

INITIAL TEST RESULTS OF PATHPROX – A RUNWAY INCURSION ALERTING SYSTEM

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Abstract

This paper describes the initial test results of PathProx – a runway incursion alerting system, intended to help minimize the number of runway incursions and provide conflict alerts for all aircraft and vehicles on the airport surface. Rannoch Corporation is the developer of PathProx, an avionics system designed to provide timely alerts directly to the pilot. The test results presented in this paper are primarily based on testing accomplished at Dallas - Fort Worth International Airport in October 2000, as part of the NASA Runway Incursion Prevention System (RIPS) tests.

Airport surface incursions have been identified as one of the most significant safety hazards in civil aviation, and yet thus far, there is no operational system to alert pilots automatically at the onset of such conflicts. PathProx is designed to monitor aircraft that are on the airport surface area and the airport's arrival and departure zones, and issues alerts when conflicts are detected.

The testing at DFW was accomplished with PathProx installed on the NASA B-757 Airborne Research Integrated Experiment System (ARIES) aircraft. Included as part of the installation were avionics to receive traffic position information from both ADS-B and STIS-B. This was used as the source of information on other traffic in the PathProx algorithms. The PathProx alerts were annunciated aurally as well as visually on a Head Up Display (HUD) and Electronic Moving Map (EMM). The testing included conducting simulated runway incursion scenarios, intended to generate conflict alerts.

Introduction

Rannoch Corporation is in the process of developing PathProx to provide runway incursion alerting to pilots in the airport surface environment.

PathProx is the commercial name for the product, while the generic name for the NASA project is RIAAS (Runway Incursion Advisory and Alerting System). The development is being funded partially by NASA through a cooperative agreement.

Runway Incursion Definitions

A runway incursion is defined by the FAA [1] to be “any occurrence at an airport involving an aircraft, vehicle, person, or object on the ground, that creates a collision hazard or results in the loss of separation with an aircraft taking off, intending to take off, landing, or intending to land.” The three primary causes of runway incursions are:

1. Pilot Deviations (PD) - An action of a pilot that results in violation of a Federal Aviation Regulation.
2. Operational Errors (OE) - An occurrence attributable to an element of the ATC system.
3. Vehicle/Pedestrian Deviations (VPD) - Incursions resulting from a vehicle operator, non-pilot operator of an aircraft, or a pedestrian who deviates onto the movement area (including the runway) without ATC authorization.

The FAA also recently started categorizing incursions by their severity [1]. There are four categories of severity, with Category A being the most severe and Category D the least. Category A is where the separation decreases and the participants take extreme action to narrowly avoid a collision. Category D is where there is little or no chance of collision and no evasive action is required. The number of runway incursions has increased significantly in the last few years, with a total of 431 being recorded in the year 2000 [2]. In addition to the increase in the total number, there has been a significant number of the most severe (Category A) incidents. For the years 1997-2000,

Category A incidents comprised 7 per cent of the total, with a total number of 90 such incidents [1].

Runway Incursion Incidents

Following are descriptions of three incidents that were near collisions resulting from runway incursions.

Chicago O'Hare, April 1, 1999: A China Airlines 747 freighter landed on Runway 14R and was cleared to taxi to the cargo area. The crew apparently became confused and reentered the runway. A Korean Air 747-400, taking off on Runway 14R, flew over the nose of the China Airlines plane at less than 50 feet, as it was raising its landing gear.

Los Angeles International, November 22, 1999: An Aeromexico MD-80 failed to hold short of an active runway and wandered into the path of a departing United Airlines 757. The United pilot lifted the 757 off early and missed the MD-80 by approximately 60 feet.

Providence, December 6, 1999: A United Airlines 757 landed on Runway 5R and turned off the runway onto a taxiway. It had been instructed to turn onto a taxiway leading to the terminal, but instead mistakenly turned back onto Runway 5R. The ground controller then cleared a Fedex cargo plane for takeoff on 5R. It passed directly overhead of the United 757. The United pilot informed the controller of the takeoff being in close proximity. However, the controller then gave takeoff clearance to a US Airways Metrojet, also on 5R. The pilots refused takeoff until the location of the United 757 was confirmed.

PathProx Application

With proper conflict detection and alerting available to the controllers and/or pilots, the incidents described above could have been prevented. PathProx runway incursion alerts are generated on-board the aircraft and are provided to the pilot. Providing the alerts directly to the cockpit has the advantage of minimizing the delays associated with ground based alerting systems in

reporting alerts. This was recognized by the NTSB in a recommendation concerning the prevention of runway incursion related accidents [3].

The operational concept established for the implementation of PathProx includes providing the following safety benefits:

- Extend conflict alerting to the airport surface
- Improved prevention of incursions by providing early alerting
- Improved capability of pilots for detection of conflicts
- Improved response to incursions by providing timely conflict alerting. This will minimize the number of the most severe incursions by allowing pilots to respond faster in taking evasive actions.

PathProx and RIPS System Overview

The NASA Runway Incursion Prevention System (RIPS) consists of both avionics and ground systems elements [4]. 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 without the ground system elements using aircraft-to-aircraft surveillance provided by ADS-B.

Figures 1 and 2 show the RIPS airborne and system architecture. Figure 1 is the avionics installed on the B-757. A SGI Onyx served as the hardware platform for the PathProx software. Runway incursion alerts were displayed on both a HUD and a Navigation Display (ND), illustrated in Figure 3. The ND presents an ownship proximate view of the movement area and traffic information. Highlighting the traffic symbol in red identified the location of the intruding traffic. Text messages were also displayed on both the ND and HUD. The RIPS Audio Alert System was used to provide runway incursion alert annunciations in the cockpit. Runway Traffic Alerts (RTAs) were annunciated in the cockpit as "Runway Traffic, Runway Traffic."

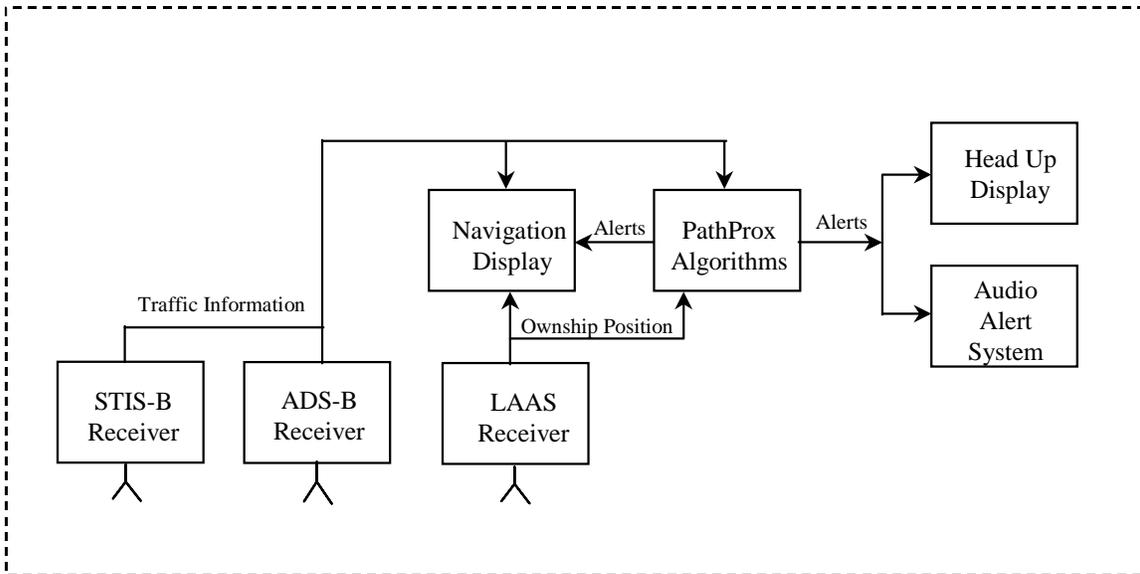


Figure 1. NASA RIPS Avionics Integration

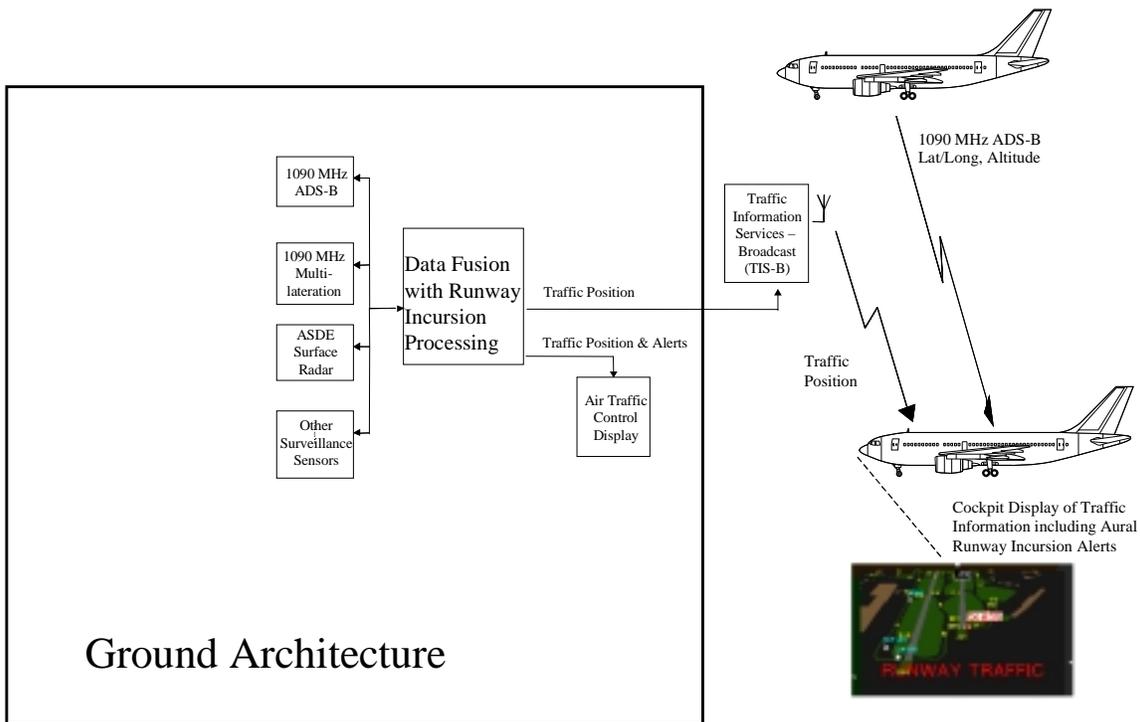


Figure 2. Systems Architecture

Runway Conflict Alerts (RCAs) were annunciated as “Runway Conflict, Runway Conflict.”

Ownship position determination was provided by differentially corrected GPS (Global Positioning System) LAAS (Local Area Augmentation System) and the Inertial Navigation System (INS). An INS/GPS blending technique was implemented to enhance accuracy performance. In addition, PathProx translated the aircraft position from the navigation reference (roughly the center of the aircraft) to the nose.

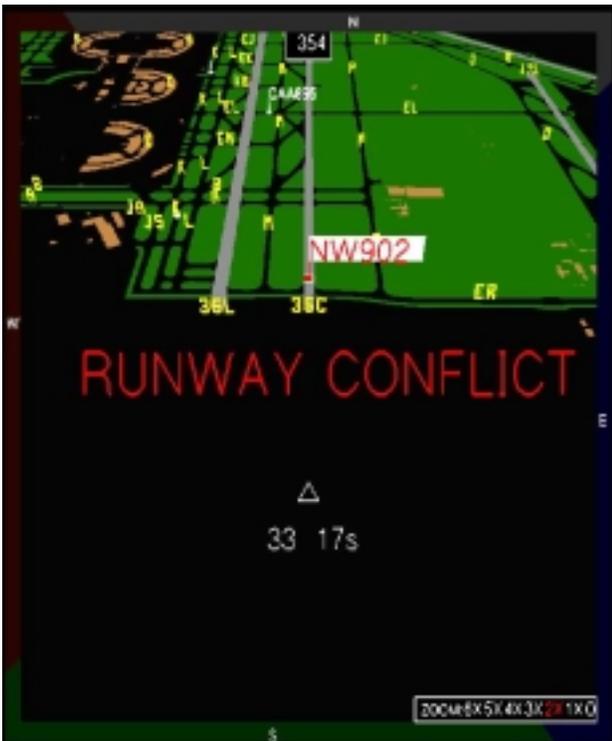


Figure 3. Conflict Alert Display (NASA)

Traffic information was obtained from both the 1090 MHz ADS-B and a STIS-B (Surface Traffic Information Service – Broadcast) data link. A Universal Access Transceiver (UAT) data link was used to provide ground systems derived traffic information to the B757.

The implementation of PathProx also requires an infrastructure outside of the aircraft (Figure 2). Optimum implementation involves a ground system that includes a combination of airport surface surveillance sensors. Aircraft and vehicle position information is then broadcast to the aircraft via STIS-B. PathProx will also operate

when STIS-B is not present at an airport, by using traffic information available from ADS-B equipped aircraft.

Alerting Concept

PathProx is designed to handle over forty different runway incursion scenarios. Figure 4 depicts four common scenarios that were simulated during the testing at DFW. The alerts are determined based on a combination of aircraft and vehicle states and conditions including location, speed, track angle. State determination includes arrival, departure, taxi, and stopped. PathProx will provide two types of alerts, analogous to TCAS. A Runway Traffic Alert 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 is provided when a runway incursion has been detected, and there is potential for collision. An RCA indicates that the aircraft involved in the conflict need to take evasive action to avoid the potential collision. PathProx does not provide guidance information to the pilot for taking evasive action. Information provided with each alert includes identification of the incurring aircraft (or vehicle), the runway associated with the aircraft, separation distance and time to conflict. This should provide enough information to the pilot to determine proper evasive action.

Two of the benefits of PathProx is that it does not rely on air traffic controller input; nor does it rely on ground systems to generate incursion alert messages. This makes it possible for equipped aircraft to benefit from increased safety even when flying into airports that are not equipped with ground-based incursion prevention and detection systems.

Flight Tests

NASA conducted flight tests of PathProx as part of the Aviation Safety Program RIPS project at Dallas - Fort Worth Airport during September and October of 2000. Four runway incursion scenarios were simulated involving the NASA 757 ARIES and a test van (see Figure 4). In scenario 1 the 757 was conducting an approach when the test van

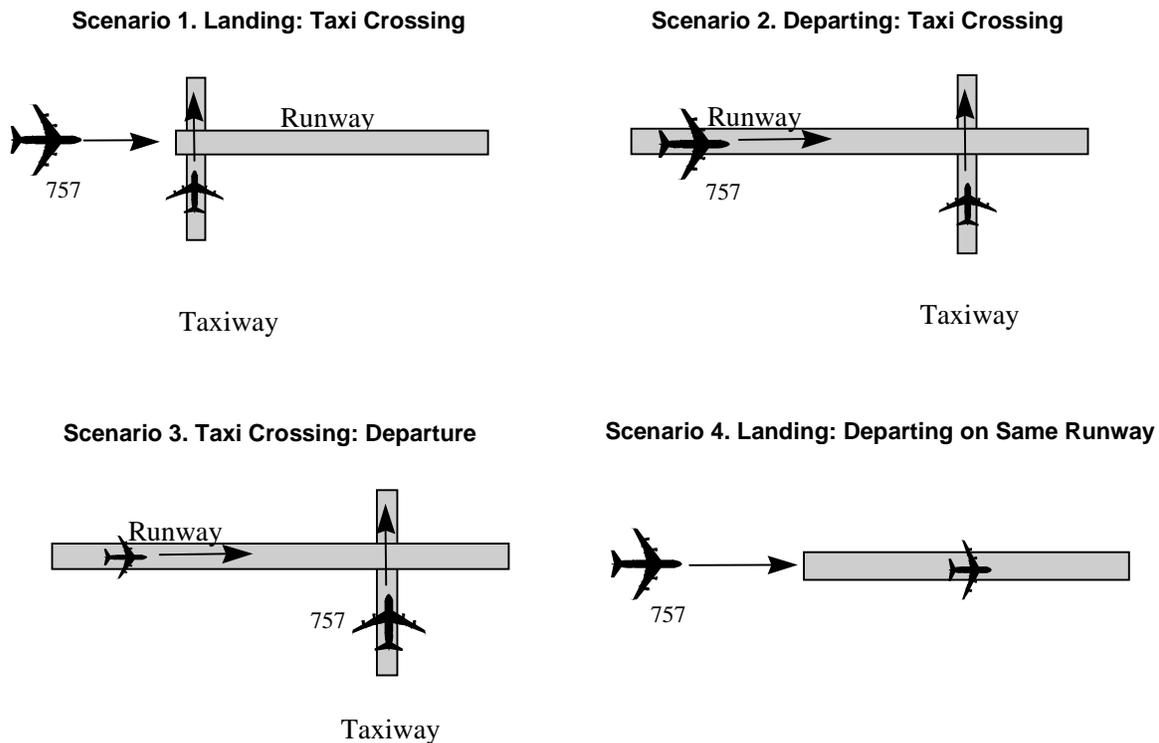


Figure 4. DFW Runway Incursion Test Scenarios

(simulating another aircraft) taxis onto the active runway. In scenario 2 the 757 initiates a takeoff when the test van taxis onto the runway. Scenario 3 is the reverse of scenario 2, with the test van simulating an aircraft taking off, when the 757 taxis onto the runway. In scenario 4 the 757 is on approach when the test van simulates an aircraft departing on the same runway, causing a loss of separation. Prior to the flight tests, NASA had conducted tests of the same scenarios in the Langley Research Center Research Flight Deck (RFD) simulator. This allowed the researchers to optimize the timing of the scenarios, as well as obtain feedback from NASA test pilots.

A total of 47 test runs were conducted, which included a mix of the four incursion scenarios. In addition the source of traffic data for the test van was alternated between STIS-B only and both STIS-B and ADS-B.

PathProx performed as designed throughout all of the DFW testing. Alerts were generated during 44 of the 47 test runs. The three runs with no alerts were all attributed to erroneous data and data drop-outs associated with STIS-B and ADS-B traffic data. There were also three other runs where the alerts were late, again due to missing or erroneous traffic data.

A graphic illustrating when the alerts occurred for scenario 1 is shown in Figure 5. Typically the RTA occurred with the aircraft at an altitude of 350 feet. The test van normally was 20 m (meters) over the hold line and 50 m from the runway. The RCA typically occurred with the aircraft at 200 feet, and the test van on the runway. This provided sufficient warning for the pilot to do a go-around. In some cases the pilots elected to initiate the go-around when they received the RTA. The average time between the RTA and RCA for scenario 1 was 13 seconds.

For scenario 2, the rejected takeoff, the aircraft reached an average speed of 60 knots when the RTA was received. The test van was 10 m over the hold line and 65 m from the runway. The RCA was usually received 2 seconds after the RTA. This was due to the critical nature of this scenario, which requires providing the warning to the pilot as soon as possible. In all cases the pilot was able to safely reject the takeoff. Due to timing of the scenarios, single alerts (RCA-only) were received in some runs.

For scenario 3, where the 757 was now the intruding aircraft and the test van was simulating an aircraft on takeoff, the RTA occurred with the nose of the aircraft 1 m over the hold line. The RCA typically occurred 6 seconds later, with the aircraft 25 m over the hold line and 50 m from the runway. The pilot was able to safely stop the aircraft prior to entering the runway. This scenario illustrated the benefit of providing a correction of the position reference to the nose of the aircraft instead of the aircraft centroid or antenna location. This enabled more accurate and timely alerting.

For scenario 4, where the aircraft was conducting an approach with the van simulating a departure, the RTA typically occurred with the aircraft at 350 feet altitude and the test van just over the hold line. The RCA normally occurred with the aircraft at 130 feet altitude and the test van on the runway traveling at 60 knots. The average separation distance between the vehicles was 8600 feet at the time of the RCA. Again in all cases the pilot was able to safely execute a go-around.

PathProx generated only two false alerts throughout all of the DFW testing. Both were the direct results of erroneous ADS-B data.

Summary and Conclusions

The primary conclusion of the initial testing is that the baseline design of PathProx was demonstrated to be capable of providing aircraft-based runway incursion alerting. The alert thresholds chosen for the four scenarios tested provided adequate safety margins. The testing showed that the pilot could safely take evasive action when the RCA was issued. In most cases, the RTA occurred several seconds before the RCA, thus demonstrating the advanced warning capability of a two-level alerting approach.

Regarding the integration of PathProx with the supporting airborne and ground systems, the test results indicate that the basic system architecture supports aircraft-based incursion alerting. The 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, due to erroneous position reports. Indications are that the maturity of the prototype systems involved played a significant role in the availability and integrity of the traffic data.

Continuing development of PathProx will include further optimization of the alert thresholds for all incursion scenarios, including both traffic and conflict alert levels. There will be more investigation regarding whether some level of verification of the traffic data is required to better handle erroneous information. This may include outlier rejection and track smoothing. Additional simulator testing is planned by NASA which will provide more feedback from pilots regarding the alerting algorithms.

References

- [1] FAA Runway Safety Report, FAA Office of Runway Safety, June 2001.
- [2] FAA Runway Safety Program website, www.faa.gov/runwaysafety.
- [3] NTSB Most Wanted Transportation Safety Improvements, www.nts.gov, and Recommendation A-00-66, July 6, 2000.
- [4] “*Plan of Test – Runway Incursion Prevention System (RIPS) and Hold Short Advisory Landing Technology (HSALT) DFW Flight Experiment*,” D. Jones, NASA Langley Research Center, August 2000.
- [5] “*PathProx – A Runway Incursion Alerting System*,” R. Cassell, C. Evers, E. Yang, Rannoch Corporation, 19th Digital Avionics Systems Conference, October 2000.

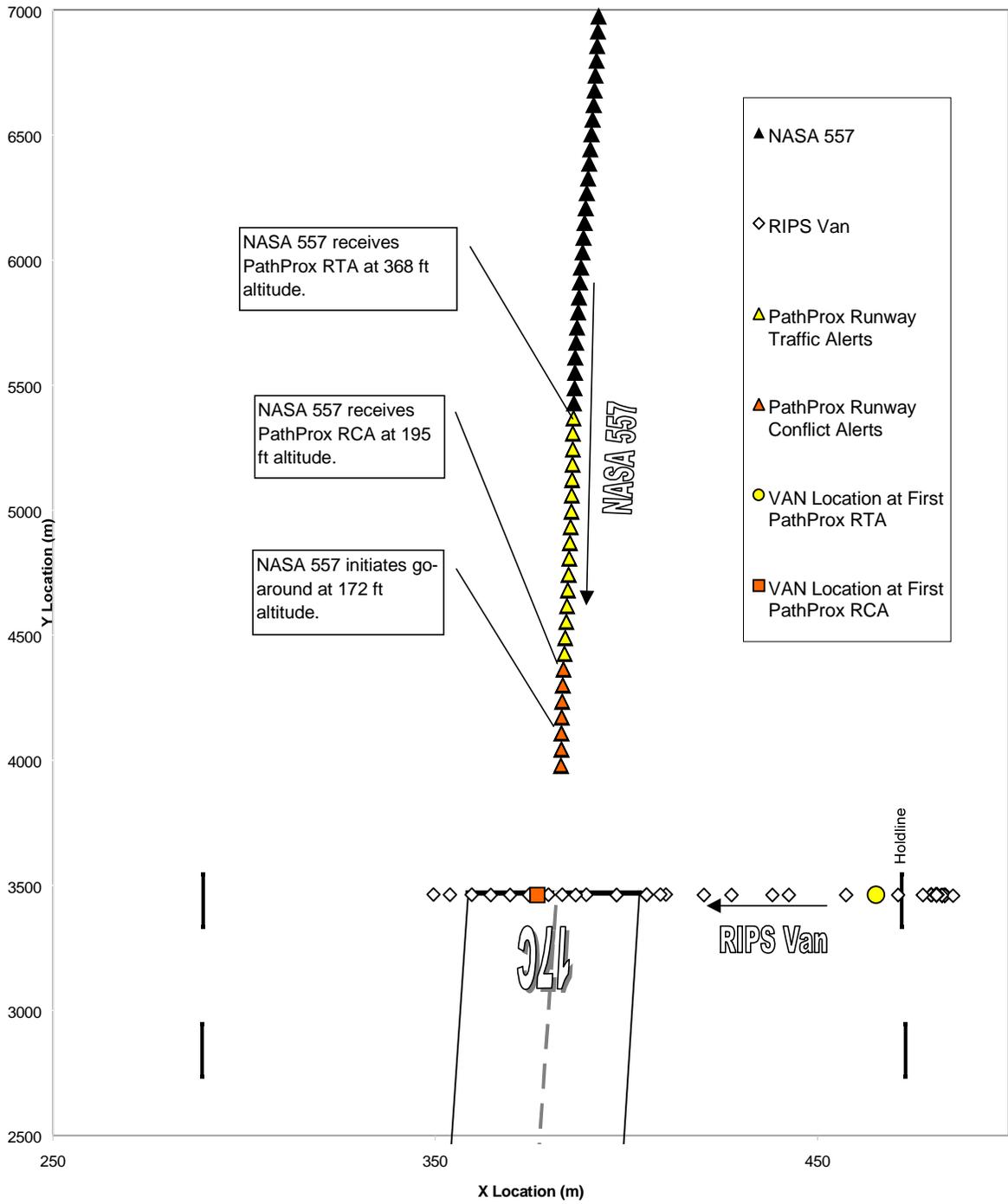


Figure 5. PathProx Alerts for DFW Test Scenario 1