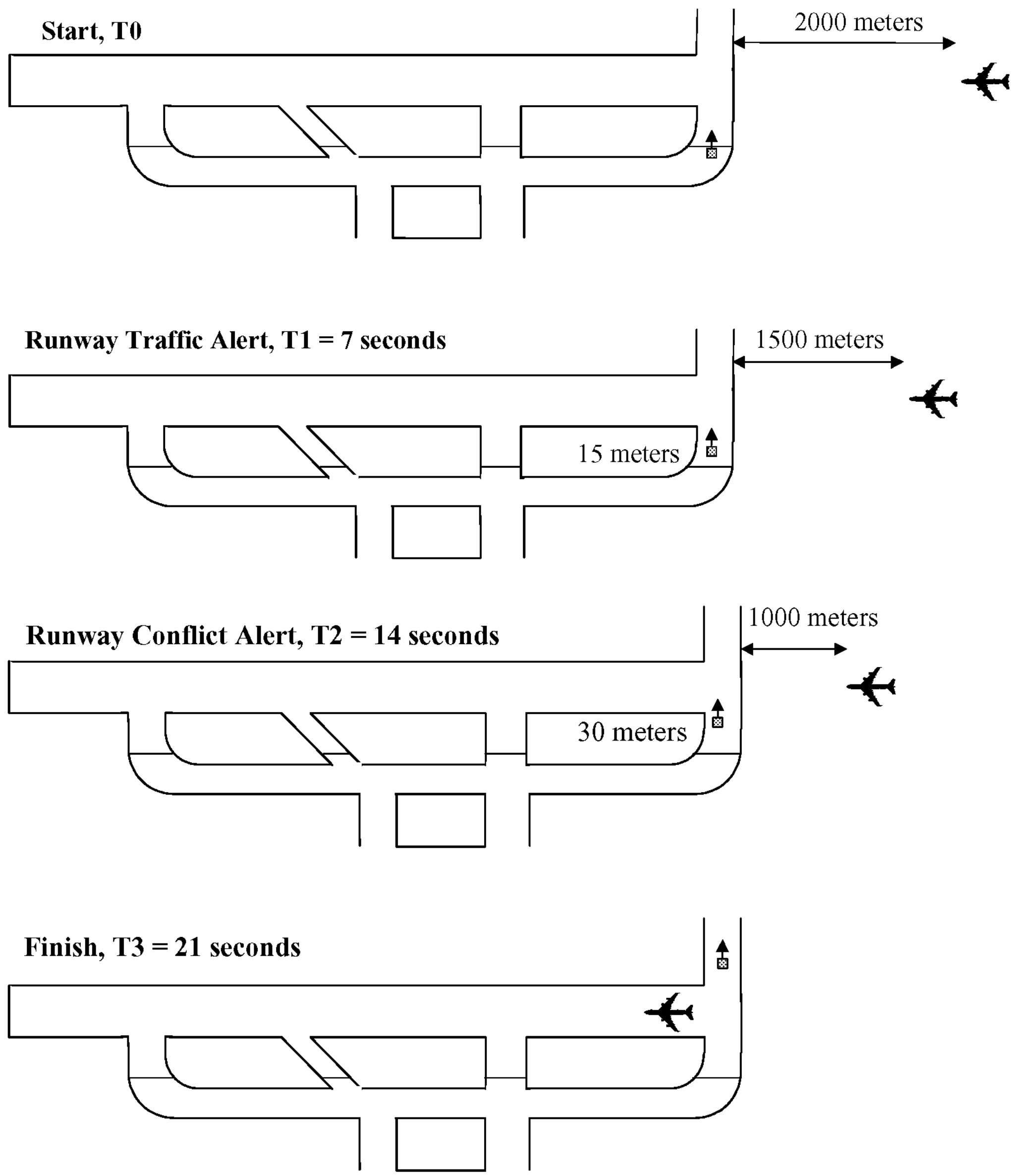

Figure 5. RIPS Scenario 1

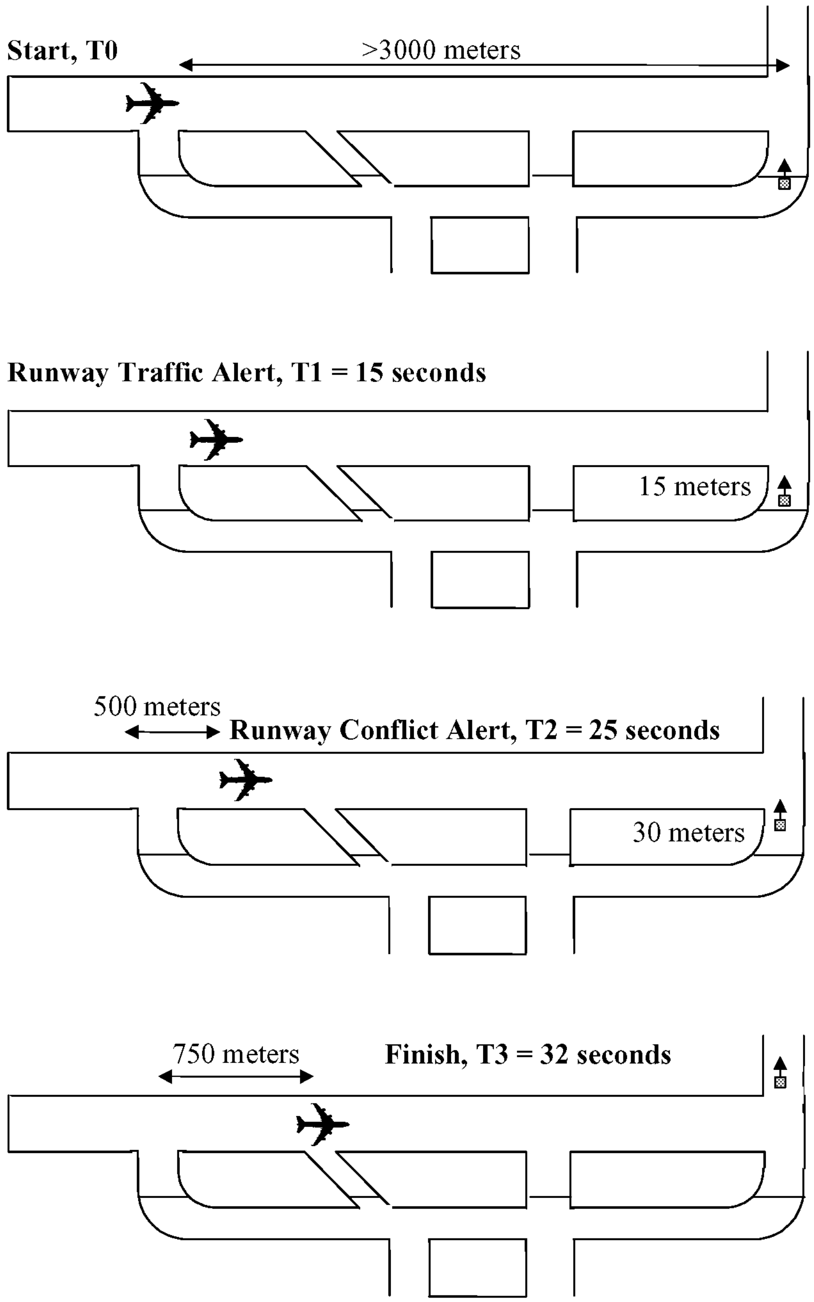

Figure 6. RIPS Scenario 2

Scenario 3 – Taxi (NASA B757)/Departure (Test vehicle)

Scenario 3, shown in Figure 7, is similar to Scenario 2 except the test vehicle is emulating a departing aircraft and the NASA B757 is the incurring taxi traffic.

At the start of this test run, the B757 was positioned just behind a hold line of a taxiway that crosses the runway. The test vehicle accelerated to 70 mph from the departure end of the runway. The B757 then began crossing the hold line. An RTA was issued (for RIAAS algorithm only). This is an advisory warning and the subject pilot was not required to take evasive action. An RCA was then generated by all three systems indicating that an incursion had occurred or was eminent. At that time, both the B757 and test vehicle were brought to a complete stop. The test vehicle then exited the runway.

Scenario 4 – Arrival (NASA B757)/Departure (Test vehicle)

Scenario 4, illustrated in Figure 8, is similar to Scenario 1 only the test vehicle emulated a departing aircraft.

The captain positioned the aircraft for intercept of the runway localizer 7-10 nautical miles from the runway. Coupled approaches were flown to 100 feet altitude. As the aircraft came within approximately 1 nm of the threshold, the test vehicle entered the runway and accelerated to approximately 60 kts. An RTA was issued (for RIAAS algorithm only). This is an advisory warning and the captain was not required to take do a go-around. An RCA was then issued by the three systems. At this time the captain initiated a go-around maneuver following standard operational practices. If no alerts were received before the aircraft reached 150 ft AGL, the captain automatically initiated a go-around maneuver. After the RCA, the test vehicle exited the runway.

3.2 Data Collection

The analyses contained in this report were performed using data logged by the B757 Data Acquisition System (DAS). Table 3 provides a summary of the test runs. Some of the key data logged includes:

- UTC time
- Ownship position
- Traffic identification
- Traffic ADS-B X –Y position
- Traffic STIS-B X – Y position
- Traffic and Ownship Altitude
- Traffic and Ownship Speed
- Traffic and Ownship Heading
- Alert status

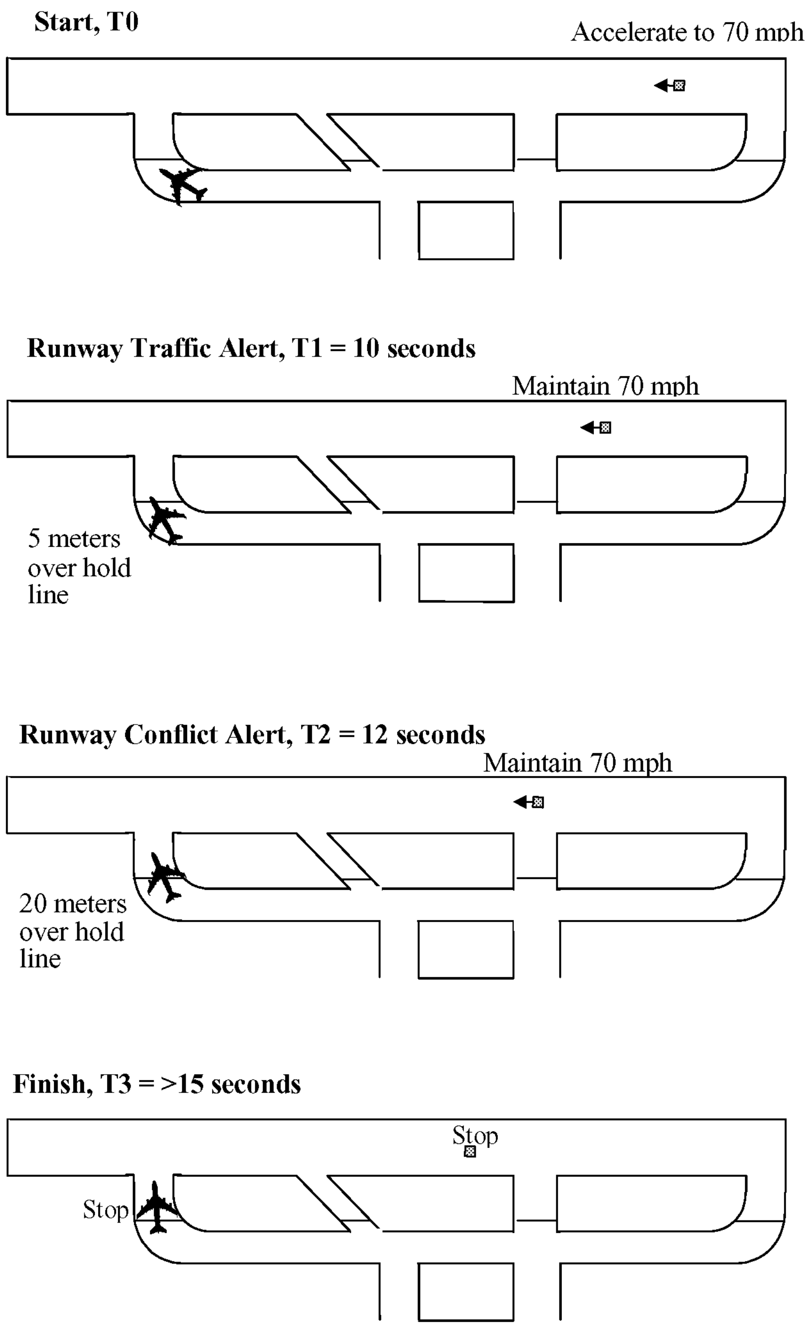

Figure 7. RIPS Scenario 3

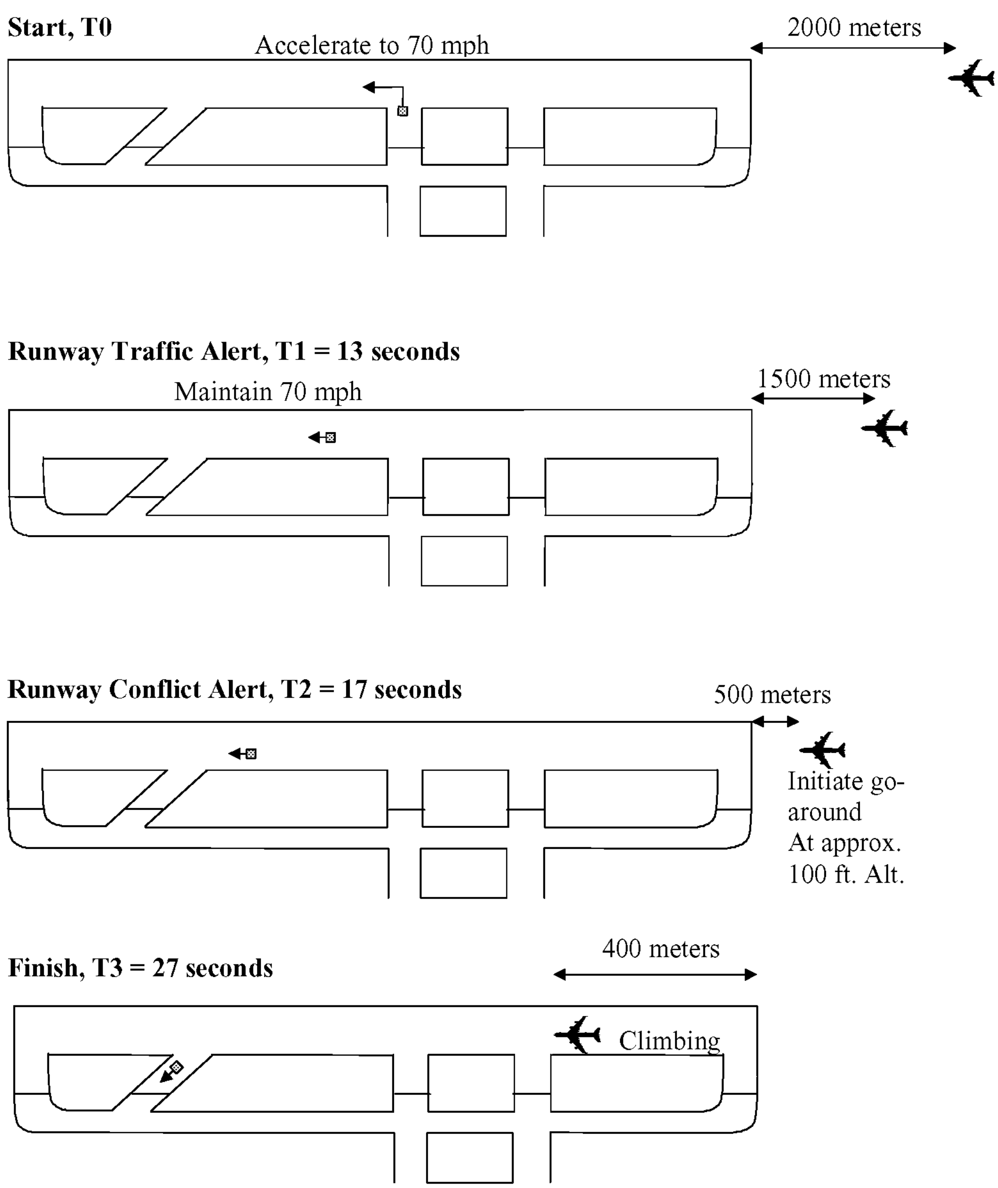

Figure 8. RIPS Scenario 4

Table 3. Experiment Matrix (NASA B757)

Test No.	Subject	Surv Source	Scenario	Display Source	Alert Displayed	Gate	False Alert	Flaps
1	P1	AT	S1	R	Y	N	N	-
2	P1	AT	S2	I	Y	N	N	-
3	P1	AT	S3	R	Y	N	N	-
4	P1	AT	S4	I	Y	N	N	-
5	P1	T	S1	G	Y	N	N	-
6	P1	T	S2	G	Y	N	N	-
7	P1	T	S3	I	Y	N	N	-
8	P1	T	S4	R	Y	N	N	-
9	P1	AT	S1	I	Y	N	N	-
10	P1	AT	S2	R	Y	Y	N	-
11	P1	AT	S3	G	Y	Y	N	-
12	P1	AT	S4	G	Y	N	N	-
13	P1	AT	S1	-	N	N	N	-
14	P1	T	SF	-	N	N	HA	30
15	P1	A	SF	-	N	N	CA	30
16	P1	T	SF	-	N	N	AA	20
17	P1	A	MEL	-	N	N	HA	30
18	P1	T	MEL	-	N	N	CA	30

Abbreviations:

- Subject: Pn (subject pilot number (n=1 to 4))
- Surv Source: A (Target ADS-B only), T (STIS-B only w/o ADS-B), AT (Target ADS-B & STIS-B w/ ADS-B)
- Scenario: Sn (RI scenario number (n=1 to 4)), SF (Stopping Factor assessment), MEL (missed exit logic)
- Display Source: Algorithm driving display- R (RIAAS), I (RSM), G (GBS)
- Alert Displayed: Y (alert provided to pilot),N (alert not provided to pilot)
- Gate: Y (run starts/ends at gate), N (run does not start/end at gate)
- False Alert: HA (test vehicle at hold line on ARIES arrival), CA (test vehicle cross runway on ARIES arrival), AA (test vehicle simulating arriving aircraft on ARIES arrival), N (no false alert testing)
- Flaps: 20 or 30 degrees

4.0 TEST ANALYSIS AND RESULTS

4.1 STIS-B Surveillance Evaluation

4.1.1 Latency

Latencies of 2 to 6 seconds for STIS-B position reports were recorded. The average latency was 3.5 seconds. These values exceeded the implementation goal of less than 2 seconds. A 3.5 second latency will correspond directly to a 3.5 second delay in alerting. Latency was computed using ownship DGPS/inertial position and B757 STIS-B position data. The time difference between when ownship was reported to cross a given point and STIS-B reported the B757 as having crossed the same point was used as a measure of latency. Latency was sampled over several points. Further analysis is required to identify the source of the delays, but the key ground-based contributors to latency are:

- Surveillance sensor intercommunication and processing
- Surveillance data fusion
- Data link processing
- STIS-B data transmission

4.1.2 Update Rate

The UAT was configured to provide a STIS-B target update interval of one second. Figure 9 provides the performance for STIS-B transmissions of ground system generated NASA B757 track updates. The average update interval was slightly over 1 second. A separate analysis of the surveillance data conducted for the FAA yielded approximately the same average update interval of 1.06 Hz [Ref. 6]. There were periods where updates were not received for more than 10 seconds. These gaps were not repeated in the same location from run to run, suggesting that STIS-B data link coverage may not have been the problem. The NASA B757 did experience gaps in STIS-B updates for some targets even though the data shows that the B757 continued to receive STIS-B data from other targets during the period of lost updates. For instance, 10 seconds of DAL218 updates were missing even though STIS-B updates were being received on other traffic (file r177stsis88). The missing updates resulted in problems for the aircraft-based alerting systems in several cases.

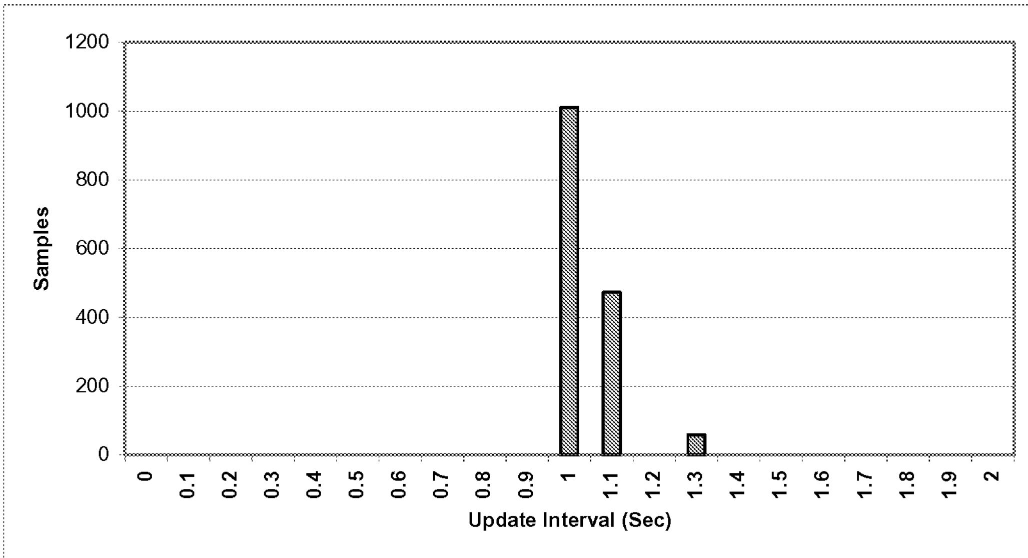

Figure 9. STIS-B Reception Performance

4.1.3 Position Accuracy

Figures 10A and 10B are plots of the STIS-B reports for the test vehicle and ownship, respectively, traveling along the centerline of the runway. The difference between the STIS-B and the ADS-B positions is approximately equal to the STIS-B cross track position error. That is because the ADS-B absolute error is significantly smaller than the STIS-B absolute error. The data in Figure 10A indicates STIS-B errors as large as 10 meters. There is an angular change in cross track error along the centerline. It is not obvious what might have caused this. The analysis of the surveillance data conducted for the FAA indicated bias errors on the fused surveillance data ranging up to 15 meters and standard deviations up to 6 meters [Ref. 6]. The magnitude of the STIS-B (fusion) errors was mostly due to the ASDE-3 radar. The reason for this is that the fused solution was heavily weighted by the ASDE-3 position reports.

Figure 11 illustrates the along track error by showing the difference between the STIS-B reported position and the nose location of the B757. These measurements were made by comparing the ownship DGPS/inertial position (corrected to the nose) to the STIS-B B757 reported position. The STIS-B reported position is negative, reflecting that the reported position is behind the position of the nose. Some of this difference could be removed by the ground-based surveillance processing. Correcting the position would provide a more accurate means to detect when an aircraft has violated the hold line. The impact of the STIS-B position errors is relatively less accurate incursion alerting and greater susceptibility to false alerts.

4.1.4 Speed Accuracy

STIS-B speed information for the test vehicle was examined. The surveillance server had three surface surveillance sources for fusion to compute test vehicle position: 1090 MHz ADS-B, 1090 MHz multilateration and ASDE-3. As described in section 4.2.5, ADS-B provides very accurate

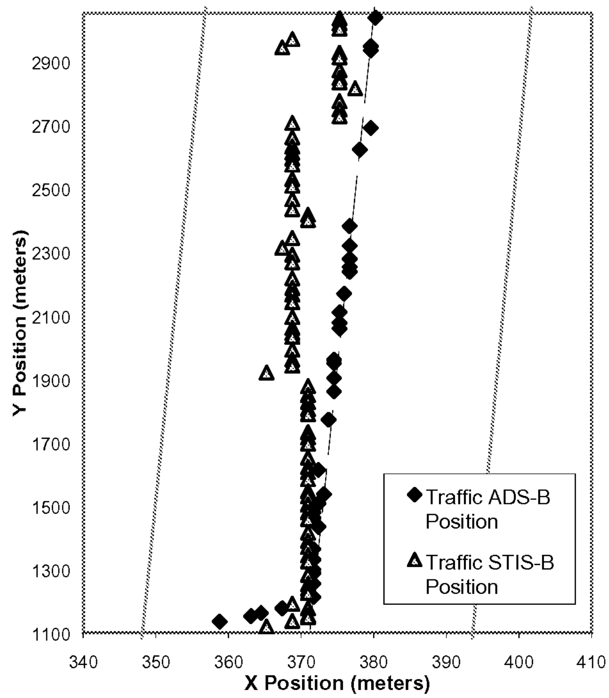

Figure 10A. Traffic STIS-B Position Accuracy Compared to ADS-B

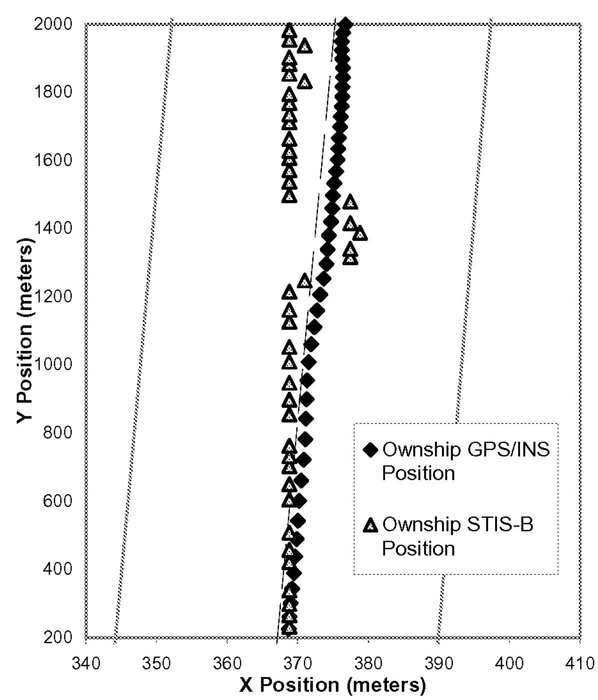

Figure 10B. Ownship STIS-B Position Accuracy

speed information. However, the fusion processing output provided via STIS-B was of lower quality than the ADS-B surveillance data. At the lower speeds the data was more erratic and jumped significantly at times between updates on the order of 9 m/s. STIS-B traffic speeds for the majority of the time were very reliable at high speeds and only fluctuated by approximately 2 m/s when traffic maintained a constant speed. Also, occasionally when the reported traffic positions indicated a low speed being maintained at anywhere between 5 and 10 m/s, the corresponding STIS-B reported speeds were much lower at around 0.5 m/s. This caused some problems for RIAAS in determining the correct vehicle state. RSM does not use velocity information provided by STIS-B.

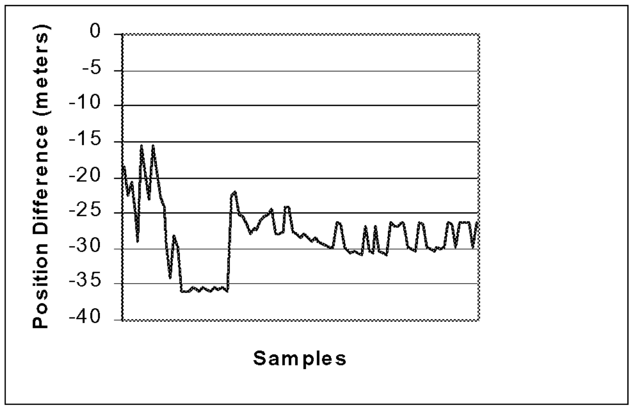

Figure 11. STIS-B Position Along Track Accuracy (NASA B757)

4.1.5 Track Angle Accuracy

Figure 12 provides a plot of the B757 track angle logged from STIS-B and the associated ownship's DGPS heading as a truth source. STIS-B traffic headings incurred errors as large as 49 degrees. In certain instances traffic headings were reported to be more than 10 degrees from the runway heading, which adversely affected RIAAS's incursion algorithms. This in turn affected the alert processing by causing RIAAS to prematurely clear an active alert. RSM does not use track angle information provided by STIS-B.

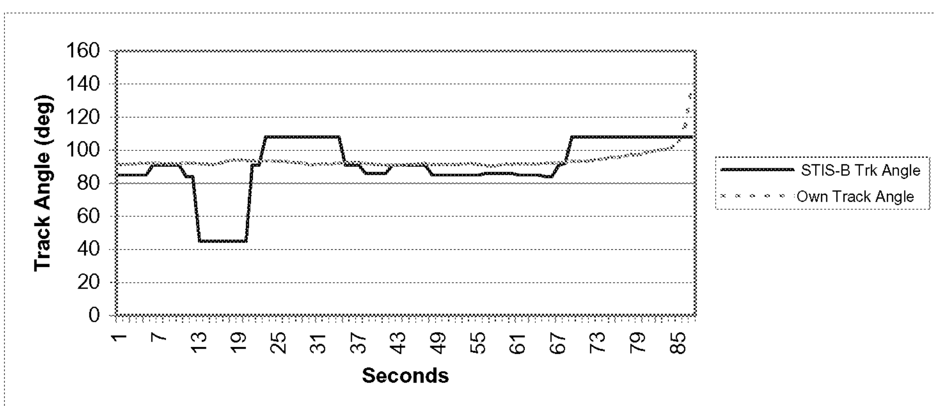

Figure 12. STIS-B Track Angle Plot (NASA B757)

4.1.6 Data Integrity

STIS-B experienced a false identification problem whereby a flight ID is assigned to two distinctly separate ground tracks at the same time. This would generally only happen for short periods of time. One example is where AAL2576 was assigned to STIS-B IDs 47955 and 76 at the same time (file r177stis88). These two tracks were almost 250 meters apart. Another example is TDX733, which was assigned to STIS-B IDs 11210 and 77 (file r177stis88). Incursion alerts and associated aircraft identification is provided to the CDTI. Displaying a false identification during an alert situation or during normal operations is a potential safety issue.

4.2 ADS-B Surveillance Evaluation

4.2.1 Latency

Truth data was not available for an accurate latency performance assessment of ADS-B.

4.2.2 Update Rate

ADS-B surveillance was reliable for scenarios 1 and 4, where the B757 was airborne on approach and the test vehicle was on the runway or taxiway. The B757's ADS-B receiver successfully decoded vehicle ADS-B transmissions on average once per second. Consistent ADS-B reception performance was not achieved in scenarios 2 and 3 where the B757 was on the ground. During some runs reliable reception was achieved, while other runs had large gaps in ADS-B reception. The failure mechanism needs to be further investigated.

The 1090 MHz ADS-B position reports are transmitted with an update interval of one half second. Figure 13 provides the ADS-B reception performance for NASA B757, receiving ADS-B transmissions from the ground vehicle. Based on the samples from several different runs, the average update interval was 1.2 seconds. There were periods where updates were not received for more than 10 seconds. The missing updates contributed to late alerts for the aircraft-based alerting systems in several cases.

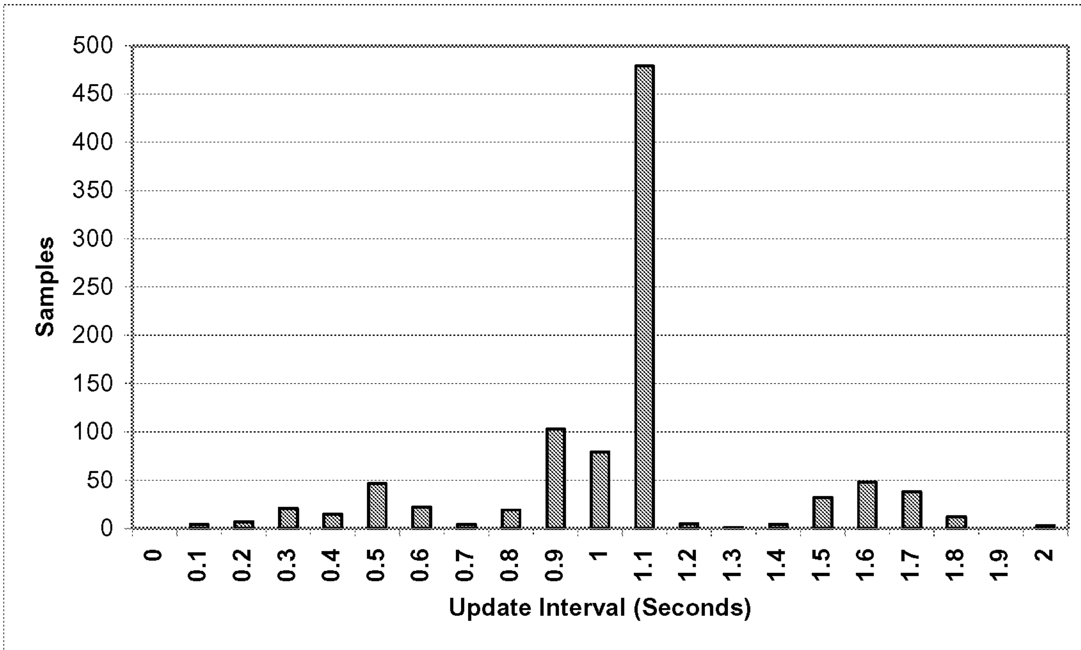

Figure 13. ADS-B Reception Performance of Test Vehicle Transmissions

4.2.3 Position Accuracy

ADS-B reports are more accurate than STIS-B. In comparison to the STIS-B plot (Figure 10), ADS-B provides test vehicle position reports that more precisely follow centerline (Figure 16) while the vehicle is traveling along the centerline. Along track errors will be similar to the cross track errors shown. ADS-B position report accuracy is nearly equivalent to the accuracy of LAAS. An analysis of the DFW LAAS indicated 95% position accuracy of approximately 2 meters [Ref. 7]. The benefit of better ADS-B accuracy as compared to STIS-B should be more accurate runway incursion alerting and minimization of false alerts.

4.2.4 Speed Accuracy

ADS-B speed data was more accurate than STIS-B as illustrated in Figure 15. The ADS-B reported speeds were more consistent with normal operation of a vehicle than the STIS-B reported speeds. The STIS-B appeared to have a problem accurately reporting speeds below 15 m/s. There were still times when errors approaching 4 meters/sec were evident at the lower speeds of less than 8 meters/sec.

4.2.5 Track Angle Accuracy

ADS-B track angle data was fairly consistent the majority of the time, and had little adverse effect during alert processing. As noted with the STIS-B data, occasional track angle jumps in the data had the potential to affect the RIAAS incursion alerting. Up until the time of the demonstration, there was a software error on the B757 systems, which caused some headings to be reported with a 180-degree error. This error caused RIAAS to erroneously determine entry/exit of the test vehicle from the runway safety zone and erroneously declare the heading of the vehicle on the runway. Occasionally, this error resulted in delayed alerts and toggling on/off of alerts for RIAAS, which uses ADS-B heading information. Figure 14 provides a comparison of ADS-B versus STIS-B track angle data for the test vehicle after the ADS-B problem was fixed. Similar to the comparison of ownship DGPS to STIS-B, figure 12, the ADS-B track angle data was smoother than the STIS-B data. The figure also shows that the ADS-B track angle plot leads the STIS-B track angle information reflecting either a lower latency of ADS-B over STIS-B or STIS-B track processing introduced delays.

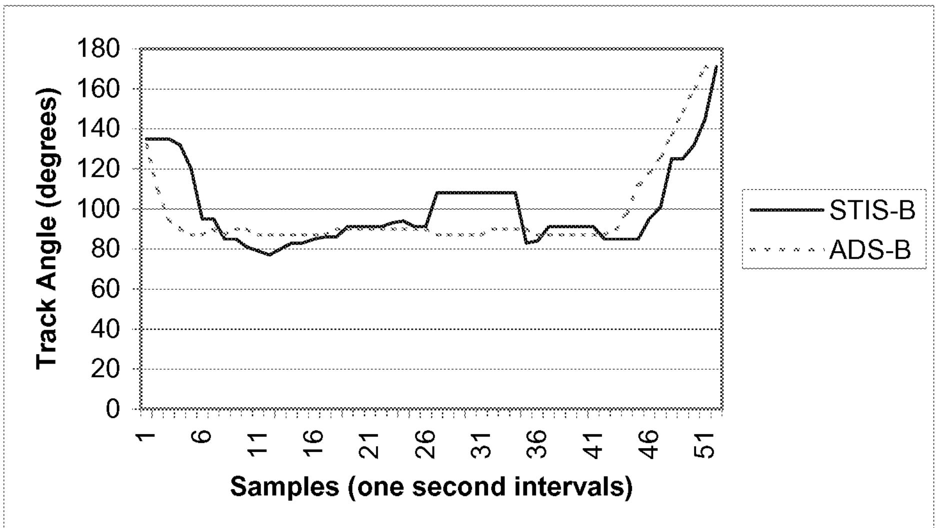

Figure 14. ADS-B vs. STIS-B Track Angle for Test Vehicle

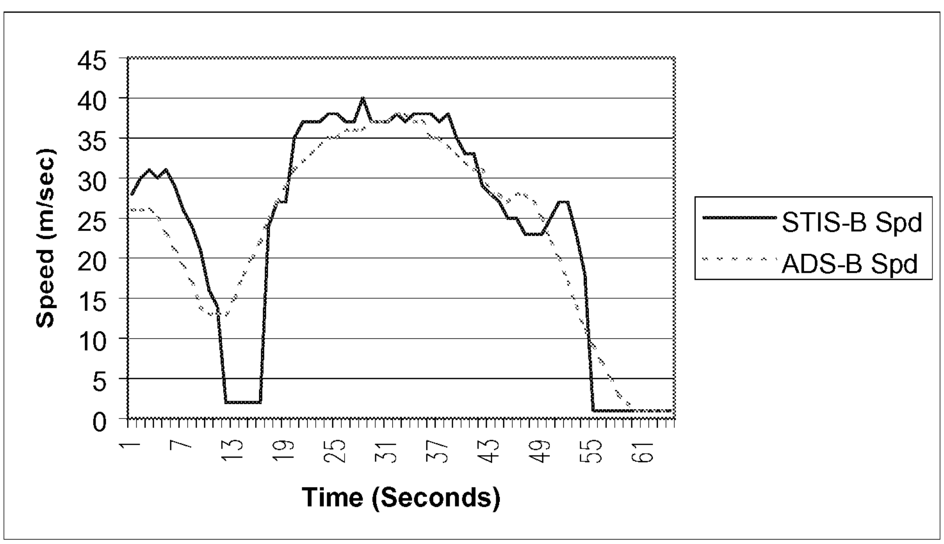

Figure 15. ADS-B versus STIS-B Speed for Test vehicle

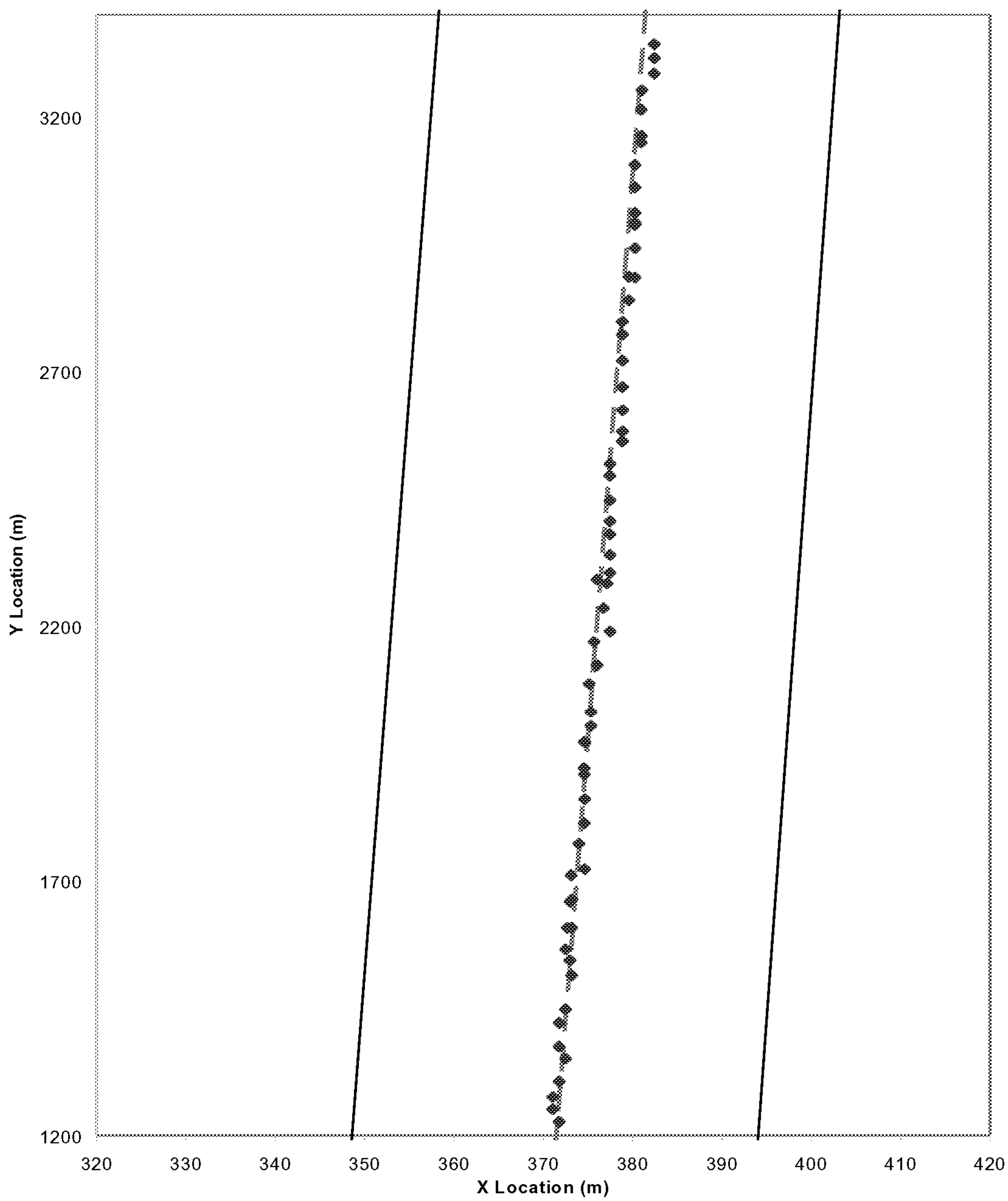

Figure 16. ADS-B Position for Test Vehicle Traveling on Centerline

4.2.6 Data Integrity

ADS-B provided a high level of integrity with respect to traffic information and identification. The traffic ID problems identified with STIS-B were not experienced with ADS-B. The only integrity related problem experienced with the ADS-B data was due to incorrect processing of the heading information on-board the NASA B757.

4.3 Ownship Navigation Evaluation

4.3.1 LAAS Accuracy

A LAAS system was used to provide the NASA B757 with highly accurate position information. Preliminary test results at DFW indicated position accuracies on the order of 1-2 meters [5]. This accuracy is achieved by blending LAAS position information with an on-board inertial guidance system. RIAAS applies a position offset of 22 meters to the ownship reported position to determine the location of the nose of the aircraft. This correction provides for more timely alerts in scenarios where the B757 violates the hold lines. It is estimated that the correction provides for reliable alerting almost 4 seconds sooner than if no correction were performed. The B757 also has highly accurate speed and track information.

4.3.2 Conclusions

Although complete performance data analysis was not available at the time this report was written, the initial conclusion is that the position, speed, and track performance was more than adequate to support the implementation of RIAAS and RSM. Alert response time performance benefited from the position offset correction for ownship. This capability was not provided for ADS-B and STIS-B traffic position updates. The position accuracy should support reliable determination of the aircraft tail location. Knowledge of tail location can be used to determine when aircraft are clear of the runway safety zone.

4.4 Runway Incursion Alerting Evaluation

4.4.1 RIAAS Alerting Performance

RIAAS performed as designed throughout testing. Alerts were accurate and timely. Out of 47 runs, RIAAS properly alerted on 44 of them. The three missed alerts were caused by missing and erroneous traffic data. A small number of RIAAS alerts were issued late. This was directly attributable to gaps in both STIS-B and ADS-B data. RIAAS generated two false alerts over the course of testing, both directly caused by erroneous traffic data.

4.4.1.1 RIAAS Scenario Alert Plots

Figures A-1 through A-4 are plots of actual RIAAS runs, performed at DFW during testing. These plots represent typical RIAAS performance with good traffic data and proper scenario timing. Scenarios 1-3 were ADS-B/STIS-B runs, while scenario 4 was STIS-B-only.

Figure A-1 is a plot of a Scenario 1 run, representing an Arrival/Taxi situation. As ownship gets within 2000 meters of the runway threshold and traffic pulls across the hold line, an RTA is issued, providing a heightened measure of caution. Ownship continues as if landing. As ownship gets within 1000 meters of the threshold, an RCA is issued. A few seconds later, ownship initiates a go-around at 172 ft altitude, safely clearing traffic and a potential collision. The vehicle proceeds across the runway, ending the scenario.

Figure A-2 is a plot of a Scenario 2 run, representing a Departure/Taxi situation. Ownship pulls onto the runway and proceeds to begin its take off roll. Once ownship has reached a minimum departure speed, traffic rolls across the hold line, and an RTA is issued, providing a heightened awareness of a potential conflict. Traffic continues crossing toward the runway. Finally, an RCA is issued as traffic crosses more than 15 meters over the hold line. Ownship is traveling at 60 kts at this point. A few moments later, ownship initiates an aborted take off, slowing to taxi speed and safely pulling off the runway with over 2000 meters separation remaining.

Figure A-3 is a plot of a Scenario 3 run. This is very similar to Scenario 2, only ownship and traffic switch roles. Traffic pulls onto the runway and proceeds to begin its take off roll. Once traffic has reached a minimum "high-speed" state, ownship rolls across the hold line and an RTA is issued, providing a heightened awareness of a potential conflict. Ownship continues crossing toward the runway. Finally, an RCA is issued as ownship crosses more than 10 meters over the hold line. Traffic is traveling at 57 kts at this point, with a separation distance of 3110 meters. Ownship comes to a halt in response to the RCA, stopping a safe distance from the runway and avoiding a potential collision with the departing traffic.

Figure A-4 is a plot of a Scenario 4 run, representing an Arrival/Departure situation. Ownship is preparing for an arrival. Traffic crosses the hold line and an RTA is issued, providing a heightened awareness of a potential conflict. Traffic continues onto the runway to initiate its take off roll. As ownship gets within 600 meters of the runway threshold, an RCA is issued. Ownship initiates a go-around at 217 meters altitude, and safely avoids a potential collision with the departing traffic.

4.4.1.2 RIAAS Alert Performance Summary

RIAAS alerts are summarized in Tables 4 through 7, and alert data is presented in Tables 8 through 19 by scenario and alert type (RTAs and RCAs). Time between first RTA and first RCA is also documented when applicable. Due to timing of the scenarios, single alerts (RTA-only or RCA-only) were received in some runs.

RIAAS performed as designed throughout all of DFW testing. Problems with alerting were all attributed to erroneous data and data drop-outs associated with STIS-B and ADS-B operation. RIAAS exhibited a 100% success rate for runs in which reliable and accurate traffic data was supplied. Alert timing results varied due to timing of the scenarios (i.e. vehicle movement relative to ownship movement) as can be expected. A comprehensive summary of RIAAS alerting performance is found in Appendix B.

Scenario 1

Tables 4, and 8 through 10 represent alert data for all RIAAS Scenario 1 runs. Important variables for this scenario are ownship distance to threshold, traffic distance to hold line and traffic distance to runway.

As shown in Table 8, the average ownship distance to threshold at the time of the first RTA alert was 1839.2 meters before the runway threshold. Negative distance values indicate that the aircraft had not crossed the threshold when the alert occurred. The RTAs occurred within 1967.7 and 1498.9 meters from threshold. The average traffic distance over the hold line at the time of the first RTA was 19.6 meters. Even at the maximum distance over the hold line, traffic was not on the runway. One run from the 16th, Matrix Run #1 was labeled an outlier. The alert was received late relative to the rest of the RTAs, resulting from bad scenario timing. Bad scenario timing generally occurs when the vehicle is either too early or too late in crossing the hold line/runway edge, or when vehicle speeds are too fast or too slow at specific points throughout the run.

As shown in Table 9, the average ownship distance to threshold at the time of the first RCA alert was 964.6 meters before the runway threshold. At the minimum, ownship distance to threshold was 941 meters when a RCA occurred. In all cases, traffic was on the runway, indicated by a NA in the traffic distance to hold line column, when the RCA occurred. However, sufficient advanced alerting was provided for ownship to safely perform a go-around. Three runs were labeled outliers in the RCA study. The first, from October 16th, Matrix Run #1 is the same run that was labeled an outlier for the RTA study, and was a result of bad scenario timing. The second outlier, from October 16th, Matrix Run #9, was the result of a false alert, caused by bad ADS-B data. The alert came on prematurely in response to this erroneous data, then cleared before legitimately alerting. The final outlier is from October 17th, Matrix Run #19. The timing of this scenario was off a bit, as traffic had actually crossed the runway completely before ownship was close enough to the runway threshold to cause an RCA.

As shown in Table 10, time between first RTA and first RCA was calculated and compared for each run in which both an RTA and an RCA were received. For Scenario 1, all runs resulted in both an RTA and an RCA. The average time between alerts was 13.5 seconds. There was one outlier for this study; Matrix Run #1 from October 16th. This run had improper alerts due to the scenario timing. The average value of 13.5 seconds appears to be consistent with the predicted results for this scenario. Figure A-1 shows typical RIAAS alerting performance for Scenario 1.

Scenario 2

Tables 5 and 11 through 13 represent alert data for all RIAAS Scenario 2 runs. Important variables for this scenario are ownship speed, separation distance, traffic distance to hold line and traffic distance to runway.

As shown in Table 11, the average ownship departure speed at the time of the first RTA was 30.2 m/s or 59 kts. The maximum speed at time of alert was 37.4 m/s or 73 kts. The average separation distance at the time of the first RTA was 3223.5 meters. The average traffic distance over the hold line at the time of the RTA was 10.8 meters. There was one outlier for Scenario 2 RTA's. Matrix Run #6 from October 17th, resulted in a late alert. It appears as though this is a scenario timing issue, caused by a late start for the vehicle.

As shown in Table 12, the average ownship speed at the time of the first RCA was 33.8 m/s or 66 kts with a maximum speed of 44.5 m/s or 87 kts. The average separation distance at the time of the first RCA alert was 3167.7 meters with a minimum value of 3054 meters. The RCA occurred well before traffic entered the runway. The average traffic distance to hold line at the time of the first RCA was 26.2 meters, with a maximum value of 39.9 meters. There was one outlier for this set. Matrix Run #56 on October 20th resulted in a late alert. Traffic ADS-B data did not update for a period of time, while the vehicle was moving. Once the data updated, RIAAS alerted properly.

Five Scenario 2 runs resulted in multiple alert types. In four of these runs, the RTA was received before the RCA. In the remaining run, improper timing of the scenario caused the RCA to come first, followed by the RTA. This run was considered an outlier, and was not used to calculate time between alert values.

Table 13 shows the average time between the first RTA and the first RCA was 1.7 seconds, with a maximum value of 3.1 seconds and a minimum of 0.9 seconds. Figure A-2 shows typical RIAAS alerting performance for Scenario 2.

Scenario 3

Tables 6 and 14 through 16 represent alert data for all RIAAS Scenario 3 runs. Important variables for this scenario are ownship distance to hold line, ownship distance to runway edge, traffic speed and separation distance.

Table 14 shows that the average ownship distance to hold line at the time of the first RTA alert was 1.2 meters over the hold line. The maximum distance over the hold line is 1.5 meters. The average traffic speed at the time of the first RTA was 28.6 m/s or 56 kts. The average separation distance at the time of the first RTA was 2710.3 meters. There were no outliers in the RTA study for Scenario 3.

As shown in Table 15, the average ownship distance to hold line for Scenario 3 RCA's at the time of the first alert was 25 meters over the hold line. The maximum value for ownship distance to hold line was 36.0 meters. The average traffic speed at the time of the first alert was 28.7 m/s or 56 kts, with a maximum value of 34 m/s or 66 kts. The average separation distance at the time of the first alert was 2844.3 meters, with a maximum value of 3195 meters. Timing of scenarios for Matrix #s 21 and 25 from October 17th, and Matrix #39 from October 18th all resulted in RCA's only. Traffic was early in executing each run. As a result, when ownship got within the alerting range, the ensuing alert was an RCA instead of an RTA as traffic was already on the runway. These three runs were eliminated from this study as they were considered outliers. Looking at separation distance for all of the runs in Table 6, it is obvious that scenario timing was not consistent for Scenario 3 throughout testing as separation distance at the time of the first alert varied widely with each run.

Three Scenario 3 runs resulted in multiple alert types, while seven runs resulted in RCA's only. In all of the multiple-alert runs, the RTA was received before the RCA. The average time between alerts was 6 seconds with a maximum value of 11.1 seconds and a minimum value of 2.5 seconds. The results varied a considerable amount, again, due to varied timing of the scenarios. Based on these variations, the resulting time between alerts looks acceptable. Results can be seen in Table 16. Figure A-3 shows typical RIAAS alerting performance for Scenario 3.

Scenario 4

Tables 7 and 17 through 19 represent alert data for all RIAAS Scenario 4 runs. Important variables for this scenario are ownship distance to threshold, separation distance, distance to runway (edge) and traffic speed.

Table 17 shows that the average ownship distance to threshold at the time of the first RTA was 1853.1 meters. The maximum value at the time of the first alert was 1982.2 meters and the minimum value was 1544.4 meters. The average separation distance at the time of the first RTA was 3610.3 meters. The average traffic distance to runway was 70.1 meters from the runway edge while still off the runway. Two runs were eliminated from this study as outliers. Matrix Run #26 from October 18th was eliminated due to bad scenario timing, as the first alert was received while the vehicle was just barely off the runway, and traveling at a speed three times greater than average for this scenario. Matrix Run #30, also from October 18th, was eliminated again due to bad scenario timing. The vehicle was on the runway at the time of the alert, traveling more than four times the average for this scenario. All other values were as expected based on RIAAS design criteria and scenario timing.

RIAAS RCA data is found in Table 18. The average ownship distance to threshold at the time of first RCA was 478.7 meters, with a minimum distance of 254.9 meters. The average separation distance at the time of the first alert was 2635.6 meters, with a minimum distance of 2343 meters. The average traffic distance to runway edge at the time of the first alert was 18 meters over (on the runway). Matrix Run #8 from October 16th was eliminated from this study as an outlier. The timing of the scenario resulted in an early alert, while the vehicle was traveling at about half the average speed for this scenario. All other values were as expected.

Seven Scenario 4 runs resulted in multiple alert types. The average time between the first RTA and the first RCA was 21 seconds. The standard deviation was 3.1 seconds, with a maximum value of 26 seconds and a minimum value of 16.9 seconds. Three Scenario 4 runs resulted in RTA's only. This was caused by early initiation of go-arounds, as pilots either responded to one of the other systems which happened to alert before a RIAAS RCA was generated, or they initiated a go-around in response to a RIAAS RTA as opposed to waiting for the RCA. Values were as expected here, and can be seen in Table 19. Figure A-4 shows typical RIAAS alerting performance for scenario 4.

RIAAS False Alerts

Not all false alerts were received during RIPS incursion runs. Every false alert captured in the DAS data has been noted, regardless of the type of test being performed. RIAAS generated only two false alerts throughout all of DFW testing. Both false alerts were direct results of erroneous data. Table H-1 lists the scenario information and traffic/ownship positions at the time of each false alert. In one case, traffic was traveling away from ownship at a high rate of speed. Traffic heading suddenly flipped 180 degrees indicating that it was headed straight toward ownship, resulting in a RIAAS alert. The second case of a false alert occurred toward the end of a successful run. Traffic had cleared the runway and crossed the hold line going away from the runway. On the very next data update, erroneous position data indicated that traffic was 50 meters closer to the runway than it in fact was, causing RIAAS to falsely re-issue the alert it had just cleared.

Table 4. Scenario 1 RIAAS Alert Summary

Date	Matrix #	Alert Type	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	1	RTA		XX			XX	Alerts OK.
16-Oct	1	RCA		XX			XX	
16-Oct	9	RTA		XX		XX		Alerts OK. Bad ADS-B data.
16-Oct	9	RCA				XX		
17-Oct	5	RTA			XX		XX	Late Alerts (approximately 3-4 sec).
17-Oct	5	RCA		XX			XX	
17-Oct	19	RTA		XX		XX		Alerts OK. False Alert - due to bad position data.
17-Oct	19	RCA		XX		XX		
18-Oct	23	RTA					XX	Alerts OK.
18-Oct	23	RCA					XX	
18-Oct	27	None						Traffic data indicates no van movement.
18-Oct	45	RTA					XX	Alerts OK.
18-Oct	45	RCA					XX	
18-Oct	37	RTA					XX	Alerts OK.
18-Oct	37	RCA					XX	
19-Oct	41	RTA					XX	Alerts OK.
19-Oct	41	RCA					XX	
20-Oct	63	RTA		XX			XX	Alerts OK.
20-Oct	63	RCA		XX			XX	
20-Oct	55	RTA		XX			XX	Alerts OK.
20-Oct	55	RCA		XX			XX	
20-Oct	59	RTA		XX			XX	Alerts OK.
20-Oct	59	RCA		XX			XX	

Table 5. Scenario 2 RIAAS Alert Summary

Date	Matrix #	Alert Type	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	10	RCA		XX			XX	Alert OK.
17-Oct	2	RTA		XX			XX	Alerts OK. Bad position data.
17-Oct	2	RCA		XX			XX	
17-Oct	6	RCA			XX		XX	Alerts OK
17-Oct	6	RTA		XX			XX	
17-Oct	20	RTA		XX			XX	Alerts OK.
17-Oct	20	RCA		XX			XX	
17-Oct	24	RCA		XX			XX	Alerts OK.
18-Oct	28	RCA					XX	Alert OK.
18-Oct	42	RTA					XX	Alerts OK.
18-Oct	42	RCA					XX	
18-Oct	38	RTA					XX	Alerts OK.
18-Oct	38	RCA					XX	
19-Oct	46	RCA					XX	Alert OK.
20-Oct	56	RCA			XX		XX	Late Alert. Bad ADS-B data.
20-Oct	64	RTA		XX			XX	Alerts OK.
20-Oct	64	RCA		XX			XX	

Table 6. Scenario 3 RIAAS Alert Summary

Date	Matrix #	Alert Type	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	3	RTA		XX			XX	Alerts OK.
16-Oct	3	RCA		XX			XX	
16-Oct	11	RTA		XX		XX		Alerts OK. Data gaps. Bad data.
16-Oct	11	RCA		XX		XX		
17-Oct	7	RCA		XX			XX	Alert OK.
17-Oct	21	RCA		XX			XX	Alert OK.
17-Oct	25	RCA		XX			XX	Alert OK.
17-Oct	29	RCA			XX		XX	Alert OK. Data gaps
18-Oct	47	RCA					XX	Alert OK. Data gap
18-Oct	39	RCA					XX	Alerts OK.
19-Oct	43	None						No STIS-B data received.
20-Oct	57	RTA		XX			XX	Alerts OK.
20-Oct	57	RCA		XX			XX	
20-Oct	65	RCA		XX			XX	Alert OK. Data gaps
20-Oct	61	None						No STIS-B data received

Table 7. Scenario 4 RIAAS Alert Summary

Date	Matrix #	Alert Type	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	4	RTA		XX			XX	Alerts OK.
16-Oct	4	RCA		XX			XX	
16-Oct	8	RTA			XX		XX	Alerts OK. Data gaps
16-Oct	8	RCA		XX			XX	
17-Oct	12	RTA		XX			XX	Alerts OK.
17-Oct	12	RCA		XX			XX	
17-Oct	22	RTA		XX			XX	Alert OK.
18-Oct	26	RTA					XX	Alerts OK. Bad heading data
18-Oct	26	RCA					XX	
18-Oct	30	RTA					XX	Alerts OK. Data gaps
18-Oct	30	RCA					XX	
18-Oct	44	RTA					XX	Alert OK.
18-Oct	40	RTA					XX	Alert OK.
19-Oct	48	RTA					XX	Alerts OK.
19-Oct	48	RCA					XX	
20-Oct	58	RTA		XX			XX	Alerts OK.
20-Oct	58	RCA		XX			XX	Alerts OK.
20-Oct	62	RTA			XX		XX	Late Alerts (approximately 2 sec)
20-Oct	62	RCA		XX			XX	
20-Oct	66	RTA		XX			XX	Alerts OK.
20-Oct	66	RCA		XX			XX	

Table 8. Scenario 1 RIAAS RTAs

Scenario 1 RTA					
Date	UTC	Matrix Run #	Ownship Dist to T.H. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
16-Oct	24954.5	9	-1824.7	10.6	-66.9
17-Oct	20628.3	5	-1498.9	35.6	-41.9
17-Oct	32227.2	19	-1904.9	9.9	-67.6
18-Oct	19077.7	23	-1732.9	24	-45.4
18-Oct	28680.3	45	-1964.3	14.1	-55.4
18-Oct	31388.3	37	-1884	14.8	-54.7
19-Oct	18534.4	41	-1745.1	38.3	-31.1
20-Oct	20959.8	63	-1953.1	21.9	-47.5
20-Oct	29977.5	55	-1916.1	8.3	-61.1
20-Oct	32729.8	59	-1967.7	18.3	-51.1
		AVERAGE	-1839.2	19.6	-52.3
		STDEV	146.6	10.5	11.4
		MINIMUM	-1498.9	8.3	-31.1
		MAXIMUM	-1967.7	38.3	-67.6

Table 9. Scenario 1 RIAAS RCAs

Scenario 1 RCA					
Date	UTC	Matrix Run #	Ownship Dist to T.H. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
17-Oct	20636.1	5	-975.9	NA	19.4
18-Oct	19089.8	23	-965.4	NA	9.3
18-Oct	28695.0	45	-969.3	NA	3.8
18-Oct	31402.0	37	-968.7	NA	3.9
19-Oct	18546.2	41	-976.6	NA	9.6
20-Oct	20974.6	63	-951.3	NA	3.8
20-Oct	29993.3	55	-968.2	NA	20.3
20-Oct	32746.5	59	-941	NA	5.7
		AVERAGE	-964.6	NA	9.5
		STDEV	12.3	NA	6.8
		MINIMUM	-941	NA	3.8
		MAXIMUM	-976.6	NA	20.3

Note - Distances to threshold, runway, and hold line have positive values for locations across these points and negative values for distances further away.

Table 10. Scenario 1 Time Between RIAAS Alerts

Scenario 1 Time between first RTA and first RCA		
Date	Matrix Run #	Time Between First RTA and First RCA (s)
16-Oct	9	13.0
17-Oct	5	7.9
17-Oct	19	15.0
18-Oct	23	11.6
18-Oct	45	14.9
18-Oct	37	14.1
19-Oct	41	12.1
20-Oct	63	15.1
20-Oct	55	14.9
20-Oct	59	16.6
	AVERAGE	13.5
	STDEV	2.5
	MINIMUM	7.9
	MAXIMUM	16.6

Table 11. Scenario 2 RIAAS RTAs

Scenario 2 RTA						
Date	UTC	Matrix Run #	Ownship Speed (m/s)	Separation Dist. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
17-Oct	30971.07	20	32.6	3227.0	14.1	-55.4
18-Oct	27461.46	42	37.4	3133.0	13.4	-64.1
18-Oct	32511.49	38	25.9	3254.0	9.9	-67.6
20-Oct	33871.66	64	24.7	3280.0	5.6	-71.9
		AVERAGE	30.2	3223.5	10.8	-64.8
		STDEV	6.0	64.1	3.9	7.0
		MINIMUM	24.7	3133.0	5.6	-55.4
		MAXIMUM	37.4	3280.0	14.1	-71.9

Table 12. Scenario 2 RIAAS RCAs

Scenario 2 RCA						
Date	UTC	Matrix Run #	Ownship Speed (m/s)	Separation Dist. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
16-Oct	33848.17	10	15.9	3242.0	37.5	-32.0
17-Oct	22952.3	2	30.6	3220.0	16.2	-53.2
17-Oct	24305.21	6	42.0	3054.0	30.5	-39.0
17-Oct	30973.04	20	38.9	3158.0	31.2	-38.3
17-Oct	35895.96	24	44.5	3098.0	24.0	-45.4
18-Oct	22760.77	28	33.1	3211.0	21.3	-56.2
18-Oct	27462.44	42	40.6	3097.0	19.9	-57.7
18-Oct	32514.44	38	34.2	3163.0	39.9	-37.7
19-Oct	24933.63	46	29.2	3183.0	22.0	-55.5
20-Oct	33872.65	64	28.6	3251.0	19.9	-57.7
		AVERAGE	33.8	3167.7	26.2	-47.3
		STDEV	8.4	66.8	8.1	9.9
		MINIMUM	15.9	3054.0	16.2	-32.0
		MAXIMUM	44.5	3251.0	39.9	-57.7

Table 13. Scenario 2 Time Between RIAAS Alerts

Scenario 2 Time between first RTA and first RCA		
Date	Matrix Run #	Time Between RTA and RCA (s)
17-Oct	20	1.9
18-Oct	42	0.9
18-Oct	38	3.1
20-Oct	64	1.0
	AVERAGE	1.7
	STDEV	1.0
	MINIMUM	0.9
	MAXIMUM	3.1

Table 14. Scenario 3 RIAAS RTAs

Scenario 3 RTA						
Date	UTC	Matrix Run #	Ownship Dist. To H.L. (m)	Ownship Dist. To RWY (m)	Traffic Speed (m/s)	Separation Dist. (m)
16-Oct	23013.77	3	1.5	-76.0	31.7	2221.0
16-Oct	33480.24	11	1.2	-76.3	26.8	2713.0
20-Oct	17479.9	57	0.9	-67.5	27.3	3197.0
		AVERAGE	1.2	-73.3	28.6	2710.3
		STDEV	0.3	5.0	2.7	488.0
		MINIMUM	0.9	-67.5	26.8	2221.0
		MAXIMUM	1.5	-76.3	31.7	3197.0

Table 15. Scenario 3 RIAAS RCAs

Scenario 3 RCA						
Date	UTC	Matrix Run #	Ownship Dist. To H.L. (m)	Ownship Dist. To RWY (m)	Traffic Speed (m/s)	Separation Dist. (m)
16-Oct	23018.69	3	11.8	-65.7	29.0	2102.0
16-Oct	33491.06	11	33.5	-44.0	27.8	2403.0
17-Oct	19569.06	7	26.8	-47.8	22.6	3188.0
17-Oct	34254.3	29	30.6	-44.0	26.8	3195.0
18-Oct	30252.03	47	25.0	-44.5	29.3	2933.0
20-Oct	17481.87	57	10.5	-57.9	34.0	3110.0
20-Oct	19934.05	65	36.9	-32.5	31.6	2979.0
		AVERAGE	25.0	-48.1	28.7	2844.3
		STDEV	10.3	10.8	3.6	424.9
		MINIMUM	10.5	-32.5	22.6	2102.0
		MAXIMUM	36.9	-65.7	34.0	3195.0

Table 16. Scenario 3 Time Between RIAAS Alerts

Scenario 3 Time between first RTA and first RCA		
Date	Matrix Run #	Time Between RTA and RCA (s)
16-Oct	3	4.3
16-Oct	11	11.1
20-Oct	57	2.5
	AVERAGE	6.0
	STDEV	4.5
	MINIMUM	2.5
	MAXIMUM	11.1

Table 17. Scenario 4 RIAAS RTAs

Scenario 4 RTA						
Date	UTC	Matrix Run #	Ownship Dist. To T.H. (m)	Separation Dist. (m)	Traffic Dist. To RWY (m)	Traffic Speed (m/s)
16-Oct	21419.44	4	-1855.9	3526.0	-79.3	5.1
16-Oct	24191.03	8	-1544.4	3210.0	-70.8	6.7
17-Oct	21474.46	12	-1878.5	3550.0	-79.3	5.7
17-Oct	29449.51	22	-1982.2	3652.0	-72.2	6.7
18-Oct	29301.27	44	-1825.8	3640.0	-67.2	7.7
18-Oct	30897.48	40	-1926.2	3783.0	-76.4	5.7
19-Oct	21485.25	48	-1932.4	3750.0	-72.2	6.7
20-Oct	18464.35	58	-1953.8	3755.0	-74.3	6.2
20-Oct	21833.35	62	-1696.8	3504.0	-42.9	8.7
20-Oct	30635.6	66	-1934.9	3733.0	-66.4	7.2
		AVERAGE	-1853.1	3610.3	-70.1	6.6
		STDEV	135.9	173.3	10.5	1.1
		MINIMUM	-1544.4	3210.0	-42.9	5.1
		MAXIMUM	-1982.2	3783.0	-79.3	8.7

Table 18. Scenario 4 RIAAS RCAs

Scenario 4 RCA						
Date	UTC	Matrix Run #	Ownship Dist. To T.H. (m)	Separation Dist. (m)	Traffic Dist. To RWY (m)	Traffic Speed (m/s)
16-Oct	21442.07	4	-254.9	2343.0	21.7	31.4
17-Oct	21494.15	12	-578.4	2561.0	19.8	26.2
18-Oct	18505.7	26	-500.8	2720.0	6.3	34.3
18-Oct	21677.83	30	-576.7	2733.0	14.4	28.8
19-Oct	21506.9	48	-558.5	2751.0	21.1	29.8
20-Oct	18486.14	58	-513.3	2656.0	21.8	27.5
20-Oct	21850.08	62	-574.5	2707.0	17.8	26.8
20-Oct	30662.17	66	-272.6	2614.0	21.3	30.4
		AVERAGE	-478.7	2635.6	18.0	29.4
		STDEV	135.9	134.7	5.4	2.7
		MINIMUM	-254.9	2343.0	6.3	26.2
		MAXIMUM	-578.4	2751.0	21.8	34.3

Table 19. Scenario 4 Time Between RIAAS Alerts

Scenario 4 Time between first RTA and first RCA		
Date	Matrix Run #	Time Between Alerts (s)
16-Oct	4	23.0
17-Oct	12	20.0
18-Oct	26	17.7
19-Oct	48	22.0
20-Oct	58	21.2
20-Oct	62	16.9
20-Oct	66	26.0
	AVERAGE	21.0
	STDEV	3.1
	MINIMUM	16.9
	MAXIMUM	26.0

4.4.2 RSM Alerting Performance

RSM exhibited reliable and consistent alerting performance when accurate and reliable traffic information was available. It appears as though all problems with alerting were attributed to erroneous data, data drop-outs, or other data-related problems. Results varied from run to run depending on the timing of each individual scenario, as can be expected.

4.4.2.1 RSM Scenario Alert Plots

Figures C-1 through C-4 are plots of actual RSM runs, performed during testing at DFW. These plots represent typical RSM performance with good traffic data and proper scenario timing. Scenarios 1-4 were ADS-B/STIS-B runs.

Figure C-1 is a plot of a Scenario 1 run, representing an Arrival/Taxi situation. As ownship gets within 1 nm of the runway threshold and traffic is 16 m across the hold line, an RCA is issued. A few seconds later, ownship initiates a go-around at 326 ft altitude, safely clearing traffic and a potential collision. Traffic proceeds across the runway, ending the scenario.

Figure C-2 is a plot of a Scenario 2 run. This scenario represents a Departure/Taxi situation. Ownship pulls onto the runway and proceeds to begin its take off roll. Once ownship has reached a minimum departure speed, traffic rolls across the hold line and continues toward the runway. As traffic is almost 40 m over the hold line, an RCA is generated with vehicle separation distance of 3086 m. Ownship is traveling at 78 kts at this point. Three seconds later, ownship initiates an aborted take off, slowing to taxi speed and safely pulling off the runway.

Figure C-3 is a plot of a Scenario 3 run. This is very similar to Scenario 2, with ownship and traffic switching roles. Traffic pulls onto the runway and proceeds to begin its take off roll. Once traffic has reached a minimum take off speed, ownship begins to roll across the hold line. Ownship continues crossing toward the runway. An RCA is issued as ownship passes 30 meters over the hold line and vehicle separation is 2265 meters. Traffic is traveling at 58 kts at the time of the alert. Ownship comes to a halt in response to the RCA, stopping a safe distance from the runway edge and avoiding a potential collision with the departing traffic.

Figure C-4 is a plot of a Scenario 4 run. This scenario represents an Arrival/Departure situation. Ownship is preparing for an arrival. Traffic crosses the hold line and continues toward the runway. As ownship nears 1700 meters from the runway threshold, an RCA is issued. Traffic is still off the runway, 36 meters from runway edge. Traffic continues onto the runway to initiate its take off roll. Ownship initiates a go-around at 282 ft altitude, and safely avoids a potential collision with the departing traffic.

4.4.2.2 RSM Alert Performance Summary

RSM alerts are summarized in Tables 20 through 23, and alert data is presented in Tables 24 through 27 and is sorted by scenario. A comprehensive summary of RSM alerting performance is found in Appendix D.

Scenario 1

Table 24 presents RCA alert results for RSM Scenario 1 runs. Important variables for this scenario are ownship distance to threshold, traffic distance to hold line, and traffic distance to runway edge. As shown in Table 24, the average ownship distance to threshold at the time of the first RCA was 1753.6 meters before the runway threshold. The alerts occurred while ownship distance to threshold values ranged from 1426.2 to 1922.9 meters. The average traffic distance over the hold line at the time of the first alert was 30.8 meters. For valid Scenario 1 runs, all of the alerts began before traffic reached the runway. Three runs were labeled outliers in the scenario 1 RSM alert analysis. The first, from October 16th, Matrix Run #1, was a result of bad scenario timing. The second outlier, Matrix Run #41, flown on October 19th appeared to be a result of timing as well, as the alert was not generated until traffic was on the runway. The final outlier was Matrix Run #27 from October 18th. An RSM alert was not generated during this run due to erroneous ADS-B data. The target did appear but its indicated position did not change throughout the run, while the vehicle was in fact moving.

Scenario 2

Table 25 presents RCA alert results for RSM Scenario 2 runs. Important variables for this scenario are ownship speed, separation distance, traffic distance to hold line and traffic distance to runway edge. As shown in Table 25, the average ownship departure speed at the time of the first RCA was 37.8 m/s or 73 kts, with a maximum recorded speed of 50.3 m/s or 98 kts. The average separation distance at the time of the first alert was 3135.5 meters. The average traffic distance over the hold line at the time of alert was 29.6 meters. Matrix Run #56 from October 20th was omitted as an outlier. RSM did not alert on this run due to missing traffic data. ADS-B did not update for 30 seconds during this run.

Scenario 3

Table 26 presents alert data for RSM Scenario 3 runs. Important variables for this scenario are ownship distance to hold line, ownship distance to runway edge, traffic speed and Separation distance. As shown in Table 26, the average ownship distance to hold line at the time of the first alert was 28 meters. Ownship never reached the runway at the time of the first RSM alert for any valid scenario 3 runs. The average traffic departure speed at the time of the first alert was 23.6 m/s or 46 kts. The maximum speed recorded at the time of the first alert was 30.4 m/s or 59 kts. The average separation distance at the time of first alert was 2973.6 meters. Traffic and ownship were never closer than 2072.2 meters at the time of the first RSM alert.

Two runs were eliminated from the Scenario 3 RSM alert analysis as outliers. The first was Matrix Run #25 Flown on October 17th. It appears as though the timing of the scenario was off, as ownship was on the runway when the alert was generated. The second outlier was Matrix Run #43 flown on October 19th. There was no ADS-B or STIS-B traffic data for this run in the DAS files. Without this data, the run could not be analyzed.

Scenario 4

Table 27 presents alert data for the RSM Scenario 4 runs. Important variables for this scenario are ownship distance to threshold, separation distance, traffic distance to runway edge and traffic speed. As shown in Table 27, the average ownship distance to threshold at the time of the first alert was 1663.2 meters before the runway threshold. The alerts occurred while ownship's distance to threshold ranged from 1342.2 to 1792.5 meters. The average separation distance at the time of the first alert was 3424 meters. The average traffic distance to runway edge at the time of first alert was 32 meters (away from runway). Traffic's average speed at the time of first alert was 12.6 m/s or 25 kts, which did not vary much from run to run.

Two runs, Matrix Run #26, and Matrix Run #66 of October 18th and 20th respectively, were eliminated from this analysis as outliers. Both appear to be the result of bad scenario timing, as traffic was on the runway at the time of first alert for both runs.

RSM False Alerts

Not all false alerts were received during RIPS incursion runs. Every false alert captured in the DAS data has been noted, regardless of the type of test being performed. A detailed description of each false alert can be found Appendix H. RSM generated 4 false alerts throughout all of DFW testing. It appears as though all four were directly caused by ownship's own STIS-B-generated position track. This track, referred to as "ownship's ghost", would tend to lag a few seconds behind ownship's true position due to latency in the STIS-B data. When ownship decelerated, the distance between the ghost and ownship would begin to decrease. On a number of runs, this would cause an alert as there appeared to be a vehicle approaching ownship from behind at close range. Filtering out the STIS-B-based ID for ownship before processing STIS-B data would solve this problem. This was difficult to do during DFW testing, as ownship was given multiple IDs in the STIS-B data.

Table 20. Scenario 1 RSM Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	1		XX			XX	
16-Oct	9		XX			XX	
17-Oct	5		XX			XX	
17-Oct	19		XX			XX	
18-Oct	23		XX			XX	
18-Oct	27						RSM did not alert, erroneous ADS-B data.
18-Oct	45		XX			XX	
18-Oct	37		XX			XX	
19-Oct	41		XX			XX	
20-Oct	63		XX			XX	
20-Oct	55		XX			XX	
20-Oct	59		XX			XX	

Table 21. Scenario 2 RSM Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	10		XX			XX	
17-Oct	2		XX			XX	
17-Oct	6		XX			XX	
17-Oct	20		XX			XX	
17-Oct	24		XX			XX	
18-Oct	28		XX			XX	
18-Oct	42		XX			XX	
18-Oct	38		XX			XX	
19-Oct	46		XX			XX	
20-Oct	56		XX				RSM did not alert. ADS-B did not update for 30 sec.
20-Oct	64		XX			XX	

Table 22. Scenario 3 RSM Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	3		XX			XX	
16-Oct	11		XX			XX	
17-Oct	7				XX		False alert on ID 84 (not RIPS Van – looks like ownship's ghost) This occurred on approach, 3.5 minutes before the actual incursion.
17-Oct	21		XX			XX	
17-Oct	25		XX			XX	
17-Oct	29		XX			XX	
18-Oct	47		XX			XX	Data gap.
18-Oct	39		XX			XX	ADS-B data gap.
19-Oct	43		XX			XX	No ADS-B data.
20-Oct	57		XX			XX	
20-Oct	65		XX			XX	
20-Oct	61						RSM did not alert. No STIS-B data received.

Table 23. Scenario 4 RSM Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	4		XX			XX	
16-Oct	8		XX			XX	
17-Oct	12		XX			XX	
17-Oct	22		XX			XX	
18-Oct	26		XX			XX	
18-Oct	30						RSM did not alert, erroneous ADS-B data.
18-Oct	44		XX			XX	
18-Oct	40		XX			XX	
19-Oct	48		XX			XX	
20-Oct	58		XX			XX	
20-Oct	62		XX			XX	
20-Oct	66		XX			XX	

Table 24. Scenario 1 RSM Alerts

Scenario 1					
Date	UTC	Matrix Run #	Ownship Dist to T.H. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
16-Oct	24955.5	9	-1686.1	22.0	-55.5
17-Oct	20628.3	5	-1426.2	35.6	-41.9
17-Oct	32229.1	19	-1739.9	40.7	-36.8
18-Oct	19079.3	23	-1630.3	45.3	-24.2
18-Oct	28680.3	45	-1922.9	23.2	-46.3
18-Oct	31388.3	37	-1842.5	25.4	-44.1
20-Oct	20960.8	63	-1848.8	26.8	-42.7
20-Oct	29978.5	55	-1839.6	15.3	-54.1
20-Oct	32730.8	59	-1846.5	43.2	-26.3
		AVERAGE	-1753.6	30.8	-41.3
		STDEV	153.6	10.6	10.8
		MINIMUM	-1426.2	15.3	-24.2
		MAXIMUM	-1922.9	45.3	-55.5

Note - Distances to threshold, runway, and hold line have positive values for locations across these points and negative values for distances further away.

Table 25. Scenario 2 RSM Alerts

Scenario 2						
Date	UTC	Matrix Run #	Ownship Speed (m/s)	Separation Dist. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
16-Oct	33849.2	10	22.6	3222.0	60.0	-9.2
17-Oct	22953.3	2	35.8	3172.8	15.3	-54.1
17-Oct	24304.2	6	40.0	3101.5	7.5	-62.0
17-Oct	30972.1	20	37.8	3184.8	30.3	-39.2
17-Oct	35896.9	24	50.3	3021.2	43.2	-26.3
18-Oct	22761.8	28	36.2	3164.3	20.6	-56.9
18-Oct	27462.4	42	43.6	3066.6	19.2	-58.3
18-Oct	32516.4	38	39.7	3086.4	44.2	-33.3
19-Oct	24934.6	46	35.6	3151.8	36.4	-41.1
20-Oct	33874.6	64	36.0	3183.3	19.2	-58.3
		AVERAGE	37.8	3135.5	29.6	-43.9
		STDEV	7.0	63.3	16.2	17.2
		MINIMUM	22.6	3021.2	7.5	-9.2
		MAXIMUM	50.3	3222.0	60.0	-62.0

Table 26. Scenario 3 RSM Alerts

Scenario 3						
Date	UTC	Matrix Run #	Ownship Dist. To H.L. (m)	Ownship Dist. To RWY (m)	Traffic Speed (m/s)	Separation Dist. (m)
16-Oct	33494.0	11	46.1	-31.4	30.4	2265.2
16-Oct	23018.7	3	14.3	-63.2	29.8	2072.2
17-Oct	19566.1	7	22.3	-52.4	17.5	3241.2
17-Oct	27968.8	21	58.3	-19.2	17.5	3346.2
17-Oct	34252.3	29	23.1	-51.5	13.4	3402.8
18-Oct	30251.0	47	24.3	-45.2	29.3	2935.3
18-Oct	33017.9	39	12.4	-57.1	13.4	3384.4
20-Oct	17482.9	57	16.6	-51.9	30.4	3097.0
20-Oct	19932.1	65	35.1	-34.4	30.4	3018.3
		AVERAGE	28.0	-45.1	23.6	2973.6
		STDEV	15.5	14.1	7.8	486.9
		MINIMUM	12.4	-19.2	13.4	2072.2
		MAXIMUM	58.3	-63.2	30.4	3402.8

Table 27. Scenario 4 RSM Alerts

Scenario 4						
Date	UTC	Matrix Run #	Ownship Dist. To T.H. (m)	Separation Dist. (m)	Traffic Dist. To RWY (m)	Traffic Speed (m/s)
16-Oct	21422.4	4	-1585.6	3261.0	-30.0	13.4
16-Oct	24193.0	8	-1342.2	3006.5	-23.6	14.9
17-Oct	21476.4	12	-1691.1	3363.3	-42.2	11.3
17-Oct	29451.5	22	-1792.5	3465.5	-37.9	11.8
18-Oct	29302.3	44	-1718.6	3528.2	-31.5	13.9
18-Oct	30900.4	40	-1757.7	3562.4	-38.6	12.4
19-Oct	21487.2	48	-1772.9	3577.8	-28.6	13.4
20-Oct	18467.3	58	-1715.0	3517.5	-36.5	11.8
20-Oct	21834.3	62	-1593.0	3400.0	-19.3	10.8
		AVERAGE	-1663.2	14.9	-32.0	12.6
		STDEV	140.6	182.8	7.5	1.3
		MINIMUM	-1342.2	3006.5	-19.3	10.8
		MAXIMUM	-1792.5	3577.8	-42.2	14.9

4.4.3 Ground-Based System Alerting Performance

GBS had 11 missed alerts and 9 false alerts, with a total of 34 out of 47 runs resulting in proper alerts during DFW testing. The majority of the false alerts were caused by a false target, while others appeared to be the result of erroneous traffic altitude and speed data.

4.4.3.1 GBS Scenario Alert Plots

Figures E-1 through E-4 are plots of actual GBS runs, performed during testing at DFW. These plots represent typical GBS performance with good traffic data and proper scenario timing. Scenarios 1 and 2 were STIS-B only while scenarios 3 and 4 were ADS-B/STIS-B runs.

Figure E-1 is a plot of a Scenario 1 run, representing an Arrival/Taxi situation. As ownship gets within approximately 1300 meters of the runway threshold and traffic is on the runway, an RCA is issued. A few seconds later, ownship initiates a go-around at 277 ft altitude, safely clearing traffic and a potential collision. Traffic proceeds across the runway, ending the scenario.

Figure E-2 is a plot of a Scenario 2 run. This scenario represents a Departure/Taxi situation. Ownship pulls onto the runway and proceeds to begin its take off roll. Once ownship has reached a minimum departure speed, traffic rolls across the hold line and continues toward the runway. With traffic on the runway, an RCA is generated with a vehicle separation distance of 2616 m. Ownship is traveling at 117 kts at this point. Several seconds later, ownship initiates an aborted take off, slowing to taxi speed and safely pulling off the runway.

Figure E-3 is a plot of a Scenario 3 run. This is very similar to Scenario 2, with ownship and traffic switching roles. Traffic pulls onto the runway and proceeds to begin its take off roll. Once traffic has reached a minimum take off speed, ownship begins to roll across the hold line. Ownship continues crossing onto the runway. An RCA is issued with a vehicle separation of 2321 meters. Traffic is traveling at 64 kts at the time of alert. Ownship comes to a halt in response to the RCA, stopping a safe distance from the runway edge and avoiding a potential collision with the departing traffic.

Figure E-4 is a plot of a Scenario 4 run. This scenario represents an Arrival/Departure situation. Ownship is preparing for an arrival. Traffic crosses the hold line and continues toward the runway. As ownship nears 1400 meters from the runway threshold, an RCA is issued. Traffic is on the runway traveling at 28 kts. Ownship initiates a go-around at 228 ft altitude, and safely avoids a potential collision with the departing traffic.

4.4.3.2 GBS Alert Performance Summary

GBS alerts are summarized in Tables 28 through 31, and alert data is presented in Tables 32 through 35 and is sorted by scenario. A comprehensive summary of GBS alerting performance is found in Appendix F.

It should be noted that GBS alerting performance varied throughout testing as a number of criteria thresholds were changed midway through the testing process. Originally, arrivals were not processed until they were within 0.5 nm of the runway threshold. This was extended to 1 nm.

In addition, Scenarios 1 and 2 were changed so that traffic would actually cross the runway, versus just crossing the hold line. GBS is designed to process safety logic on aircraft only when they have reached the runway or "runway corridor". In the original scenario designs, the incursion vehicle stopped before it reached the runway corridor. As a result, no alerts were generated by GBS until the scenarios were changed to account for this. It appears as though the original criteria and scenario designs were major contributors to, if not the direct causes of the missed alerts in Scenario 1 for October 16th and 17th.

Scenario 1

Table 32 summarizes Scenario 1 alerting for GBS. Important variables for Scenario 1 are ownship distance to threshold and traffic distance to runway edge. The average ownship distance to threshold at the time of first alert was 1286.5 meters before the runway threshold. Ownship distance to threshold ranged from 1160.8 to 1546.9 meters. The average traffic distance over runway edge at time of first alert was 11.6 meters. Traffic was on the runway at the time of first GBS alert for all Scenario 1 runs. On one run, Matrix Run #63, October 20th, GBS generated a false alert more than one minute before it should have alerted. This run was removed for the purpose of this analysis.

Scenario 2

Table 33 summarizes Scenario 2 GBS alert performance. Important variables for this scenario are ownship speed, separation distance and traffic distance to runway edge. The average ownship departure speed at the time of the first RCA was 39.9 m/s (78 kts). The highest recorded speed at the time of first alert was 59.8 m/s (117 kts). The average separation distance at the time of the first alert was 2638.8 meters. GBS alert thresholds are set such that distances of less than 3658 meters will trigger an alert for a DEPARTURE approaching a TAXI. The average traffic location was 22 meters over the runway edge. One run, Matrix Run #10, flown on October 16th generated a false alert and was considered an outlier for this analysis.

Scenario 3

Table 34 summarizes GBS alert performance for the Scenario 3 runs. Important variables for this scenario are ownship distance to runway edge, traffic speed and separation distance. The average ownship distance to runway edge at the time of first alert was 19.3 meters. Ownship was on the runway at the time of all GBS alerts for Scenario 3. It should be noted that the GBS alerts use the aircraft centroid as an approximate reference point. This is approximately 24 m behind the nose. Therefore the alerts occurred with the GBS reference point nominally 5 m away from the runway edge. This is in accordance with the logic in the algorithms at the time of the test. The average traffic speed at the time of first alert was 29.8 m/s (58 kts), and the average separation distance was 2512.3 meters. As shown in Table 29 there were several runs where no alert was generated due to the fact that the aircraft stopped before the criteria for a GBS alert was satisfied. This occurred when one of the other alerting algorithms was being displayed in the cockpit. As soon as the pilot received one of those alerts the aircraft was immediately stopped. In runs 3, 7, 43, and 57 ownship stopped before GBS could alert.

Scenario 4

Table 35 summarizes GBS alert performance for the Scenario 4 runs. Important variables for this scenario are ownship distance to threshold, separation distance, traffic distance to runway edge and traffic speed. At the time of the first alert, the average ownship distance to threshold was 1266.5 meters before the runway threshold. Values for this distance varied from 1098.3 to 1403 meters. The average separation distance at the time of the first alert was 3133 meters. The average traffic distance to runway edge at the time of first alert was 23.4 meters. Traffic was on the runway at the time of the first GBS alert for all valid Scenario 4 runs. The average traffic speed at time of first alert was 17.7 m/s (34 kts). Two runs, Matrix Run #8, flown October 16th and Matrix Run #62, flown October 20th were both treated as outliers for Scenario 4 due to bad scenario timing and a false alert.

GBS False Alerts

GBS had 9 false alerts throughout DFW testing. Not all false alerts were received during RIPS incursion runs. Every false alert captured in the DAS data has been noted, regardless of the type of test being performed. GBS false alerts are summarized in detail in Appendix H. A few false alerts appeared as though they may have been caused by faulty altitude and heading data for target IDs, but the majority of the false alerts were caused by one apparent false target that was located well off the East side of Runway 35C. This target changed IDs a number of times throughout testing. It remained in the same location (1879.9, 1859.8) meters on the local coordinate system for the airport. This appears to be on or near Exit Q3.1 of Runway 35R. This target caused GBS to generate alerts for long time periods. On a few occasions, the alerts would start while ownship was miles out from the airport, and continue through an entire run into the next. These false alerts resulted in the erroneous reporting of a Runway Conflict Alert. Preliminary analysis indicates that these false alerts may have been related to a GBS STOPPED_TIMEOUT alert. The GBS STOPPED_TIMEOUT alert is designed to provide ATC with an alert to indicate that a target is stopped on the runway for an extended period of time. This is not a runway incursion alert. The RIPS avionics is designed for runway incursion alerting, not other types of alerting. For future implementations a review regarding which GBS alerts are transmitted to the RIPS avionics needs to be performed. In summary, there were no false alerts involving the aircraft and vehicle used in the RIPS testing. All were due to other targets received by the ground surveillance system.

Table 28. Scenario 1 GBS Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	1						GBS did not alert on this run.
16-Oct	9						GBS did not alert on this run.
17-Oct	5						GBS did not alert on this run.
17-Oct	19						GBS did not alert on this run.
18-Oct	23		XX			XX	
18-Oct	27		XX			XX	ADS-B data gap.
18-Oct	45		XX			XX	
18-Oct	37		XX			XX	
19-Oct	41		XX			XX	
20-Oct	63				XX		GBS falsely alerted throughout entire run. Note, the DAS data only displays one alert, cannot determine if the proper alert was generated and not recorded.
20-Oct	55		XX			XX	
20-Oct	59		XX			XX	

Table 29. Scenario 2 GBS Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	10				XX		GBS alerted on ownship before the run was performed. Note, the DAS data only displays one alert, cannot determine if the proper alert was generated and not recorded.
17-Oct	2					XX	
17-Oct	6						GBS did not alert on this run.
17-Oct	20		XX			XX	ADS-B data gap.
17-Oct	24		XX			XX	
18-Oct	28		XX			XX	
18-Oct	42		XX			XX	
18-Oct	38		XX			XX	
19-Oct	46				XX		GBS alerted constantly throughout entire run on a stationary traffic ID 207. Note, the DAS data only displays one alert, cannot determine if the proper alert was generated and not recorded.
20-Oct	56		XX			XX	ADS-B data gap.
20-Oct	64		XX			XX	

Table 30. Scenario 3 GBS Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	3						No alert – ownship stopped before alert criteria was met.
16-Oct	11		XX			XX	
17-Oct	7						No alert – ownship stopped before alert criteria was met.
17-Oct	21		XX			XX	
17-Oct	25		XX			XX	
17-Oct	29						DAS data file stopped recording before end of run – it cannot be determined if GBS alerted.
18-Oct	47		XX			XX	ADS-B data gap.
18-Oct	39		XX			XX	
19-Oct	43						No alert – ownship stopped before alert criteria was met.
20-Oct	57						No alert – ownship stopped before alert criteria was met.
20-Oct	65		XX			XX	
20-Oct	61				XX		GBS falsely alerted throughout entire run. Note, the DAS data only displays one alert, cannot determine if the proper alert was generated and not recorded.

Table 31. Scenario 4 GBS Alert Summary

Date	Matrix #	Alert Early	Alert On-Time	Alert Late	False Alert YES	False Alert NO	Notes
16-Oct	4						GBS did not alert on this run.
16-Oct	8		XX			XX	
17-Oct	12		XX			XX	
17-Oct	22		XX			XX	
18-Oct	26		XX			XX	
18-Oct	30		XX			XX	ADS-B data gap.
18-Oct	44		XX			XX	
18-Oct	40		XX			XX	
19-Oct	48		XX			XX	
20-Oct	58		XX			XX	
20-Oct	62				XX		GBS falsely alerted throughout entire run. The GBS alert type did switch when the proper alert should have been received, then switched back.
20-Oct	66		XX			XX	

Table 32. Scenario 1 GBS Alerts

Scenario 1					
Date	UTC	Matrix Run #	Ownship Dist to T.H. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
18-Oct	19085.2	23	-1246.5	88.8	20.3
18-Oct	20955.0	27	-1160.8	77.6	8.1
18-Oct	28691.1	45	-1195.7	90.4	20.9
18-Oct	31395.2	37	-1391.2	79.0	9.5
19-Oct	18542.3	41	-1190.0	77.6	8.1
20-Oct	29987.4	55	-1274.5	75.4	5.9
20-Oct	32735.7	59	-1546.9	77.6	8.1
		AVERAGE	-1286.5	80.9	11.6
		STDEV	137.8	6.0	6.3
		MINIMUM	-1160.8	75.4	5.9
		MAXIMUM	-1546.9	90.4	20.9

Note - Distances to threshold, runway, and hold line have positive values for locations across these points and negative values for distances further away.

Table 33. Scenario 2 GBS Alerts

Scenario 2						
Date	UTC	Matrix Run #	Ownship Speed (m/s)	Separation Dist. (m)	Traffic Dist. To H.L. (m)	Traffic Dist. To RWY (m)
17-Oct	22965.1	2	23.7	2766.6	91.8	22.3
17-Oct	30984.8	20	31.3	2697.3	94.0	24.5
17-Oct	35903.8	24	59.8	2616.3	94.0	24.5
18-Oct	22774.5	28	30.1	2700.0	80.0	5.4
18-Oct	27477.2	42	55.2	2233.8	90.0	15.4
18-Oct	32526.2	38	37.9	2682.7	109.3	30.8
20-Oct	24532.4	56	56.1	2598.1	97.8	20.3
20-Oct	33886.4	64	25.2	2815.5	111.4	32.9
		AVERAGE	39.9	2638.8	96.0	22.0
		STDEV	14.8	178.4	10.2	8.7
		MINIMUM	23.7	2233.8	80.0	5.4
		MAXIMUM	59.8	2815.5	111.4	32.9

Table 34. Scenario 3 GBS Alerts

Scenario 3						
Date	UTC	Matrix Run #	Ownship Dist. To H.L. (m)	Ownship Dist. To RWY (m)	Traffic Speed (m/s)	Separation Dist. (m)
16-Oct	33514.7	11	94.7	17.3	27.8	1727.7
17-Oct	27984.6	21	112.1	34.6	28.3	3019.8
17-Oct	31367.3	25	94.7	17.2	26.8	3065.4
18-Oct	30271.7	47	83.8	14.3	31.4	2305.4
18-Oct	33047.4	39	81.6	12.1	31.9	2634.1
20-Oct	19953.7	65	89.9	20.4	32.9	2321.3
		AVERAGE	92.8	19.3	29.8	2512.3
		STDEV	10.9	8.0	2.5	504.6
		MINIMUM	81.6	12.1	26.8	1727.7
		MAXIMUM	112.1	34.6	32.9	3065.4

Table 35. Scenario 4 GBS Alerts

Date	UTC	Matrix Run #	Ownship Dist. To T.H. (m)	Separation Dist. (m)	Traffic Dist. To RWY (m)	Traffic Speed (m/s)
17-Oct	21484.3	12	-1182.7	2950.5	20.1	17.5
17-Oct	29460.3	22	-1216.7	2989.2	21.5	17.5
18-Oct	18492.1	26	-1385.7	3264.1	12.2	16.5
18-Oct	21666.3	30	-1313.4	3211.0	45.1	21.6
18-Oct	29309.1	44	-1260.5	3136.3	26.8	16.0
18-Oct	30910.3	40	-1098.3	3044.8	22.9	20.1
19-Oct	21493.1	48	-1403.0	3272.5	19.3	14.4
20-Oct	18475.2	58	-1183.3	3084.5	20.7	18.0
20-Oct	30644.5	66	-1354.6	3244.4	21.5	17.5
		AVERAGE	-1266.5	3133.0	23.4	17.7
		STDEV	104.6	122.1	9.0	2.1
		MINIMUM	-1098.3	2950.5	12.2	14.4
		MAXIMUM	-1403.0	3272.5	45.1	21.6

4.4.4 Relative Comparison of Alert Performance

4.4.4.1 Combined Alert Plots

Figures G-1 through G-4 are plots of actual RIPS runs conducted at DFW. Each plot displays the performance of all three systems, indicating ownship and traffic location at the time of the first alert for each individual system. All four scenarios are represented here, displaying typical performance of each system for every scenario. It should be noted that the performance of each system, as portrayed in these plots, may be affected when one of the other systems is the display system for a given run. Ownship response (i.e. rejected take off, go-around, emergency stop, etc) will be dictated by the alerts of the display system selected in the cockpit at that time of that run.

Figure G-1 is a plot of scenario 1. As traffic first crosses the hold line, a RIAAS RTA is generated followed immediately by an RSM alert. Traffic continues to taxi onto the runway. Just after traffic crosses the runway edge, a GBS alert is generated, followed a few moments later by a RIAAS RCA as traffic is approximately on the centerline of the runway. Ownship initiates a go-around in response to the RIAAS RCA, as RIAAS was the display system for this run.

This plot gives a depiction of typical system performance for all three systems in scenario 1. Generally, the RIAAS RTA came a few seconds before the RSM alert. Usually eight to ten seconds later, the GBS alert was generated. Finally, approximately five seconds after the GBS alert, the RIAAS RCA was generated. This observed performance was consistent throughout testing at DFW.

Figure G-2 is a plot of scenario 2. Ownship pulls onto the runway and proceeds to begin its take off roll. Traffic rolls across the hold line, resulting in a RIAAS RTA, followed immediately by a RIAAS RCA and an RSM alert. Traffic continues to cross the runway. Just as traffic passes the centerline of the runway, a GBS alert is generated. Ownship initiates a rejected take off in response to the RIAAS RCA, as RIAAS was the display system for this run.

Figure G-2 shows typical performance in scenario 2 for the three systems throughout DFW testing. RIAAS generated an RTA, usually followed by an RCA one to two seconds later. The RSM alert would usually be generated at approximately the same time as the RIAAS RCA. Finally, GBS would generate an alert 10 to 15 seconds after the RIAAS RCA/RSM alerts.

Figure G-3 is a plot of scenario 3. This scenario is very similar to scenario 2, with ownship and traffic reversing roles. Traffic pulls onto the runway and proceeds to begin its take off roll. Ownship rolls across the hold line, resulting in a RIAAS RTA. Ownship continues taxiing toward the runway, and a RIAAS RCA is generated, followed closely by an RSM alert. Ownship crosses onto the runway and moments later, a GBS alert is generated, allowing plenty of time for evasive action. GBS was the display system for this run.

Figure G-3 displays typical performance of each system for scenario 3, as seen in DFW testing. A RIAAS RTA was generated, usually followed by a RIAAS RCA approximately 5 seconds later. The RSM alert was generated usually within a second of the RIAAS RCA. The RSM alert was followed 10 to 20 seconds later by the GBS alert.

Figure G-4 is a plot of scenario 4. This scenario represents an Arrival/Departure situation. As ownship is approaching for a landing, traffic rolls across the hold line toward the runway edge. A RIAAS RTA is generated soon after the hold line is violated, followed a few moments later by an RSM alert. Traffic pulls onto the runway and begins to accelerate into its take off roll. As traffic reaches the centerline a GBS alert is generated. Traffic continues to accelerate. As ownship gets closer to the runway threshold, the RIAAS RCA is generated. Ownship performs a go-around in response to the GBS alert, as GBS was the display system for this run.

Figure G-4 displays typical performance of each system for scenario 4, as seen in DFW testing. A RIAAS RTA was generated, followed a few seconds later by the RSM alert. GBS would then alert 8 to 10 seconds after the RIAAS RTA and RSM alerts, followed by the RIAAS RCA 10 to 15 seconds after that.

4.4.4.2 Combined Alert Performance Summary

The alerting performance of each system is broken down into two groups: ADS-B/STIS-B runs (both traffic data sources available) and STIS-B-only (ADS-B is turned off) runs. Total alert performance is also presented. In the STIS-B-only runs, GBS uses ASDE-3 and multilateration data only. Results for each system can be seen in Tables 36 through 38.

For ADS-B/STIS-B runs, RIAAS alerted properly in 31 of 32 runs. The only missed alert was in a scenario 1, where the RIPS vehicle was moving but ADS-B updates showed no position change throughout the course of the run. RSM alerted properly on 29 of the 32 runs. One of the missed-alerts occurred in the same run as that mentioned for RIAAS, and was a result of erroneous ADS-B data. RSM also missed alerts in a scenario 2 and a scenario 4. Again with both of these scenarios, RSM did not alert because ADS-B position data indicated that the RIPS vehicle was not moving when in fact it was.

For STIS-B only runs, RIAAS alerted properly in 13 of 15 runs. Missed alerts occurred in two of the four scenario 3 runs performed with RIAAS. In both missed-alert cases, no STIS-B data was transmitted. Because these were STIS-B only runs, no traffic data was available for alert processing. RSM alerted properly in 14 of 15 STIS-B-only runs. The only run in which RSM did not alert was one of the same scenario 3 runs in which RIAAS did not alert. Again, these were all a result of STIS-B-data not being available during STIS-B-only testing.

GBS alerted properly in 34 of 47 runs. There were four missed alerts for scenario 1, two missed alerts for scenario 2, six missed alerts for scenario 3 and one missed alert for scenario 4. However almost all of the missed alerts were due to the original scenario design, where conditions to satisfy the GBS alerting criteria were not met. The first four runs for scenario 1 were conducted prior to changing the alerting logic, thus no alerts were generated. Most of the missed alerts on scenario 3 were also due to the aircraft stopping prior to the alerting criteria being satisfied. Finally there were several runs where a false alert occurred, which may have prevented the system from recording the proper alert.

Overall, RIAAS alerted in 44 of 47 runs, RSM alerted in 43 of 47 runs, and GBS alerted in 34 of 47 total runs. All missed alerts for both RIAAS and RSM were a direct result of erroneous or missing traffic data. Most of the missed alerts for GBS were related to the original alerting criteria, subsequently changed, and due to the conduct of some specific scenarios where the GBS alerting criteria were not satisfied.

Table 36. RIAAS Alert Summary By Data Source

	ADS-B/STIS-B		STIS-B Only		All Runs	
Scenario	# Runs	# Alerts	# Runs	# Alerts	# Runs	# Alerts
1	8	7	4	4	12	11
2	8	8	3	3	11	11
3	8	8	4	2	12	10
4	8	8	4	4	12	12
Total	32	31	15	13	47	44

Table 37. RSM Alert Summary By Data Source

	ADS-B/STIS-B		STIS-B Only		All Runs	
Scenario	# Runs	# Alerts	# Runs	# Alerts	# Runs	# Alerts
1	8	7	4	4	12	11
2	8	7	3	3	11	10
3	8	8	4	3	12	11
4	8	7	4	4	12	11
Total	32	29	15	14	47	43

Table 38. GBS Alert Summary By Data Source

	ADS-B/STIS-B		STIS-B Only		All Runs	
Scenario	# Runs	# Alerts	# Runs	# Alerts	# Runs	# Alerts
1	8	5	4	3	12	8
2	8	7	3	2	11	9
3	8	5	4	1	12	6
4	8	7	4	4	12	11
Total	32	24	15	10	47	34

5.0 SUMMARY AND CONCLUSIONS

The primary conclusion of this report is that the three types of approaches to generating runway incursion alerts in the cockpit demonstrated feasibility during the DFW RIPS testing. This included two different aircraft-based alerting systems and a ground-based system. Out of the 47 test runs, RIAAS provided alerts on 44, RSM on 43, and GBS on 34. All of the missed alerts by RIAAS and RSM were a direct result of erroneous or missing traffic data. Most of the missed alerts for GBS were related to the original alerting criteria, subsequently changed, and due to the conduct of some specific scenarios where the GBS alerting criteria were not satisfied. In these instances the relative locations of the aircraft and test vehicle did not meet the GBS criteria for alert. RIAAS generated 2 false alerts during the testing, both the result of erroneous traffic data. RSM generated 4 false alerts, which were the result of the ownship-generated STIS-B traffic reports. GBS generated 9 false alerts during the testing, most of which were due to an apparent false ASDE-3 target located off the runway. The testing showed that the pilot could safely take evasive action (i.e., go-around, rejected take off, stop taxi) when the alerts normally occurred on all three systems for the four incursion scenarios tested. However, for the scenarios involving violation of hold lines, the GBS alerts occurred significantly later than did the aircraft-based systems. In those two scenarios (1 and 3) the GBS alerts did not occur until the vehicle/aircraft was on the runway. The two aircraft-based systems alerted well before the vehicle and aircraft reached the runway.

Regarding the integration of the supporting airborne and ground systems, the test results indicate that the basic system architecture demonstrated will support both aircraft-based and ground-based incursion alerting. One obvious conclusion is that alert logic performance is very dependent on the performance of the traffic and ownship position information. This information must be reliable, timely and accurate to ensure optimum runway incursion alerting performance. The NASA B757 airborne systems demonstrated excellent performance with respect to ownship information. However, there were a number of issues identified regarding the generation and processing of traffic information using STIS-B and ADS-B. Missing or erroneous STIS-B and ADS-B data resulted in a number of missed, late, and false alerts. The prototype nature of the systems involved probably played a significant role in the availability and integrity of the traffic data. One specific conclusion regarding traffic information is that STIS-B information had significantly longer latency than did ADS-B. This translates directly into delayed alerting on targets using position reports from STIS-B. ADS-B position reports were also significantly more accurate than STIS-B.

The testing showed that aircraft-based alerting has demonstrated several key advantages over having ground based alerts provided via data link, including:

- Shorter time delay between the time the alerts are generated and when they are annunciated to the flight crew.
- More timely alert generation. One reason for this is the capability to use ownship position data to accurately determine the ownship nose location. This provides a means to very accurately determine when ownship has violated a hold line on entering a runway.

A similar computation can be made for the tail location to determine when an aircraft has failed to clear the hold line on exiting a runway.

- Ground infrastructure is not required when aircraft are equipped with ADS-B.

Aircraft-based alerts provided to the flight crew will in some cases occur in advance of ground-based alerts provided to ATC. For example, in the case where ownship violates the hold line, an aircraft-based alert can occur sooner than the ground-based alerts due to the ability to accurately determine nose position. There is a safety benefit to alerting the flight crew as soon as the aircraft has crossed the hold line. This may present an issue regarding the difference in timing for the two alerting systems. The compatibility of aircraft-based alerts reported to the flight crew and ground-based alerts reported to ATC needs further investigation.

One of the systems, RIAAS, demonstrated a two-stage alerting concept, which includes a Traffic Alert and a higher priority Conflict Alert. The other two, RSM and GBS, provided a single conflict alert. The intent of the two stage alerting is to provide advanced warning to the pilot of a pending conflict. When the Traffic Alert occurs, the flight crew has the option of either continuing the procedure or taking evasive action. The test results indicated that evasive action could be taken following the Conflict Alert, maintaining safe separation. For three of the scenarios tested there was sufficient time (10-20 seconds) between the two RIAAS alerts for the pilot to determine the best course of action. For the rejected take off scenario (2) there was minimal time between the two alerts, and in some instances only the Conflict Alert was generated. Further simulation and testing is required to validate and optimize the two-stage alerting approach.

Analysis of the test results yielded several recommendations regarding the supporting infrastructure and the alerting systems, including:

- Further development of ground and avionics systems should include enhancement of availability and integrity of ADS-B and STIS-B traffic information. The ground system should provide integrity monitoring of surveillance data prior to STIS-B transmission. The probability of transmitting false target data needs to be extremely low. STIS-B should transmit a parameter equivalent to the ADS-B Navigation Uncertainty (NUC). This will indicate the accuracy of the surveillance information. The latency in the STIS-B transmissions should also be minimized to reduce alert delays.

- A reference point correction for the ADS-B target should be performed. It is recommended that the ADS-B MASPS (Minimum Aviation System Performance Standard) [5] be amended to include a requirement that the reported position is referenced to a standard location on the aircraft. If the position is provided to a known location then the alerting systems can apply the correction to other critical aircraft points of reference (i.e., nose, tail).

- The ground system should provide STIS-B position reports that are corrected to a reference point, such as the nose or centroid of the aircraft. The ground system has knowledge of the surveillance sensor(s) used to determine the fused position. Each sensor can use a different reference point. For instance, ASDE-3 position is referenced to the target centroid and multilateration position is referenced to the transponder antenna(s) location. The avionics does not have the knowledge of which sensor is used to compute the ground system derived traffic reports.

- Careful review regarding which GBS alerts are transmitted to the RIPS avionics needs to be performed. RIPS is designed to provide runway incursion alerting. Other types of GBS alerts may not be appropriate for presentation to the flight crews.

- Aircraft-based incursion alerting systems should incorporate some level of integrity checking on traffic information to minimize missed and false alerts.

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APPENDIX A – RIAAS ALERT PLOTS

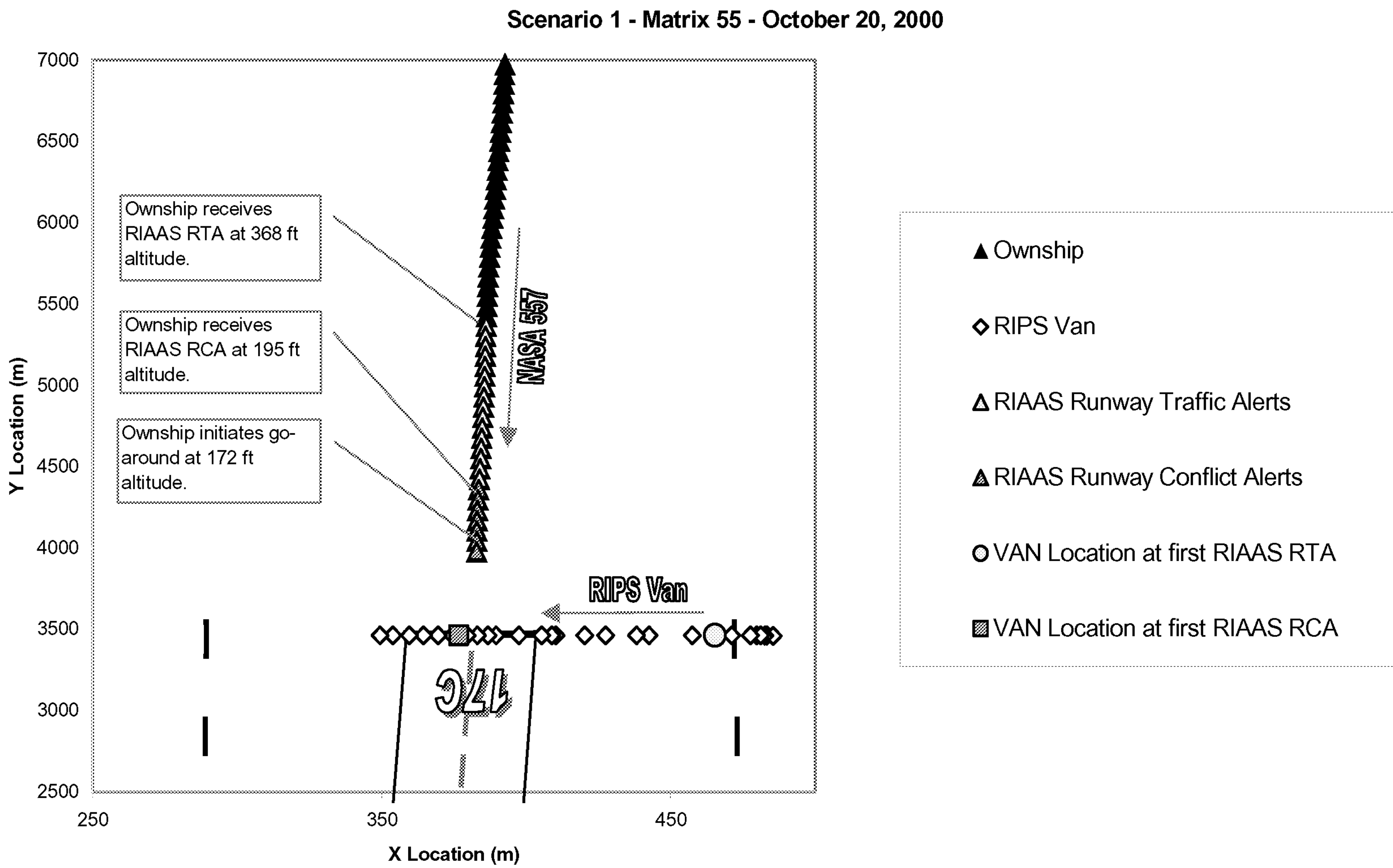
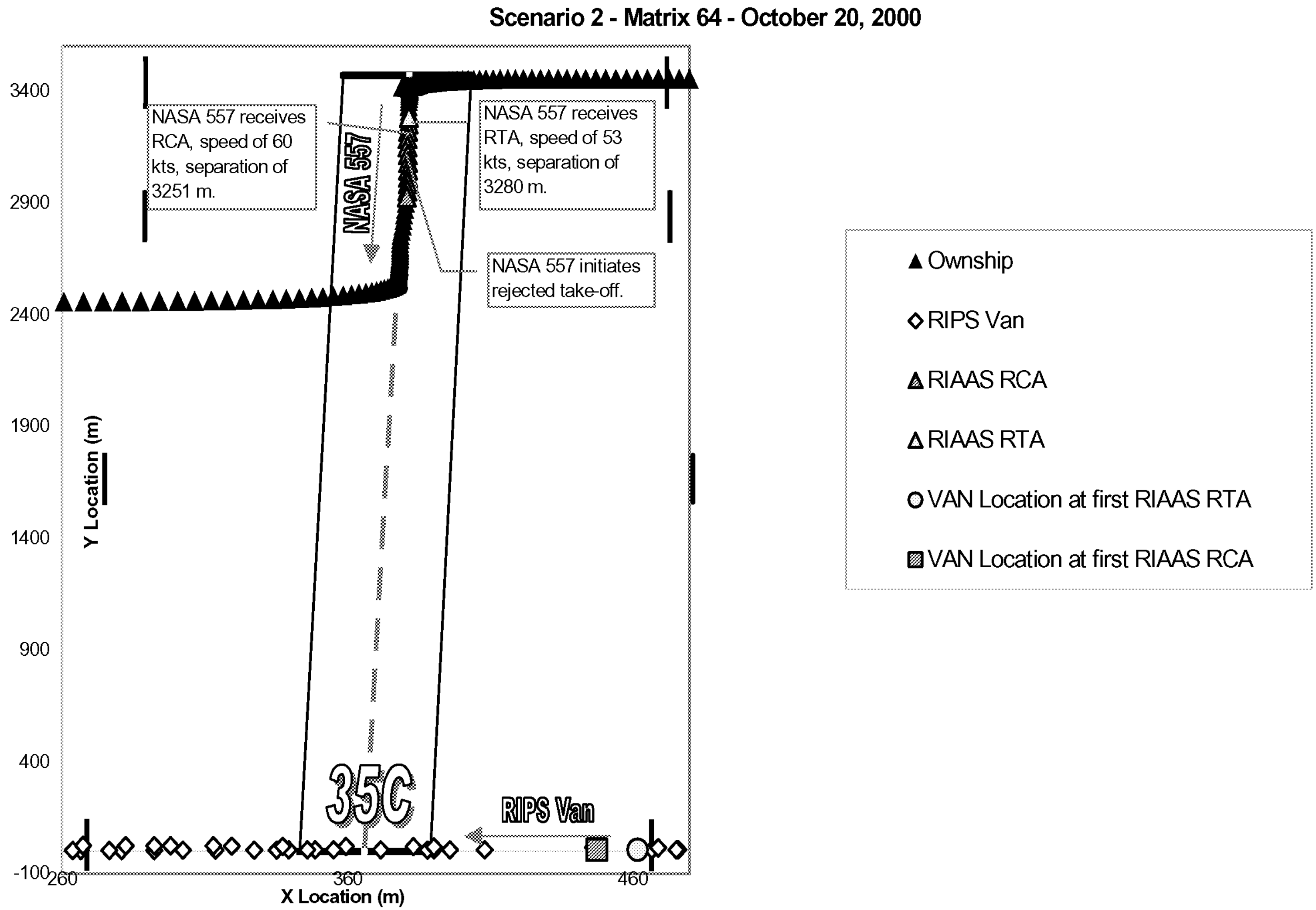

Scenario 1 - Matrix 55 - October 20, 2000
Y Location (m)
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
250
350
450
X Location (m)
Ownship receives RIAAS RTA at 368 ft altitude.
Ownship receives RIAAS RCA at 195 ft altitude.
Ownship initiates go-around at 172 ft altitude.
NASA 557
RIPS Van
17C
Ownship
RIPS Van
RIAAS Runway Traffic Alerts
RIAAS Runway Conflict Alerts
VAN Location at first RIAAS RTA
VAN Location at first RIAAS RCA

Figure A-1



Scenario 2 - Matrix 64 - October 20, 2000
3400
2900
2400
1900
1400
900
400
-100
260
360
460
X Location (m)
Y Location (m)
NASA 557 receives RCA, speed of 60 kts, separation of 3251 m.
NASA 557 receives RTA, speed of 53 kts, separation of 3280 m.
NASA 557 initiates rejected take-off.
NASA 557
35C
RIPS Van
Ownship
RIPS Van
RIAAS RCA
RIAAS RTA
VAN Location at first RIAAS RTA
VAN Location at first RIAAS RCA

Figure A-2

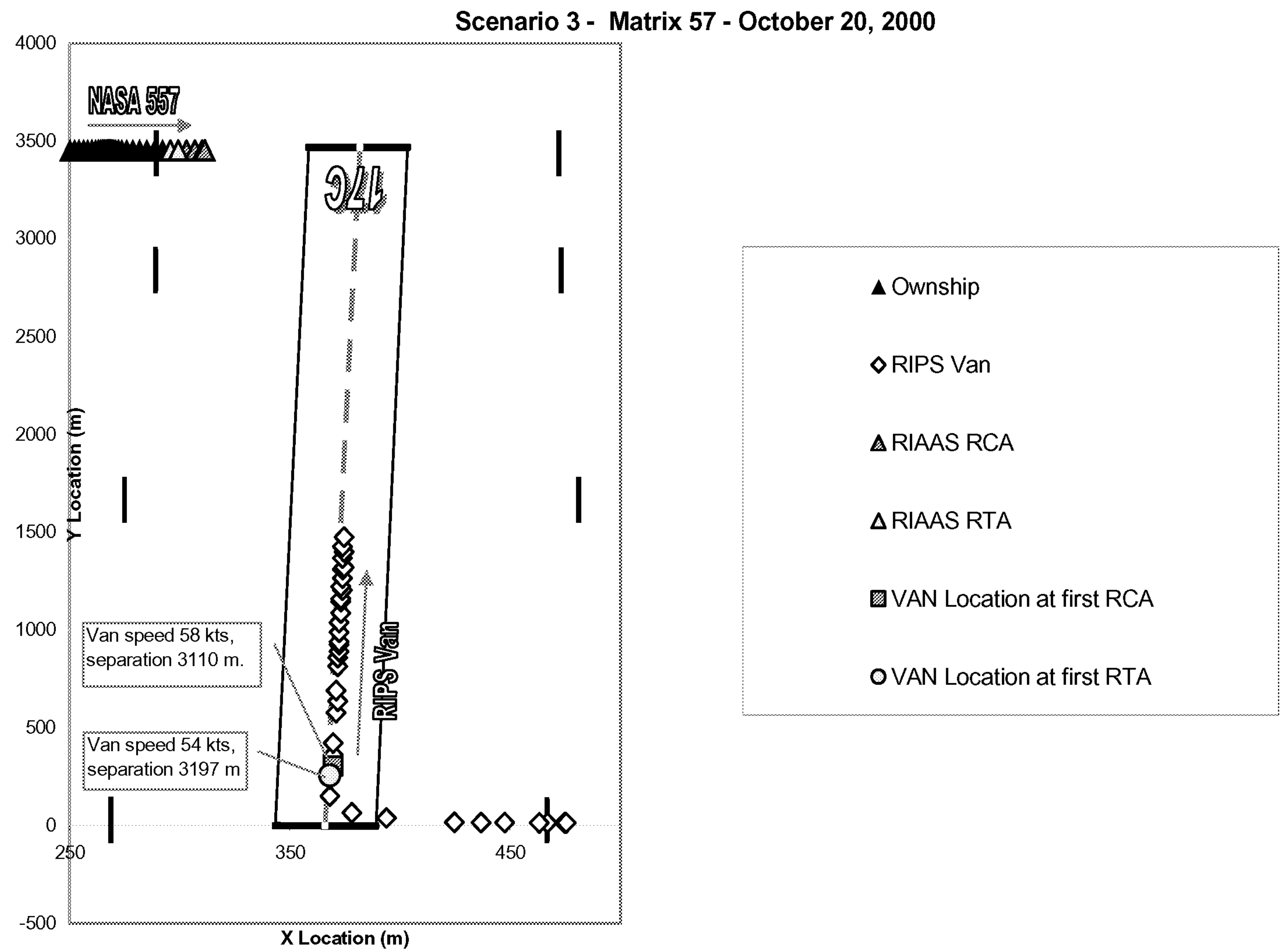
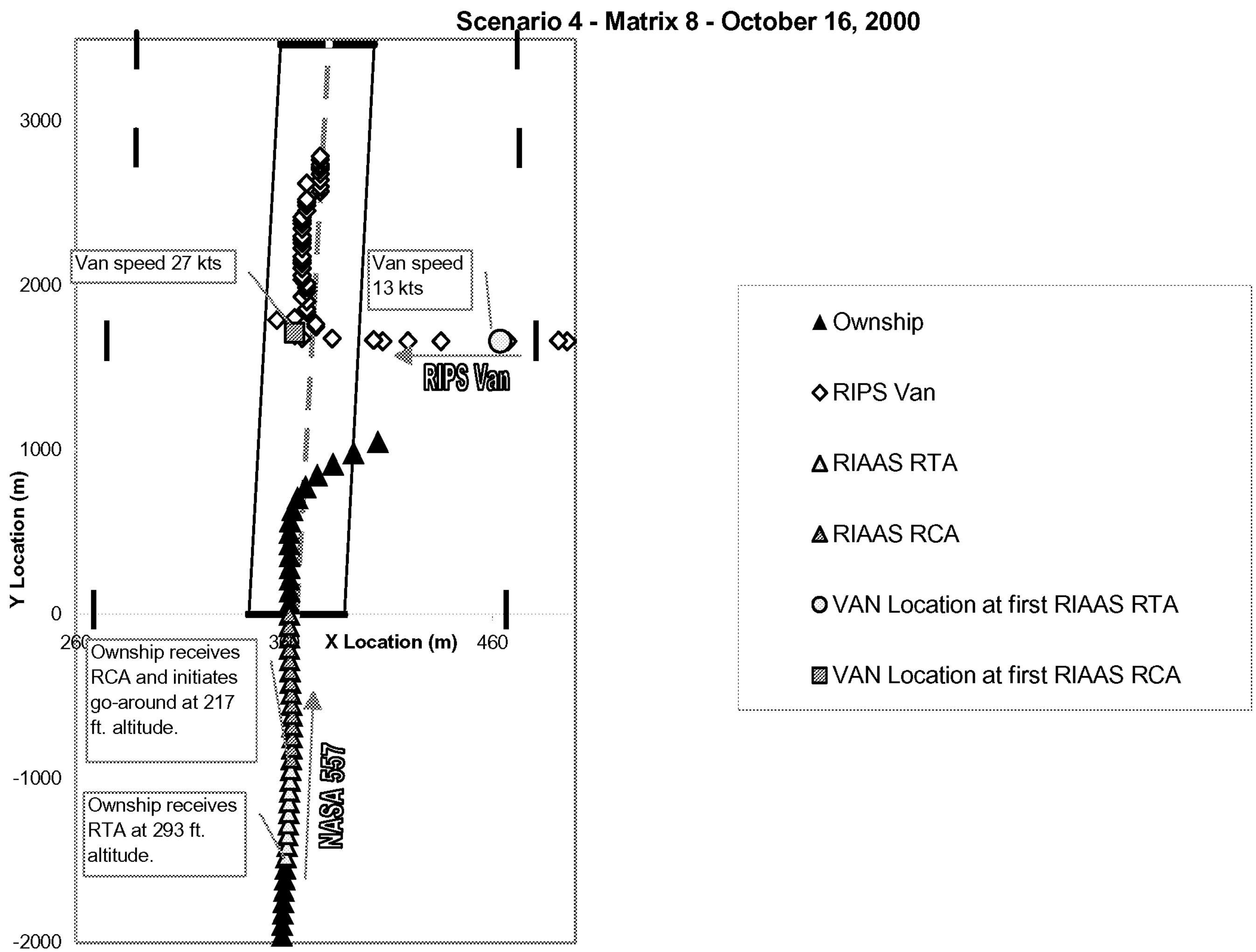

Scenario 3 - Matrix 57 - October 20, 2000
NASA 557
17C
RIPS Van
Van speed 58 kts, separation 3110 m.
Van speed 54 kts, separation 3197 m
Y Location (m)
X Location (m)
4000
3500
3000
2500
2000
1500
1000
500
0
-500
250
350
450
Ownship
RIPS Van
RIAAS RCA
RIAAS RTA
VAN Location at first RCA
VAN Location at first RTA

Figure A-3



Scenario 4 - Matrix 8 - October 16, 2000
3000
2000
1000
0
-1000
-2000
Y Location (m)
260
460
X Location (m)
Van speed 27 kts
Van speed 13 kts
RIPS Van
NASA 557
Ownship receives RCA and initiates go-around at 217 ft. altitude.
Ownship receives RTA at 293 ft. altitude.
Ownship
RIPS Van
RIAAS RTA
RIAAS RCA
VAN Location at first RIAAS RTA
VAN Location at first RIAAS RCA

Figure A-4

APPENDIX B – RIAAS ALERT SUMMARY

Table B-1 – RIAAS Alert Summary

Flight Information											Ownship					Traffic						Details						General Notes
							Data Type															Correct Alert?		Alert Timing				
Date	RIAAS UTC of First Alert (seconds)	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
16-Oct	20589.15	20590.09	1	R-170	7	1		X	RIAAS	RTA	-1183	NA	-22.6	0.2	68.5	5.8	7.7	-69.8	87	3.6	1191	X			X			Alerts OK. Improper timing of the van in crossing the runway resulted in ownship receiving the alert at a point much closer to the runway threshold than is expected and observed in later scenario 1 runs.
16-Oct	20592.07	20593.04	1	R-170	7	1		X	RIAAS	RCA	-982.7	NA	-22.9	0.1	67.7	4.7	22.7	-54.8	84	5.1	989	X			X			
16-Oct	21418.11	21419.44	4	R-170	8	4		X	RSM	RTA	-1856	NA	-21.4	0.1	69.2	1669.8	5.8	-79.3	81	5.1	3526	X			X			Alerts OK.
16-Oct	21441.11	21442.07	4	R-170	8	4		X	RSM	RCA	-254.9	NA	-22.3	0	71.4	2088.5		21.7	0	31.4	2343	X			X			
16-Oct	23012.77	23013.77	3	R-170	10	3		X	RIAAS	RTA	3453.4	1.5	-76	278.4	1.7	1233.5	NA	21.8	179	31.7	2221	X			X			Alerts OK.
16-Oct	23017.09	23018.69	3	R-170	10	3		X	RIAAS	RCA	3453.9	11.8	-65.7	276.1	2	1352.8	NA	22	180	29	2102	X			X			
16-Oct	24189.65	24191.03	4	R-170	12	8	X		RIAAS	RTA	-1544	NA	-22.5	0.3	69.1	1665	14.4	-70.8	277	6.7	3210	X				X	2.15	Alerts OK. First traffic update came after van was 14.4 meters over hold line.
16-Oct	24198.61	24199.89	4	R-170	12	8	X		RIAAS	RCA	-934.1	NA	-22.5	0.2	68	1716.1	NA	13.8	313	13.9	2650	X			X			
16-Oct	24953.03	24954.55	1	R-170	13	9		X	RSM	RTA	-1825	NA	-22.2	0.2	68	5.7	10.6	-66.9	84	5.7	1831	X			X			Alerts OK. False Alert - Bad ADS-B position (position was approximately 60m off). RCA cleared and was re-generated.
16-Oct	24966.07	24967.34	1	R-170	13	9		X	RSM	RCA	-949.1	NA	-22.1	0.2	67.8	2.9	65.2	-9.3	90	8.7	952	X						
16-Oct	33479.23	33480.24	3	R-170	25	11		X	GBS	RTA	3455.4	1.2	-76.3	276.8	2.5	743.2	NA	19.3	182	26.8	2713	X			X			Alerts OK. Data gaps of 3, 3.5 and 8 seconds caused cleared/toggled alerts. Traffic state erroneosly toggled between taxi and highspeed. A False Alert was received. As traffic turned around and headed away from ownship, its heading did not change. Traffic transitioned to highspeed (while traveling away from ownship) and an alert was received.
16-Oct	33490.33	33491.06	3	R-170	25	11		X	GBS	RCA	3455.1	33.5	-44	274.9	3.4	1052.4	NA	16.3	178	27.8	2403	X			X			
16-Oct	33846.93	33848.17	2	R-170	28	10		X	RIAAS	RCA	111.8	NA	20.4	359.7	15.9	3354	37.5	-32	88	4.3	3242	X			X			Alert OK. Timing of the scenario resulted in an RCA only. Alert timed out as there was a data gap, once data came back, Ownship was changing states.
17-lOct	1596.633	19569.06	3	R-171	5	7	X		RSM	RCA	3456.2	26.8	-47.8	94.7	2.9	269.3	NA	22	176	22.6	3188	X			X			Alert OK. Timing of the scenario resulted in an RCA only. Ownship speed is incorrect, as it shows ownship traveling at 0.5 m/s, while in fact it is closer to 5.0 m/s (based on position data).

Table B-1 – RIAAS Alert Summary Continued

Flight Information											Ownship					Traffic						Details						General Notes
							Data Type															Correct Alert?		Alert Timing				
Date	RIAAS UTC of First Alert (seconds)	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
17-Oct	2655.693	20628.25	1	R-171	7	5	X		GBS	RTA	-1499	NA	-21.2	0.2	65.6	22.3	35.6	-41.9	300	12.9	1522	X				X	3.50	Late Alerts (approximately 3-4 sec). Algorithm Alerted properly once valid data was received.
17-Oct	2663.613	20636.13	1	R-171	7	5	X		GBS	RCA	-975.9	NA	-22.6	0.1	65.8	37.8	NA	19.4	241	7.7	938	X			X			
17-Oct	3502.093	21474.46	4	R-171	8	12		X	GBS	RTA	-1879	NA	-20.8	0.2	64.6	1671	5.8	-79.3	87	5.7	3550	X			X			Alerts OK.
17-Oct	3522.073	21494.15	4	R-171	8	12		X	GBS	RCA	-578.4	NA	-22.1	0.3	66.7	1983.2	NA	19.8	0	26.2	2561	X			X			
17-Oct	4979.553	--	2	R-171	10	2		X	RSM	RTA	227.8	NA	22.5	359.7	28.8	3465	8.3	-61.1	87	5.1	3237	X			X			Alerts OK. Traffic position data jumped 30 meters backwards at one point. A data gap caused an alert to clear early. RIAAS got this alert, but based on update times, it was not read into shared memory before the alert state changed to an RCA, so it was not displayed during the flight and is not found in the DAS data.
17-Oct	4980.153	22952.3	2	R-171	10	2		X	RSM	RCA	245.6	NA	22.5	359.7	30.6	3465.3	16.2	-53.2	87	6.7	3220	X			X			
17-Oct	6333.693	24305.21	2	R-171	12	6	X		GBS	RCA	411.4	NA	20.7	0.4	42	3466	30.5	-39	262	8.7	3054	X				X		Alerts OK
17-Oct	6353.693	24325.88	2	R-171	12	6	X		GBS	RTA	1471	NA	22.5	360	43.3	3466.6	6	-62.5	276	7.7	1998	X			X			
17-Oct	10004.05	27975.74	3	R-171	14	21		X	RIAAS	RCA	3455.6	NA	9	269.7	3.7	284.2	NA	21.2	180	25.7	3171	X			X			Alert OK. Timing of the scenario resulted in an RCA only, and caused the alert to come late (relative to position) as the van was on the runway when the first alert was received. Traffic state erroneously toggled, causing cleared alerts and alert toggling.
17-Oct	11477.11	29449.51	4	R-171	16	22		X	RSM	RTA	-1982	NA	-22.2	0.3	63.8	1669.7	12.9	-72.2	90	6.7	3652	X			X			Alert OK. Go-around was initiated early. Only an RTA was received as a result.
17-Oct	12999.11	30971.07	2	R-171	18	20		X	RSM	RTA	236.5	NA	19.6	359	32.6	3464	14.1	-55.4	90	6.2	3227	X			X			Alerts OK.
17-Oct	13001.05	30973.04	2	R-171	18	20		X	RSM	RCA	305.2	NA	19.4	358.9	38.9	3463.8	31.2	-38.3	87	8.7	3158	X			X			
17-Oct	13388.55	31360.42	3	R-171	19	25	X		RSM	RCA	3450.1	NA	20.1	282.5	3	186.4	NA	22.4	173	25.7	3263	X			X			Alert OK. Timing of the scenario resulted in an RCA only, and caused the alert to come late (relative to position) as the van was on the runway when the first alert was received. Traffic state erroneously toggled throughout entire run, causing toggling alerts.

Table B-1 – RIAAS Alert Summary Continued

Flight Information											Ownship					Traffic						Details						General Notes
							Data Type															Correct Alert?		Alert Timing				
Date	RIAAS UTC of First Alert (seconds)	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS	System Displayed	Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
17-Oct	14255.13	32227.16	1	R-171	20	19		X	RIAAS	RTA	-1905	NA	-22.2	0.2	63.7	9.1	9.9	-67.6	87	5.7	1915	X			X			Alerts OK. False Alert - Traffic had moved across the hold line on the far side of the runway, and without changing heading, appears to have "jumped" back over the hold line by almost 50 meters.
17-Oct	14270.17	32241.92	1	R-171	20	19		X	RIAAS	RCA	-952	NA	-22.8	0.1	63.1	6.6	62.4	-12.2	90	7.2	959	X			X			
17-Oct	16282.67	34254.3	3	R-171	23	29		X	GBS	RCA	3457.1	30.6	-44	90.2	5.3	262.5	NA	15.6	175	26.8	3195	X				X	1	Alert OK. Timing of the scenario resulted in an RCA only. Two data gaps, one of which was 5 seconds, caused cleared alerts. Traffic state erroneously toggled throughout run, causing alert toggling.
17-Oct	17923.69	35895.96	2	R-171	27	24	X		GBS	RCA	360.4	NA	21.9	0.2	44.5	3458.9	24	-45.4	266	9.8	3098	X			X			Alerts OK. Traffic state erroniously toggles to taxi for one update, causing alert toggling.
18-Oct	1723.264	18488.62	4	R-172A	1	26	X		RIAAS	RTA	-1688	NA	-17.9	181	65.3	1813.9	72.2	-13	268	19.5	3499	X						Alerts OK. Traffic heading jumped to 162 degrees (not within the +/- 10 degree tolerance for High Speed State) and briefly transitioned to taxi state, causing the RTA to toggle.
18-Oct	1740.964	18505.7	4	R-172A	1	26	X		RIAAS	RCA	-500.8	NA	-19.3	181	68.4	2221.9	NA	6.3	174	34.3	2720	X						
18-Oct	2313.304	19077.71	1	R-172A	2	23	X		GBS	RTA	-1733	NA	-19.1	180.4	64.9	10	24	-45.4	278	9.8	1751	X						Toggled back to RTA once after initial RCA was received.
18-Oct	2324.864	19089.77	1	R-172A	2	23	X		GBS	RCA	-965.4	NA	-19.1	180.5	67.2	9.2	NA	9.3	342	0.5	994	X						
18-Oct			1	R-172A	4	27		X	RSM	None																		Traffic data indicates no van movement.
18-Oct	4911.224	21675.64	4	R-172A	5	30		X	GBS	RTA	-709	NA	-18.2	180.3	66.4	2137.6	NA	17.8	178	28.8	2848	X						Alerts OK. RIAAS alerted on the only 3 TIS updates received during this run.
18-Oct	4914.244	21677.83	4	R-172A	5	30		X	GBS	RCA	-576.7	NA	-17.8	180.3	66.8	2224.5	NA	14.4	177	28.8	2733	X						
18-Oct	5995.784	22760.77	2	R-172A	7	28		X	RIAAS	RCA	287.9	NA	21.1	181	33.1	3464.3	21.3	-56.2	87	7.2	3211	X						Alert OK. Timing of scenario resulted in an RCA only.
18-Oct	10696.3	27461.46	2	R-172B	8	42	X		GBS	RTA	340.2	NA	21.7	180	37.4	3465.6	13.4	-64.1	283	5.7	3133	X						Alerts OK.
18-Oct	10697.2	27462.44	2	R-172B	8	42	X		GBS	RCA	379.6	NA	21.7	180.2	40.6	3465.6	19.9	-57.7	283	5.7	3097	X						

Table B-1 – RIAAS Alert Summary Continued

Flight Information											Ownship					Traffic						Details						General Notes
							Data Type															Correct Alert?		Alert Timing				
Date	RIAAS UTC of First Alert (seconds)	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
18-Oct	11914.8	28680.26	1	R-172B	9	45		X	RSM	RTA	-1964	NA	-18.5	181	64.3	3.7	14.1	-55.4	92	5.7	2004	X						Alerts OK.
18-Oct	11929.7	28695.02	1	R-172B	9	45		X	RSM	RCA	-969.3	NA	-19.1	180	69.4	2.8	NA	3.8	87	5.1	996	X						RIAAS got this alert, but based on update times, it was not read into shared memory before the alerts cleared, so it was not displayed during the flight and is not found in the DAS data.
18-Oct	12536.26	29301.27	4	R-172B	10	44	X		RIAAS	RTA	-1826	NA	-19.1	180.6	65.1	1806.8	17.9	-67.2	276	7.7	3640	X						Alert OK. Go-around was initiated early resulting in an RTA only.
18-Oct	13487.3	30252.03	3	R-172B	12	47		X	GBS	RCA	3451.1	25	-44.5	262.3	3.5	519	NA	22.6	0	29.3	2933	X						Alert OK. Timing of scenario resulted in an RCA only. Alerts toggled on and off due to data gaps of up to 10 seconds, and due to erroneous traffic state changes.
18-Oct	14132.74	30897.48	4	R-172B	13	40		X	RSM	RTA	-1926	NA	-17	180.2	64.9	1802.1	8.7	-76.4	87	5.7	3783	X						Alert OK. Go-around was initiated early resulting in an RTA only.
18-Oct	14622.72	31388.27	1	R-172B	14	37		X	RIAAS	RTA	-1884	NA	-18	179.9	64.7	9.2	14.8	-54.7	87	7.2	1936	X						Alerts OK.
18-Oct	14636.78	31402.05	1	R-172B	14	37		X	RIAAS	RCA	-968.7	NA	-16.6	180	69.1	8.8	NA	3.9	90	5.1	1005	X						RIAAS got this alert, but based on update times, it was not read into shared memory before the alerts cleared, so it was not displayed during the flight and is not found in the DAS data.
18-Oct	15746.68	32511.49	2	R-172B	16	38		X	RSM	RTA	233.9	NA	21.6	178.9	25.9	3462.2	9.9	-67.6	87	6.2	3254	X						Alerts OK.
18-Oct	15749.78	32514.44	2	R-172B	16	38		X	RSM	RCA	324.9	NA	22.3	179.4	34.2	3462.7	39.9	-37.7	87	10.8	3163	X						
18-Oct	16279.7	33044.49	3	R-172B	17	39		X	RIAAS	RCA	3438.5	NA	13.5	218.9	2.7	797.3	NA	22.1	0	31.9	2640	X						Alerts OK. Timing of the scenario resulted in an RCA only, and caused the alert to come late (relative to position) as the van was on the runway when the first alert was received.
19-Oct	1694.434	18534.4	1	R-173	18	41	X		GBS	RTA	-1745	NA	-18	180.4	66.6	7.9	38.3	-31.1	277	11.8	1744	X						Alerts OK.
19-Oct	1706.514	18546.21	1	R-173	18	41	X		GBS	RCA	-976.6	NA	-18.8	180.5	65.7	10	NA	9.6	225	0	964	X						
19-Oct	4644.974	21485.25	4	R-173	20	48		X	GBS	RTA	-1932	NA	-20.2	179	60.7	1802.1	12.9	-72.2	87	6.7	3750	X						Alerts OK.
19-Oct	4666.954	21506.9	4	R-173	20	48		X	GBS	RCA	-558.5	NA	-20.1	179	64.3	2199.4	NA	21.1	180	29.8	2751	X						
19-Oct			3	R-173	22	43	X		RSM	None																		No TIS data received.
19-Oct	8093.934	24933.63	2	R-173	24	46		X	RIAAS	RCA	269.5	NA	18.9	179.8	29.2	3462.2	22	-55.5	87	8.2	3183	X						Alert OK. Timing of scenario resulted in an RCA only.

Table B-1 – RIAAS Alert Summary Continued

Flight Information											Ownship					Traffic						Details						General Notes
Date	RIAAS UTC of First Alert (seconds)	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	Data Type: STIS-B	Data Type: ADS-B/STIS-B	System Displayed	Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	Correct Alert? YES	Correct Alert? NO	Alert Timing: Early	Alert Timing: On-Time	Alert Timing: Late	Alert Timing: Time Deviation (s)	
20-Oct	1152.742	17479.9	3	R-174	1	57		X	RIAAS	RTA	3452	0.9	-67.5	97.4	2.6	257.1	NA	22.6	357	27.3	3197	X			X			Alerts OK.
20-Oct	1155.282	17481.87	3	R-174	1	57		X	RIAAS	RCA	3452.1	10.5	-57.9	97.5	2.8	343.9	NA	21.2	3	34	3110	X			X			
20-Oct	2137.302	18464.35	4	R-174	2	58		X	RSM	RTA	-1954	NA	-20.5	180	66	1800.4	10.8	-74.3	272	6.2	3755	X			X			Alerts OK.
20-Oct	2158.482	--	4	R-174	2	58		X	RSM	RCA	-513.3	NA	-16.5	180.6	69.4	2142.9	NA	21.8	179	27.5	2656	X			X			Looks as though DAS data ends 6 seconds earlier than it should have, as RIAAS output files showed that data was still being received for 6 sec after the DAS data stops
20-Oct	3606.442	19934.05	3	R-174	4	65		X	GBS	RCA	3457.9	36.9	-32.5	274.1	1.5	478.4	NA	22.8	0	31.6	2979	X			X			Alert OK. Timing of scenario resulted in an RCA only. Two data gaps, 5.7 and 6 seconds, caused cleared alerts. Traffic state erroneously toggled on a few updates.
20-Oct	4632.742	20959.81	1	R-174	5	63		X	RSM	RTA	-1953	NA	-18.5	180.2	64.4	4.9	21.9	-47.5	270	9.3	1959	X			X			Alerts OK.
20-Oct	4647.862	20974.58	1	R-174	5	63		X	RSM	RCA	-951.3	NA	-17.9	180.4	65.2	4.9	NA	3.8	270	4.6	956	X			X			
20-Oct	5506.342	21833.35	4	R-174	6	62	X		RIAAS	RTA	-1697	NA	-18.3	180.2	65.3	1806.8	42.2	-42.9	282	8.7	3504	X				X	2	Late Alerts (approximately 2 sec). Alert actually should have come on sooner, but traffic displayed a speed of zero and was considered stopped (even though its position was changing slightly, perhaps 2/2.5 m/s).
20-Oct	5523.282	21850.08	4	R-174	6	62	X		RIAAS	RCA	-574.5	NA	-18.2	179.7	67.5	2132.9	NA	17.8	176	26.8	2707	X			X			
20-Oct			3	R-174	8	61	X		RSM	None																		No TIS data received
20-Oct	8209.282	24536.34	2	R-174	11	56		X	RSM	RCA	1040.5	NA	18.7	181	46	3463.1	NA	9.2	342	0.5	2422	X				X		Late Alert. Due to timing of data transmission, only an RCA was received. Traffic ADS-B position erroneously did not change for 30 seconds (reported same position). RIAAS switched to TIS and properly alerted.
20-Oct	13650.8	29977.53	1	R-174	9	55		X	RIAAS	RTA	-1916	NA	-18.3	180.1	62.1	7.5	8.3	-61.1	258	4.6	1925	X			X			Alerts OK.
20-Oct	13665.74	29993.28	1	R-174	9	55		X	RIAAS	RCA	-968.2	NA	-20.2	180.2	64.4	6.6	NA	20.3	0	3.6	974	X			X			
20-Oct	14308.76	30635.6	4	R-174	13	66		X	GBS	RTA	-1935	NA	-19.5	180.1	61.7	1798.3	18.7	-66.4	272	7.2	3733	X			X			Alerts OK.
20-Oct	14334.76	30662.17	4	R-174	13	66		X	GBS	RCA	-272.6	NA	-22.3	179.9	66.3	2341.5	NA	21.3	180	30.4	2614	X			X			
20-Oct	16402.34	32729.77	1	R-174	16	59	X		GBS	RTA	-1968	NA	-17	180.2	59.9	12.5	18.3	-51.1	269	8.7	1981	X			X			Alerts OK.
20-Oct	16418.96	32746.5	1	R-174	16	59	X		GBS	RCA	-941	NA	-18	180.1	62.8	9.1	NA	5.7	342	0.5	950	X			X			
20-Oct	17544.74	33871.66	2	R-174	12	64		X	RIAAS	RTA	183	NA	21.7	179.7	24.7	3462.7	5.6	-71.9	267	5.7	3280	X			X			Alerts OK.
20-Oct	17545.78	33872.65	2	R-174	12	64		X	RIAAS	RCA	212.8	NA	21.7	179.9	28.6	3463.5	19.9	-57.7	267	7.2	3251	X			X			

Table B-1 – RIAAS Alert Summary Continued

Key T.H. = Threshold H.L. = Holdline RWY = Runway

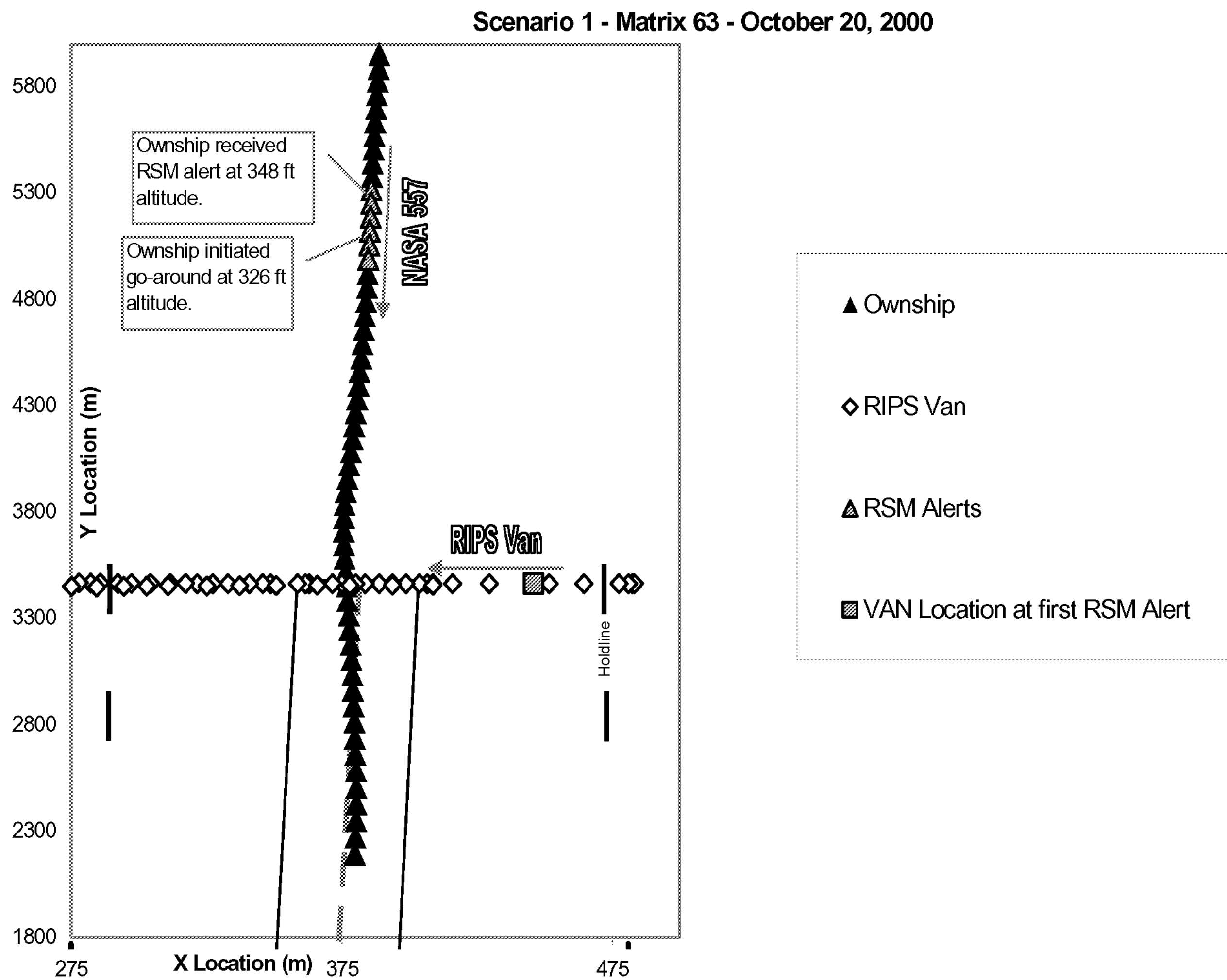
Dist. To T.H. --> neg. value indicates that aircraft has not reached runway threshold yet, pos. value indicates that aircraft has crossed the threshold.

Dist. To H.L. --> neg. value indicates that vehicle has not crossed holdline yet, pos. value indicates that vehicle has crossed the holdline in the direction of the runway.

Dist. To RWY --> neg. value indicates that vehicle has not crossed runway edge (in direction of runway centerline), pos. value indicates that vehicle has crossed the runway edge and is currently on or over the runway.

Note: Ownship position has been corrected to the nose for all scenario 3's

APPENDIX C – RSM ALERT PLOTS



Scenario 1 - Matrix 63 - October 20, 2000
Y Location (m)
X Location (m)
5800
5300
4800
4300
3800
3300
2800
2300
1800
275
375
475
Ownship received RSM alert at 348 ft altitude.
Ownship initiated go-around at 326 ft altitude.
NASA 557
RIPS Van
Holdline
Ownship
RIPS Van
RSM Alerts
VAN Location at first RSM Alert

Figure C-1

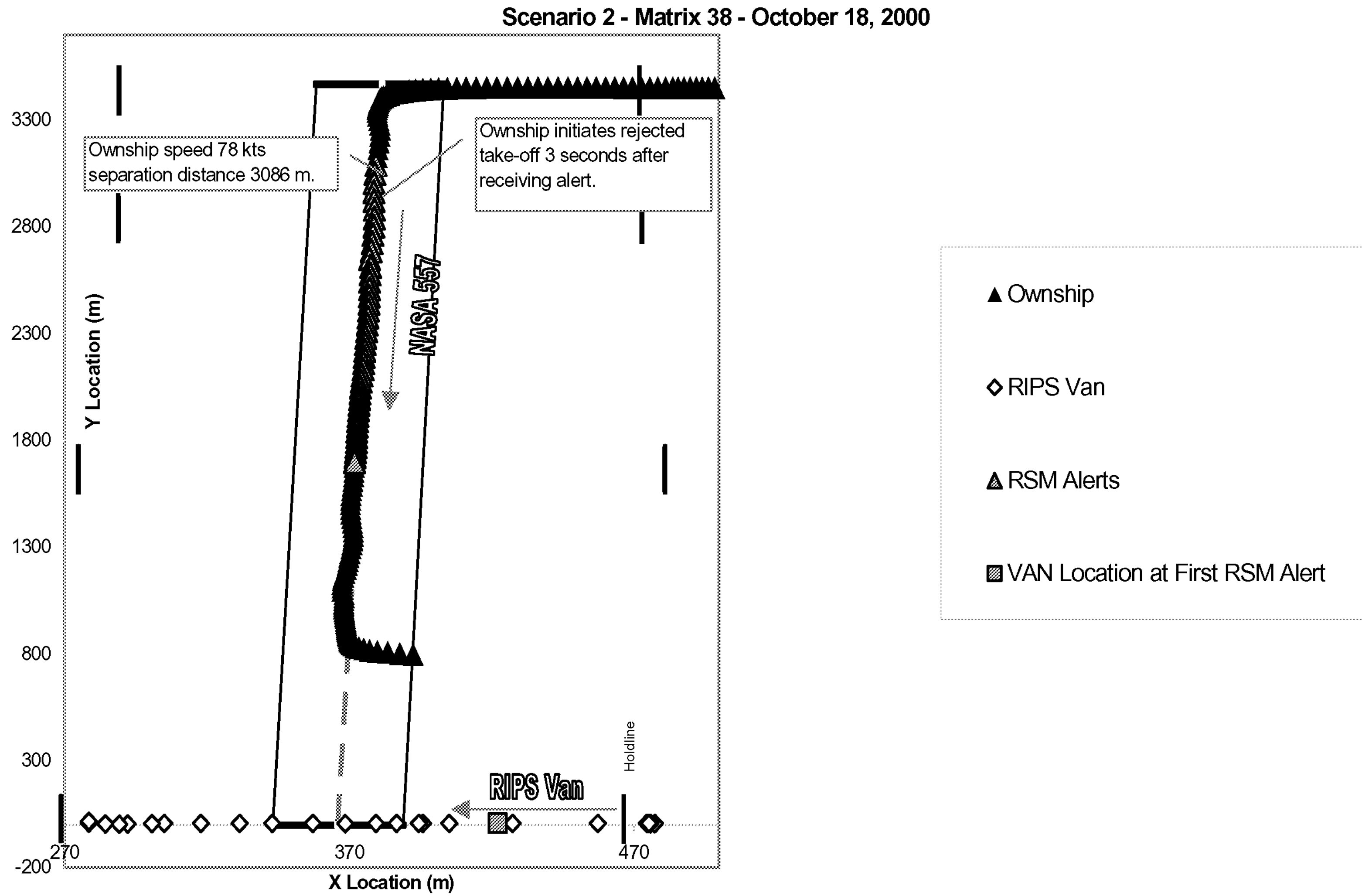

Scenario 2 - Matrix 38 - October 18, 2000
Ownship speed 78 kts
separation distance 3086 m.
Ownship initiates rejected
take-off 3 seconds after
receiving alert.
NASA 557
RIPS Van
Holdline
Y Location (m)
X Location (m)
3300
2800
2300
1800
1300
800
300
-200
270
370
470
Ownship
RIPS Van
RSM Alerts
VAN Location at First RSM Alert

Figure C-2

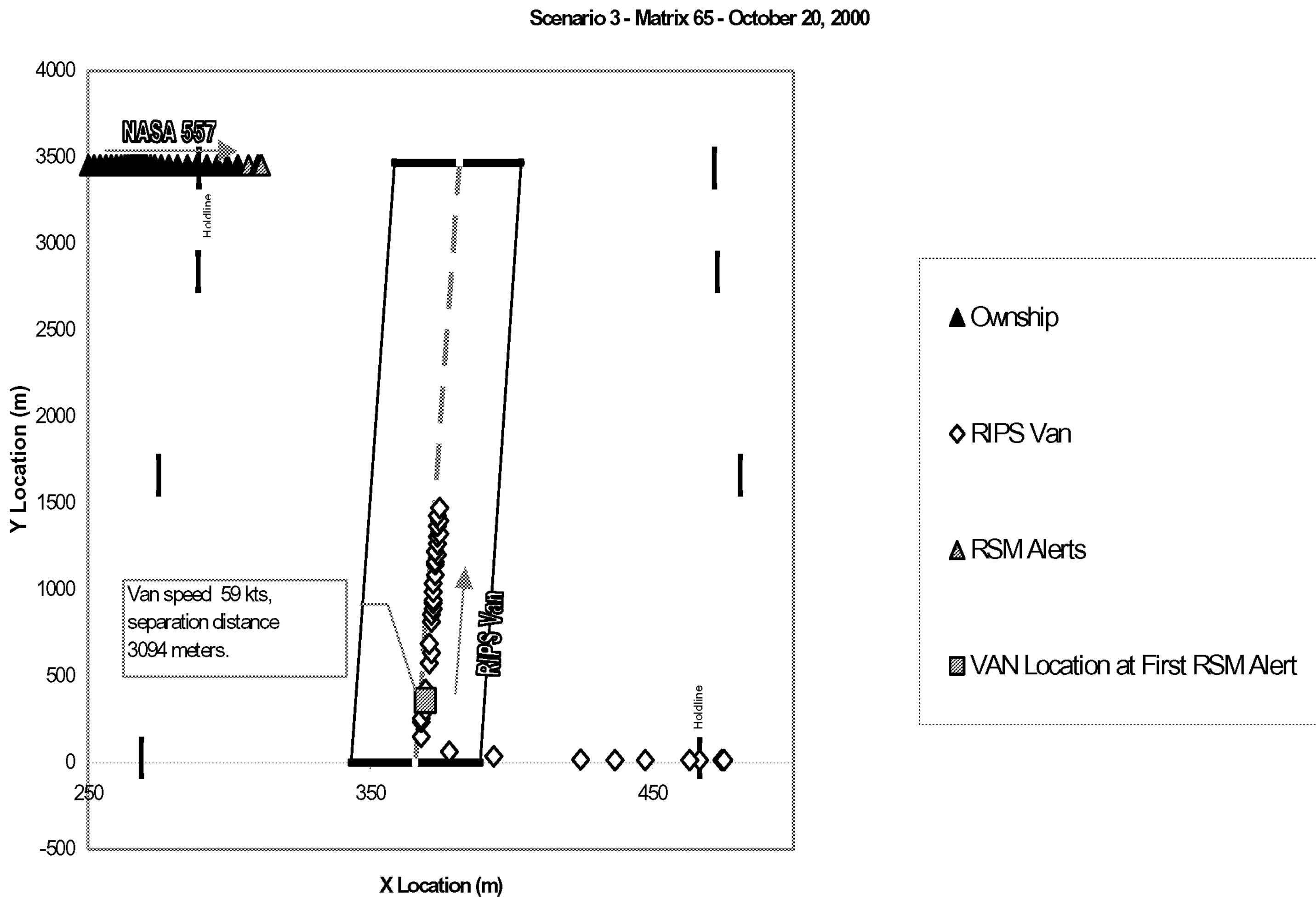

Scenario 3 - Matrix 65 - October 20, 2000
Y Location (m)
X Location (m)
4000
3500
3000
2500
2000
1500
1000
500
0
-500
250
350
450
NASA 557
Holdline
Holdline
RIPS Van
Van speed 59 kts, separation distance 3094 meters.
Ownship
RIPS Van
RSM Alerts
VAN Location at First RSM Alert

Figure C-3

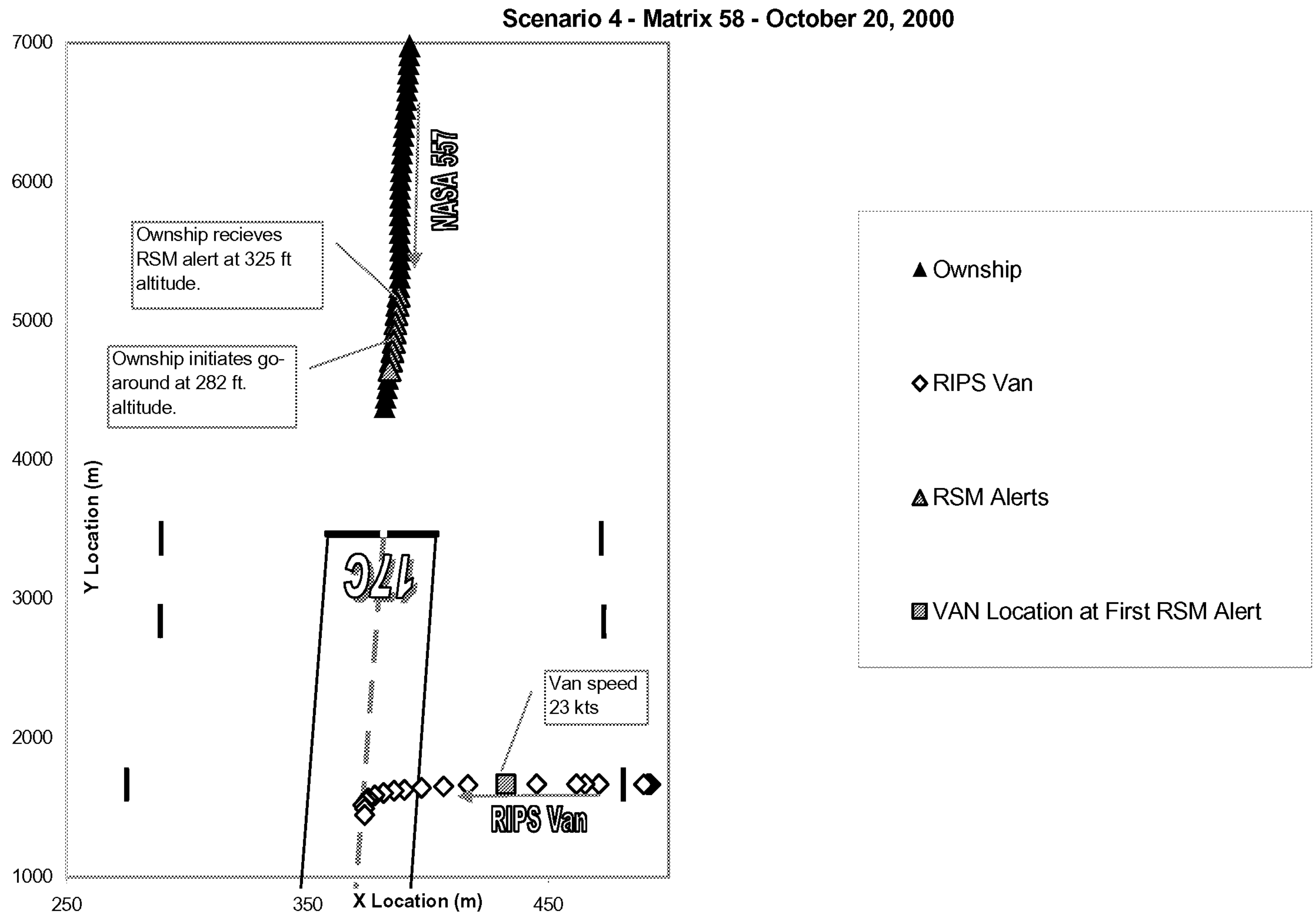

Scenario 4 - Matrix 58 - October 20, 2000
7000
6000
5000
4000
3000
2000
1000
Y Location (m)
250
350
450
X Location (m)
Ownship recieves RSM alert at 325 ft altitude.
Ownship initiates go-around at 282 ft. altitude.
NASA 557
17C
Van speed 23 kts
RIPS Van
Ownship
RIPS Van
RSM Alerts
VAN Location at First RSM Alert

Figure C-4

APPENDIX D – RSM ALERT SUMMARY

Table D-1 – RSM Alert Summary

Flight Information									Ownship					Traffic						Details						General Notes
						Data Type														Correct Alert?		Alert Timing				
Date	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
16-Oct	20592.056	1	R-170	7	1		X	RIAAS	-1010.36	NA	NA	-0.38	67.84	4.61	16.3	-61.2	84	4.63	1018.76	X			X			Traffic heading appears to be 180 degrees off.
16-Oct	21422.389	4	R-170	8	4		X	RSM	-1585.6	NA	NA	0.29	68.42	1674.76	55.09	-29.98	98	13.4	3260.99	X			X			Traffic heading appears to be 180 degrees off. Alert toggled off once.
16-Oct	23018.686	3	R-170	10	3		X	RIAAS	14.48	14.32	-63.18	282	1.29	2084.31	NA	NA	180	29.8	2072.18	X			X			Alert toggled off twice.
16-Oct	24193.002	4	R-170	12	8	X		RIAAS	-1342.17	NA	NA	-0.09	68.62	1663.78	61.46	-23.61	275	14.9	3006.5	X			X			
16-Oct	24955.529	1	R-170	13	9		X	RSM	-1686.08	NA	NA	360	67.72	3.72	22.01	-55.48	84	7.2	1765.89	X			X			Traffic heading appears to be 180 degrees off.
16-Oct	33494.015	3	R-170	25	11		X	GBS	14.0317	46.09	-31.41	274	3.99	2278.83	NA	NA	177	30.4	2265.22	X			X			Alert toggled off three times.
16-Oct	33849.151	2	R-170	28	10		X	RIAAS	130.809	NA	20.03	0.53	22.64	3352.47	60.04	-9.19	90	7.2	3222.04	X			X			Traffic heading appears to be 180 degrees off.
17-Oct	19566.109	3	R-171	5	7	X		RSM	3454.25	22.26	-52.31	95.3	2.19	214.96	NA	25.77	196	17.5	3241.21		X					Apparent false alert on another ID (ID 84, confirmed it was not Rips van) approximately 3.5 minutes before legitimate alert. Alert toggled off 7 times once legitimate alerting began.
17-Oct	20628.252	1	R-171	7	5	X		GBS	-1426.23	NA	NA	0	65.79	21.48	35.56	-41.93	300	12.9	1449.34	X			X			Traffic data taken from RIAAS traffic output file, DAS STIS-B-data was non-existent for this run.
17-Oct	21476.431	4	R-171	8	12		X	GBS	-1691.06	NA	NA	0	64.56	1671.32	42.90	-42.17	90	11.3	3363.25	X			X			Traffic heading appears to be 180 degrees off.
17-Oct	22953.281	2	R-171	10	2		X	RSM	292.72	NA	25.08	0.6	35.75	3464.14	15.34	-54.77	87	6.69	3172.77	X			X			Traffic heading appears to be 180 degrees off.
17-Oct	24304.23	2	R-171	12	6	X		GBS	367.58	NA	27.14	360	40	3467.58	7.47	-62.02	45	1.03	3101.55	X			X			This heading looks to be 180 degrees off until time of alert, though subsequent headings appeared to be correct. Alert toggled off once.
17-Oct	27968.849	3	R-171	14	21		X	RIAAS	3455.9	58.27	-19.22	270	4.24	109.94	NA	20.05	5	17.5	3346.17	X			X			Traffic heading appears to be 180 degrees off until time of alert, though subsequent headings appeared to be correct. Alert toggled off 7 times.
17-Oct	29451.481	4	R-171	16	22		X	RSM	-1792.54	NA	NA	360	64.37	1672.21	47.21	-37.86	92	11.8	3465.52	X			X			Traffic heading appears to be 180 degrees off.
17-Oct	30972.052	2	R-171	18	20		X	RSM	279.19	NA	24.19	0.22	37.75	3462.92	30.33	-39.15	87	8.75	3184.77	X			X			Traffic heading appears to be 180 degrees off. Alert toggled off 3 times.
17-Oct	31356.481	3	R-171	19	25	X		RSM	3454.95	NA	8.72	280	3.86	98.63	NA	20.18	202	19	3353.25	X			X			Alert toggled off 9 times.

Table D-1 – RSM Alert Summary Continued

Flight Information									Ownship					Traffic						Details						General Notes
						Data Type														Correct Alert?		Alert Timing				
Date	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
17-Oct	32229.13	1	R-171	20	19		X	RIAAS	-1739.86	NA	NA	0.66	64.12	7.045	40.66	-36.83	87	10.3	1748.14	X			X			
17-Oct	34252.33	3	R-171	23	29		X	GBS	3456.91	23.1	-51.51	89.2	4.95	55.8198	NA	7.34	45	13.4	3402.79	X			X			This heading looks to be 180 degrees off, though subsequent headings appeared to be correct. Alert toggled off once.
17-Oct	35896.94	2	R-171	27	24	X		GBS	439.89	NA	26.3	0.14	50.29	3458.87	43.18	-26.31	268	14.9	3021.18	X			X			Alert toggled off once.
18-Oct	18489.12	4	R-172A	1	26	X		RIAAS	-1580.4	NA	NA	180	65.33	1878	NA	17.16	264	19.6	3404.19	X			X			
18-Oct	19079.27	1	R-172A	2	23	X		GBS	-1630.31	NA	NA	180	65.08	10.13	45.34	-24.15	277	10.8	1640.96	X			X			
18-Oct	--	1	R-172A	4	27		X	RSM	--	--	--	--	--	--	--	--	--	--	--		X					RSM did not alert on this run. ADS-B data was being transmitted, but was erroneous (indicated that van never moved)
18-Oct	--	4	R-172A	5	30		X	GBS	--	--	--	--	--	--	--	--	--	--	--		X					RSM did not alert on this run. ADS-B data was being transmitted, but was erroneous (indicated that van never moved)
18-Oct	22761.75	2	R-172A	7	28		X	RIAAS	300.69	NA	21.4	181	36.22	3462.73	20.61	-56.89	87	7.2	3164.29	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	27462.44	2	R-172B	8	42	X		GBS	399.83	NA	24.11	180	43.6	3464.07	19.20	-58.29	283	5.66	3066.59	X			X			Alert toggled off once.
18-Oct	28680.26	1	R-172B	9	45		X	RSM	-1922.87	NA	NA	181	64.31	3.81	23.22	-46.27	87	8.23	1927.69	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	29302.25	4	R-172B	10	44	X		RIAAS	-1718.59	NA	NA	181	65.14	1809.37	53.59	-31.48	269	13.9	3528.19	X			X			
18-Oct	30251.05	3	R-172B	12	47		X	GBS	3453.05	24.33	-45.16	262	3.54	518.96	NA	20.34	0	29.3	2935.27	X			X			Alert toggled off three times. Large ADS-B gap, analysis used STIS-B.
18-Oct	30900.43	4	R-172B	13	40		X	RSM	-1757.73	NA	NA	180	64.95	1804.27	46.46	-38.61	81	12.4	3562.35	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	31388.27	1	R-172B	14	37		X	RIAAS	-1842.46	NA	NA	180	64.82	7.58	25.37	-44.12	87	9.26	1851.07	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	32516.41	2	R-172B	16	38		X	RSM	376.54	NA	21.09	180	39.68	3461.17	44.23	-33.27	87	10.8	3086.42	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	33017.92	3	R-172B	17	39		X	RIAAS	3454.94	12.43	-57.06	265	2.25	69.26	NA	13.88	149	13.4	3384.38	X			X			Alert came on, then cleared, then came on again 27 seconds later, then toggled off twice. There was a 24 second gap in ADS-B data. Traffic heading appears to be 180 degrees off until traffic is on runway and following zero degree heading.
19-Oct	18536.37	1	R-173	18	41	X		GBS	-1573.53	NA	NA	180	66.23	8.02	NA	2.37	273	17	1581.63	X			X			Late alert due to bad scenario timing. Traffic was on runway at time of alert.
19-Oct	21487.21	4	R-173	20	48		X	GBS	-1772.93	NA	NA	179	60.7	1804.71	56.42	-28.58	81	13.4	3577.83	X			X			Traffic heading appears to be 180 degrees off.

Table D-1 – RSM Alert Summary Continued

Flight Information									Ownship					Traffic						Details							General Notes
Date	DAS UTC of First Alert (seconds)	Scenario	Flight #	Flight Card #	Matrix Run #	Data Type: STIS-B	Data Type: ADS-B/STIS-B	System Displayed	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	Correct Alert? YES	Correct Alert? NO	Alert Timing: Early	Alert Timing: On-Time	Alert Timing: Late	Alert Timing: Time Deviation (s)		
19-Oct	22595.64	3	R-173	22	43	X		RSM	3456.38	13.26	-56.23	282	3.09	--	--	--	--	--	--	X			X				No traffic ADS-B data, and no traffic STIS-B data updates anywhere near time of alert (based on DAS data). Do not know source of data that RSM was alerting on.
19-Oct	24934.62	2	R-173	24	46		X	RIAAS	311.33	NA	26.93	180	35.56	3462.67	36.35	-41.14	87	10.3	3151.8	X			X				Traffic heading appears to be 180 degrees off.
20-Oct	17482.85	3	R-174	1	57		X	RIAAS	3455.82	16.57	-51.85	97.6	3.34	362.48	NA	19.59	0	30.4	3097.03	X			X				Alert toggled off once.
20-Oct	18467.3	4	R-174	2	58		X	RSM	-1715.05	NA	NA	181	67.14	1802.16	48.62	-36.45	0	11.8	3517.48	X			X				Traffic heading appears to be 180 degrees off.
20-Oct	19932.08	3	R-174	4	65		X	GBS	3455.38	35.07	-34.42	273	2.25	438.56	NA	20.34	0	30.4	3018.3	X			X				Alert toggled off once.
20-Oct	20960.8	1	R-174	5	63		X	RSM	-1848.78	NA	NA	180	64.76	5.03	26.78	-42.71	0	9.26	1854.77	X			X				Traffic heading appears to be 90 degrees off.
20-Oct	21834.33	4	R-174	6	62	X		RIAAS	-1593.05	NA	NA	181	65.46	1806.82	65.77	-19.3	280	10.8	3400	X			X				
20-Oct	--	3	R-174	8	61	X		RSM	--	--	--	--	--	--	--	--	--	--	--		X						RSM did not alert on this run.
20-Oct	--	2	R-174	11	56		X	RSM	--	--	--	--	--	--	--	--	--	--	--		X						RSM did not alert on this run.
20-Oct	29978.51	1	R-174	9	55		X	RIAAS	-1839.58	NA	NA	179	62.25	7.58	15.34	-54.15	0	6.69	1848.53	X			X				Traffic heading appears to be 90 degrees off.
20-Oct	30643.47	4	R-174	13	66		X	GBS	-1417.61	NA	NA	179	62.63	1872.03	NA	21.47	0	17	3289.65	X			X				Traffic heading appears to be 180 degrees off.
20-Oct	32730.76	1	R-174	16	59	X		GBS	-1846.45	NA	NA	182	60.77	12.68	43.18	-26.31	269	12.9	1859.67	X			X				
20-Oct	33874.62	2	R-174	12	64		X	RIAAS	280.947	NA	22.24	181	36.01	3463.46	19.20	-58.29	0	7.2	3183.3	X			X				Traffic heading appears to be 90 degrees off.

Key T.H. = Threshold H.L. = Holdline RWY = Runway

Dist. To T.H. --> neg. value indicates that aircraft has not reached runway threshold yet, pos. value indicates that aircraft has crossed the threshold.

Dist. To H.L. --> neg. value indicates that vehicle has not crossed holdline yet, pos. value indicates that vehicle has crossed the holdline in the direction of the runway.

Dist. To RWY --> neg. value indicates that vehicle has not crossed runway edge (in direction of runway centerline), pos. value indicates that vehicle has crossed the runway edge and is currently on or over the runway.

NA --> Not Applicable.

Note: Ownship position has been corrected to the nose for all scenario 3's

APPENDIX E – GBS ALERT PLOTS

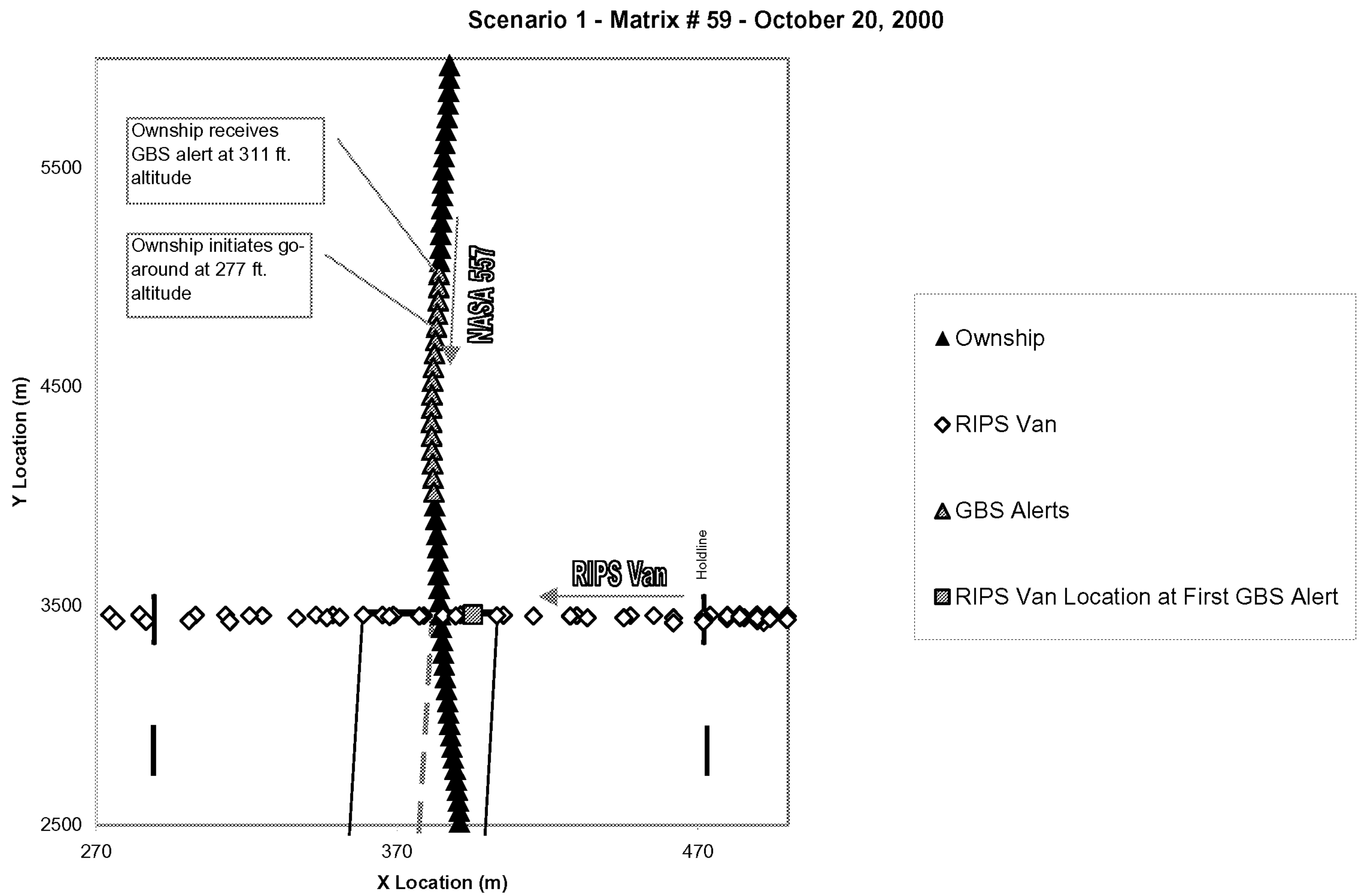
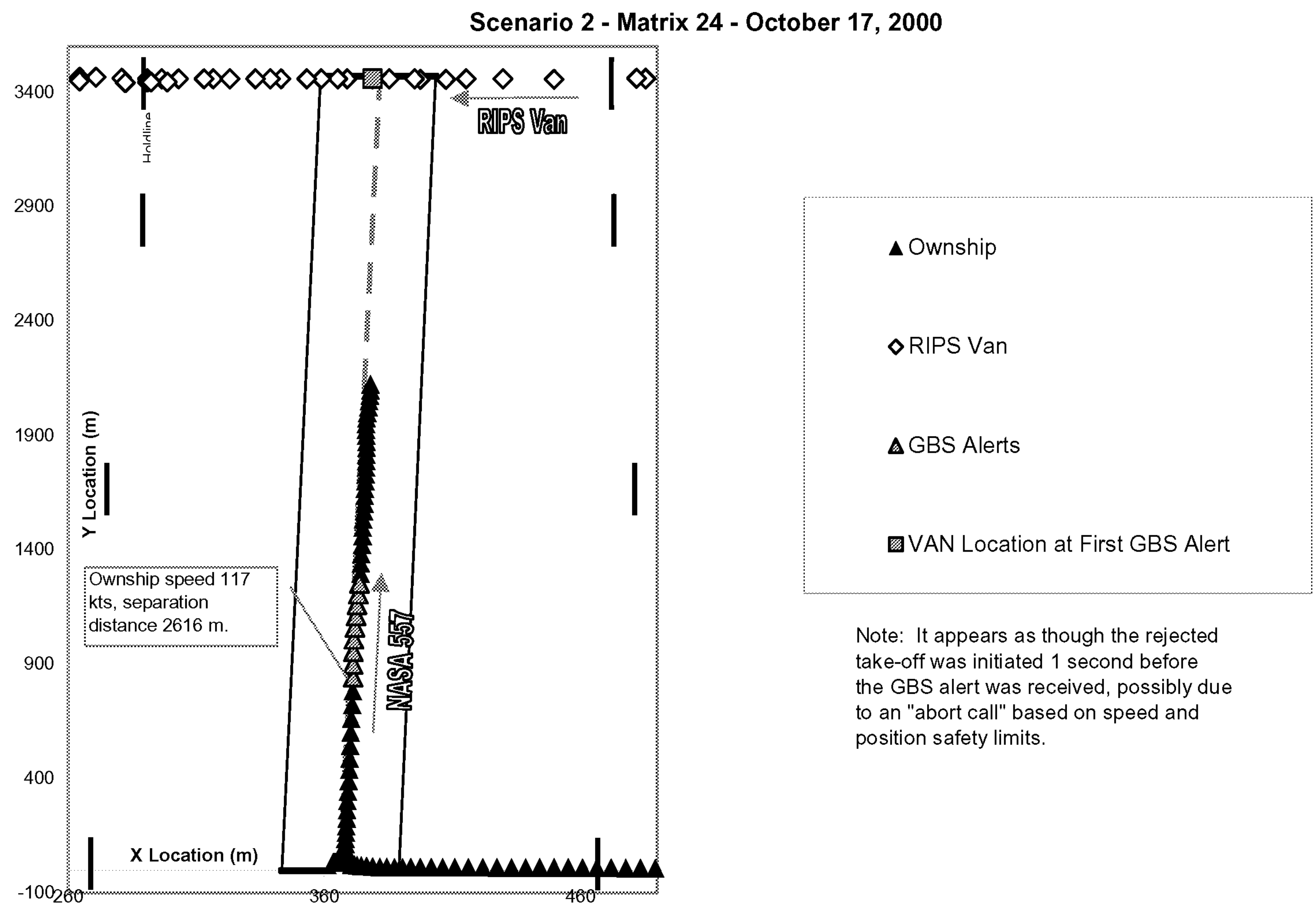

Scenario 1 - Matrix # 59 - October 20, 2000
Ownship receives GBS alert at 311 ft. altitude
Ownship initiates go-around at 277 ft. altitude
NASA 557
RIPS Van
Holdline
5500
4500
3500
2500
Y Location (m)
270
370
470
X Location (m)
Ownship
RIPS Van
GBS Alerts
RIPS Van Location at First GBS Alert

Figure E-1



Note: It appears as though the rejected take-off was initiated 1 second before the GBS alert was received, possibly due to an "abort call" based on speed and position safety limits.

Figure E-2

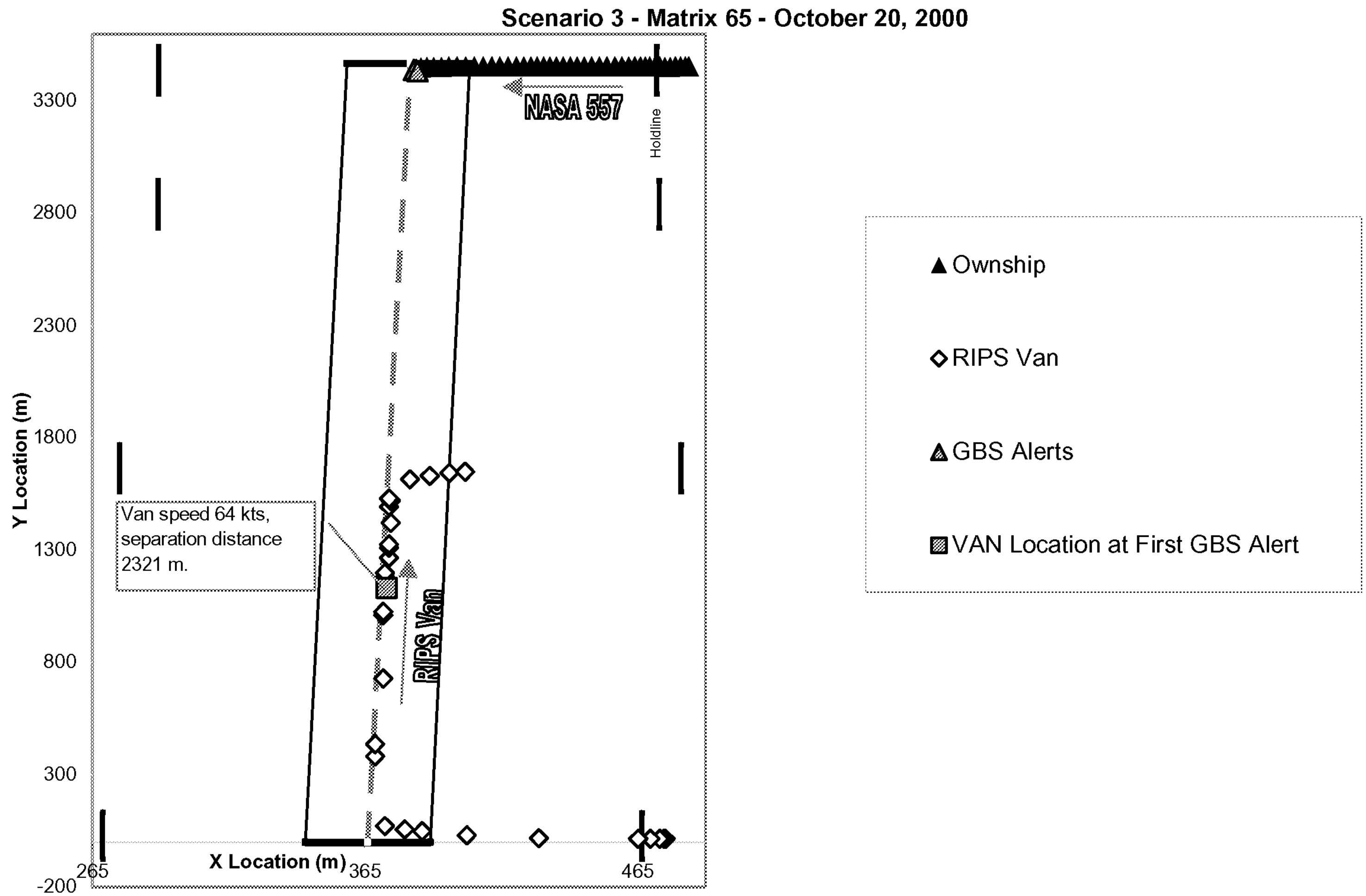

Scenario 3 - Matrix 65 - October 20, 2000
Y Location (m)
3300
2800
2300
1800
1300
800
300
-200
X Location (m)
265
365
465
NASA 557
Holdline
RIPS Van
Van speed 64 kts, separation distance 2321 m.
Ownship
RIPS Van
GBS Alerts
VAN Location at First GBS Alert

Figure E-3

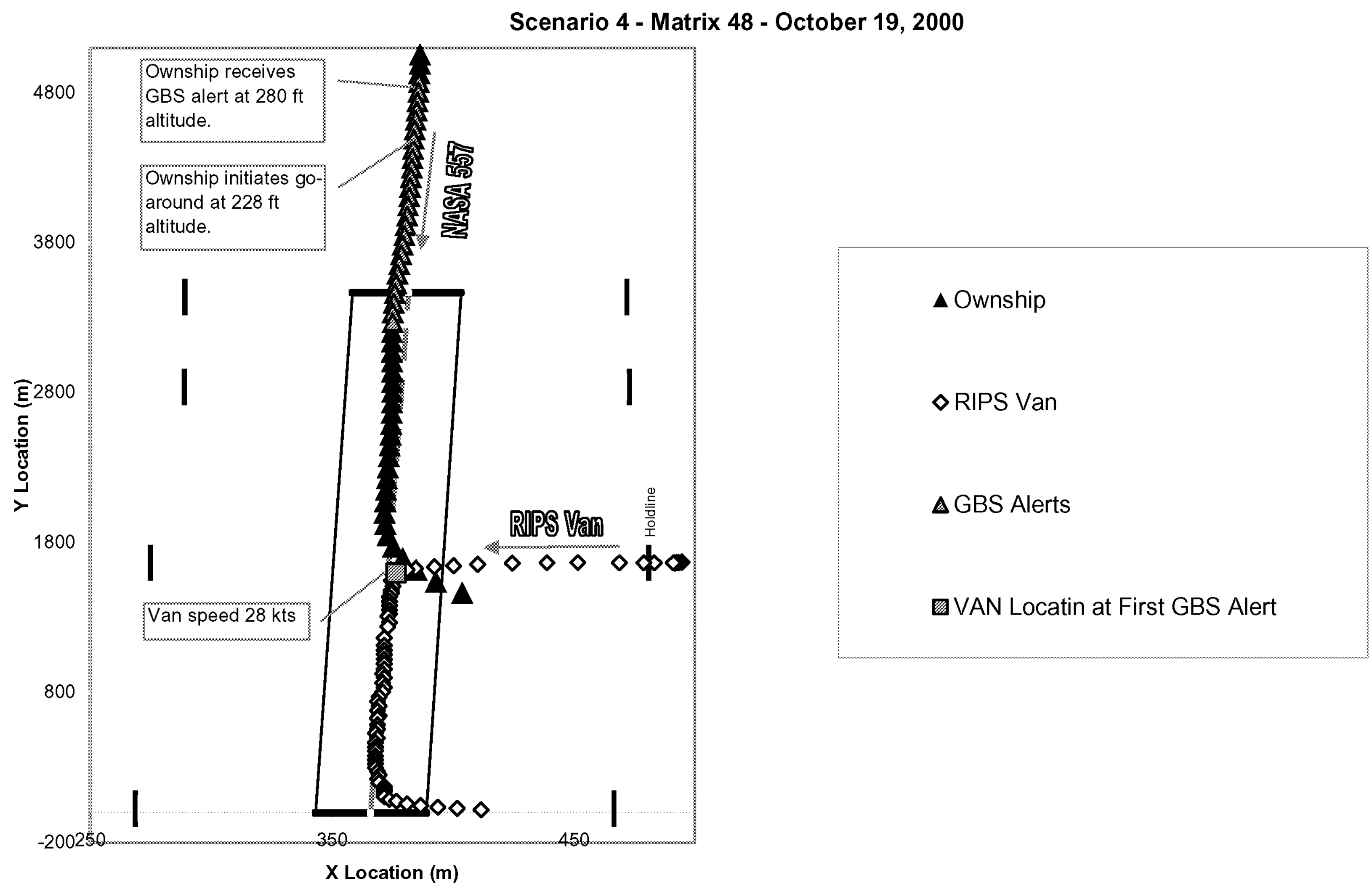

Scenario 4 - Matrix 48 - October 19, 2000
Ownship receives GBS alert at 280 ft altitude.
Ownship initiates go-around at 228 ft altitude.
NASA 557
RIPS Van
Holdline
Van speed 28 kts
4800
3800
2800
1800
800
-200
250
350
450
Y Location (m)
X Location (m)
Ownship
RIPS Van
GBS Alerts
VAN Locatin at First GBS Alert

Figure E-4

APPENDIX F – GBS ALERT SUMMARY

Table F-1 – GBS Alert Summary

Flight Information										Ownship					Traffic						Details						General Notes
Date	DAS UTC of First Alert (seconds)	Scenario	Flight#	Flight Card #	Matrix Run #	Data Type: STIS-B	Data Type: ADS-B/STIS-B	System Displayed	GBS Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	Correct Alert?: YES	Correct Alert?: NO	Alert Timing: Early	Alert Timing: On-Time	Alert Timing: Late	Time Deviation (s)	
16-Oct	--	1	R-170	7	1		X	RIAAS		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
16-Oct	--	4	R-170	8	4		X	RSM		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
16-Oct	--	3	R-170	10	3		X	RIAAS		--	--	--	--	--	--	--	--	--	--	--		X					No alert – Ownship stopped before alerting criteria was met
16-Oct	24201.86	4	R-170	12	8	X		RIAAS	24	-745.0	NA	NA	-0.3	68.2	1768.2	NA	20.72	356.0	15.4	2513.2	X			X			
16-Oct	--	1	R-170	13	9		X	RSM		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
16-Oct	33514.68	3	R-170	25	11		X	GBS	33	44.4	NA	17.3	339.5	2.6	1772.0	NA	NA	180.0	27.8	1727.7	X			X			
16-Oct	33638.56	2	R-170	28	10		X	RIAAS	9	43.4	NA	27.0	33.2	0.1	132.0	56.80	-12.85	45.0	10.3	3295.5		X					Alerted approximately 3.5 minutes earlier than other systems. Alerted throughout the run, then ended at approximately the same time as the others. Alert occured as the van was preparating for the run.
17-Oct	--	3	R-171	5	7	X		RSM		--	--	--	--	--	--	--	--	--	--	--		X					No alert – Ownship stopped before alerting criteria was met
17-Oct	--	1	R-171	7	5	X		GBS		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
17-Oct	21484.30	4	R-171	8	12		X	GBS	24	-1182.7	NA	NA	0.0	64.7	1767.8	NA	20.07	165.0	17.5	2950.5	X			X			ADS-B traffic heading appears to be 180 degrees off.
17-Oct	22965.09	2	R-171	10	2		X	RSM	37	698.0	NA	28.0	1.5	23.7	3464.4	NA	22.33	270.0	7.0	2766.6	X			X			Traffic data was interpolated for this run, as there was none logged in the DAS files at time of the alert.
17-Oct	--	2	R-171	12	6	X		GBS		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
17-Oct	27984.60	3	R-171	14	21		X	RIAAS	33	3448.2	NA	34.6	343.5	2.8	428.6	NA	22.95	180.0	28.3	3019.8	X			X			
17-Oct	29460.34	4	R-171	16	22		X	RSM	24	-1216.7	NA	NA	359.6	65.9	1772.5	NA	21.47	168.0	17.5	2989.2	X			X			Traffic heading appears to be 180 degrees off.
17-Oct	30984.85	2	R-171	18	20		X	RSM	37	763.2	NA	24.8	0.6	31.3	3458.9	NA	24.49	342.0	0.5	2697.3	X			X			Used STIS-B data for traffic info (ADS-B gap)
17-Oct	31367.31	3	R-171	19	25	X		RSM	33	3423.2	NA	17.2	353.9	3.2	357.9	NA	28.05	183.0	26.8	3065.4	X			X			

Table F-1 – GBS Alert Summary Continued

Flight Information										Ownship					Traffic						Details						General Notes
						Data Type															Correct Alert?		Alert Timing				
Date	DAS UTC of First Alert (seconds)	Scenario	Flight#	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	GBS Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
17-Oct	--	1	R-171	20	19		X	RIAAS		--	--	--	--	--	--	--	--	--	--	--		X					GBS did not alert on this run.
17-Oct	--	3	R-171	23	29		X	GBS		--	--	--	--	--	--	--	--	--	--	--		X					DAS file ended before run was complete – cannot determine if GBS alerted.
17-Oct	35903.84	2	R-171	27	24	X		GBS	37	844.2	NA	27.8	359.9	59.8	3460.4	NA	24.49	342.0	0.5	2616.3	X			X			
18-Oct	18492.07	4	R172A	1	26	X		RIAAS	24	-1385.7	NA	NA	181.0	65.9	1878.4	NA	12.23	217.0	16.5	3264.1	X			X			
18-Oct	19085.18	1	R172A	2	23	X		GBS	24	-1246.5	NA	NA	180.5	66.2	10.1	NA	20.34	342.0	0.5	1256.6	X			X			
18-Oct	20954.95	1	R172A	4	27		X	RSM	24	-1160.8	NA	NA	179.9	66.2	8.0	NA	8.09	342.0	0.5	1168.8	X			X			Analysis Used STIS-B data for traffic info (ADS-B gap)
18-Oct	21666.31	4	R172A	5	30		X	GBS	24	-1313.4	NA	NA	180.2	65.1	1897.4	NA	45.00	214.0	21.6	3211.0	X			X			Analysis Used STIS-B data for traffic info (ADS-B gap)
18-Oct	22774.54	2	R172A	7	28		X	RIAAS	37	762.8	NA	24.9	181.0	30.1	3462.6	NA	5.39	90.0	5.1	2700.0	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	27477.20	2	R172B	8	42	X		GBS	37	1260.2	NA	15.7	180.1	55.2	3493.8	NA	15.42	225.0	0.0	2233.8	X			X			
18-Oct	28691.09	1	R172B	9	45		X	RSM	24	-1195.7	NA	NA	180.0	68.9	2.6	NA	20.93	90.0	4.6	1198.3	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	29309.14	4	R172B	10	44	X		RIAAS	24	-1260.5	NA	NA	180.9	67.5	1875.8	NA	27.05	208.0	16.0	3136.3	X			X			
18-Oct	30271.71	3	R172B	12	47		X	GBS	33	3439.6	NA	14.3	203.0	4.5	1113.8	NA	11.72	1.0	31.4	2305.4	X			X			Used STIS-B data for traffic info (ADS-B gap)
18-Oct	30910.27	4	R172B	13	40		X	RSM	24	-1098.3	NA	NA	180.1	68.8	1946.4	NA	22.92	2.0	20.1	3044.8	X			X			Traffic heading appears to be 180 degrees off up to time of alert, but looks to be correct in following updates
18-Oct	31395.16	1	R172B	14	37		X	RIAAS	24	-1391.2	NA	NA	180.2	66.4	9.4	NA	9.49	90.0	5.1	1400.6	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	32526.25	2	R172B	16	38		X	RSM	37	779.6	NA	19.4	179.7	37.9	3462.1	NA	30.98	90.0	6.7	2682.7	X			X			Traffic heading appears to be 180 degrees off.
18-Oct	33047.44	3	R172B	17	39		X	RIAAS	33	3452.5	NA	12.1	196.4	2.2	797.3	NA	19.59	0.0	31.9	2634.1	X			X			
19-Oct	18542.27	1	R-173	18	41	X		GBS	24	-1190.0	NA	NA	180.5	65.9	12.7	NA	8.09	225.0	0.0	1202.8	X			X			
19-Oct	21493.12	4	R-173	20	48		X	GBS	24	-1403.0	NA	NA	179.0	62.3	1869.5	NA	19.32	28.0	14.4	3272.5	X			X			Traffic heading appears to be 180 degrees off.
19-Oct	--	3	R-173	22	43	X		RSM		--	--	--	--	--	--	--	--	--	--	--		X					No alert – Ownship stopped before alerting criteria was met

Table F-1 – GBS Alert Summary Continued

Flight Information										Ownship					Traffic						Details						General Notes
						Data Type															Correct Alert?		Alert Timing				
Date	DAS UTC of First Alert (seconds)	Scenario	Flight#	Flight Card #	Matrix Run #	STIS-B	ADS-B/STIS-B	System Displayed	GBS Alert Type	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Dist. To T.H. (m)	Dist. To H.L. (m)	Dist. To Runway (m)	Heading (Deg)	Speed (m/s)	Separation (m)	YES	NO	Early	On-Time	Late	Time Deviation (s)	
19-Oct	--	2	R-173	24	46		X	RIAAS		--	--	--	--	--	--	--	--	--	--	--	X			X			GBS alerted constantly throughout entire run on a stationary traffic ID 207.
20-Oct	--	3	R-174	1	57		X	RIAAS		--	--	--	--	--	--	--	--	--	--	--		X					No alert – Ownship stopped before alerting criteria was met
20-Oct	18475.17	4	R-174	2	58		X	RSM	24	-1183.3	NA	NA	181.1	68.7	1901.2	NA	20.72	0.0	18.0	3084.5	X			X			Traffic heading appears to be 180 degrees off.
20-Oct	19953.73	3	R-174	4	65		X	GBS	33	3453.8	NA	20.4	231.0	2.2	1132.8	NA	16.03	0.0	32.9	2321.3	X			X			
20-Oct	20889.94	1	R-174	5	63		X	RSM	9	-6224.5	NA	NA	179.5	57.6	5.0	-9.68	-79.17	0.0	0.0	6230.0		X					Alert came on a minute and 10 seconds before RIAAS and RSM, while the VAN was stopped well behind the hold line. The alerts continued well beyond the point where the other two systems stopped alerting.
20-Oct	21847.13	4	R-174	6	62	X		RIAAS	9/24	-748.8	NA	NA	179.9	67.1	2083.1	NA	18.57	175.0	26.8	2831.8	X			X			GBS actually alerted throughout entire run, but this is where the system began alerting based in response to ownship.
20-Oct	--	3	R-174	8	61	X		RSM	9/33	--	--	--	--	--	--	--	--	--	--	--		X					GBS actually alerted throughout entire run, on two ID's, but not on ownship. No STIS-B data.
20-Oct	24532.40	2	R-174	11	56		X	RSM	37	865.1	NA	16.5	179.9	56.1	3463.0	NA	20.34	342.0	0.5	2598.1	X			X			Used STIS-B data for traffic information (ADS-B gap)
20-Oct	29987.37	1	R-174	9	55		X	RIAAS	24	-1274.5	NA	NA	178.8	64.1	7.6	NA	5.93	0.0	3.6	1282.2	X			X			Traffic heading appears to be 90 degrees off.
20-Oct	30644.45	4	R-174	13	66		X	GBS	24	-1354.6	NA	NA	178.9	62.6	1889.8	NA	21.51	0.0	17.5	3244.4	X			X			Traffic heading appears to be 180 degrees off.
20-Oct	32735.68	1	R-174	16	59	X		GBS	24	-1546.9	NA	NA	181.5	61.1	8.0	NA	8.09	342.0	0.5	1555.0	X			X			
20-Oct	33886.43	2	R-174	12	64		X	RIAAS	37	647.2	NA	21.2	181.9	25.2	3462.6	NA	33.14	0.0	4.6	2815.5	X			X			Traffic heading appears to be 90 degrees off.

Key T.H. = Threshold H.L. = Holdline RWY = Runway

Dist. To T.H. --> neg. value indicates that aircraft has not reached runway threshold yet, pos. value indicates that aircraft has crossed the threshold.

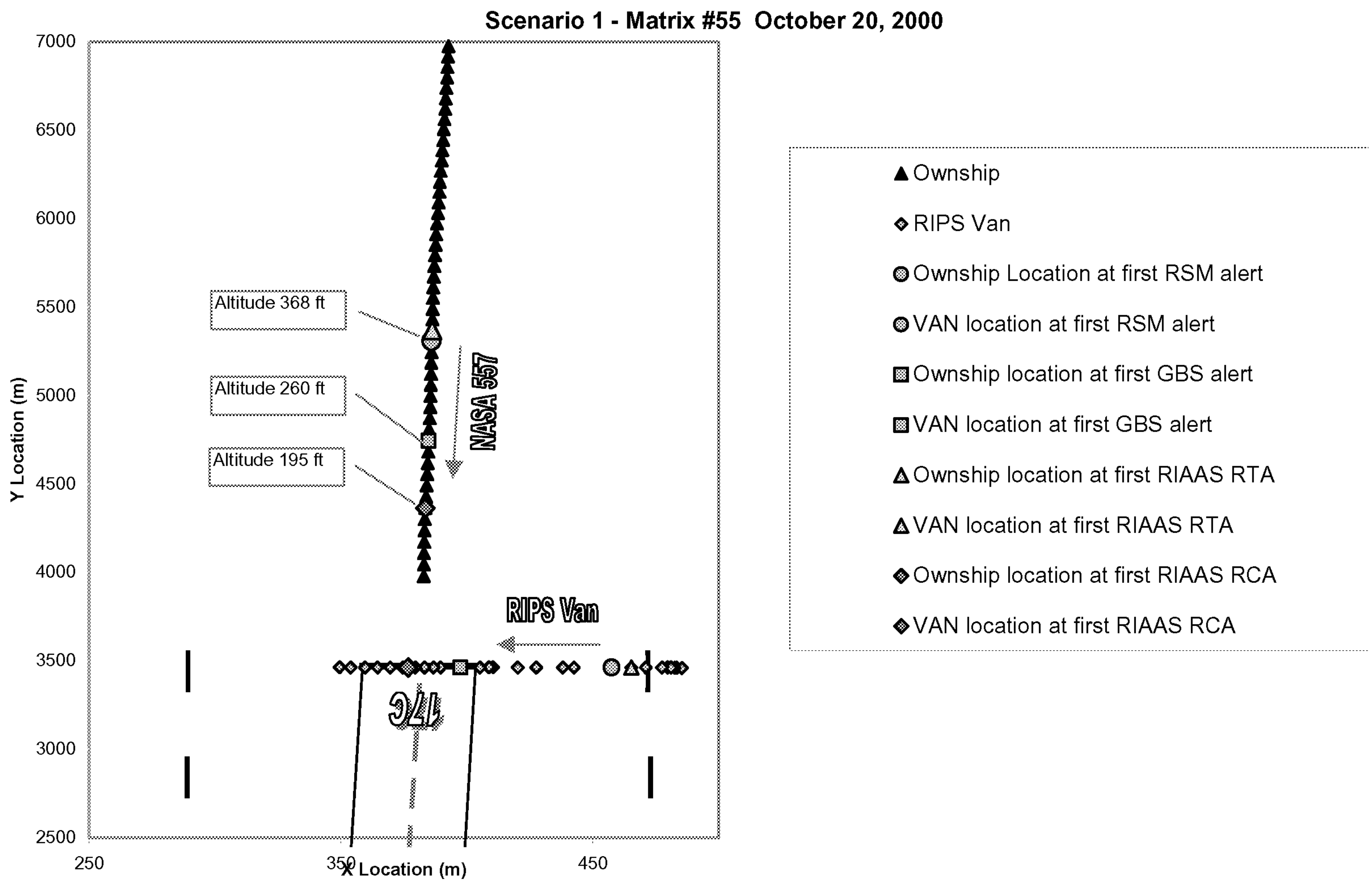
Dist. To H.L. --> neg. value indicates that vehicle has not crossed holdline yet, pos. value indicates that vehicle has crossed the holdline in the direction of the runway.

Dist. To RWY --> neg. value indicates that vehicle has not crossed runway edge (in direction of runway centerline), pos. value indicates that vehicle has crossed the runway edge and is currently on or over the runway.

NA --> Not Applicable.

Note: Ownship position has been corrected to the nose for all scenario 3's

APPENDIX G – COMBINED ALERT PLOTS



Scenario 1 - Matrix #55 October 20, 2000
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
Y Location (m)
250
350
450
X Location (m)
Altitude 368 ft
Altitude 260 ft
Altitude 195 ft
NASA 557
RIPS Van
17C
Ownship
RIPS Van
Ownship Location at first RSM alert
VAN location at first RSM alert
Ownship location at first GBS alert
VAN location at first GBS alert
Ownship location at first RIAAS RTA
VAN location at first RIAAS RTA
Ownship location at first RIAAS RCA
VAN location at first RIAAS RCA

Figure G-1

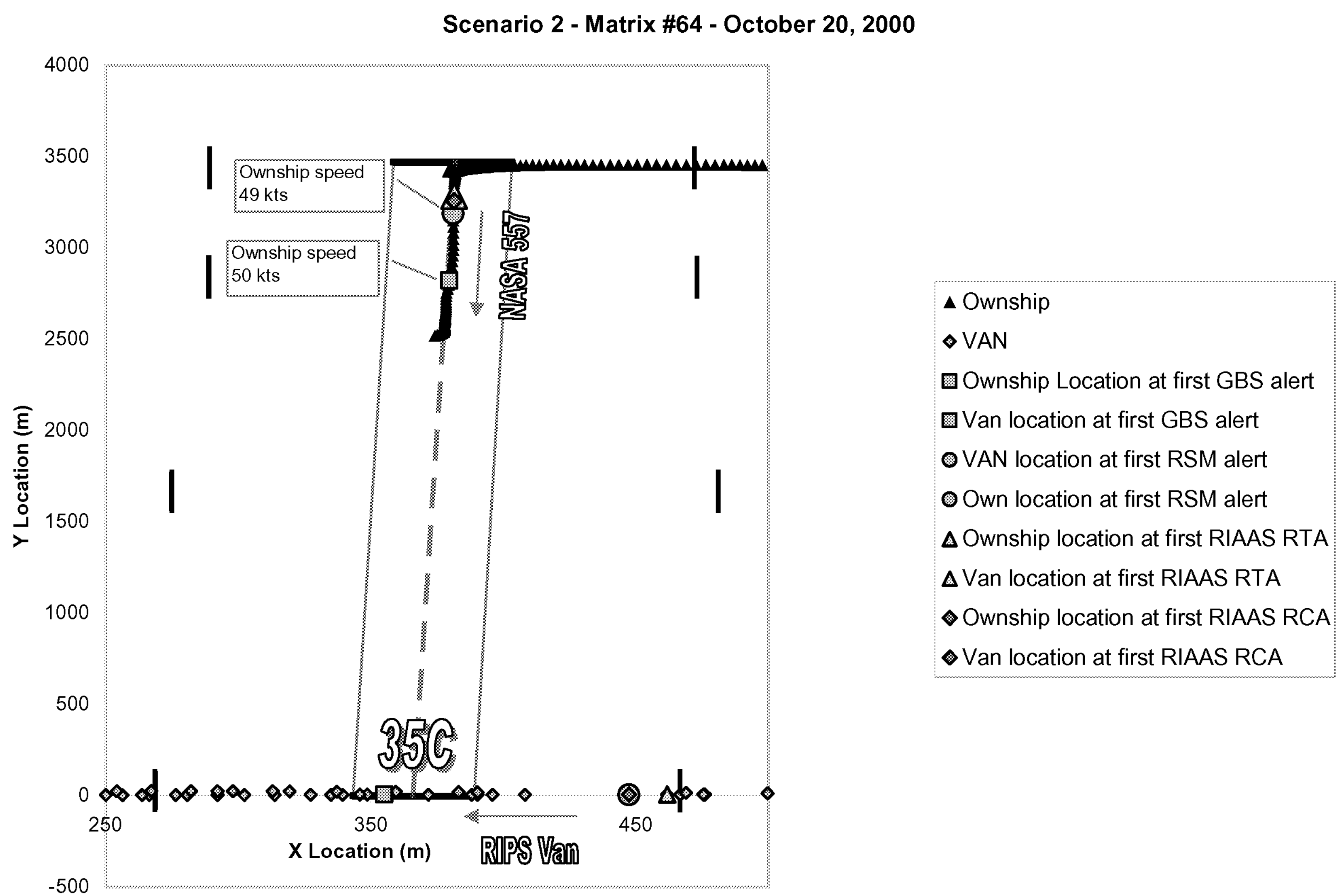

Scenario 2 - Matrix #64 - October 20, 2000
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Y Location (m)
250
350
450
X Location (m)
Ownship speed
49 kts
Ownship speed
50 kts
NASA 557
35C
RIPS Van
Ownship
VAN
Ownship Location at first GBS alert
Van location at first GBS alert
VAN location at first RSM alert
Own location at first RSM alert
Ownship location at first RIAAS RTA
Van location at first RIAAS RTA
Ownship location at first RIAAS RCA
Van location at first RIAAS RCA

Figure G-2

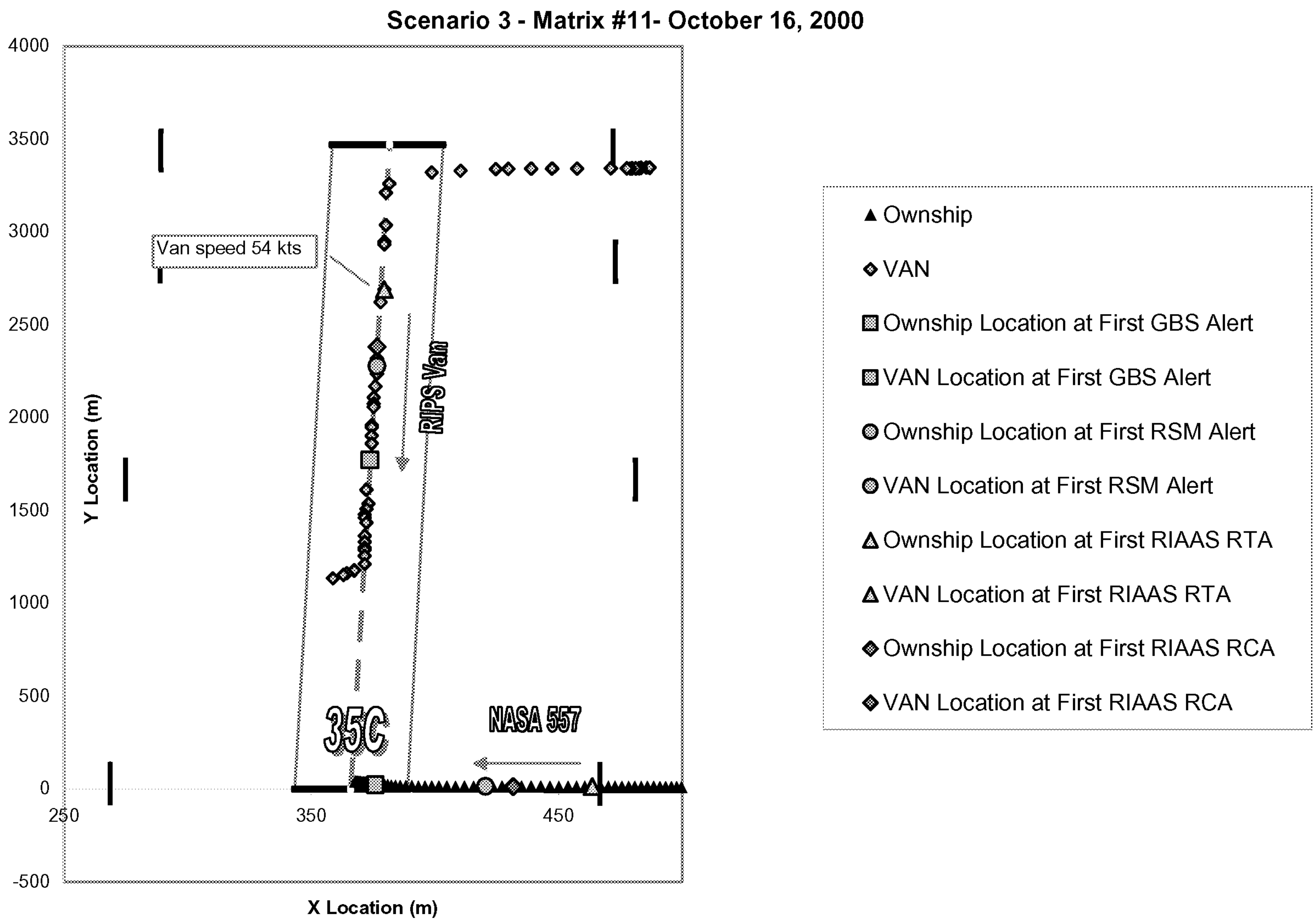
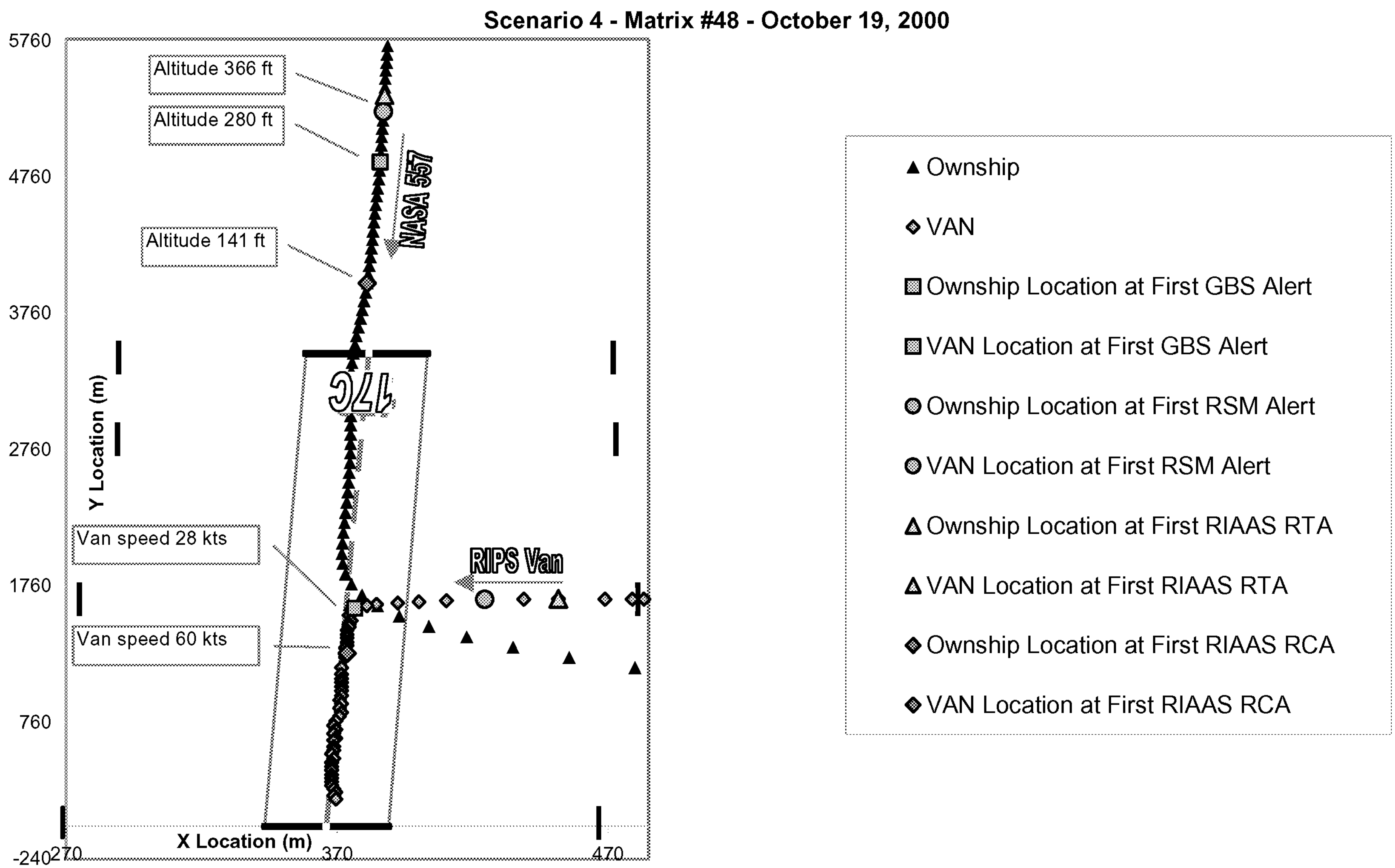

Scenario 3 - Matrix #11- October 16, 2000
4000
3500
3000
2500
2000
1500
1000
500
0
-500
Y Location (m)
250
350
450
X Location (m)
Van speed 54 kts
RIPS Van
35C
NASA 557
Ownship
VAN
Ownship Location at First GBS Alert
VAN Location at First GBS Alert
Ownship Location at First RSM Alert
VAN Location at First RSM Alert
Ownship Location at First RIAAS RTA
VAN Location at First RIAAS RTA
Ownship Location at First RIAAS RCA
VAN Location at First RIAAS RCA

Figure G-3



Scenario 4 - Matrix #48 - October 19, 2000
5760
4760
3760
2760
1760
760
-240
270
370
470
Y Location (m)
X Location (m)
Altitude 366 ft
Altitude 280 ft
Altitude 141 ft
Van speed 28 kts
Van speed 60 kts
NASA 557
17C
RIPS Van
Ownship
VAN
Ownship Location at First GBS Alert
VAN Location at First GBS Alert
Ownship Location at First RSM Alert
VAN Location at First RSM Alert
Ownship Location at First RIAAS RTA
VAN Location at First RIAAS RTA
Ownship Location at First RIAAS RCA
VAN Location at First RIAAS RCA

Figure G-4

APPENDIX H – FALSE ALERTS

Table H-1 RIAAS False Alerts

False Alerts - RIAAS											
Date	UTC	Test System(s)	Scenario	Matrix Run #	Ownship Dist. To TH (m)	Ownship Dist. To RWY (m)	Ownship Dist. To HL (m)	Traffic Dist. To TH (m)	Traffic Dist. To RWY (m)	Traffic Dist. To HL (m)	Notes
16-Oct	33564.4	RIPS	3	11	3405.5	11.4	NA	1372	22.4	NA	Traffic was headed away from ownship on the runway after the end of the test run. Traffic transitioned to high-speed state. At one point, traffic heading erroneously flipped 180 degrees, indicating that it was headed toward ownship at a high rate of speed when it was in fact still heading away from ownship, thus causing a false alert.
17-Oct	32250.6	RIPS	1	19	-412.9	-20.6	NA	7.5	-32.1	42.5	Alert had properly cleared as traffic crossed the hold line away from the runway. On the very next update, an erroneous position update, indicating a 50m jump backwards, caused a false alert, as it appeared (based on the erroneous position) that traffic was well over the hold line in the direction of the runway, when it in fact was not.

Table H-2 – RSM False Alerts

False Alerts - IDS											
Date	UTC	Test System(s)	Scenario	Matrix Run #	Ownship Dist. To TH	Ownship Dist. To RWY	Ownship Dist. To HL	Traffic Dist. To TH	Traffic Dist. To RWY	Traffic Dist. To HL	Notes
16-Oct	25768.2	MEL	NA	17	684.4	21.1	NA	1.3	-77.9	-8.7	RSM alerted on ownship's TIS-based position updates. DAS TIS data shows ID106 lagging a few seconds behind ownship as the alert was received. DAS data indicates that RSM was alerting on ID106 / Flight "NSA557".
16-Oct	31448.1	SF	NA	15	958.4	22.2	NA	16.0	-89.8	-12.3	RSM alerted on ownship's TIS-based position updates. DAS TIS data shows ID32 lagging a few seconds behind ownship as the alert was received. DAS data indicates that RSM was alerting on ID32 / Flight "NSA557". The Van did not move during these alerts. Once the false alerting ended, the RIPS Van pulled onto the runway behind ownship, and alerting began again. Separation was just under 1500m at that point.
17-Oct	19353.5	RIPS	3	7	NA	NA	NA	129.5	-82.1	-12.6	RSM alerted on what appears to be ownship's TIS-based position updates. DAS TIS data shows ID84 lagging a few seconds behind ownship as the alert was received. The alert cleared, and a short time later RSM alerted on another ID (11224886), which did not show up in the TIS data. There was no ADS-B data for this run (was turned off). This occured off the runway, over 400m off of the runway edge for 35C.
20-Oct	24119.3	SF	NA	68	1816.9	21.7	NA	3320.0	20.3	NA	It is not clear whether RSM alerted on ownship's TIS-based position upates or on the RIPS Van. The Van did appear to be on the runway and traveling toward ownship at around 20 m/s. Unfortunately, the ID in the DAS data which RSM is alerting on does not match any of the ID's in the TIS data.

Table H- 3 – GBS False Alerts

False Alerts - GBS											
Date	UTC	Test System(s)	Scenario	Matrix Run #	Ownship Dist. To TH	Ownship Dist. To RWY	Ownship Dist. To HL	Traffic Dist. To TH	Traffic Dist. To RWY	Traffic Dist. To HL	Notes
16-Oct	33638.6	RIPS	2	10	43.4	18.8	NA	3338.5	-12.8	56.4	Ownship was sitting still near the threshold of 35C, as the RIPS Van was traveling away from ownship, up the runway to set up for the run. Just as the Van was pulling off the runway, GBS began alerting, and continued to alert all the way up to and through the run. The run was executed, and both IDS and RIAAS alerted properly. All 3 systems ended alerting at approximately the same time after the run was over. There were no other vehicles nearby at the time of the false alert, and the TIS-based ownship position was not changing at the time of the false alert.
17-Oct	30347.7	MEL	NA	35	2687.5	17.8	NA	3338.6	-80.6	-11.1	Ownship had just landed and was slowing to a stop, well over the halfway point of Runway 35C. An aircraft (ID 19, FLT N2610Z) flew over part of Runway 35C near the threshold. TIS data indicated that this aircraft was on the ground, which was clearly untrue as it was traveling at close to 130 knots and its heading was not consistant with that of any of the runways.
19-Oct	NA	MEL	NA	53	NA	NA	NA	NA	NA	NA	Ownship was over 7 miles from the runway at the beginning of the DAS data file for this run. GBS alerted throughout the entire run, regardless of ownship position, indicating that this false alert was independent of the data and was probably the result of a transmission problem or computer glitch of some sort.
19-Oct	NA	RIPS	2	46	NA	NA	NA	NA	NA	NA	GBS was still producing the same false alert as in the previous run. The false alert continued throughout the entire run. It appears as though the alert was still "stuck" on due to some sort of computer problem.

Table H-3 continued – GBS False Alerts

False Alerts - GBS											
Date	UTC	Test System(s)	Scenario	Matrix Run #	Ownship Dist. To TH	Ownship Dist. To RWY	Ownship Dist. To HL	Traffic Dist. To TH	Traffic Dist. To RWY	Traffic Dist. To HL	Notes
19-Oct	NA	RAMP	NA	NA	NA	NA	NA	NA	NA	NA	GBS was still producing a false alert on the same target as the previous two false alerts. That target was stationary and was across the airport from ownship as RAMP operations were being conducted. The alert came on 12 seconds after data began recording for this run, and stayed on for the duration of the run.
20-Oct	20889.9	RIPS	1	63	-6224.5	NA	NA	5.0	-79.9	-10.4	GBS falsely alerted on a different ID on this run, though the position of this ID source was the exact same position as that for the ID that caused false alerts in the last 3 runs ((1879.77, 1859.79) meters on the x-y scale of the airport). Ownship was still a good way out in an arrival state, while the Van was completely stopped, sitting behind the hold line at the time of the falst alert.
20-Oct	NA	RIPS	4	62	NA	NA	NA	NA	NA	NA	GBS falsely alerted on the same ID as in the last run. This ID (220) is located at the exact same position (1879.77, 1859.79)m as recorded above. GBS switched to a different alert once the scenario was begun, and alerted properly based on ownship/Van movement. Once this alert state ended, GBS went back to the original alert.
20-Oct	NA	SF	NA	69	NA	NA	NA	NA	NA	NA	GBS falsely alerted throughout entire run on ID 220
20-Oct	NA	RIPS	3	61	NA	NA	NA	NA	NA	NA	GBS falsely alerted throughout entire run on ID 220

APENDIX I – ACRONYMS

ADS-B	Automatic Dependent Surveillance – Broadcast
AGL	Above Ground Level
AMASS	Airport Movement Area Safety System
ARIES	Airborne Research Integrated Experiment System
ARTS	Automated Radar Tracking System
ASDE-3	Airport Surface Detection Equipment radar
ASR-9	Airport Surveillance Radar
ATC	Air Traffic Control (Air Traffic Controller)
ATIDS	Airport Traffic Identification System
CDTI	Cockpit Display of Traffic Information
CNS	Communications Navigation and Surveillance
CPDLC	Controller-Pilot Data Link Communications
DAS	Data Acquisition System
DFW	Dallas-Fort Worth International Airport
DGPS	Differential Global Positioning System
FAA	Federal Aviation Administration
FIS-B	Flight Information Services – Broadcast
GBS	Ground-Based Alerting System
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
HSALT	Hold Short Advisory Landing Technology
HUD	Heads-Up Display
IDS-RSM	Integrated Display System – Runway Safety Monitor
INS	Inertial Navigation System
LAAS	Local Area Augmentation System
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NUC	Navigation Uncertainty
OD	Operational Deviations
OE	Operational Errors
PD	Pilot Deviations
PVT	Position, Velocity and Time
RCA	Runway Conflict Alert
RIAAS	Runway Incursion Advisory and Alerting System
RIPS	Runway Incursion Prevention System
RSM	Runway Safety Monitor
RTA	Runway Traffic Alert
RTO	Rejected Take off
SA	Situational Awareness
SGI	Silicon Graphics Incorporated
SSR	Secondary Surveillance Radar
STIS-B	Surface Traffic Information Services – Broadcast
TCAS	Traffic Alerting and Collision Avoidance System

UAT	Universal Access Transceiver
UTC	Universal Time Constant
VPD	Vehicle / Pedestrian Deviations
WAAS	Wide Area Augmentation System

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13. ABSTRACT *(Maximum 200 words)*
NASA's Aviation Safety Program Synthetic Vision System project conducted a Runway Incursion Prevention System (RIPS) flight test at the Dallas-Fort Worth International Airport in October 2000. The RIPS research system includes advanced displays, airport surveillance system, data links, positioning system, and alerting algorithms to provide pilots with enhanced situational awareness, supplemental guidance cues, a real-time display of traffic information, and warnings of runway incursions. This report describes the aircraft and ground based runway incursion alerting systems and traffic positioning systems (Automatic Dependent Surveillance - Broadcast (ADS-B) and Traffic Information Service - Broadcast (TIS-B)). A performance analysis of these systems is also presented.

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runway incursion, flight test, incursion alerts, surveillance system, ADS-B, TIS-B, runway incursion prevention system, aviation safety

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