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Results of Human-In-The-Loop Simulation Evaluating an Enhanced Runway Safety System With Ground-Based Direct Pilot Warnings

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Abstract

This document describes a human-in-the-loop simulation evaluating the effectiveness of integrated ground-based warning systems for improved runway safety. The evaluated warning systems contained technologies to enhance pilot awareness, as well as warn pilots about runway safety risks. Pilots experienced simulation scenarios with warning systems that provided either visual or audio warnings about surface traffic. In addition, pilots experienced simulation scenarios in a baseline condition, with no warnings. The ground-based warnings consisted of airport surface lights including Runway Entrance Lights, Take-off Hold Lights, Arrival Warning Lights, and an Auditory Arrival Runway Incursion Alerting System. Eye tracking was used to examine where pilots focused their attention when they are taxiing, departing, and arriving. Results indicate significant safety benefits of ground-based pilot warnings by reducing the likelihood of runway safety incidents.

KEYWORDS: runway safety, direct pilot warning, runway entrance lights, take-off hold lights, arrival warning lights, AMASS, direct AMASS alerting, human error induction methodology, human error reduction methodology, airport surface simulation, runway conflicts, runway collisions, human-in-the-loop simulation, arrival runway incursion alerting system, runway safety incidents

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Section 1

Introduction

Runway incursions at towered airports in the United States (U.S.) have been a major area of concern for the Federal Aviation Administration (FAA) for the past several years. The U.S. National Airspace System (NAS) has approximately 500 FAA/contract towered airports that handle approximately 176,000 operations per day. Of the approximately 257 million operations at U.S. towered airports from Fiscal Year (FY) 2001 through FY 2004, there were 1,395 runway incursions, averaging one incursion per day during the four year period (FAA 2005).

The safety service of the Air Traffic Organization (ATO) of the FAA is tasked to determine the feasibility of a system to mitigate runway incursions at airports that have scheduled passenger service in order to address National Transportation Safety Board (NTSB) recommendation A-00-66 (NTSB, 2000). NTSB recommends that any implemented ground movement safety system should provide a direct warning[1] to the flight crew. Additionally, simulations should demonstrate that the system prevents runway incursions.

The FAA is researching a prototype ground movement safety system per the NTSB recommendation, and initial phases of system planning were completed in FY 2004 (Andrews, Dorfman, Estes, Jones & Olmos, 2005). This phase included runway incursion risk ranking of airports (prioritized needs assessment), identification of possible near-term technologies applicable to runway incursion mitigation, and establishment of recommended solution sets. The initial set of possible technologies included the Airport Movement Area Safety System (AMASS), Runway Status Lights System (RWSL), and a set of technologies to enhance pilot awareness about the runway. The RWSL consists of Runway Entrance Lights (REL) and Take-off Hold Lights (THL).

This document provides the results of a Human in the Loop Simulation conducted in FY 2006 that evaluated the benefits and limitations of such a ground movement safety system to support the FAA ATO in their feasibility assessment.

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[1] This document uses a definition of direct pilot warning that is adapted from Laughery & Wogalters (1997): "Warning consists of information that facilitates operators' awareness of safety hazards and enables them to make informed decisions to initiate appropriate behavior to avoid the hazards." Note that this definition of warning may include various elements such as markings, signage, and surface lights, as well as auditory or visual warnings in the cockpit.

1.1 Background

Initial versions of the prototype ground movement safety system were evaluated in a simulation study in FY 2005 to assess the completeness of the recommended solution and identify modifications as needed, see Moertl (2005). The results of that simulation indicated that the lighting systems provided benefits, specifically:

- REL eliminated unsafe runway crossings at the tested intersections.
- THL reduced unsafe take-off maneuvers by 86%.
- AWL (Arrival Warning Lights) reduced unsafe landings by 63%.
- An experimental auditory warning system reduced the number of unsafe arrivals by 80%.

The findings also demonstrated limitations of the evaluated warning configurations:

- The illumination of THL was not always appropriately perceived, processed or responded to by pilots. This was in part due to the lack of conspicuity of the simulated lighting configuration, as well as the variability in the scan patterns of pilots during the take-off maneuver; not all pilots noticed the illuminated lights.
- The illumination of AWL was not always appropriately processed or responded to by simulation participants. This was due in part to the location and conspicuity of the AWL configuration, as well as due to the variability of the pilot scan patterns during the landing maneuver; not all pilots noticed the illuminated lights.
- The auditory warnings were not always appropriately processed by pilots. This was in part related to the low volume of the warning, perceived inconsistency between visual and auditory warnings as well as insufficient clarification of procedural control responsibilities.

To respond to the identified shortcomings, and compare different lighting configuration concepts, research was subsequently performed to improve system effectiveness. Moertl, McGarry, and Hawkins (2006) performed a simulation to compare three THL configurations to improve signal detection. The first THL configuration consisted of a single row of lights that was placed close to the runway centerline; lights were spaced longitudinally 100 feet (ft) apart. The second configuration consisted of two lateral rows of lights that were longitudinally spaced 200 ft apart. The third configuration consisted of lateral bars of six lights that were longitudinally spaced 300 ft apart. Though no differences in response times to the three THL configurations were detectable, pilots rated the effectiveness of THL Configuration Three highest. THL Configuration Two was rated the next most effective, and THL Configuration One was consistently rated the lowest.

To identify alternative arrival warning methodologies, Moertl & Andrews (2006) held a workshop with a panel of eighteen runway safety experts including representatives from the FAA, airports, airlines, and air traffic control; who suggested runway safety solutions for the development of an integrated ground movement safety infrastructure. The workshop provided a common terminology and framework for direct pilot warnings. The participants arrived at recommendations and a suggested set of thirty-three technological ground and cockpit-based direct pilot warning solutions toward the development of an integrated ground movement safety infrastructure. Based on these recommendations, an improved ground movement safety system with direct pilot warning capabilities was outlined by Moertl, Domino, & Peed (2006).

This document describes a study that assessed the safety benefits and limitations of the improved ground movement safety system based on the lessons learned in earlier research. The following subsections outline the evaluated technologies that are part of the safety system. Section two describes the methodology of the study and Section three describes the study results. Section four contains conclusions and next-step research recommendations.

1.2 Runway Status Lights System

The RWSL is currently being researched by Massachusetts Institute of Technology (MIT) Lincoln Lab (Thompson and Eggert, 2001) and under operational evaluation at Dallas Fort Worth International airport (DFW). It is designed to reduce the risk of runway incursions by visually warning pilots and ground vehicle operators when the potential for a runway incursion exists. The RWSLs currently consist of REL and THL[2]. REL provide a warning in the form of steady red lights at the runway hold short marking; see Figure 1-1 and Figure 1-2. THL are on the runway and provide warnings to departing aircraft. The current RWSL concept does not include any warnings for arrivals. When the RWSL, driven by a surveillance network (e.g., ASDE-X), detects an aircraft in the process of taking off, landing, and/or crossing the runway, the REL or THL illuminate. The REL and THL systems in this simulation were based on specifications by Thompson and Eggert (2001) as well as the RWSL site adaptation at DFW and as specified by the RWSL website at http://www.rwsl.net/.

[2] Additions to the RWSL that are currently being considered are Runway Intersection Lights (RIL) and Final Approach Runway Occupancy Signal (FAROS).

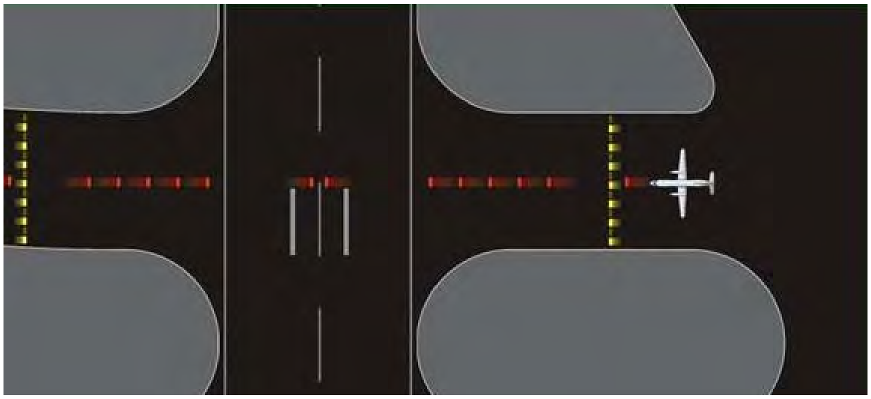

Figure 1-1. Illustration of REL

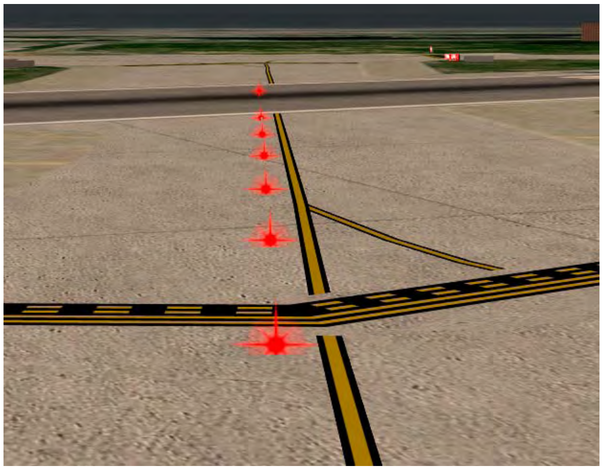

Figure 1-2. REL as Seen From the Cockpit

1.2.1 Runway Entrance Lights

REL are intended to warn pilots who taxi toward the runway hold-short environment that another aircraft is either landing (within 0.75 nautical miles of the landing threshold) or departing on the runway at a speed higher than 30 knots[3] (kts), and is located prior to that runway intersection. REL consist of red in-pavement fixtures that are installed longitudinally along the taxi path, beginning just prior to the taxiway/runway hold position marking and extending to the runway edge, with one additional REL installed near the

[3] In the simulation a threshold of 35 knots was used.

runway centerline on the line extended from the last two lights on the taxiway. REL are directed toward the taxiway hold line and are oriented to be visible only to pilots and vehicle operators who cross/enter the runway from that location. The longitudinal spacing for the lights is between 12.5 ft to 50 ft so that four lights were positioned between the hold line and the runway edge. A final light was placed at the straight extensions of the lights at the runway centerline.

The REL system is designed to provide a direct status indicator to pilots that a runway is unsafe to cross/enter. The system is fully automatic, surveillance-driven, and does not require input from the Air Traffic Control Tower (ATCT). However, the ATCT can set the brightness levels and can activate and deactivate the system by manual override.

All REL are simultaneously illuminated when an aircraft is on final approach. REL progressively turn off at the lighted taxiways just prior to the landing aircraft passing the taxiway. All REL turn off as the landing aircraft reaches taxi-speed.

All REL illuminate when a departing aircraft accelerates beyond 30 kts. All REL turn off when the departing aircraft transitions to airborne status or decelerates below maximum taxi-speed.

The turning off or absence of illuminated REL does not constitute a clearance to cross/enter the runway. REL indicate runway status only.

1.2.2 Take-off Hold Lights

THL are intended to warn pilots who are about to initiate a take-off that another aircraft is on the runway or is predicted to enter the departure runway, indicating it is not safe for takeoff (see Figure 1-3). THL illuminate if an aircraft is located in the departure region of a runway, or is in process of taking off and another aircraft is on the runway, or is predicted to enter that departure runway. Different from REL, THL require the presence of two aircraft or one aircraft and a vehicle to be triggered. The system is fully automatic, surveillance-driven, and does not require input from ATCT. However, the ATCT can set the brightness levels and can activate and deactivate the system by manual override. Like for REL, extinguished THL do not constitute a clearance to depart from a runway. THL indicate runway status only.

The THL configuration evaluated in this study consisted of 18 lights extending 1,600 ft (see Figure 1-3). The lateral THL spacing followed the same principle as runway aiming point markings that are laterally spaced at the same distance as touch-down zone lights. THL were spaced at half of the lateral spacing between the inner sides of the touch down zone lights and the runway centerline, at 36 ft in this case[4]. The lights were spaced to longitudinally fall between the runway centerline lights at 200 ft apart.

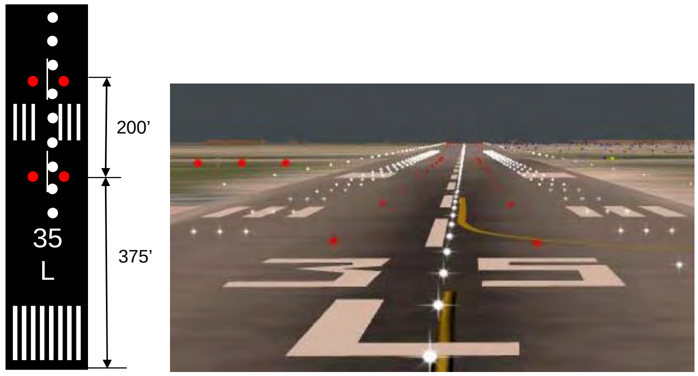

Figure 1-3. THL Configuration 2

1.2.3 Arrival Warning Lights

The evaluated AWL consist of flashing Precision Approach Path Indicators (PAPI) and illuminated THL. PAPI continue to indicate the vertical glide path angle as under current operations. The warning indicates to an arrival aircraft that it is unsafe to land and that therefore, a go-around maneuver should be initiated. The THL, in addition, warn a departing aircraft on the arrival runway that a take-off is unsafe because a go-around is currently ongoing on the same runway.

The AWL system is fully automatic, surveillance-driven, and not actuated by the ATCT. It is controlled by a surface surveillance and warning system such as AMASS that uses aircraft position information to determine potential conflicts. When AWL activate, the ATCT receives an auditory warning in the ATCT.

The ATCT can set the brightness levels of the THL, and can activate and deactivate the AWL system. Illuminated AWL do not constitute an Air Traffic Control (ATC) clearance.

[4] All runways in this simulation were 150 ft wide. For runways that are less than 150 ft wide, the markings and lateral spacing of the markings would have been decreased in proportion to the actual runway width, see FAA (2005a).

1.3 Auditory Runway Incursion Alerting System

The Arrival Runway Incursion Alerting System (ARIAS) is a ground-based direct pilot warning system to increase runway safety for arrival aircraft. The ARIAS provides auditory warnings to the flight crew during approach to a runway if a conflict is predicted on that runway. Flight crews respond to the warning by preparing to initiate a go-around maneuver and by contacting ATC about the conflict.

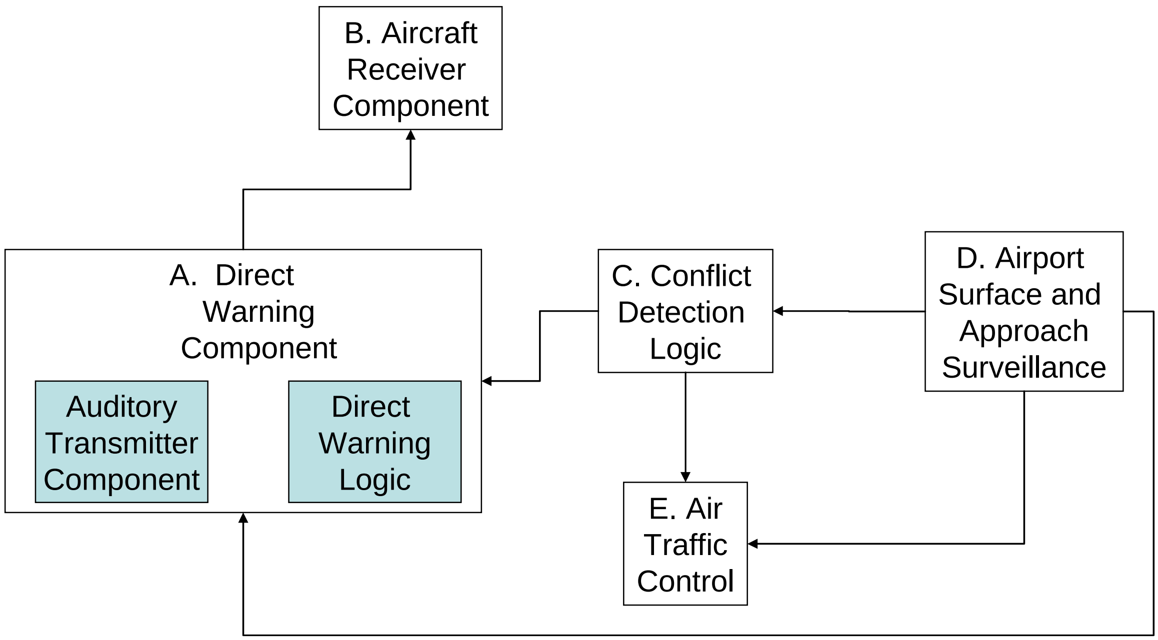

Figure 1-4. Functional Depictions of ARIAS Components

Referring to the diagram in Figure 1-4, the Direct Warning Component (A) receives input from a conflict detection logic that predicts conflicts on the airport surface for arrival situations, (C). The conflict detection logic determines conflicts based on inputs from airport surface and approach surveillance (D) which are also forwarded to Air Traffic Control (E). The direct warning logic determines if warning timing is appropriate for the current conflict and formulates an auditory warning message that is transmitted to the flight-deck (B). Air Traffic Control receives a warning in the tower cab at the same time.

The ARIAS system is fully automatic, surveillance-driven, and not activated by the ATCT. It is controlled by AMASS, that uses aircraft position information to determine potential conflicts.

The technologies that were outlined above were evaluated in a Human-in-the-Loop simulation. The following sections in this document describe the performed simulation and results. The last section provides conclusions and summarizes the findings.

Section 2

Study Objectives and Method

The objective of this simulation study was to evaluate ground-based direct pilot warnings concerning the prevention of runway incursions.

The study objective was addressed in a flight simulation. In this simulation, pilots were asked to complete scenarios in which they operated a flight-deck simulator under approximated realistic conditions and either did, or did not receive warnings about an impending runway incursion. Pilots were asked to provide feedback about the warning systems and rated the systems on various dimensions. Also, pilot response times to the alerts were assessed as was distance to conflicting aircraft.

Pilots were asked to complete flying and taxiing tasks in the simulator with the assistance of a second (confederate) pilot. This was done to approximate realistic flight-crew operations. The confederate pilot communicated via radio with an ATCT controller from whom the crew received clearances and taxi instructions. The confederate pilot also provided assistance with various cockpit tasks, including checklist completion.

2.1 Participants

Twelve pilots participated in this simulation. All pilots, regardless of their experience, operated the same simulator. Eleven pilots held commercial/ATP/CFI pilot certificates. The average age of the pilots was 45 years, and they had an average of 20 years of pilot experience. The average overall flight hours were 6900 with an average of 120 hours flown in the previous 90 days. The pilots were paired into six matched pairs, based on experience. Four pairs consisted of commercial and professional pilots, and two pairs consisted of general aviation pilots.

2.2 Simulation Environment

The MITRE Corporation’s Center for Advanced Aviation System Development’s (CAASD) Integrated Air Traffic Management (ATM) laboratory hosts an integrated terminal area and flight simulation environment (Oswald and Bone, 2002). This medium fidelity simulation environment supports end-to-end evaluations from both flight-deck and ATC perspectives. The main simulation functions that were used in this study included a cockpit simulator (with external visual scene), a ground traffic generator, and an airport surface traffic display. All applications run on networked Linux workstations. The simulation was adapted to the Louisville International Standiford Field (SDF) and Los Angeles International (LAX) terminals and airport surface movement areas.

The cockpit is an enclosed, fixed base, mid-fidelity transport aircraft simulator (see Figure 2-1). It is configured as a generic twin-engine, large weight category, jet aircraft with an auto-throttle system. Though configured as transport aircraft, General Aviation pilots provided with appropriate training have effectively used this simulator in previous CAASD studies. The simulation includes audio capabilities supporting aircraft environmental sounds (e.g., slipstream noise), and ATC communication. The cockpit provides two standard flight crew positions, and an observer position. For aircraft control, both the left and right seat positions are equipped with side-stick controllers. The center pedestal houses the throttle quadrant, flap handle, and speed brake lever. Twenty-one inch touch-screen displays are located in front of the left and right seat positions, and display the Primary Flight Display (PFD) instruments and Navigation Display (ND). A nineteen inch display occupies the center instrument panel and displays engine and flap status and landing gear status information.

Figure 2-1. MITRE/CAASD's Cockpit Simulator

The cockpit out-the-window (OTW) view is projected via three large scale high-resolution projectors, on a 130-degree field-of-view, curved screen providing pilots with a virtual three-dimensional representation of the simulated airport surface and its environment. Various visibility conditions such as night, dusk, and haze are approximated as appropriate. The main OTW elements are aircraft, airport surface structures, surrounding terrain, and various environmental features including weather (e.g., haze). Airport surface signage, enhanced markings, and lighting are implemented as appropriate.

The simulation capability allows pseudo-pilots to control aircraft on the airport surface and in the immediate surrounding airspace (Figure 2-2 depicts the pseudo-pilot interface). The simulation capability includes a ground traffic generator to produce airport surface ground traffic, such as aircraft and/or vehicles that the participating pilots saw through the cockpit window. The ground traffic movement is initiated and timed based on the pilots' aircraft movements to provide the desired encounter geometries.

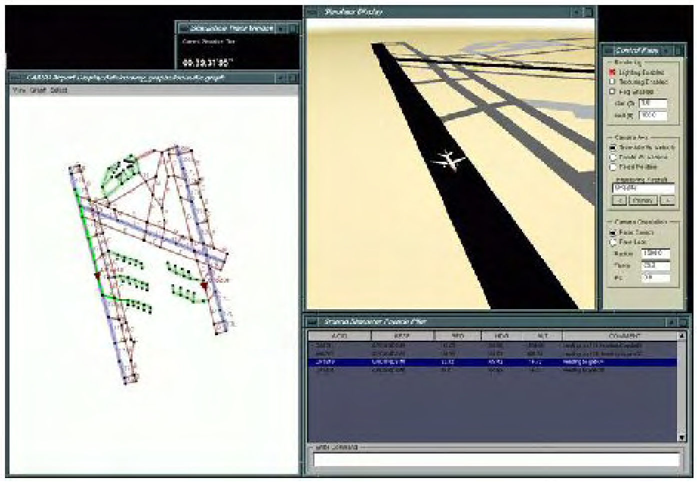

Figure 2-2. Screen Capture of the Ground Traffic Generator and Pseudo-Pilot Interface

The simulation environment also contains the Applied Science Laboratories 6000 Series H6 head-mounted eye tracker. The eye tracker consists of a magnetic receiver which is placed directly behind the pilot's seat, a magnetic transmitter, camera, and a monocle on the pilots head. The transmitter is located on a headband that pilots wear, tightened to a comfortable point. See Appendix J, Eye Tracker Information, for a more detailed description of the eye tracker.

2.3 Simulation Scenarios

There were a total of eleven possible experimental scenarios. Prior to seeing the experimental scenarios, pilots saw three familiarization/warm-up scenarios. These were provided to make pilots comfortable with the cockpit simulator, and to introduce them to the warning technologies. Five of the experimental scenarios were shown to pilots in either a baseline condition (without warnings), or in a matched warning condition (with visual warnings); two of the experimental scenarios were shown with either an AWL warning, or in the matched scenario with an ARIAS warning; the remaining four scenarios were shown only in a warning condition (see Table 2-1).

Table 2-1. Overview of Simulation Scenarios

Scenario	Conditions	Participant	Scenario Type
1 (b)	Experimental Only	Taxies toward runway 35R for departure and erroneously cleared to cross runway 11 while conflict a/c is on approach on that runway	Runway Crossing
2 (a & b)	Baseline + Experimental	After landing on runway 24R, enters closely spaced parallel runway, while conflict a/c is on departure roll on runway 24L	Runway Crossing
3 (a & b)	Baseline + Experimental	Cleared for take-off, but conflict a/c that landed prior to the departure clearance remains on same runway 25L	Departure
4 (a & b)	Baseline + Experimental	Cleared for take-off on runway 29, conflict a/c starts departure roll on intersecting runway 35L and causes conflict at intersection	Departure
5 (b)	Experimental Only	Cleared for take-off, conflict a/c enters runway 35L	Departure
6 (b)	Experimental Only	Is in TIPH on runway 29, while conflict a/c arrives on same runway	Departure
7 (b)	Experimental Only	Cleared for take-off on runway 25R, conflict a/c arrives on closely spaced parallel runway 25L and enters pilots departure runway	Departure
8 (b & c)	Experimental Only	On approach for 35R, conflict a/c erroneously turns onto runway 35R	Arrival
9 (a & b)	Baseline + Experimental	On approach for 25L, then is switched onto runway 25R where a conflict aircraft is in position and holding	Arrival
10 (a & b)	Baseline + Experimental	On approach for 35R, a conflict a/c is in position and holding on 35R and never initiates take-off	Arrival
11 (b & c)	Experimental Only	On approach for 35R, conflict a/c is on approach on intersecting runway 29	Arrival

Note: a: baseline condition; b: warning light condition; c: audio warning condition

There were two runway-crossing scenarios. One of these two scenarios was shown only in the warning condition, with no matched baseline, while the other one was shown in a baseline and warning condition.

There were five departure scenarios. Two scenarios were shown in both a baseline and a warning condition, while three were only shown in the warning condition.

There were four arrival scenarios. Two scenarios were shown in a baseline condition, and in the warning condition. The remaining two scenarios were shown only in the warning condition (with auditory or visual warnings). See Appendix M for more information on the scenario conditions.

The scenarios that had matching baseline and warning conditions were used to compare performance between the baseline and warning conditions. Those scenarios that did not have a matched baseline or ARIAS warning condition were used for eye tracking analysis, and for the calculation of the likelihood of a runway safety incident.

Table 2-2. Scenario Conditions Used in Analysis

“Matched” scenarios used for analysis

Condition	Scenario(s)
Runway Crossing Baseline	2a
Runway Crossing Warning (REL)	2b
Departure Baseline	3a & 4a
Departure Warning (THL)	3b & 4b
Arrival Baseline	9a & 10 a
Arrival Warning(AWL)	9b & 10b
Arrival Warning (AWL)	8b & 11b
Arrival Warning (ARIAS)	8c & 11c

2.4 Experimental Design

The experiment followed a between-subjects design. Pilots were paired to see the same scenarios but in different conditions. Pairings occurred based on type of flying experience, age, and type of pilot license. Between the two pilots, each pair saw each of the four alert types. An in-house ATCT controller served as a confederate, and issued control instructions to the pilot.

The paired groups of pilots were presented with the simulation scenarios in randomized order. The design was not completely crossed, and not all scenarios were shown in a baseline condition in order to manage simulation duration within schedule constraints. Between the two pilots in the pair, each group saw all four warning types. Conflict opportunities were embedded in these scenarios, and pilots were given enough information through background chatter between the controller and simulation pilot to detect these conflict opportunities. See Appendix F for the scenario run order.

Pilots were not aware in which condition (baseline or warning) they would see the scenarios. This was done to reduce pilot expectations of receiving a warning in each scenario. Each pilot was shown 2 of the 4 non-matched scenarios, and one of the two conditions for the other 7 scenarios for a total of nine experimental scenarios. Their paired counterpart saw the matched scenario conditions, and the other 2 of 4 non-matched scenarios. Table 2-3 shows an example of the conditions and scenarios seen by the pilot pairs. The letter “a” refers to the baseline condition of that scenario number, letter “b” to the warning light condition, and letter “c” to the audio warning condition.

Table 2-3. Example of Scenarios Shown to Pilot Pairs

	Scenario																	
Pilot Pair	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5b**	**6b**	**7b**	**8b**	**8c**	**9a**	**9b**	**10a**	**10b**	**11b**	**11c**
Pilot 1	x	x		x		x				x	x		x		x			x
Pilot 2			x		x		x	x	x			x		x		x	x	

2.5 Procedure

Pilots were briefed prior to entering the cockpit simulator on the different warning technologies they would be experiencing in the study. Then pilots were brought into the simulator for training and data collection. After completing the experimental scenarios, pilots were debriefed by the experimenters.

2.5.1 Pilot Briefing

Members of the experiment team briefed each pilot individually concerning the experimental procedure. The briefing covered the following topics:

- Pilot rights and informed consent
- Pilots' role in the study
- Study objectives
- Study methodology
- Information about the eye-tracking methodology
- Training on REL, THL, AWL, and ARIAS
- Cockpit familiarization
- Training on taxiing and departing in the simulator

Following the briefing, the pilot was asked to sign the informed consent document and to complete the demographics questionnaire.

2.5.2 Training

The purpose of the training was to familiarize pilots with the simulation environment and the warning technologies that they would later experience in the simulation. Specifically, the training procedure was intended to be realistic in the way that it approximated how pilots learn about new airport systems in the real world.

Pilots learned about the runway safety technologies by reading a brochure and viewing pictorial material about the technologies. The training material is contained in Appendix C, "Training Material". Pilots were instructed to thoroughly read and understand the material that informed them about how to use the technology. Pilots were also encouraged to ask any questions to help them understand the technologies.

The training procedure familiarized pilots with the following warning technologies:

- Runway Entrance Lights
- Take-off Hold Lights
- Arrival Warning Lights
- Auditory Runway Incursion Alerting System

Pilots were then afforded a warm-up with the flight simulator, until they felt comfortable with the operations. The pilot was asked to taxi on the airport surface, take off, and fly an approach to the simulated airport. More training was provided on the equipment, if needed, and as determined by the experimenter.

2.5.3 Scenario Runs

Once pilots indicated that they felt comfortable operating the cockpit simulator, they were given two familiarization runs to introduce them to the warning systems. After completing the familiarization trials, the eye-tracker was calibrated. Then the experimental trials began. Each scenario lasted approximately five minutes. The pilots received their flight instructions at the start of each scenario from the confederate pilot. These instructions informed the pilot as to the nature of the scenario (arrival, departure), which airport they were at (LAX, SDF), and where they would be at the start of the scenario (taxiway, runway, approach). Dependent on the scenario, the confederate pilot initiated a radio call to the simulation air traffic controller to request taxi instructions, a departure clearance, or an arrival clearance. The controller provided the pilot with the appropriate instructions. During the scenarios, pilot workload was assessed. There was a short break between each scenario to prepare the simulator for the next run during which the pilot responded to survey questions about the seen scenario on a laptop computer.

2.5.4 Debriefing

At the end of the simulation, the pilot was informed about the purpose of the simulation. During the debriefing, pilots were asked to complete an exit survey and give any additional comments they had on the different warning systems and their effectiveness.

2.6 Data Collection

Pilots completed a demographics questionnaire during the initial briefing session. The demographics questionnaire solicited information related to pilot experience (see Appendix A, Pilot Demographics Form). Aircraft ground movement and aircraft positions, throttle settings and speeds were recorded, as well as the time the alert illuminated/sounded. Workload was also assessed using the Air Traffic Workload Input Technique (ATWIT), see Stein, 1985. Eye tracking data was collected during each scenario. The eye tracker recorded fixations, durations, and locations.

At the end of each scenario run, the pilots completed the National Aeronautics and Space Administration (NASA) Task Load Index (TLX) workload rating form and a post-run questionnaire (see Appendix K, post-run questionnaires). The post-run questionnaire consisted of questions that were presented on a laptop computer about the scenario and warning system. Pilots were asked to rate their situation awareness during the scenario, whether or not they were aware of the conflict, and rate the effectiveness of the warning. All of the rating questions were on a 5 point scale, ranging from low to high. In addition, the experimenter and controller recorded their observations on the confederate pilot form (see Appendix I) and experimenter form (see Appendix H), and any pilot comments.

At the end of the simulation, the pilots completed a post-simulation questionnaire and were debriefed by the experimenter (see Appendix L, Post-Simulation Questionnaire). The post-simulation questionnaire assessed the perceived effectiveness and usability of the warning systems as well as the fidelity of the simulation.

2.7 Confederate Pilot, Air Traffic Controller, and Simulation Pilots

During the scenarios, a confederate pilot assisted pilots in the cockpit. The confederate pilot was a MITRE employee who took the role of crewmember for the simulation. The confederate pilot was responsible for briefing the pilot prior to the start of each scenario as to the specifics of that scenario (e.g., if it was a departure or arrival, which airport, which runway, scenario start location), handling radio communications with the air traffic controller, and reading departure/landing checklists. The confederate pilot support the detection or resolution of any conflicts, and if they were questioned by the pilot about conflicts, gave evasive, non-scripted responses.

The air traffic controller was also a MITRE employee. The Controller gave the pilot clearances and instructions during the course of the scenarios. All instructions were scripted. The Controller also communicated with the other simulation pilots. This chatter was also scripted and intended to increase scenario realism, as well as offer cues to the pilot about potential conflicts. If the pilot requested (through the confederate pilot) any clarifications to instructions received from ATC, the Controller repeated the scripted responses.

The background traffic simulation pilots who participated in the simulation were all MITRE employees. Their task was to read from the script in each scenario to create realistic background “chatter”. In a few scenarios, their chatter also provided the participant pilots with clues to the fact that there was a conflict. The background traffic simulation pilots did not communicate directly with the participant or confederate pilots and communicated only with the ATC controller.

Section 3

Results

This section presents the simulation results. The twelve pilots were grouped into pairs and data analysis was performed based on matched baseline and warning conditions. Table 3-1 indicates the number of runway safety scenarios.

Table 3-1. Number of Runway Safety Scenarios

	Runway Crossing	Departure	Arrival	Total
Number of baseline and warning paired scenarios	1	2	2	5
Number of unpaired warning scenarios	1	3	0	4
Number of paired AWL and ARIAS warning scenarios	0	0	2	2
Total	**2**	**5**	**4**	**11**

This section is structured following the three types of scenarios that pilots saw: runway crossing, departure, and arrival scenarios. For each subsection, the number of observed safety incidents[5] is reported first. Then the pilot's reported workload, situation awareness and survey results are detailed. Finally, the pilots' attention allocation and eye-movements are discussed combined over all scenario types.

[5] The term "safety incident" is used here to describe events on the airport surface that have a chance of a collision between an aircraft and another vehicle or aircraft. The definition is independent of the actual separation between the aircraft. In this case a safety incident was avoided if the participant stopped prior to entering the runway intersection.

3.1 Runway Crossing Scenarios

Pilots saw two runway crossing scenarios. In one scenario, pilots approached the runway from a perpendicular taxiway and were cleared by ATCT to cross that intersection. As pilots approached the intersection, the REL illuminated. Based on the given ATC clearance, pilots did not expect the illuminated REL. All (6) pilots correctly identified the REL, and stopped prior to the runway. No safety incidents occurred in this scenario.

Pilots saw the second scenario either in a baseline condition or in a warning condition. After landing on a runway and upon exiting on a high-speed runway exit, pilots immediately approached a closely spaced parallel runway. They approached that runway at a higher than normal taxi speed, having received a clearance by ATC to cross that runway. Pilots therefore expected to be able to cross that runway. However, just after landing, pilots could hear via radio a departure clearance given to an aircraft on that closely spaced parallel runway. This could have made them aware about a potential conflict on the active departure runway. In the baseline condition without REL, two of six pilots indeed did cross that intersection and caused a safety incident. In the warning condition, one of six pilots crossed the intersection with illuminated REL. This pilot reported seeing the illuminated REL and asked his confederate pilot about the lights while approaching the intersection. This pilot approached the intersection at relatively high speed and did not stop prior to the intersection. Table 3-2 summarizes the results.

Table 3-2. Scenario Runs and Observed Safety Incidents for Runway Crossing Scenarios

	Baseline Runs	**REL Runs**
Total runs	6	6
Safety incidents	2	1
Percentage of safety incidents	33.0 %	16.5 %

3.1.1 Subjective Data

Subjective data consisted of workload, situation awareness ratings, and questionnaire responses.

3.1.1.1 Workload

Workload ratings consisted of NASA TLX and the ATWIT continuous workload ratings.

3.1.1.1.1 NASA TLX

Pilots completed the NASA TLX workload questionnaire at the end of each scenario. The total workload rating was calculated by combining the six assessed workload factors: mental workload, physical workload, temporal demand, frustration, performance, and effort. Pilots were asked to mark on each factor the corresponding workload they perceived while performing the tasks in the scenario they had just completed. The ratings had a possible range of 0-100, with 0 being low workload and 100 being extremely high workload. The total workload ratings in the baseline condition (m=40) and the warning condition (m=42) were not significantly different, see Figure 3-1. This indicates that pilots did not notice an increase in their workload as result of REL usage.

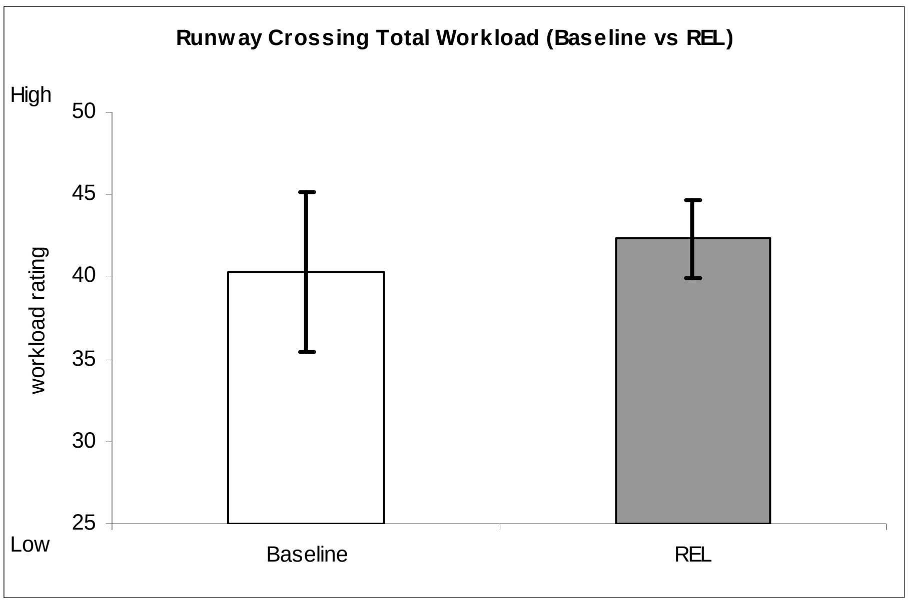

Figure 3-1. NASA TLX Total Workload Rating for Runway Crossing Scenarios, Baseline vs. REL Warning Conditions

3.1.1.1.2 Continuous Workload

During each scenario, pilots were asked to complete a continuous workload rating scale (ATWIT). Every 90 seconds, regardless of pilots' current activities, 7 buttons appeared on the bottom of the primary flight display and pilots could indicate their current workload They had 10 seconds to respond to the continuous workload rating before the buttons extinguished. Only responses that were given within the provided time were included in the analysis. Pilots responded to the continuous workload probe approximately 30%[6] of all response opportunities in the REL and associated baseline scenarios (see Appendix E).

There was no significant difference in workload between the baseline condition (the average workload rating was 2) and the REL warning condition (the average workload rating was 2.9), see Figure 3-2. Though not significant, pilot workload tended to be slightly higher in the REL condition. This suggests that REL though not strongly, at least slightly impacted pilot workload.

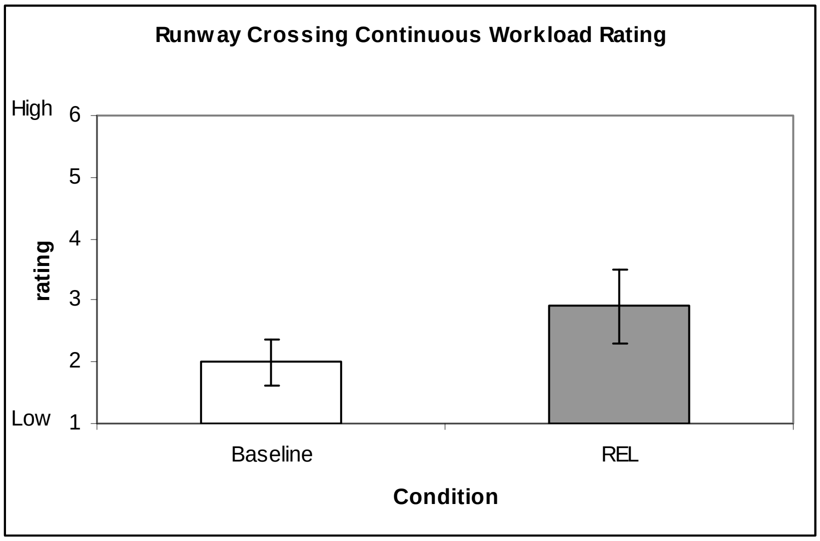

Figure 3-2. Pilot Continuous Workload Ratings

The length of time it took pilots to indicate their workload showed that there was no difference between the baseline condition and the warning condition. Pilots responded equally fast to the continuous workload rating buttons in the baseline condition (average of 2.4 sec) as in the REL warning condition (average of 2.6 sec) (see Figure 3-3).

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[6] The auditory reminders of the ATWIT may introduce interruptions to pilots during critical task performance and therefore may explain the relatively low response compliance. Also, pilots commented that they did not always respond to the auditory reminders because they were not used to them.

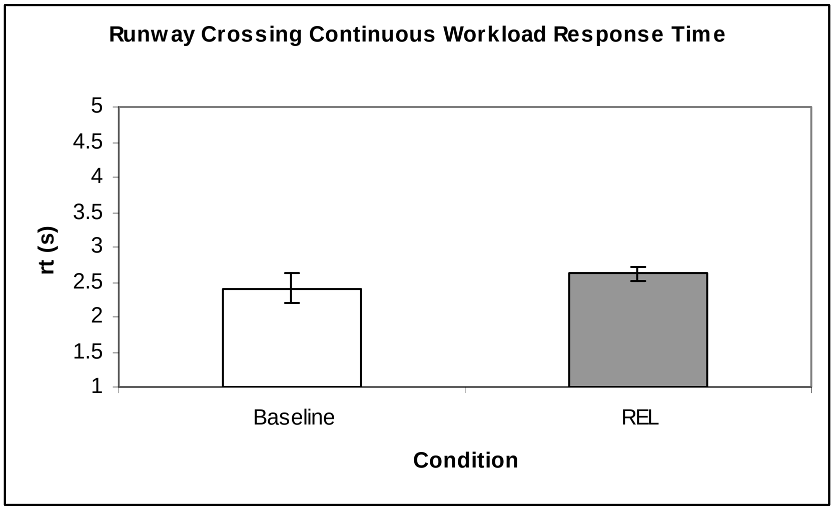

Figure 3-3. Pilot Response Time to Continuous Workload Rating Screen

3.1.1.2 Situation Awareness

Pilots were asked to rate their Situation Awareness (SA) of the runway conflict at the end of each scenario. These ratings were compared between the baseline condition (average rating of 4.0) and the warning condition (average rating of 3.2) of the runway crossing matched scenarios. There was no significant difference in reported SA between the two conditions. However, reported SA seemed slightly lower in REL scenarios as shown in Figure 3-4. This indicates that, though safety performance was slightly higher in REL scenarios than in baseline scenarios, pilots may not perceive an associated increase in their SA.

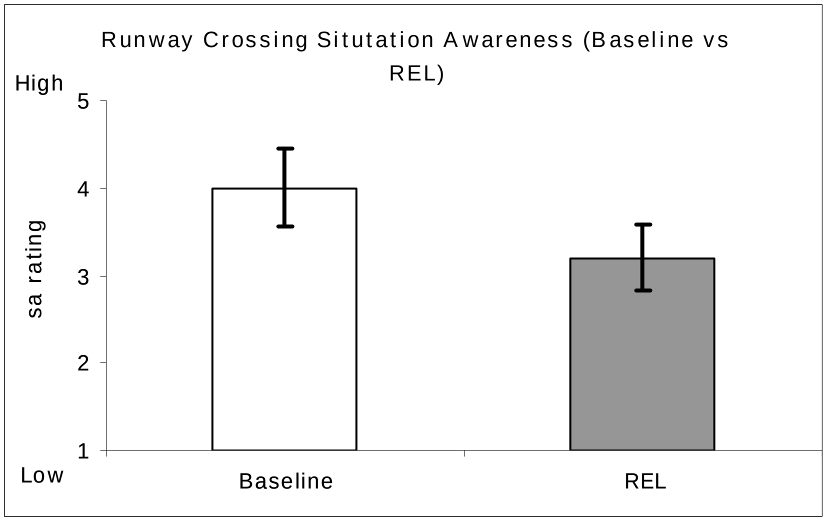

Figure 3-4. Situation Awareness Rating for Runway Crossing Scenarios, Baseline vs. REL Warning Conditions

3.1.1.3 Survey Data

Pilots were asked to complete a survey after each scenario, and one at the completion of the simulation. They were asked to comment on how detectable the warning systems were, how easy it was to decide to take action once the warning was noticed, and how effective the warning systems were. They were also asked to rate how easily the REL might be confused with other runway lighting systems. All of these questions were rated on a scale from 1 (low) to 5 (high).

Pilots rated the REL warning system high on detectability, ease of action, and effectiveness. The REL were rated low on the confusability question. Taken together, these ratings indicate that pilots generally evaluated the REL very positively, and did not find any specific shortcomings with them (see Figure 3-5).[7]

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[7] Pilots indicated low, but not all pilots used the minimal ratings concerning confusability (rating of 1). No reasons for minimal confusability were determined.

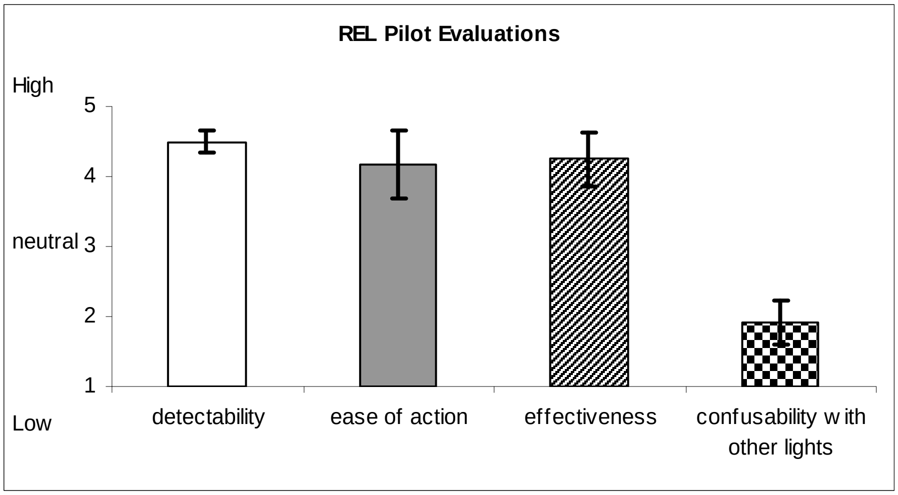

Figure 3-5. Pilot Evaluations of REL Warning Lights

3.2 Departure Scenarios

There were five departure scenarios (Scenarios 3 to 7). Two of these scenarios had both a baseline and a THL warning condition (Scenarios 3 and 4). All pilots saw either the baseline condition or warning condition for those scenarios. Three additional scenarios were only shown in the THL warning condition, and did not have a matched baseline condition (Scenarios 5, 6, and 7). Pilots saw either one or two of these warning light scenarios.

THL illuminated at three different stages at or before take-off initiation:

- THL illuminated while an aircraft was in position and holding, or taxiing into position and hold (Scenarios 3 and 7).
- THL illuminated immediately after an aircraft was cleared for take-off (Scenarios 5 and 6).
- THL illuminated during the take-off roll (Scenario 4).

THL Seen in Position and Holding on Runway:

In Scenario 3, pilots received a departure clearance by ATC while an aircraft that previously landed remained on the departure runway. Pilots saw the scenario either in an experimental condition with THL, or in a baseline condition without THL. All pilots saw the aircraft landing, and were able to see the conflict aircraft on the runway. In the baseline condition, one of six pilots aborted the take-off to avoid a safety incident[8]. In the THL warning condition, all (6) pilots either aborted their take-off or rejected the take-off clearance to avoid the safety incident.

In Scenario 7, pilots received a departure clearance and saw THL illuminate because an aircraft was crossing farther down the runway. This scenario was shown to 6 pilots in the THL warning condition. Four of six pilots rejected the departure clearance while the THL were still in view; one pilot continued the departure roll past the last illuminated THL and aborted when seeing the crossing traffic. This pilot traveled 3534 feet from the point when he saw the THL illuminate but was able to stop prior to the conflict aircraft. The pilot who continued the take-off despite THL reported not seeing the THL. The THL in this scenario were placed at a distance greater than 375 feet from the runway threshold due to a displaced landing threshold. Another pilot performed in-cockpit tasks during THL illumination and reported seeing the THL belatedly; this pilot stopped the aircraft at 2556 feet from his position when the THL illuminated.

THL Illuminated After Take-off Clearance:

In Scenario 5, pilots were cleared for departure, and after initiating their take-off, THL illuminated because of a vehicle driving on the runway. This scenario was shown to 6 pilots in the THL warning condition only, and was not shown in a baseline condition. All 6 pilots aborted their take-off.

In Scenario 6, pilots were cleared for departure after an aircraft crossed ahead of the pilot and caused THL to illuminate. The THL stayed illuminated for an aircraft on final approach behind the pilot who initiated a go-around maneuver. Therefore, in this scenario, THL were shown as part of the AWL system to the simulated arrival aircraft in addition to the departure warning that the pilots saw. This scenario was shown to 6 pilots in the THL warning condition, as there was no matched baseline condition. All 6 pilots correctly rejected their take-off clearance.

THL Illuminated During the Take-off Roll:

In Scenario 4, pilots were cleared for an immediate take-off while another conflict aircraft "erroneously" initiated a take-off on an intersecting runway. Pilots heard part of an acknowledged departure clearance by the aircraft on the intersecting runway. Pilots also heard radio communications concerning an arrival on the pilot's departure runway. In the baseline condition, all pilots either completed the take-off (5 pilots), or aborted the take-off

[8] Pilots avoided the safety incident when they safely aborted the take-off prior to the conflict. Early rotation or swerving around the conflict aircraft were counted as safety incidents.

late and ran out of runway during braking (1 pilot). This resulted in 6 safety incidents[9]. In the THL condition, five of six pilots safely aborted the take-off upon THL illumination. One pilot continued the take-off, mistakenly believing that the THL were intended for the arrival aircraft. This pilot reported not seeing a conflict aircraft and assumed that the THL were intended for the arrival aircraft behind him. He asked his pilot-not-flying to contact ATC and tell them that they would continue the take-off. Table 3-3 displays the number of scenarios and percentage of runway safety incidents.

Table 3-3. Scenario Runs and Observed Incursions for Departure Scenarios

Scenario	**Baseline**		**With THL**	
	Total runs	**Incidents** ***(Number and percentage of observations)***	**Total runs**	**Incidents** ***(Number and percentage of observations)***
Scenario 3	6	5 (83%)	6	0 (0%)
Scenario 4	6	6 (100%)	6	1 (16.5%)
Scenario 5	-	-	6	0 (0%)
Scenario 6	-	-	6	0 (0%)
Scenario 7	-	-	6	1 (17%)
Total	12	11 (92%)	30	2 (7%)

Over all scenarios, the likelihood of safety incidents was significantly lower, statistically, when THL were present compared to the baseline condition[10]. There were two cases when pilots encountered safety incidents despite THL. In one case, a pilot misinterpreted the applicability of THL thinking they were meant for an arrival aircraft. This confusion was apparently caused by the dual usage of THL for both arrival and departure situations. The distinction between different functions of the same lighting system may require additional interpretation processes by pilots; that may, especially under time pressure, result in incorrect decisions.

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[9] A safety incident was avoided if the participant was able to safely abort the take-off without running off the runway.

[10] Measured by Fisher Exact test $p < 0.01$ revealing a statistically significantly lower likelihood of safety incidents in the THL scenarios than in the baseline scenarios.

In addition, one pilot did not notice the illuminated THL and completely crossed them prior to initiating an abort well beyond the last THL.

Table 3-4 indicates the average distance traveled after THL illumination. For most scenarios, the distance traveled after THL illumination was proportional to their initial speed. In one scenario (Scenario 7), two pilots traveled farther than most others.

Table 3-4. Speeds and Distance Traveled After THL Illumination

Scenario	Number of Ob-servat-ions	Mean Speed when THL illum-inated (knots)	Standard Deviation Speed (knots)	Minimum Speed (knots)	Maximum Speed (knots)	Number of Pilots reaching a complete Stop	Average Distance Traveled until complete stop (feet)
3	6	6.8	1.7	4.9	9.1	6	66
4	6	52.58	17.9	39.7	88.0	5*	535
5	6	11.8	5.1	5.1	19.6	6	153
6	6	11.4	4.2	5.4	15.0	6	63
7	6	0.45	1.1	0.0	2.7	3 **	2033†

Notes: * One pilot continued take-off. **Three pilots did not initiate departure roll. † Two pilots showed delayed responses to THL, see description in text.

3.2.1 Subjective Data

Subjective data consisted of workload, situation awareness ratings, and questionnaire responses.

3.2.1.1 Workload

Workload ratings consisted of NASA TLX and the ATWIT continuous workload ratings.

3.2.1.1.1 NASA TLX

Workload ratings were not significantly different between warning (average rating of 40) and baseline condition (average rating of 39), see Figure 3-6. This indicates that overall, THL did not increase workload of pilots.

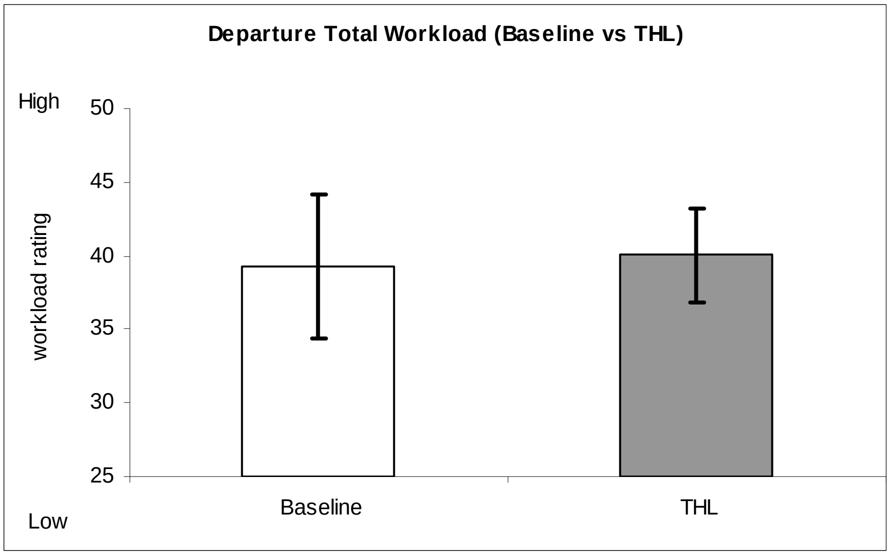

Figure 3-6. NASA TLX Total Workload Ratings for Departure Scenarios, Baseline vs. THL Warning Conditions

3.2.1.1.2 Continuous Workload

Continuous workload ratings were significantly higher in the warning condition (m=2.8) than in the baseline condition (m=1.7)[11] (see Figure 3-7). Pilots showed a response rate of 34 %. . Higher reported workload was due to the fact that there were two ratings given while aborting take-off, shortly after the THL illuminated; these workload ratings were on the extreme high end of the scale. As indicated above, there were significantly fewer safety incidents in the warning condition than in the baseline condition (92% vs. 8% for the matched baseline and warning conditions). This indicates that THL may increase the workload of pilots during certain phases of aircraft operations, e.g. during the performance of take-off maneuvers or aborted take-offs to avoid runway safety incidents. Similarly, pilots responded to the ATWIT significantly faster in the baseline condition (m=2.5 sec) than in the warning condition (m=3.7 sec) (see Figure 3-8).[12]

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[11] T-tests were performed on the matched scenarios (baseline vs. warning light), departure scenarios. There was a difference found in reported workload between the departure baseline condition and departure THL warning condition, $p<.05$.

[12] T-tests performed on the paired scenarios found that response time was significantly faster in the baseline condition as compared to the THL warning condition $p = .049$.

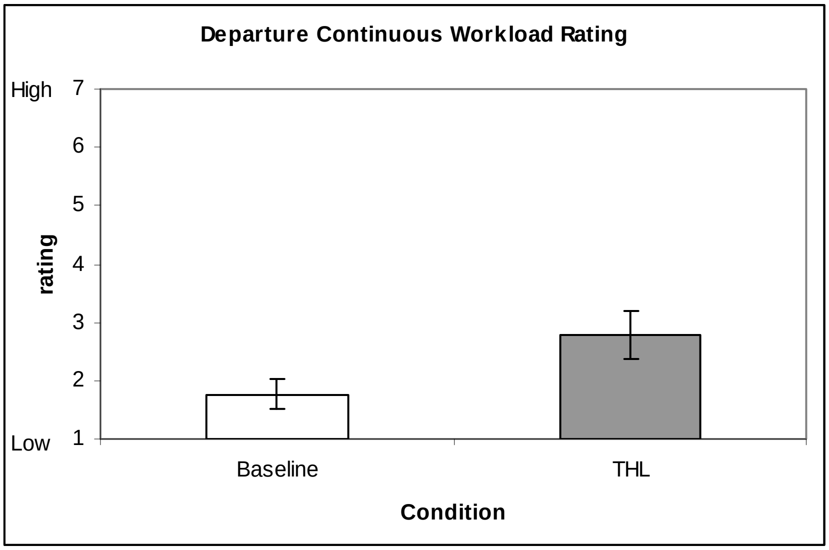

Figure 3-7. Pilot Rating of Continuous Workload in Departure Scenarios

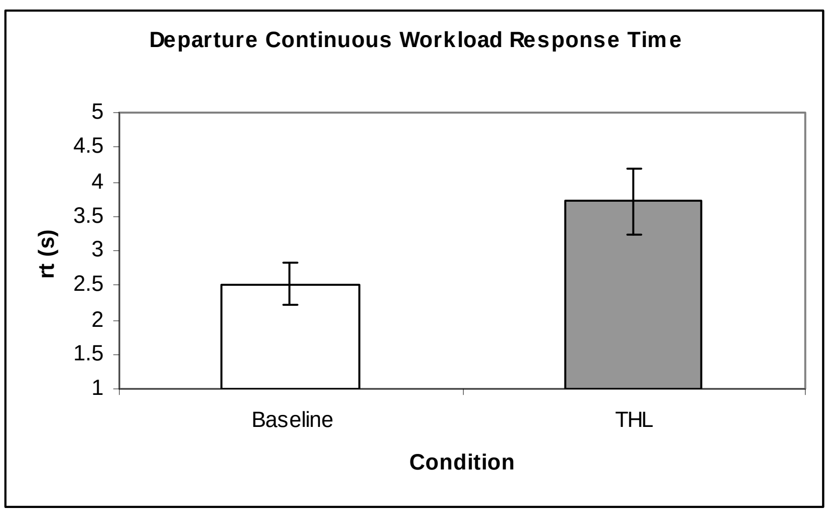

Figure 3-8. Pilot Response Time to Continuous Workload Rating in Departure Scenarios

3.2.1.2 Situation Awareness

SA was significantly higher in the warning condition (average rating of 4) as compared to baseline (average rating of 3.5), as shown in Figure 3-9.[13] The addition of the THL warning lights to the scenario seemed to help increase the situation awareness of pilots, and possibly making them more aware of the conflict on the runway.

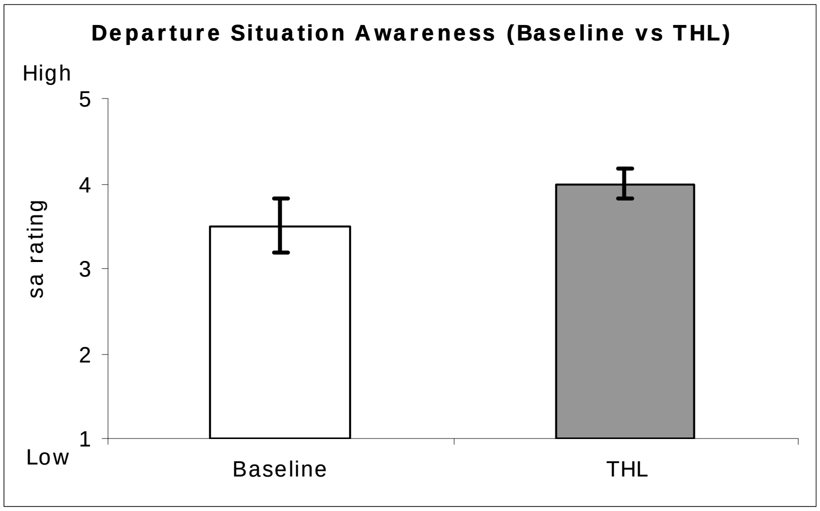

Figure 3-9. Situation Awareness Ratings for Departure Scenarios, Baseline vs. THL Warning Conditions

3.2.1.3 Survey Data

Pilots responded to questions about the detectability, ease of action, effectiveness, and confusability of the THL warning light system. The THL were rated high on detectability, ease of action, and effectiveness. Pilots rated the THL low on confusability. Even though, in one instance, there had been some confusion as to which aircraft (arriving or departing) the THL were meant for, the pilot still rated the confusability level of the THL as low[14]. Two pilots stated that there was a slight issue with the THL when they were placed at the displaced threshold and not at the departure threshold, but still rated them as effective in preventing safety incidents. In general, the pilots felt that the THL provided an effective

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[13] T-tests performed comparing the SA ratings of the baseline condition and the THL warning condition found a significant difference, $p<.05$.

[14] Pilots indicated low, but not all pilots used the minimal ratings concerning confusability (rating of 1). No reasons for minimal confusability were determined.

method for preventing runway incursions during departures and were not easily confused with other lighting systems, see Figure 3-10.

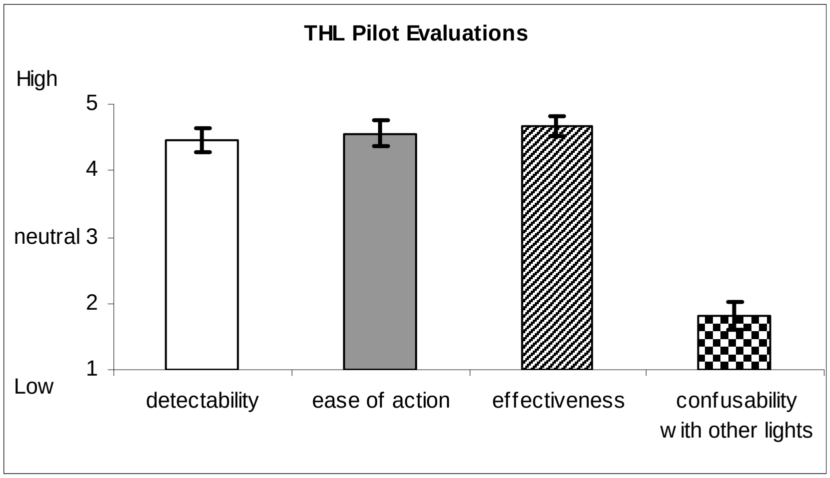

Figure 3-10. Pilot Evaluation of THL Warning Lights

3.3 Arrival Scenarios

Pilots saw four arrival scenarios (Scenarios 8 through 11). Two of these scenarios were presented to pilots in either the baseline condition or as its matched warning condition (AWL). The other two scenarios were presented with one of two different warning conditions; AWL or ARIAS. These scenarios were also matched; one had the AWL warning, and the other condition showed the ARIAS warning.

In all arrival scenarios, pilots received a clearance to land on a runway despite there being a conflict aircraft either on the designated runway, or approaching an intersecting runway. One runway safety incident occurred in the warning scenarios, see Table 3-5. This incident occurred in the ARIAS warning condition. In this scenario, the pilot heard an auditory warning just prior to touch-down and decided to continue the landing. The conflict aircraft was not in the pilot's view at this point.

In Scenario 8, pilots were cleared to land on a runway, and shortly after they received their clearance, a second aircraft mistakenly turned onto the designated runway, instead of turning onto a taxiway. This scenario was presented with either the AWL warning condition, or the ARIAS warning condition. The AWL and ARIAS warned pilots of the fact that the runway was unsafe to land on, and all pilots initiated a go-around.

In Scenario 9, pilots were cleared to land on a runway that had an aircraft departing from it. The departing aircraft blew a tire, and pilots were asked to sidestep to a different runway. All pilots accepted the sidestep request. However, on this runway was an aircraft that was in position and holding. The pilots had been able to hear the ATC instructions to this pilot at the start of the scenario. In this scenario, pilots were either presented with the baseline condition, with no warning, or with the AWL warning condition where they received warning about an unsafe landing. In both baseline condition and warning condition, all pilots initiated a go-around.

In Scenario 10, pilots were cleared to land on a runway. Prior to their landing, a second aircraft was given a departure clearance from the same runway. However, this aircraft did not respond to their clearance and did not initiate the take off. This scenario was presented to pilots in a baseline condition and a warning condition with AWL. The AWL system alerted pilots that the runway was unsafe to land on. All pilots initiated a go around.

In Scenario 11, pilots were cleared to land on a runway. At the same time, a second aircraft was cleared to land on an intersecting runway, and given instructions to slow their speed. This scenario was presented with either the AWL warning condition, or the ARIAS warning condition. The AWL or ARIAS warning system alerted pilots that the runway was unsafe to land on. In the AWL warning condition, all 6 pilots initiated a go-around. In the ARIAS warning condition, 4 pilots initiated a go-around. One pilot continued to land despite hearing the warning. In this instance, the warning sounded while the pilot was very close to landing (in flare), and the pilot decided to continue with the landing as no conflicting aircraft could be seen on the runway. One pilot did not receive the ARIAS alert, due to technical problems.

Table 3-5. Scenario Runs and Observed Safety Incidents for Arrival Scenarios

Scenario	Baseline – Total Observations	AWL – Total Observations	ARIAS – Total Observations	Safety incidents in baseline condition (number and percentage of observations)	Safety incidents in AWL condition (number and percentage of observations)	Safety incidents in ARIAS condition (number and percentage of observations)	See PAPI first	See THL first	See both at same time
8	-	6	6	-	0 (0%)	0 (0%)	2	1	1
9	6	6		0 (0%)	0 (0%)	-	4	1	0
10	6	6	-	0 (0%)	0 (0%)	-	1	3	0
11	-	6	5*	-	0 (0%)	1 (20%)	0	3	0

*In one case, the ARIAS warning was not given due to a technical problem; this data was not included in the analysis.

3.3.1 Arrival Warning Lights

The AWL system consisted of a combination of two lighting configurations; PAPI and THL. PAPI started flashing to indicate that it was unsafe to land, and THL illuminated. After each scenario, pilots indicated which of the two lighting configurations they had seen first. In the AWL condition, seven pilots indicated that they saw flashing PAPI first, and eight pilots indicated that they had seen the THL first. One pilot reported seeing both lighting configurations at the same time, 2 pilots saw the conflict aircraft before seeing the warning lights, and 5 pilots did not state which they saw first. This indicates similar detectability of THL and PAPI in the arrival scenarios.

Pilots initiated the go-around maneuvers further away from the runway when AWL gave safety warnings, than in the baseline condition. This indicates the pilots were able to determine the runway conflict earlier. Initiation of go-around was determined by pilots increased the throttle setting above 70% of the maximum setting. Figure 3-11 shows this distance in feet from the runway threshold for the two AWL scenarios. Pilots on average initiated the go-around maneuver 2734 feet further away from the runway threshold in the

AWL than in the baseline condition (6557 feet versus 3774 feet in baseline condition[15]). This indicates an advantage of AWL because pilots were able to detect a runway conflict farther from the runway, with the use of AWL, than in the baseline conditions.

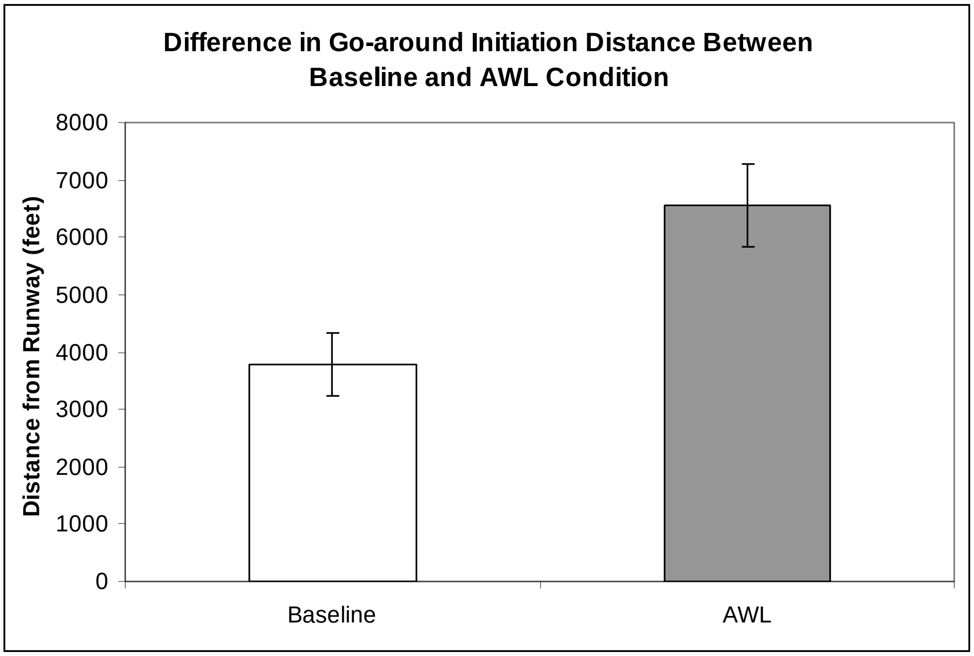

Figure 3-11. Go-Around Distance for Arrival Scenarios in Baseline and AWL Warning Condition

Analyses were also performed comparing the altitudes at which the arrival descent was changed to an ascent. There was no significant difference found in the altitude at which the go-around was initiated between the baseline (501.32 ft) and AWL warning light (660.73 ft) conditions.[16] In the comparison of the baseline vs. the matched AWL warning conditions, there was a large variability in the altitude where pilots began their go-around and no significant difference was found (see Figure 3-12). However, the trend confirms that pilots initiated the go-around earlier with AWL than in the baseline condition.

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[15] Statistically significant difference was detected using a two-way ANOVA $F(2,19) = 4.59$, $p < 0.05$ with scenario and condition as factors. The ANOVA revealed a significant main effect of condition ($F(1, 19) = 9.14$, $p < 0.05$), indicating a significant difference in go-around initiation between baseline and AWL.

[16] Paired t-tests were performed on the data, and the results were $p>.05$.

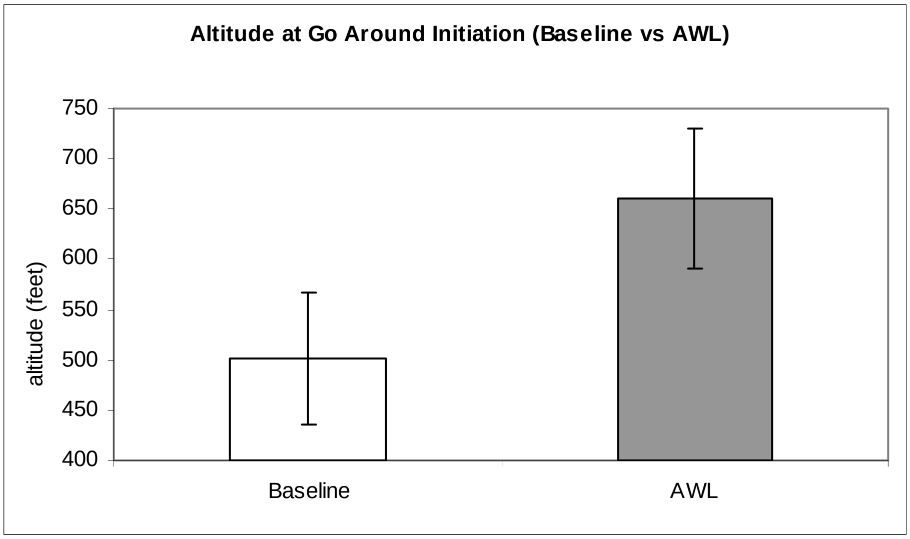

Figure 3-12. Aircraft Altitude at Go-Around Initiation

3.3.1.1 Subjective Data

Subjective data consisted of workload, situation awareness ratings, and questionnaire responses.

3.3.1.1.1 Workload

Workload ratings consisted of NASA TLX and the ATWIT continuous workload ratings.

3.3.1.1.1.1 NASA TLX

There was no significant difference in reported workload between the baseline (average rating of 46.9) and the warning condition (average rating of 40). While figure 3-13 shows slightly lower workload in the AWL warning condition, as compared to the arrival baseline condition, the variability was too large to detect a significant difference.

Figure 3-13. Total Workload Rating for Arrival Scenarios

3.3.1.1.1.2 Continuous Workload

There was no difference found in the continuous workload ratings between the baseline (average ratings of 3.1) and warning condition (average rating of 2.8), see Figure 3-14. This indicates that AWL did not increase pilot workload and confirms the NASA TLX ratings as reported above. Pilots rated their workload in 49 % of the possible workload responses.

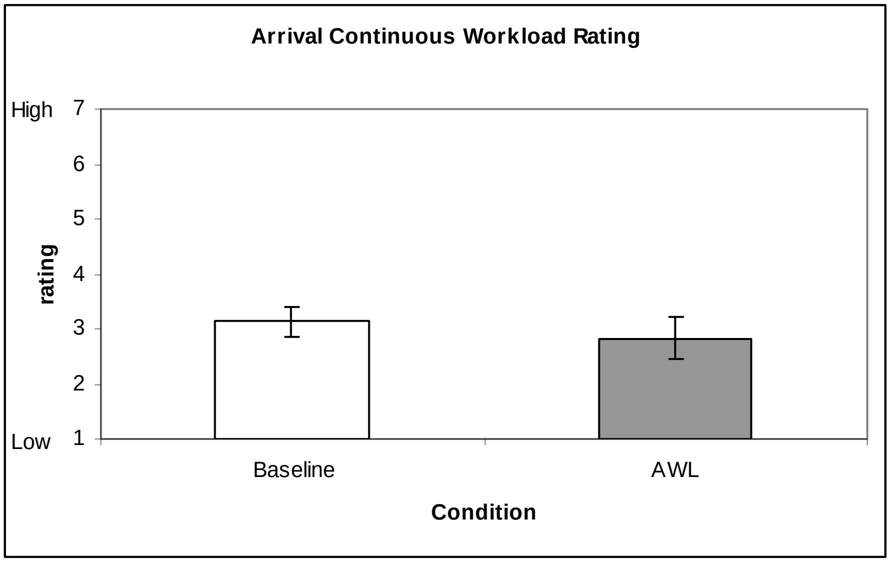

Figure 3-14. Pilot Continuous Workload Rating for Arrival Scenarios

There was also no difference in the response time to the continuous workload rating between the baseline (on average 2.9 sec) and warning condition (on average 3.5 sec), see Figure 3-15. Taken together with the NASA TLX reported workload, both workload ratings indicate that AWL did not increase the workload of pilots.

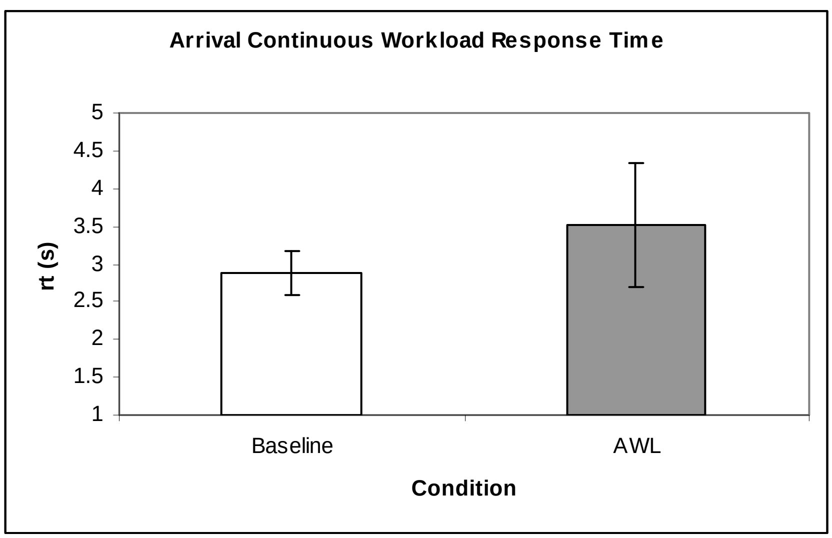

Figure 3-15. Pilot Response Time to Continuous Workload for Arrival Scenarios

3.3.1.1.2 Situation Awareness

There were no significant differences in reported situation awareness between baseline (average rating of 4) and warning condition (average rating of 3.8). Pilots reported similar levels of SA in both the arrival baseline and AWL warning conditions, as shown in Figure 3-16.

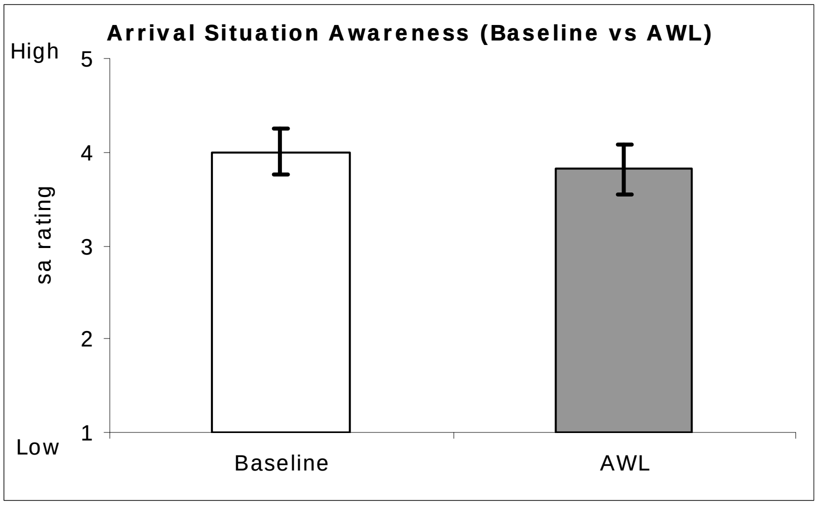

Figure 3-16. Situation Awareness Ratings for Arrival Baseline vs. AWL Conditions

3.3.1.1.3 Survey Data

Pilots reported that the AWL were easy to detect, that they knew what action to take when they saw the warning lights, and felt that AWL were highly effective in preventing unsafe landings. Pilots also rated the confusability of the AWL low, meaning that it does not appear too similar to other runway lighting systems[17]. Figure 3-17 shows that pilots didn't report any shortcomings with the AWL warning system.

[17] Pilots indicated low, but not all pilots used the minimal ratings concerning confusability (rating of 1). No reasons for minimal confusability were determined.

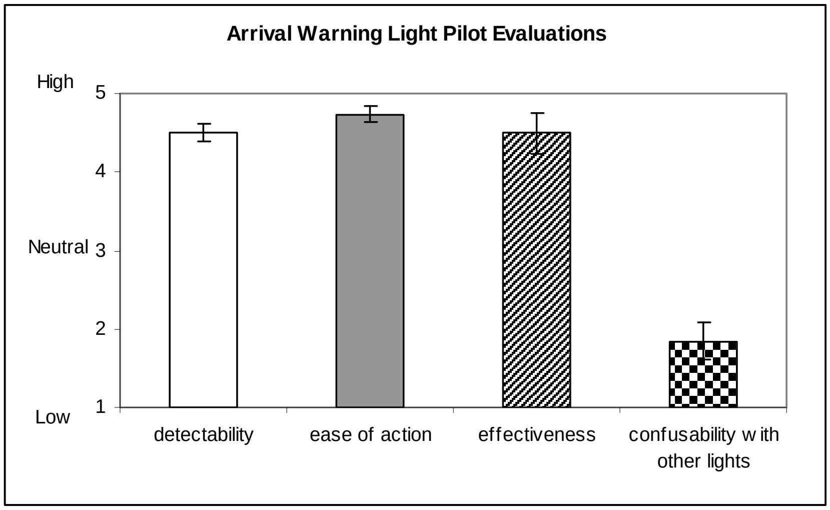

Figure 3-17. Pilot Evaluation of AWL Warning System

3.3.2 Auditory Runway Incursion Alerting System

The ARIAS provided an auditory warning to pilots when a conflict was predicted within 30 seconds. An auditory message in the cockpit warned the crew that it was unsafe to land on the runway. In the ARIAS warning scenarios[18] , one pilot continued a landing after ARIAS initiated. This pilot commented that he had received the warning so late that he decided to continue the landing because he did not see anybody on the runway. He commented that it was essential for him to know if such warning indicated a mandatory go-around instruction or not. Pilots generally suggested as a design alternative the inclusion of non-speech elements in the auditory warning that preceded the warning message. Pilots were concerned that the auditory warnings may cause pilots to miss other critical actions, and the volume of other auditory information may make it more difficult for the safety warning to be heard.

A comparison of the distance when pilots initiated the go-around between the AWL condition and ARIAS condition did not reveal a statistically significant difference between the conditions (see Figure 3-18)[19]. ARIAS was compared AWL.

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[18] One participants' data was excluded from analysis, due to a technical problem that prevented that audio alert from being audible.

[19] Statistically significant difference was detected using a two-way ANOVA $F(2,19) = 30.47$, $p < 0.001$ with scenario and condition as factors. The test revealed a significant main effect of scenario on go-around initiation distance ($F(1, 19) = 60.93$, $p < 0.001$) but not between warning conditions. Differences in go-

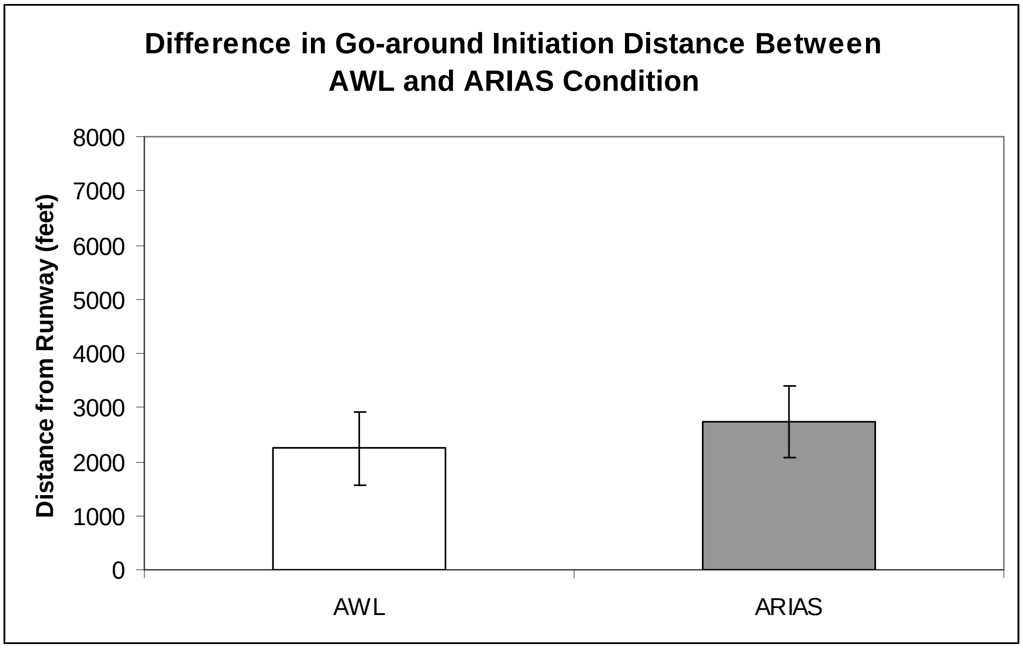

Figure 3-18. Average Distance to Runway When Go-Around Maneuver was Initiated for ARIAS versus AWL Conditions

There was no significant difference found between the altitudes at which go-around was initiated for the AWL warning light (643.54 ft) and ARIAS audio warning (637.90 ft) conditions[20] (see Figure 3-19).

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around distances between scenarios are expected because of scenario differences between approach speeds and runway layouts. Importantly, no difference between conditions was detectable.

[20] Paired t-tests were performed on the data, and the results were $p>.05$.

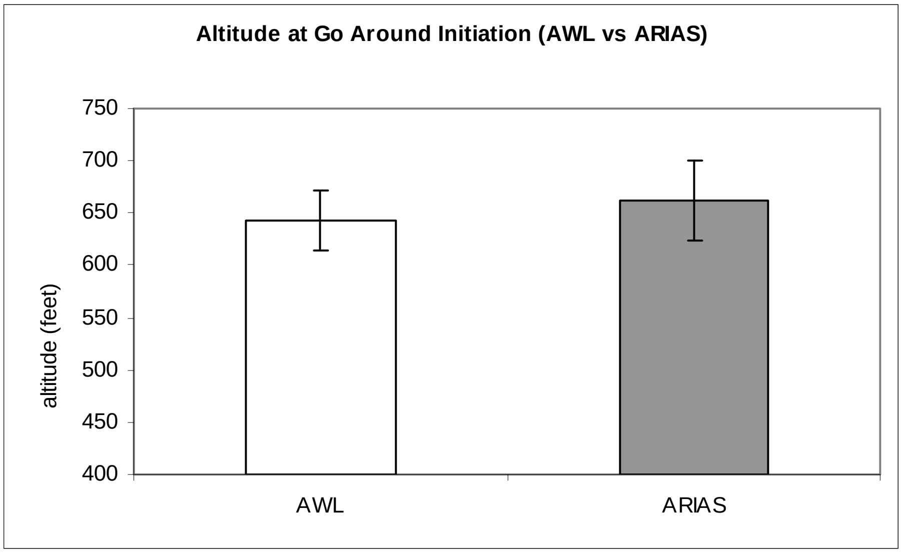

Figure 3-19. Average Altitude at Go-Around Initiation

A comparison of the time from when the warning was initiated until the throttle was increased was made between the arrival AWL condition, and the matched ARIAS warning condition. No significant difference was found. However, whereas all of the throttle increases came after the warning lights illuminated in the AWL warning condition, in the ARIAS warning condition however, five of ten pilots began their go-around prior to hearing the warning (see Figure 3-20). All except one pilot in the AWL warning condition initiated their go-around after the warning illuminated. However, if looking only at the pilots who initiated a go-around after the ARIAS warning sounded, and comparing the time to throttle increase to that of the matched pair in the AWL condition, it becomes evident that the ARIAS warning condition had a longer elapsed time to throttle increase (Figure 3-20). There is not a significant difference in the elapsed time between conditions. The elapsed time from warning to throttle increase was similar for those pilots in the AWL condition with a matched baseline condition as for those in the AWL condition with a matched ARIAS condition. While overall, there is no significant difference in the altitude or distance from the runway that pilots initiated a go-around in either the AWL or the ARIAS warning conditions, the fact that several pilots initiated prior to the audio warning sounding suggests that the timing of the warning needs to be investigated further.

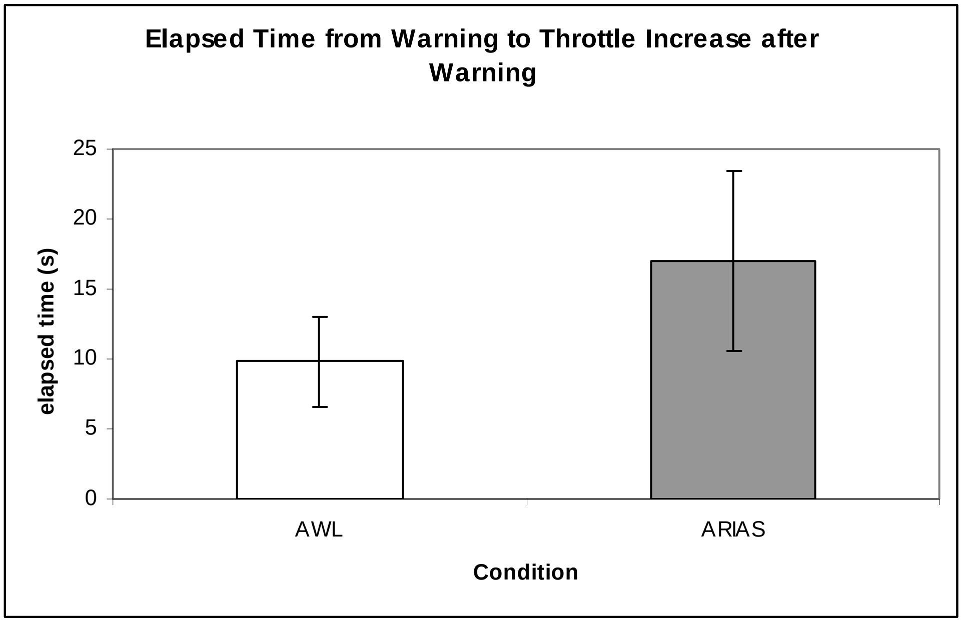

Figure 3-20. Elapsed Time From Warning to Throttle Increase in Arrival Scenarios, for Those Pilots Who Initiated Go-Around after the Warning

3.3.2.1 Subjective Data

Subjective data consisted of workload, situation awareness ratings, and questionnaire responses.

3.3.2.1.1 Workload

Workload ratings consisted of NASA TLX and the ATWIT continuous workload ratings

3.3.2.1.1.1 NASA TLX

Total reported workload for the arrival scenarios was compared between the AWL warning condition (m=41.8) and the matched ARIAS warning condition (m=41.6). There was no difference in reported workload, as shown in Figure 3-21. It is important to note that the two different warnings didn't have an effect on perceived workload.

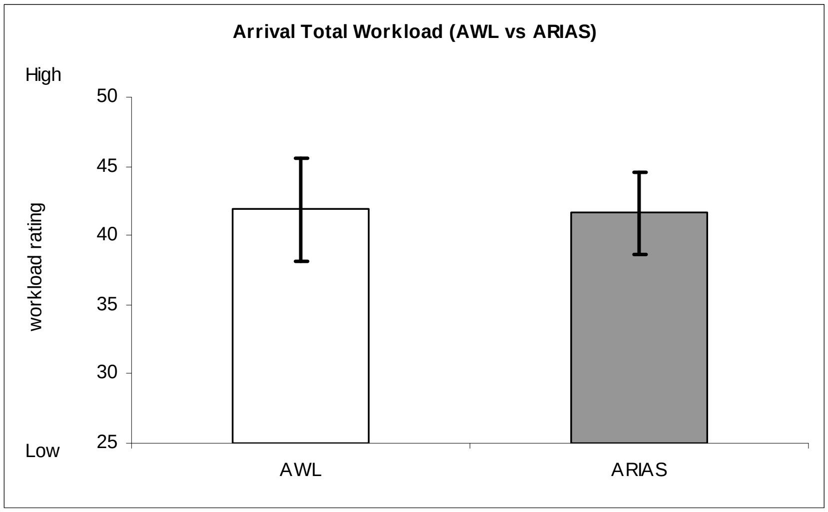

Figure 3-21. Total Workload Ratings for Arrival AWL vs. ARIAS Conditions

3.3.2.1.1.2 Continuous Workload

The continuous workload ratings were analyzed for the arrival scenarios with the AWL warning light (average rating of 3.2) vs. the ARIAS audio alert (average rating of 3.3). No difference between the ratings was found, see Figure 3-22. This confirms the workload reported on the NASA TLX.

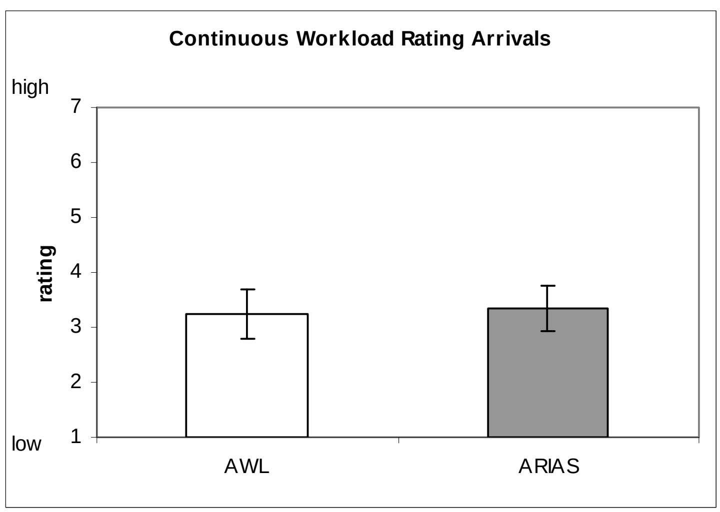

Figure 3-22. Pilot Rating of Continuous Workload for Arrival Scenarios, AWL vs. ARIAS

Looking at the response time to the continuous workload rating, there was no difference found. While figure 3-23 shows that response times were faster in the ARIAS warning condition (average of 2.3 sec vs. 3.3 sec in AWL condition), this difference was not significant, likely due to the large variability in response times.

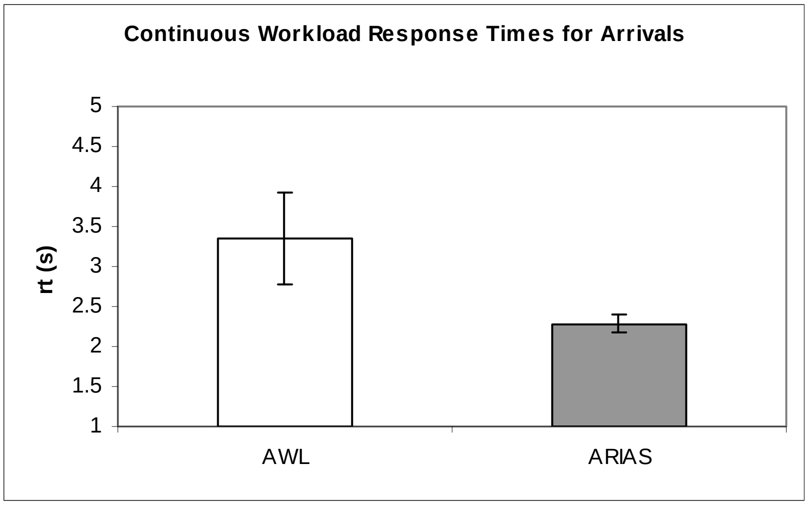

Figure 3-23. Pilot Response Time to Continuous Workload in Arrival Scenarios, AWL vs. ARIAS

3.3.2.1.2 Situation Awareness

Reported SA of the AWL condition was compared to that of the ARIAS condition. There was no significant difference in reported SA, as shown in Figure 3-24. Pilots reported similar levels of situation awareness in both the AWL (average rating of 3.4) and ARIAS warning conditions (average rating of 4)**.**

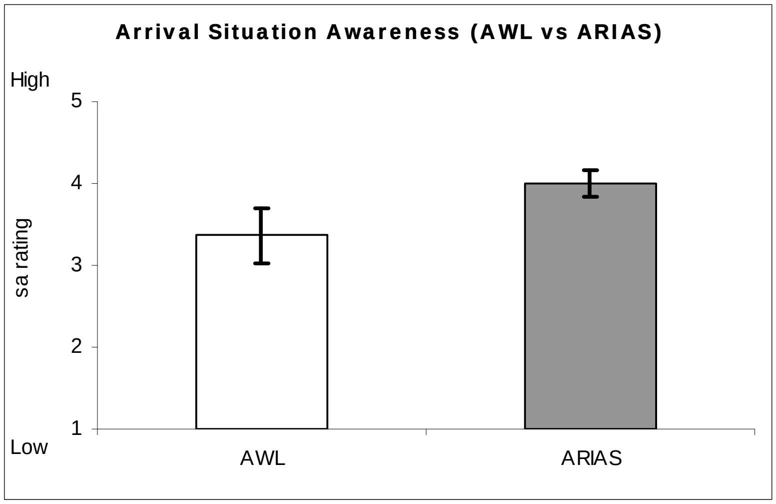

Figure 3-24. Situation Awareness Ratings for Arrival AWL vs. ARIAS Conditions

3.3.2.1.3 Survey Data

Pilots were asked to rate the detectability, ease of action, and effectiveness of the ARIAS audio warning system. The ARIAS warning was rated high on all three dimensions. Pilots felt that the audio warning was easy to detect, and once heard, it was easy to decide what action to take. The pilots also felt that the audio warning was highly effective (see Figure 3-25).

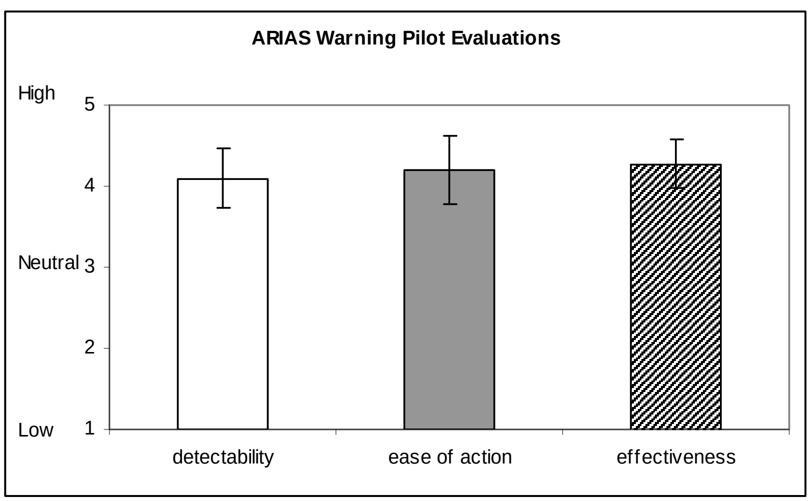

Figure 3-25. Pilot Evaluation of ARIAS Warning System

3.4 Eye Movement Data

Eye movement data was collected during the simulation using the Applied Science Laboratories 6000 Series H6 head-mounted eye tracking system. For each Area of Interest (AOI), the percentage of dwell time spent was calculated. The two AOIs were the PFD and OTW. Data from some of the pilots were excluded from certain scenarios if the dwell time spent ‘off-scene’ exceeded 60% of total dwell time because of the potential loss of eye tracker calibration during these runs. Since there were only 2 AOIs, and these were the 2 areas that the pilots would get all necessary visual information from, if the amount of time spent “off-scene” (meaning not on the AOIs) exceeded 60%, it was thought that there was a possibility that the eye tracker had lost calibration during that scenario. The data from these scenarios were then excluded from analysis.

Scenarios were combined for each condition.

Analysis of the data determined an interaction between condition and area of interest.[21] As the condition went from baseline to warning light, there was a change in the allocation of attention between the PFD and OTW. Pilots focused significantly more of their attention OTW as compared to the PFD in the baseline conditions, but in the warning conditions, the difference between the areas where attention was allocated was reduced. There were no other significant effects found (see Figure 3-26).

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[21] A 3 (warning type—REL/THL/AWL) x 2 (condition—baseline/warning) x 2 (AOI—PFD/out-the-window) ANOVA was run on the data. There was a significant interaction of condition x AOI found, $p=.05$.

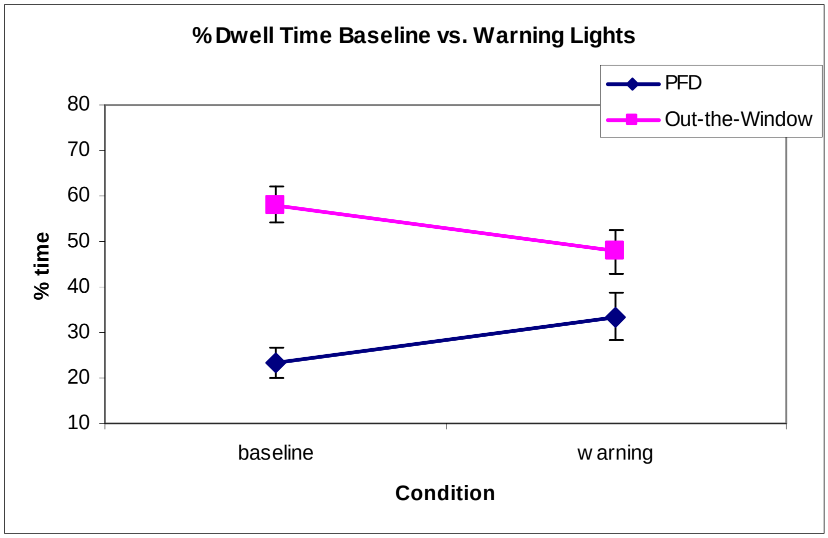

Figure 3-26. Change in Attention Allocation Between PFD and Out-the-Window From Baseline to Warning Condition

Analysis of the Baseline vs. AWL data for runway crossing scenarios, departures, and arrivals found no significant effect of either condition (baseline/warning light) or AOI (PFD/OTW).[22] However, in both the runway crossing scenarios and the departure scenarios, pilots focused more of their attention OTW than on the PFD (see Figure 3-27). Since both types of scenarios involve pilots taxiing on the runway, or beginning departure rolls, it would be expected that they are looking at the OTW more than at the PFD. In the arrival scenarios, more attention was focused on the PFD than OTW. Pilots were instructed to follow the localizer and glide path indicator as closely as possible in the arrival scenarios, so this difference in attention allocation was also expected. One explanation for the statistically insignificant findings comparing the PFD and OTW attention allocation is due to excluding certain scenarios from analysis (because of high percentages of 'off scene'); there were not enough matching data points to reach significance. Comparing the matched arrival scenarios with the AWL and ARIAS warnings found that there was significantly more attention allocated to the PFD (m=55.5 % for AWL, 46.9% for ARIAS) than OTW (m= 34.34% for

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[22] 2 (condition—baseline/warning) x 2 (AOI—PFD/out-the-window) ANOVAs were run for each of the warning types (REL, THL, AWL, ARIAS), followed by t-tests where appropriate. The analysis found that for the REL, there was no significant effect for either condition or AOI ($p>.05$) For THL, there was also no significant effect found for either condition or AOI ($p>.05$). The AOI was approaching significance ($p=.058$), with more attention focused out-the-window than on the PFD. Looking at the AWL, there was no effect for either condition or AOI ($p>.05$).

AWL, 42.24% for ARIAS).[23] The matched scenarios either have the AWL warning lights or have the ARIAS audio warning.

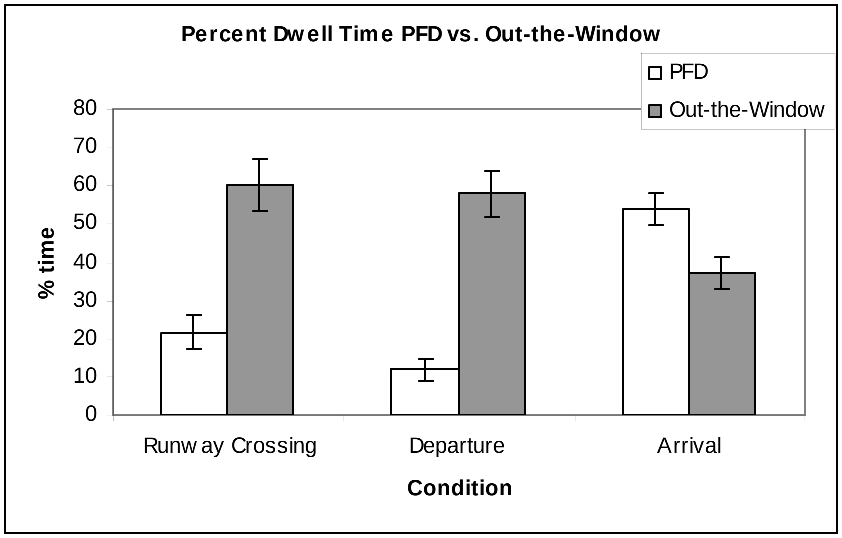

Figure 3-27. PFD vs. Out-the-Window Dwell Time for Runway Crossing, Departure and Arrival Scenarios

Additional analyses were run on the data to compare the matched conditions. Paired t-tests were run on the matched conditions. There was no difference found between the percentage of dwells on the PFD when comparing the baseline scenarios to the warning scenarios for all warning light types (REL, THL, and AWL).[24] There also was no difference in the percentage of dwell time allocated OTW when comparing the baseline scenarios to the warning light scenarios.[25] When comparing percentage of dwells on the PFD to OTW, there were some differences found. In the runway crossing warning condition (REL), there is a significant difference in the dwell time focused on the PFD (m=32.67%) vs. OTW (m=61.99%), with a higher percentage of dwell time focused OTW (see Figure 3-28).[26] There was no difference in the amount of attention allocated to the PFD between conditions

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[23] The analyses for the ARIAS warning found a significant effect for AOI ($p<.01$). The ARIAS warning was not included in the original 3 x 2 x 2 ANOVA as it does not have a baseline condition.

[24] Paired t-tests were run on the matched conditions, $p>.05$ for all warning light types.

[25] $P>.05$

[26] $P<.05$

or OTW between conditions. Pilots had attention focused OTW for most of the time during the runway crossing scenarios, which is what would be expected while taxiing or rolling down the runway.

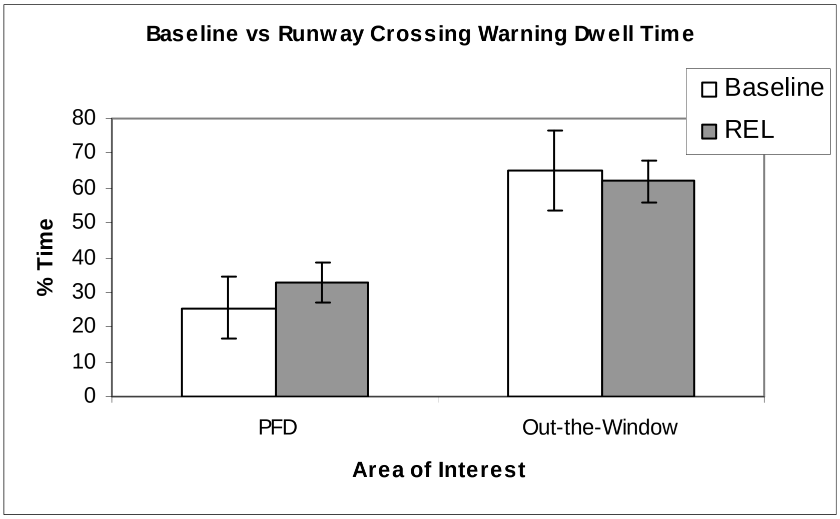

Figure 3-28. PFD vs. Out-the-Window Attention Allocation in Runway Crossing Scenarios

In the departure baseline condition, the difference in dwell time spent focused OTW (m=57.55%) as compared to on the PFD (m=11.42%) was significant, with a higher percentage of dwells OTW.[27] In the departure warning condition (THL), significantly more time was spent looking OTW (m=57.81%) than at the PFD (m=11.87%) (See Figure 3-29).[28] In the departure conditions, it was expected that pilots would focus most of their attention OTW, as they would be in position to take-off, or would be starting their take-off roll. There was no significant difference in the amount of attention allocated OTW between the baseline condition and the THL warning condition, providing evidence for the warning lights not changing where attention is, or should be, allocated.

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27 $P<.05$

28 $P<.01$

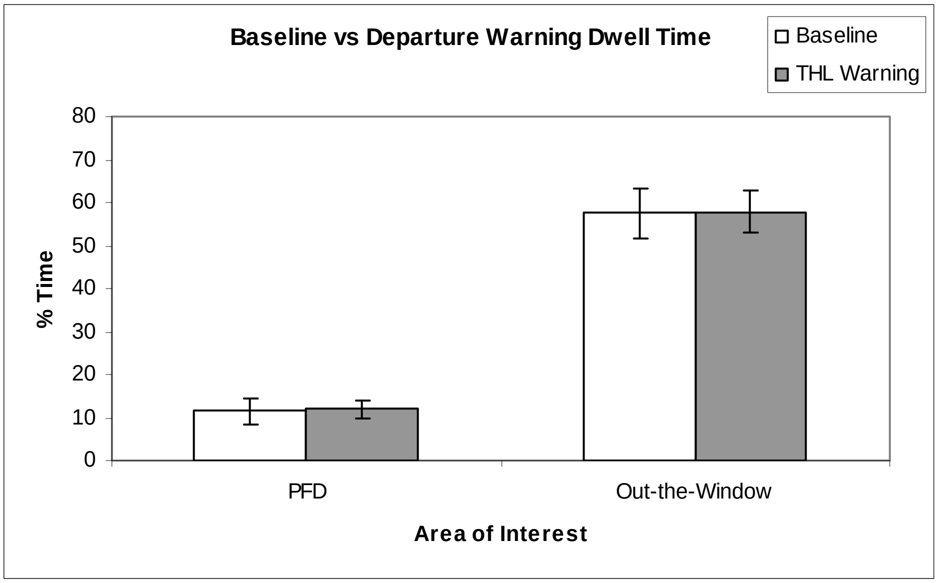

Figure 3-29. Difference in Attention Allocation Between PFD and Out-the-Window for Baseline vs. THL Conditions of Departure Scenarios

In the arrival baseline condition, significantly more time was spent looking OTW (m=56.01%) than at the PFD (m=32.26%), see Figure 3-30.[29] However, the distribution of attention changed in the warning condition (AWL). There was significantly more attention allocated to the PFD (60.92%) than OTW (28.03%) in the warning condition[30]. One possible explanation for this is the fact that in the warning condition, pilots initiated their go-around significantly earlier than in the baseline condition, and so changed their attention allocation in order to fly the go-around.

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[29] $P<.05$

[30] $P<.05$

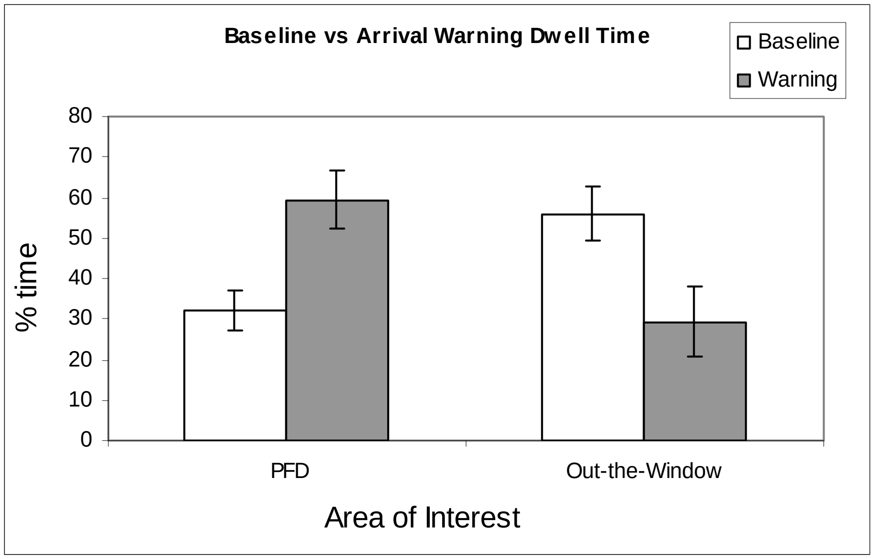

Figure 3-30. Difference in Attention Allocation Between PFD and Out-the-Window for Baseline vs. AWL Conditions for Arrival Scenarios

In the arrival scenarios comparing AWL warning scenarios to the ARIAS warning, there was an effect of AOI, with significantly more time spent looking at the PFD than OTW.[31] Figure 3-31 shows the attention allocation of pilots in the AWL and ARIAS warning conditions. Attention was more equally distributed between the PFD and OTW in the ARIAS warning condition than in the AWL warning condition. However, there is still more attention allocated to the PFD than OTW.

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[31] A 2-way ANOVA was run, using warning type and AOI as factors; there was an effect of AOI, with more attention overall focused on the PFD, $P<.05$.

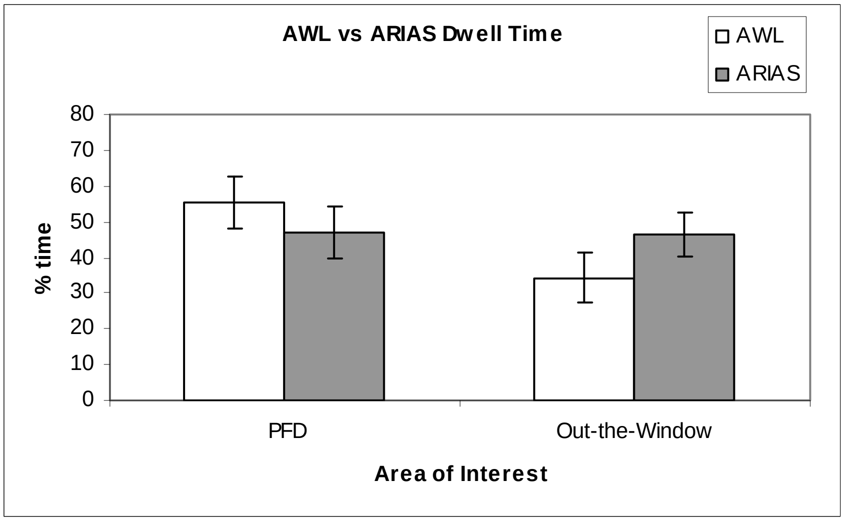

Figure 3-31. Difference in Attention Allocation between PFD and Out-the-Window for AWL vs. ARIAS Conditions of Arrival Scenarios

3.4.1 Visibility

Analyses were performed on the eye tracking data looking at differences in dwell location for the different visibilities pilots experienced.[32] There were some significant differences found. There was a significant difference in dwell time percentage between OTW and the PFD in the departure warning light scenarios with high visibility during the day.[33] People focused more of their attention OTW than on the PFD. The results were the same for the departure warning light scenario with high visibility at night; pilots focused more of their attention OTW during departures than on the PFD (see Figure 3-32).[34] There was also a significant difference found between percentages of dwell time on the PFD vs. OTW in the departure warning light scenarios with high visibility at night.[35] Pilots allocated more attention OTW than to the PFD.

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[32] Paired t-tests were run. ANOVAs were not run, as there were not data in every block (e.g.; there are no THL warnings in low, night visibility). Runway crossing scenarios were not analyzed, as they all had high visibility, and occurred in the daytime.

[33] $P<.05$

[34] $P<.05$

[35] $P<.05$

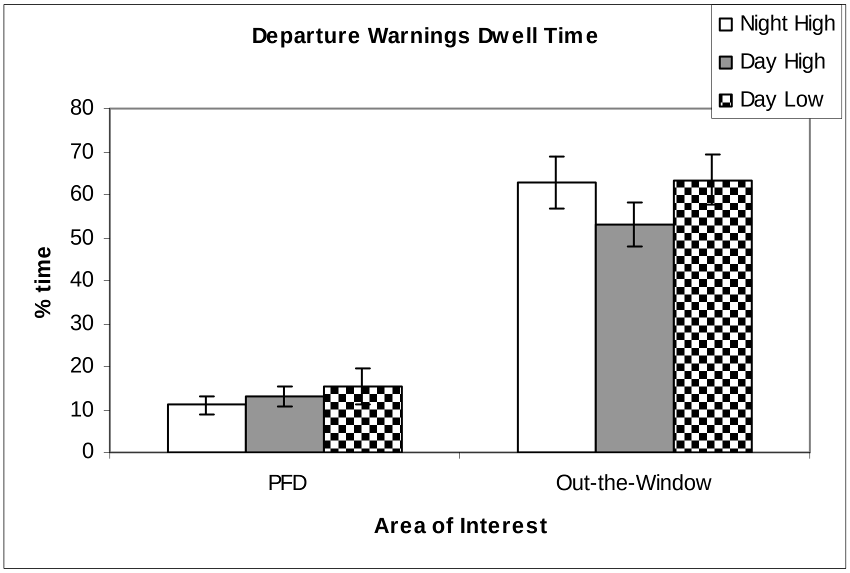

Figure 3-32. Difference in Attention Allocation Between PFD and Out-the-Window for Different Visibility Levels of Departure Scenarios

There was a significant difference found in the amount of attention allocated to the PFD as compared to OTW for arrivals at night with low visibility.[36] Pilots allocated more attention to the PFD than OTW during the night arrivals with low visibility. Looking at arrival scenarios at night, there was a difference found between the amounts of attention allocated OTW with high visibility as compared to low visibility.[37] More attention was allocated OTW in the high visibility condition. It was also found that in night arrival scenarios, significantly more attention was allocated to the PFD in low visibility conditions than in high visibility conditions (see Figure 3-33).[38] The finding of significantly more attention allocated inside the cockpit (on the PFD) than OTW in the low visibility arrivals raises the question of the effectiveness of a visual arrival warning system. The trend across all arrival scenarios was for more attention allocated to the PFD. But if pilots are focused more inside the cockpit, perhaps a visual warning that appears outside the cockpit is not always the best option.

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[36] $P<.01$

[37] $P<.05$

[38] $P<.05$

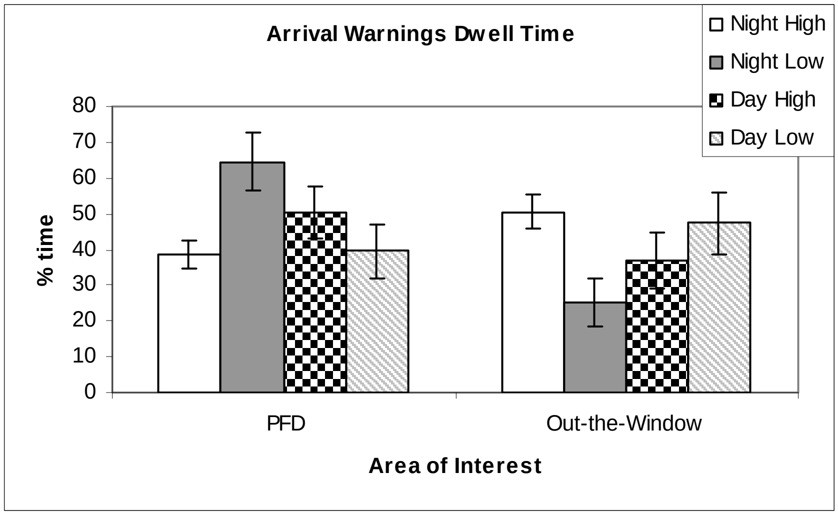

Figure 3-33. Difference in Attention Allocation Between PFD and Out-the-Window for Different Visibility Levels of Arrival Scenarios

Section 4

Conclusions

A simulation study was performed to assess the effectiveness of ground-based direct pilot warnings for the prevention of runway incursions. The evaluated warning system consisted of REL that warn during crossing and runway entrance maneuvers, THL that warn flight-crews during departure maneuvers, and AWL that warn arrivals. An auditory warning system, ARIAS, also provided warnings for arrivals.

Findings indicate that THL reduced significantly the likelihood of runway safety incidents compared to a baseline condition without THL (7% of trials with THL contained safety incidents vs. 92% without THL). This is a reduction of 86 % which is similar to the reduction that Moertl (2005) reported in his simulation study.

Arrival warning lights significantly increased the conflict detection distance from the runway so that pilots were able to initiate go-around maneuvers earlier (at 6557 feet from the runway with AWL versus 3774 feet without AWL). It was determined that though THL increased detectability of AWL when used as part of the AWL configuration, using THL in both arrival and departure cases may result in performance decrements. Pilots may confuse the applicability of the lighting between the different warnings.

Auditory arrival warnings were generally perceived to be effective, and pilots reported hearing and understanding them though one pilot continued his landing on receiving an auditory warning that he received just prior to touch-down.

Though REL reduced the number of safety incidents slightly compared to the baseline condition, the difference was not statistically significant. This reduction in safety incidents is smaller than previously found (e.g. Moertl, 2005) and indicates at least in part, that high-speed taxi maneuvers may reduce the effectiveness of REL, because the time REL are visible is shortened. Another current limitation of REL is that they do not mitigate the risk of unprotected entrances at runway intersections. Both limitations could be addressed by modifying the REL configuration such that it can be placed at runway intersections and increase the viewing duration for high-speed taxi situations.

Overall, the tested warning systems had different impact on pilot workload. Pilot workload was slightly higher in REL scenarios than in baseline scenarios though the difference did not reach significance. Pilot workload was significantly higher in THL scenarios than in the baseline scenarios which reflects the increased workload of aborting take-off maneuvers. In those THL scenarios, the increased workload was associated with a significant decrease in safety incidents. Arrival warnings did not increase pilot workload.

The tested warning systems also impacted pilots self reported situation awareness differently. REL seemed to slightly decrease pilots' situation awareness whereas THL significantly increased it. In both type of scenarios, safety performance increased as result of REL and THL which indicates limitations of self reported SA as indicator for performance. None of the other warnings evidenced an impact on pilots' self reported situation awareness. Pilots also requested information about if warnings constitute a command for the pilot to follow, or if they provide initial information that pilots need to verify before making a decision.

Recordings of pilots' eye movements show that in arrival situations, pilots allocate attention OTW approximately 42% of the time, versus 63% for runway crossing and 60% for departure situations. This indicates that during arrivals, pilots allocate more of their attention inside the cockpit than during taxi or departure operations. This may decrease detection rates of visual warnings that are located outside the cockpit for arrival operations. This is consistent with findings of Moertl (2005) who reports the results of a simulation where several pilots did not see arrival warning lights during landings. In addition, during night-time low visibility arrivals, flight-crews allocate attention even less outside the cockpit (28% of time spent OTW), potentially further reducing the likelihood of detection of the warning signal.

Overall, warnings seemed effective in reducing the likelihood of runway incursions. The described research identified needs for continued research and development activities:

First, because of the determined limitations of visual arrival warnings that are located on the ground, alternative warning methods should be examined for technical and operational feasibility. Specifically, feasibility of ARIAS should be determined, demonstrated, and described.

Second, THL should not be made part of an AWL system because of potential ambiguity concerning warning intent and should be applicable for departures only.

Third, alternative REL configurations should be identified and feasibility under approximated operational conditions should be demonstrated for these situations.

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Appendix A

Pilot Demographics Form

Pilot Demographics Form

Runway Status Light Configurations Simulation

Please complete the following background questionnaire. Your identity will be kept completely confidential and will not be included in any of the reports or documents that will be produced as a result of this study.

Employer: ____

Participant Code: _______ Date: ______________

1. Age: ____Years Sex: ____Male ____Female

2. Approximately how long have you been a pilot? ____ Years ____Months

3. With what aircraft type do you have the most experience? _____________________

4. Estimated total flight hours logged: ______
   Estimated hours logged in the past 90 days: ______

5. Type of flying you do most often: (check all that apply)

   ____ Local area, pleasure only
   ____ Personal & business, cross country
   ____ Mostly business flying
   ____ Professional pilot or full-time CFI

6. FAA Pilot Certificate Held:
   ____ Recreational ____Private ____Commercial ____ATP ____CFI

7. Ratings Held: (check all that apply)

   ____ Instrument ____ Multi-engine ____Glider ____ Rotorcraft

   Other:_____________

8. Type of aircraft currently flown most often:

   ____ Light Single ____ Complex Single ____ Light Twin

   ____ Turboprop ____ Jet

9. How many hours have you logged in multi-engine aircraft? _____________

10. What aircraft do you currently fly? ________________

11. Approximately what percentage of your current operations are at towered airports:
    ____%

12. At which position do you usually serve:

    ________ Pilot in Command

    ________ Second in Command

Appendix B

Informed Consent Document

The MITRE Corporation Center for Advanced Aviation System Development

(CAASD)

McLean, Virginia

The purpose of this simulation study is to evaluate an integrated airport safety system. During this simulation, you will be asked to operate an aircraft on a simulated airport. You will communicate with air traffic control via radio and hear radio communication with other aircraft. You will see two simulated airports, one is modeled after Louisville Standiford Field (SDF) the other one after Los Angeles International Airport (LAX). You will have time to familiarize yourself with the simulator prior to the simulation. During the simulation you will be asked to complete aircraft operations that include arriving, departing and taxiing an aircraft. After each scenario you will be asked to complete a survey. Audio, video, and aircraft operations data will be collected during each scenario for later analysis. You will be asked to wear an eye-tracker equipment similar to the one depicted on the picture in attached sheet. There are no known risks or physical discomforts associated with this experiment beyond those of ordinary life, and you will be paid **$150** compensation for your participation. Your identity will be kept completely confidential and will not be included in any of the reports or documents that will be produced as a result of this study. You may terminate your participation at any time. You will be debriefed after the completion of the study. Your participation in this research will support the improvement of runway safety technologies. We thank you for your involvement. If you have any further questions, please ask your experimenter or Peter Moertl (703-983-1080).

Statement of Consent

I acknowledge that my participation in this simulation study is entirely voluntary and that I am free to withdraw at any time. I have been informed of the general research purpose of this study. I understand that my data will be maintained in confidence, and that I may have a copy of this consent form.

Please indicate your consent by signing below.

Signature: ___________________________________ Date: _____________

Information required for mailing compensation payment

Name ____

SS # ____

Address ____

____

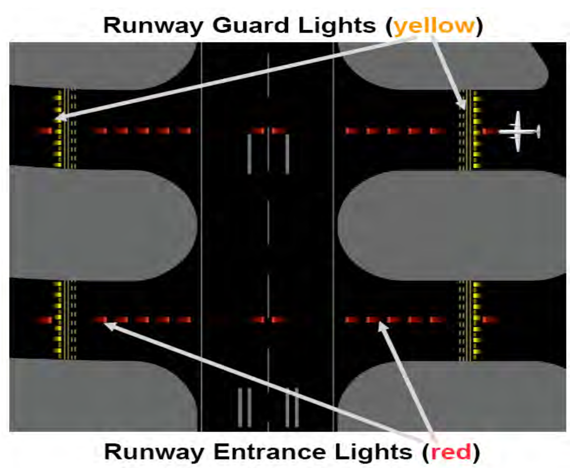
____

Appendix C

Training Material for Runway Safety Simulation, 2006

Runway Entrance Lights (REL)

REL are a series of in-pavement red lights spaced evenly along the taxiway centerline from the taxiway hold line to the runway edge. One REL is just before to the hold line in line and one REL is near the runway centerline (see Figure 1). REL are directed toward the taxiway hold line and are oriented to be visible only to pilots and vehicle operators entering or crossing the runway from that location.



Runway Entrance Lights From Cockpit

The REL system is designed to provide a direct status indicator to pilots that a runway is unsafe to cross / enter. The system is fully automatic, surveillance-driven, and is not actuated by the air traffic control tower (ATCT). However, ATCT sets the brightness levels and activates and deactivates the system.

Arrivals

All REL are simultaneously illuminated when an aircraft is on short final approach. REL progressively turn off at the lighted taxiways just prior to the landing aircraft passing the taxiway. All REL turn off as the landing aircraft decelerates to 35 knots.

Departures

All REL illuminate when a departing aircraft accelerates beyond 35 knots. REL progressively extinguish just prior to the aircraft passing the taxiway. All REL are turned off when the departing aircraft transitions to airborne status.

CAUTION

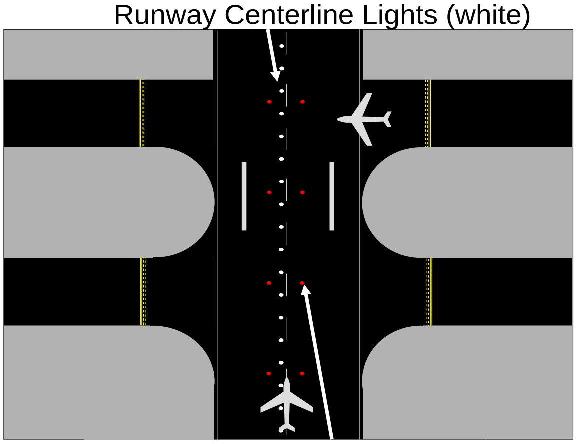
The turning off or absence of an illuminated REL does not constitute a clearance to cross / enter the runway. REL indicate runway status only.

- When the REL illuminate, the pilot should remain clear of the runway.
- When cleared to either “takeoff, cross the runway, position and hold, or immediate takeoff”, and REL are illuminated:
  stop the aircraft and indicate to Air Traffic that the aircraft has stopped with red lights and then wait for further clearance.
- If the aircraft crosses the hold line and the pilot subsequently observes illuminated REL, then if practical, the pilot should stop the airplane and notify Air Traffic that they are stopped across the hold line because of red lights.

- If remaining clear of the runway is impractical for safety reasons, then crews should proceed according to their best judgment of safety (understanding that the illuminated REL indicate the runway is unsafe to cross or enter) and contact ATC at the earliest opportunity

Take-off Hold Lights (THL)

THL consist of two series of in-pavement red lights that are spaced evenly along the runway centerline every 200 feet for 1600 feet. The first pair of THL is 375 feet from the runway threshold. They are spaced 36 feet laterally around the runway centerline markings. THL are directed toward the departure threshold and are visible only to pilots on the runway in departure position or during the initial take-off roll.



The THL system provides a direct warning to pilots who are in position for takeoff or starting their takeoff at this location. The alert indicates that the runway is not safe for takeoff at this location and that another aircraft or vehicle could come in conflict if the pilot continues the departure. One aircraft needs to be in the THL arming zone (AC 1 below), a second aircraft needs to be in the THL activation zone. The second aircraft can either be located on the runway (AC 2 below), or on approach (not shown).

The system is fully automatic, surveillance-driven, and not actuated by the ATCT. However, ATCT sets the brightness levels and activates and deactivates the system.

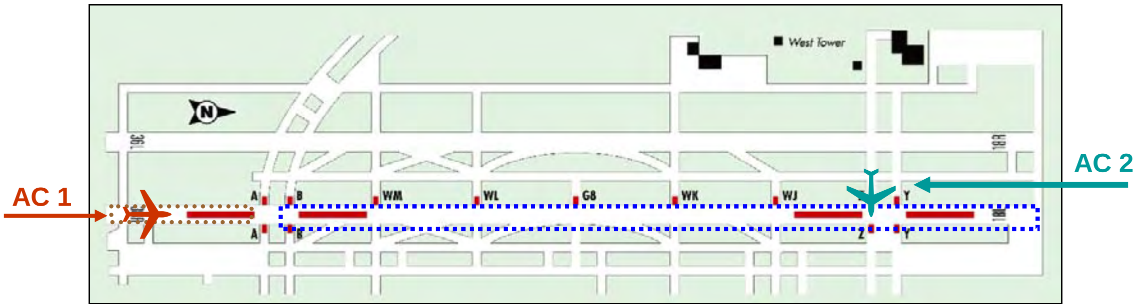
Take-off Hold Lights
as Seen From the Cockpit

CAUTION

The turning off or absence of illuminated THL does not constitute a clearance to depart on the runway. THL indicate runway status only. Illuminated THL indicate that the runway is unsafe for departure, and a takeoff is not advised.

When cleared for takeoff and the THL are illuminated, stop the aircraft and indicate to Air Traffic that you are stopped with red lights on the runway and wait for further clearance.

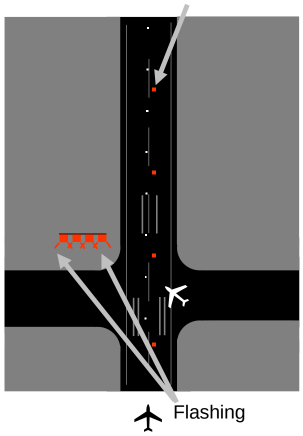
If the THL illuminate after takeoff initiation, decide immediately if the take-off can be aborted safely. In case of an abort, inform Air Traffic Control that the take-off was stopped because of red lights on the runway.



Two Aircraft are required to trigger THLs

Arrival Warning Lights (AWL)

AWL consist of flashing Precision Approach Path Indicators (PAPI) and illuminated THL. PAPI continue to indicate the vertical glide slope angle as under current operations. The illuminated THL support detection of the warning. The warning indicates to an arrival aircraft that it is unsafe to land and that therefore, a go-around maneuver should be initiated. The THL, in addition, warn a departing aircraft on the arrival runway that a take-off is unsafe because a go-around is currently ongoing on the same runway.



Arrival Occupancy Lights From Cockpit

The AWL system is fully automatic, surveillance-driven, and not actuated by the ATCT. It is controlled by an Airport Movement Safety System that uses aircraft position information to determine potential conflicts. Once a conflict is detected, the system warns only of conflicts when no other way to avoid the conflict is possible.

When AWL activate, the ATCT receives an auditory warning in the air traffic control tower. ATCT sets the brightness levels of the THL and activates and deactivates the AWL system. Illuminated AWL do not constitute an ATC clearance.

CAUTION

When seeing the illuminated AWL on their approach, pilots should immediately initiate a go-around and contact air traffic control that a go-around has been initiated because of the arrival warning lights.

Not illuminated AWL do not indicate a landing clearance.

Auditory Runway Incursion Alerting System (ARIAS)

The ARIAS provides an auditory warning to arrival aircraft about a runway on which it is unsafe to land. The ARIAS works synchronized with the AWL system and are triggered by the same logic (see AWL description).

When the ARIAS activates, a flight (here CAASD 49) approaching runway 12L will hear in the cockpit

> **"CAASD 49, traffic on 12L, CAASD 49, traffic on 12L"**

When hearing that warning the flight-crew should immediately initiate a go-around maneuver and contact ATCT because it is unsafe to land on this runway.

The ARIAS system is fully automatic, surveillance-driven, and not activated by the ATCT. It is controlled by an Airport Movement Safety System that uses aircraft position information to determine potential conflicts. Once a conflict is detected, the system warns only of conflicts when no other way to avoid the conflict is determined feasible.

When ARIAS activates, the ATCT receives an auditory warning in the air traffic control tower. An ARIAS warning does not constitute an ATC clearance.

The ARIAS relies on the same conflict detection logic as AWL so that ARIAS is triggered at the same time as AWL. The warnings are overlaid on the marker beacon frequency at 75 Mhz and transmitted via ground antenna that is directed toward the approaching aircraft.

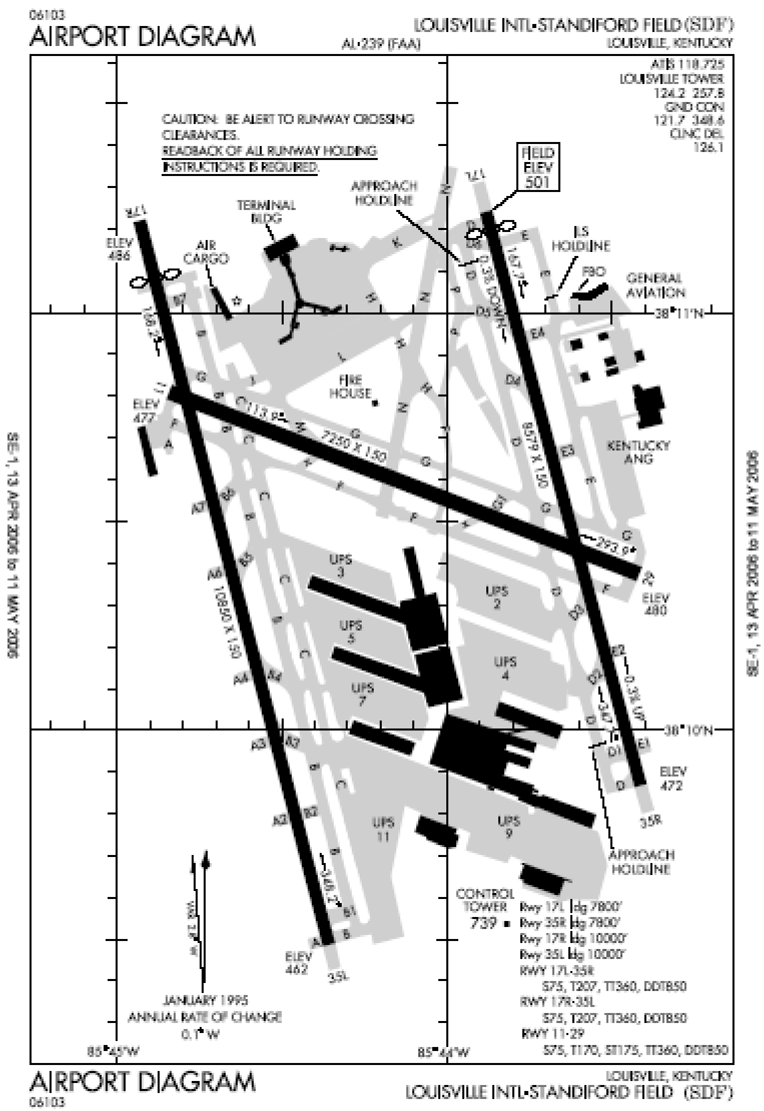
The system provides the warning as early as around 30 seconds prior to a predicted conflict on the runway.

CAUTION

To receive ARIAS warnings, the marker system must be activated onboard the aircraft.

Appendix D

SDF Airport Diagram



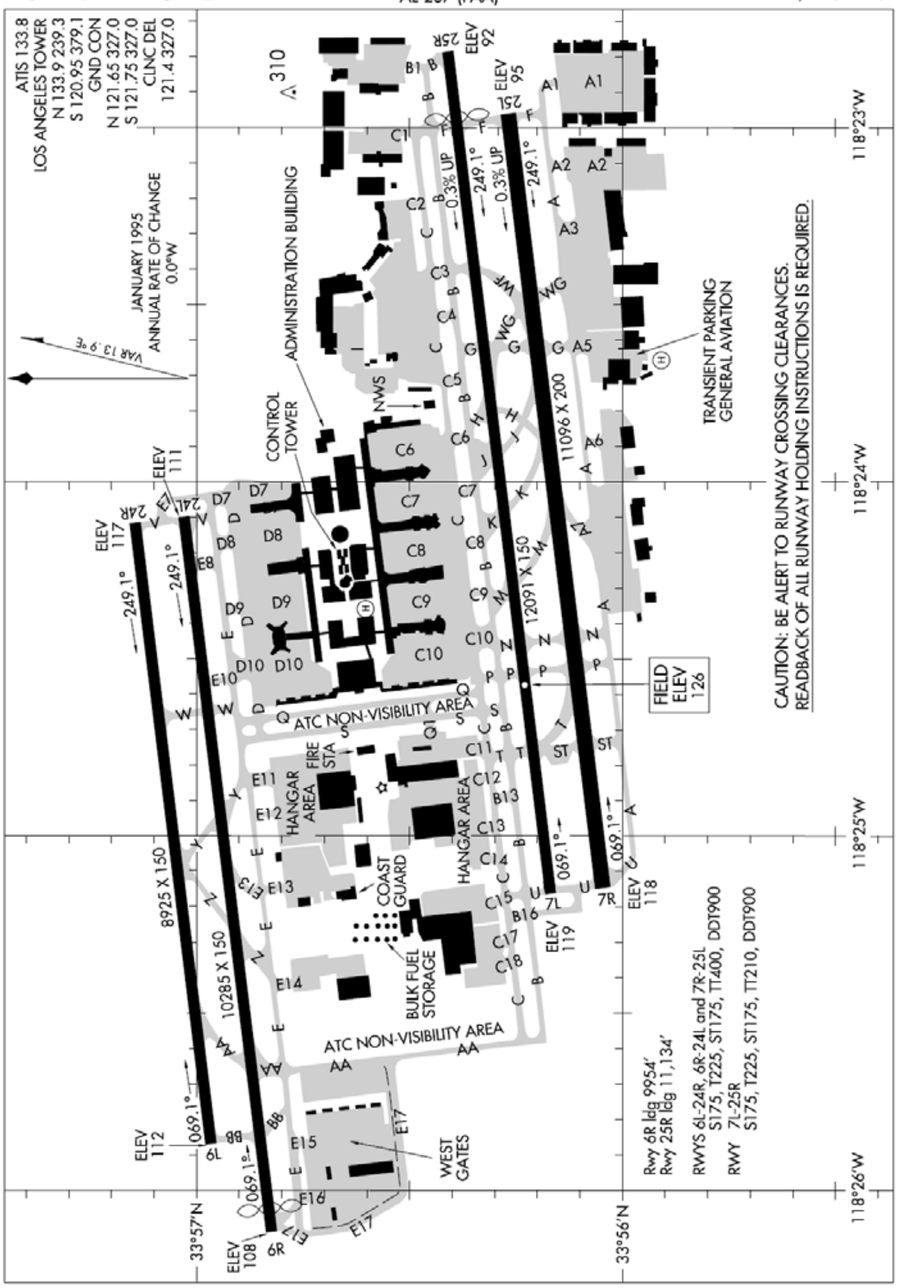
03359

AIRPORT DIAGRAM

AL-237 (FAA)

LOS ANGELES INTL (LAX)
LOS ANGELES, CALIFORNIA

SW-3, 13 APR 2006 to 11 MAY 2006



SW-3, 13 APR 2006 to 11 MAY 2006

AIRPORT DIAGRAM

03359

LOS ANGELES, CALIFORNIA
LOS ANGELES INTL (LAX)

Appendix E

Air Traffic Workload Input Technique: Continuous Workload Responses

Every 90 seconds, 7 buttons, numbered 1 to 7, appeared on the bottom of the PFD. Pilots were asked to press the number that best described the amount of workload they were currently experiencing each time the buttons appeared. The possible workload ratings ranged from 'low' (1) to 'extremely high' (7). This table provides information on the number of times pilots responded when the ATWIT appeared on the PFD, and the number of times they did not respond.

Scenario	Missed Responses	Responses	Total Chances to Respond	% Responses
1b REL Warning	8	2	10	20.00
2a REL Baseline	18	8	26	30.77
2b REL Warning	20	10	30	33.33
3a THL Baseline	6	8	14	57.14
3b THL Warning	5	8	13	61.54
4a THL Baseline	5	5	10	50.00
4b THL Warning	13	7	20	35.00
5b THL Warning	11	9	20	45.00
6b THL Warning	14	10	24	41.67
7b THL Warning	22	9	31	29.03
8b AWL Warning	5	6	11	54.55
8c ARIAS Warning	8	4	12	33.33
9a AWL Baseline	7	4	11	36.36
9b AWL Warning	3	6	9	66.67
10a AWL Baseline	5	11	16	68.75

Scenario	Missed Responses	Responses	Total Chances to Respond	% Responses
10b AWL Warning	**9**	**6**	**15**	**40.00**
11b AWL Warning	**7**	**6**	**13**	**46.15**
11c ARIAS Warning	**9**	**8**	**17**	**47.06**
TOTALS	**175**	**127**	**302**	**42.05**

Appendix F

Scenario Run Order

Line #	Pair Participant	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12
0a	Dryrun 1	Warmup	Fam1	Fam2	4a	10a	1b	8b	11b	2a*	3a*	9a*	7b*
0b	Dryryn 2	Warmup*	Fam1*	Fam2*	9b*	2b*	3b*	8c	11c	5b	6b	4b	10b
1	1-1	Warmup	Fam1	Fam2	11b	8b	1b	10a	4a	7b*	3a*	9a*	2a*
2	1-2	Warmup	Fam1	Fam2	5b	11c	8c	10b	4b	6b	3b*	9b*	2b*
3	2-1	Warmup*	Fam1*	Fam2*	3a*	2b*	9a*	4b	10b	11b	5b	6b	8c
4	2-2	Warmup*	Fam1*	Fam2*	3b*	2a*	9b*	7b*	4a	10a	11b	8b	1b
5	3-1	Warmup	Fam1	Fam2	10b	11b	8c	4a	1b	3a*	7b*	9b*	2a*
6	3-2	Warmup	Fam1	Fam2	10a	6b	11c	8b	4b	5b	3b*	9a*	2b*
7	4-1	Warmup*	Fam1*	Fam2*	9a*	2b*	3b*	11b	10a	4b	5b	8c	6b
8	4-2	Warmup*	Fam1*	Fam2*	9b*	2a*	3a*	7b*	11c	10b	4a	8b	1b
9	5-1	Warmup	Fam1	Fam2	4b	1b	8c	11b	10a	9a*	3a*	7b*	2a*
10	5-2	Warmup	Fam1	Fam2	4a	6b	8b	5b	11c	10b	9b*	3b*	2b*
11	6-1	Warmup*	Fam1*	Fam2*	2b*	9b*	3b*	5b	4a	8c	10b	6b	11b
12	6-2	Warmup*	Fam1*	Fam2*	2a*	7b*	9a*	3a*	1b	4b	8b	10b	11c
13	7-1	Warmup	Fam1	Fam2	8c	10b	11b	1b	4a	9a*	3b*	7b*	2a*
14	7-2	Warmup	Fam1	Fam2	8b	10b	11c	5b	6b	4b	9b*	3a*	2b*

*LAX scenarios/all others are SDF scenarios.

Appendix G

NASA TLX

Participant Workload Rating Form

Please rate the workload that you experienced during this scenario on each of these 6 scales by marking the appropriate position with a vertical line.

Mental Demand

Low Demand High Demand

Physical Demand

Low Demand High Demand

Temporal Demand

Low Demand High Demand

Effort

Low Effort High Effort

Performance

Low Performance High Performance

Frustration

Low Frustration High Frustration

Appendix H

Experimenter Observation Form

Date: ______ Participant: _____ Scenario: ______ Run: ______

Prior to scenario-start checklist:

1. **Check eye-tracker calibration / data-quality**
2. **Give controller next scenario number**
3. **Introduce pilot about where to start taxiing**
4. **Start eye-tracker data-collection**

Post scenario-start checklist:

1. **Give survey to pilot**
2. **Stop eye-tracker data-collection**
3. **Ask question about scenario**
4. **Participant completed survey**
5. **Survey was saved to the server**
6. **Was this run No. 6? If yes: break for 10 min.**

Observations:

1. Did pilot avoid runway conflict: _________ N/A
2. "Do you have any comments about this scenario?"

____

____

____

3. Describe pilot behavior:

Appendix I

Confederate Pilot Observation Form

Date: ______ Participant: _____ Scenario: ______ Run: ______

Observations:

1. Did pilot avoid runway conflict: _________ N/A
2. Seemed the pilot aware of the runway conflict?

   Yes _____ No _____ N/A _____

   ____

   ____

   ____

   ____

   ____

   ____

3. Additional notes about this scenario:

   ____

   ____

   ____

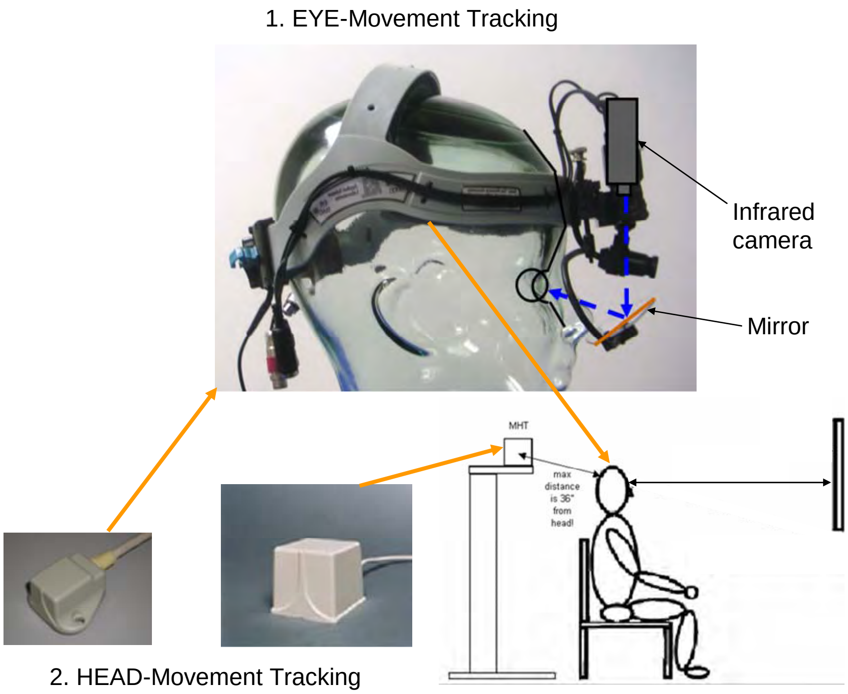
   ____

   ____

   ____

Appendix J

Eye Tracker Information



General

- You can move your head while remaining in your seat
- You will be asked to wear the head-tracker throughout the duration of the simulation
- Prior to the scenarios, the eye tracker will be calibrated
    - Will need to be repeated throughout the simulation whenever the tracker is taken off

Process

- First, the head-tracker will be adjusted to your head
- Second, the equipment will be CALIBRATED
  - During calibration, you will be asked to look at various points on a test template while the experimenter sets up the software
    - 15-20 seconds
    - During that time, you will be asked not to move your head
- Third, during the simulation, recalibration might be required from time-to-time
- Finally: **Please be careful when scratching your nose!**

Appendix K

Post Run Questionnaire

===

Participant Number: _________ Scenario Number: __________

===

Post Scenario Questionnaire

(A) After EVERY Scenario (1 through 11):

Please answer following questions as accurately as you can:

The term overall situation awareness refers here to what is commonly known as the pilot “staying ahead of the aircraft” where the pilot has a thorough understanding of the current situation and can take appropriate action as necessary.

1.	How high was your overall situation awareness during the scenario?	Very low	1	2	3	4	5	Very high	N/A
2.	How high was your awareness about other aircraft on the airport?	Very low	1	2	3	4	5	Very high	N/A

3. Was there a conflict in this scenario? Yes _____ No _____

4. If you answered “yes” on the previous question: were you aware of the conflict before any warning system activated?

   Yes _____ No _____

5. Any comments about the scenario?

____
____

(B) After REL scenarios (scenarios 6 and 7):

6. Did you see illuminated Runway Entrance Lights (REL)? Yes _____ No _____

If you saw illuminated REL, please respond to the following questions as accurately as you can:

7.	How easy were the illuminated REL to detect?	Very hard	1	2	3	4	5	Very easy	N/A
8.	How difficult was the decision to initiate action when you saw the illuminated REL?	Very difficult	1	2	3	4	5	Very easy	N/A

9. If you thought that the decision to initiate action was difficult (previous question), why was it so?
____
____

10. Any other comments?

____
____

(C) After THL scenarios (scenarios 8 to 12):

11. Did you see illuminated Takeoff Hold Lights (THL)? Yes _____ No _____

12. Did you expect based on other information in the scenario, the THL to be illuminated?

Yes ______ No _______

If you saw illuminated THL, please respond to the following questions as accurately as you can:

13.	How easy were the illuminated THL to detect?	Very hard	1	2	3	4	5	Very easy	N/A
14.	How likely are THL confused with other lights on the airport surface?	Very likely	1	2	3	4	5	Very unlikely	N/A
15.	How difficult was the decision to initiate action based on the illuminated THL?	Very difficult	1	2	3	4	5	Very easy	N/A

16. If you agreed that the decision to initiate action was difficult (previous question), why was it so?

___

___

17. Any other comments?

___

___

(D) After AWL scenarios (scenarios 13 to 16):

18. Did you see illuminated Arrival Warning Lights (AWL)? Yes _____ No _____

19. Did you expect the AWL to be illuminated? Yes _____ No _____

If you saw the illuminated AWL, please respond to the following questions as accurately as you can:

20. The AWL consisted of two lighting configurations. Which one did you notice first in this scenario (select one):

Flashing Precision Approach Path Indicator Lights (PAPIs) _____

Take-off Hold Lights (THL) _____

I saw both at the same time ____

I saw neither ____

21.	How easy were the illuminated AWL to detect?	Very hard	1	2	3	4	5	Very easy	N/A
22.	How likely are AWL confused with other lights on the airport surface?	Very likely	1	2	3	4	5	Very unlikely	N/A
23.	How difficult was the decision to initiate action based on the illuminated AWL?	Very difficult	1	2	3	4	5	Very easy	N/A

24. If you agreed that the decision to initiate action was difficult (previous question), why was it so?

____

____

25. Any other comments?

____
____

(E) After Auditory Warning scenarios (scenarios 17 and 18):

26. Did you hear an auditory arrival warning? Yes ______ No ______

27. Did you see arrival warning lights (AWL)? Yes _____ No ______

If you heard the auditory arrival warning, please respond to the following questions as accurately as you can:

28.	How easy was it to detect the auditory warnings?	Very hard	1	2	3	4	5	Very easy	N/A
29.	How difficult was the decision to initiate action based on the auditory warning?	Very difficult	1	2	3	4	5	Very easy	N/A

30. If you thought that the decision to initiate action was difficult (previous question), why was it so?

____
____

Indicate your agreement to the statements below.		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongl y agree	Not applicable/ Did not use
31.	Having both visual and auditory warnings made it easier to initiate action.	☐	☐	☐	☐	☐	☐

32. Any other comments?

Appendix L

Post Simulation Questionnaire

===

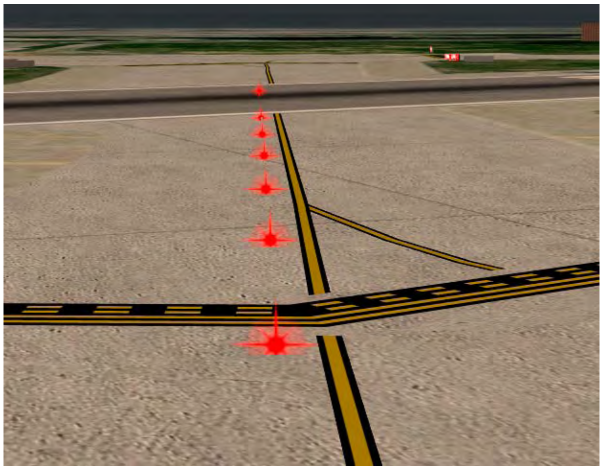
Participant Number: _________

===

Post-Simulation Survey

Runway Entrance Lights

Indicate your agreement and disagreement to the statements below.		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongly agree	Not applicable/ Did not use
1.	The REL provided effective warnings at the runway entrance area.	☐	☐	☐	☐	☐	☐



2. In what ways could REL be improved?

____

____

Take-off Hold Lights

Indicate your agreement and disagreement to the statements below.		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongly agree	Not applicable/ Did not use
3.	The THL provided effective warnings in departure situations.	☐	☐	☐	☐	☐	☐

4. In what ways could THL be improved?

____

____

Arrival Warning Lights (AWL)

Indicate your agreement and disagreement to the statements below.		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongly agree	Not applicable/ Did not use
5.	The AWL provided effective warnings during the arrival.	☐	☐	☐	☐	☐	☐

6. In what ways could AWL be improved?

____

____

Auditory Warnings

Indicate your agreement and disagreement to the statements below.		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongly agree	Not applicable/ Did not use
7.	The auditory warnings were effective in the scenarios.	☐	☐	☐	☐	☐	☐

8. In what ways could the auditory warning system be improved?

____

____

9. Have you ever experienced an auditory alert that has impaired your performance in a high-workload situation?

   Yes _____ No ______

10. If yes, please describe:

____

____

11. Do you prefer flight-deck auditory alerts with (a) speech elements, or (b) non-speech elements, or both (c).

    (a) ____

    (b) ____

    (c) ____

12. Please explain your preference.

    ____

    ____

13. What modality do you prefer for runway safety warnings?

    (a) ____

    (b) ____

    (c) ____

14. Please explain your preference.

    ____

    ____

15. Please rank the urgency of following auditory alerts by placing the numbers 1 to 11 beside them. Use the number 1 for the most urgent, and the number 11 for the least urgent). If you are unfamiliar with this alert, indicate this by a question mark:

Fire _____	**Caution _____**	**Overspeed _____**
Traffic _____	**Configuration _____**	**Decision height _____**
Windshear _____	**Ground proximity _____**	**500 feet _____**
System _____	**Autopilot disconnect _____**	

Indicate your agreement to the statements below		Strongly disagree	Some-what disagree	Neither disagree nor agree	Some-what agree	Strongly agree	Not applicable/ Did not use
16.	Overall, the simulation environment had adequate fidelity to conduct this evaluation.	☐	☐	☐	☐	☐	☐
17.	The training material prepared me well for using the warning systems in this study.	☐	☐	☐	☐	☐	☐

Alternative Arrival Warning Lighting System

Arrival warnings could (potentially) also be provided using existing approach lighting systems. The FAA would like to collect some usage data and solicit your input to determine the potential and limitations of this alternative.

18. During what percentage of your approaches do you use approach lights for visual guidance to the arrival runway? (100 % = all approaches) ________

Comments:
____

____

19. During day-light and high visibility conditions, do you use approach lights for visual guidance?
If yes, please estimate the percentage:
(100 % = all approaches during day-light and high visibility) ______

Comments:
____

____

20. If you use autoland, do you visually observe approach lights?
____

____

21. What potential problems do you see when adapting approach lights for use for arrival warnings?
____

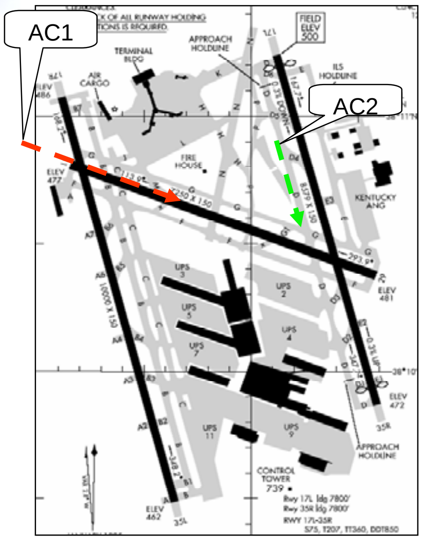
____

On a scale from 1 to 10 where 1 indicates the lowest and 10 the highest, please estimate the conspicuity of a visual warning that consists of a row of red flashing lights in the last row of the approach lighting system:

Appendix M

Scenario Descriptions

Scenario 1 – Runway Crossing



Enter/Arrival/Same Runway
Visibility: Day, High

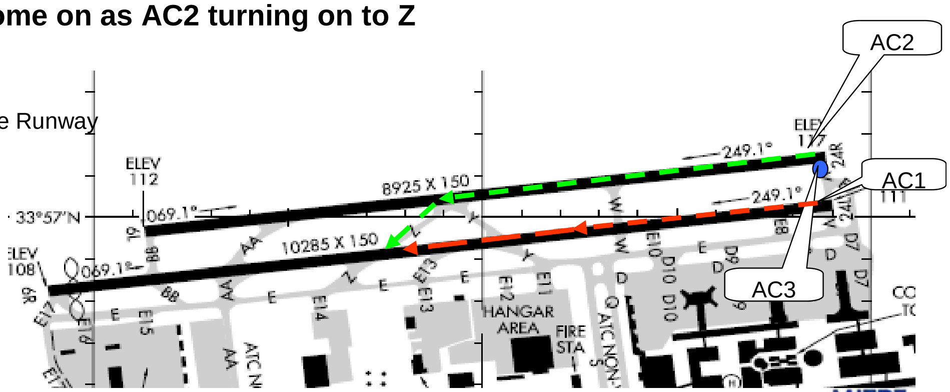
- **AC1 cleared to land on 11**
- **AC2 (participant) taxiing D to 35R**
- **AC2 cleared to cross 11**
  - **"No delay on crossing; traffic on short final"**
  - **Controller error—timing issue**

MITRE

Scenario 2 – Runway Crossing

- **AC2 (participant) just landed, crossing 24L using Z**
  - **“No delay off runway on Z. AC3 departure behind you”**
- **AC1 departing 24L**
  - **Will be cleared to depart after AC2 crosses, but begins takeoff roll early**
  - **Pilot error—AC1 should not be taking off**
- **AC3 TIPH 24L after AC2 lands**
- **RELs come on as AC2 turning on to Z**

Enter/Departure/Same Runway
Visibility: Clear, Day



MITRE

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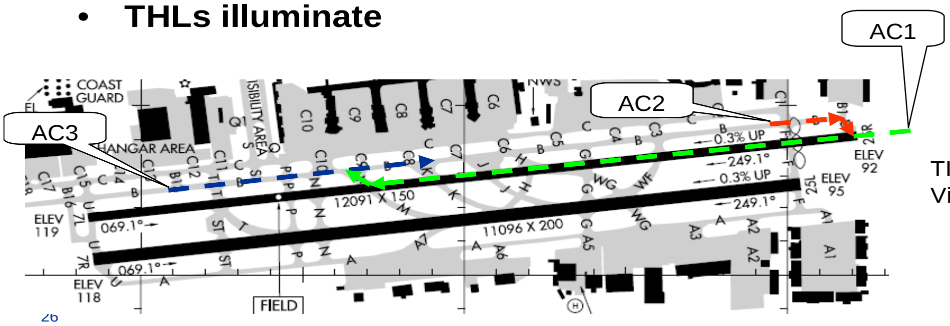
Scenario 3 - Departure

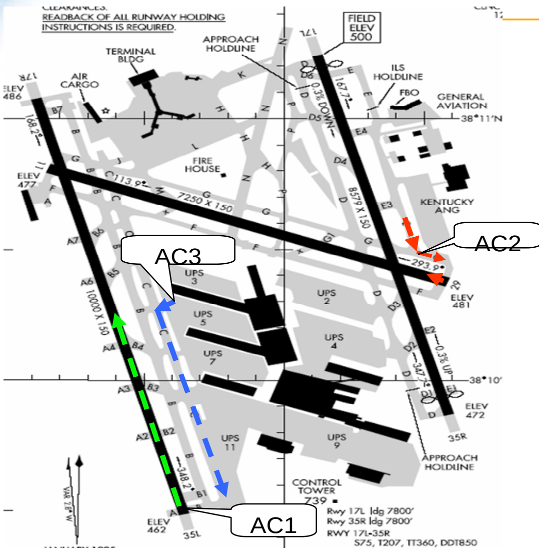
- **AC1 lands on 25R with instructions to exit at M**
- **AC2 (participant) TIPH 25R after AC1 lands, will be cleared for TO as AC1 exits runway**
- **AC3 taxiing west on B, crossing M when AC1 tries to exit**
- **AC1 doesn't exit completely at M—stops with tail on runway**
- **AC2 cleared for TO as AC1 begins turn**
  - **Controller error—didn't see if AC1 was completely off runway before issuing clearance**
- **THLs illuminate**



TIPH/Remain/Same Runway
Visibility: Night, low

MITRE

Scenario 4 - Departure



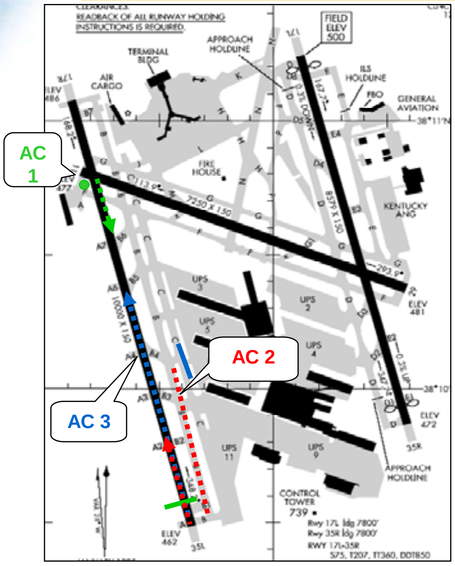
Departure/Departure/Intersecting Runways
Visibility: Day, high

- **AC1 holding for departure on 35L**
- **AC2 (participant) "cleared for immediate T/O on 29" as it turns the corner on Golf approaching the threshold of RW 29**
- **AC3 requests Taxi instructions**
- **Simultaneously AC1 takes clearance, and begins departure roll**
  - **Pilot error**
- **THLs illuminate as AC2 begins departure roll**

MITRE

Document Number Here

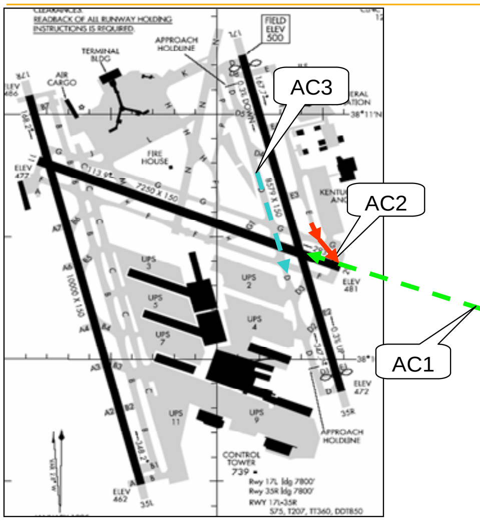
Scenario 5 - Departure



Departure/Enter/Same Runway
Visibility: Day, low

- AC2 (Participant) is cleared to taxi to 35L
- AC3 is cleared for takeoff on 35L
- AC1 (airport vehicle) cleared onto 11 from ramp area F for light check, but turns onto 35L instead
  - Operator error
- AC2 (Participant) is cleared for takeoff on 35L
- THLs illuminate as departure roll initiated

Scenario 6 - Departure



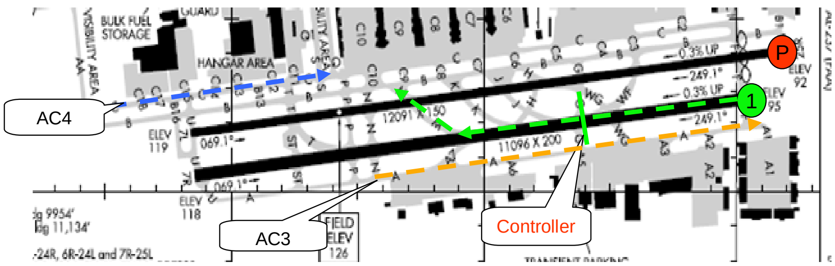
TIPH/Arrival/Same Runway
Visibility: Night, high

- AC1 cleared to land 29 prior to scenario start
- AC2 (participant) "TIPH at 29, traffic crossing downfield"
- AC3 crosses 29
- AC2 cleared for takeoff, but AC1 too close
  - Controller error
- THLs stay on
  - They were on while AC3 crossing
  - AOLs will also come on for arrival aircraft

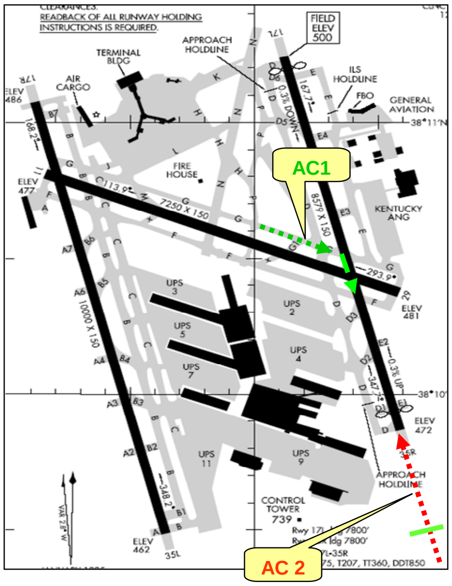
Scenario 7--THL

- AC1 arriving on 25L with instructions to turn right on M and hold short of 25R
- At scenario start AC3 begins taxi up A and AC4 begins taxi up C
- Participant (P) cleared for takeoff on 25R (as AC1 reaches trigger 1: controller decision)
- Participant begins departure roll
- AC1 turns right on taxiway M but is going too fast and cannot hold short of 25R
  - Pilot error
- THLs illuminate during takeoff roll

Departure/Enter/Same Runway
Visibility: Night, low



Scenario 8 - Arrival



Arrival/Enter/Same Runway
Visibility: Night, low

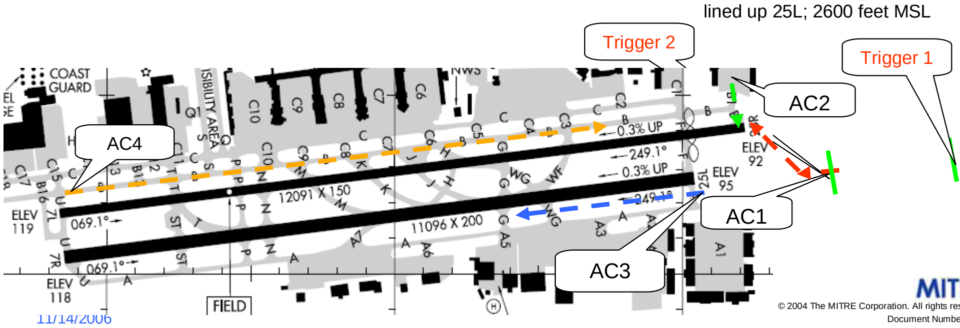
- AC2 (Participant) is cleared to land on Runway 35R
- AC1 taxiing to 35R via G and D
- AC1 turns onto 35R instead of D
  - Pilot error
- AWLs illuminate

MITRE

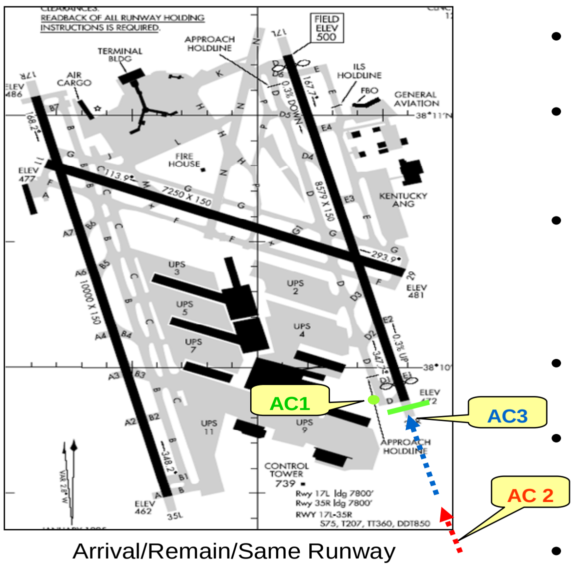
Scenario 9--AWL

- **AC2 told to TIPH 25R (trigger 1)**
- **AC1 (participant) cleared to land 25L**
- **AC3 cleared for TO 25L (trigger 1)**
- **AC3 aborts TO-blown tire (trigger 2)**
- **AC1 told to sidestep to 25R when they are ~4 miles out (trigger 1)**
- **AC4 begins taxi up C at scenario start**
- **ATC forgets about AC2—busy with AC3**
  - **Controller error**
- **AWLs illuminate**

Arrival/TIPH/Same Runway
Visibility: Day, low
AC1: 150 knots; 6 miles out
lined up 25L; 2600 feet MSL



Scenario 10 - Arrival

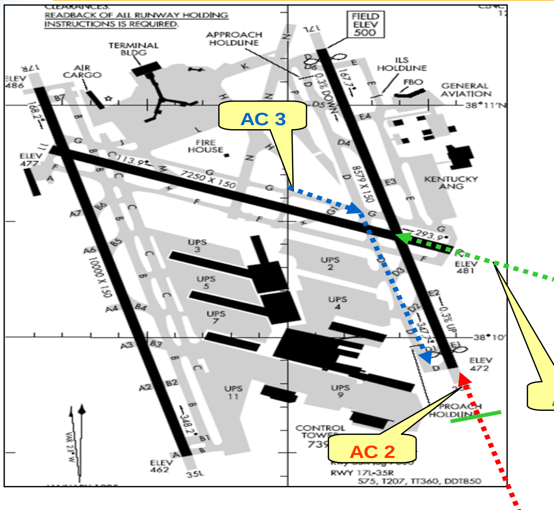


Arrival/Remain/Same Runway
Visibility: Clear, Day

- **AC3 is cleared to land on Runway 35R**
- **AC2 (Participant), five miles behind AC3, is also cleared to land on Runway 35R**
- **There is 1 departure in between AC3 and AC2 (AC1): TIPH after AC3 crosses threshold**
- **AC3 exits at D1, and AC1 is cleared for immediate takeoff**
- **AC1 does not respond and stays in position holding**
  - **Pilot error**
- **AWLs illuminate**

MITRE

Scenario 11 - Arrival



Arrival/Arrival/Intersecting Runways
Visibility: Night, low

- AC1 is cleared to land on Runway 29, with instructions to reduce to minimum speed
- AC2 (Participant) is cleared to land on Runway 35R
- Controller is distracted by AC3, who asks for repeat of taxi instructions on same radio frequency
- Separation ceases to exist between AC1 and AC2 (Participant).
  - Controller error—timing issue
- AWLs illuminate

MITRE

Appendix N

Scenario Scripts

Familiarization Scenario 1 (SDF)

Visibility: Day, High

AC1= CAASD 19

AC2= Participant/ CAASD 49

AC3= CAASD 39

CAASD 85 (no visual)

Airport 1 (no visual)

Participant: **“**Louisville Tower, CAASD 49 ready for taxi”

ATC: **“**CAASD 49, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 29.92”

Participant: **“**CAASD 49, taxi to runway 35L via Bravo.”

CAASD 19: **“**Louisville Tower, CAASD Nineteen on final for Runway Three-Five Left”

ATC: **“**CAASD Nineteen, Louisville tower, runway 35L, cleared to land, wind calm.

CAASD 19: **“**Cleared to land Runway Three-Five Left, CAASD Nineteen.”

CAASD 85: Louisville tower, CAASD eighty-five, ready to taxi

ATC: CAASD 85, taxi to runway 35R via Delta, Altimeter 2-9-9-2

<u>CAASD 85</u>: CAASD eighty-five taxiing to runway three-five right via Delta, Altimeter 2-9-9-2 .

<u>Airport 1</u>: Louisville tower, airport 1, on Delta, requesting permission to cross runway two-niner and go to UPS ramp 4.

ATC: Airport 1, tower, cross 29 on Delta and proceed to UPS 4.

<u>Airport 1</u>: Roger, crossing runway two-nine, Airport 1.

As Participant turns to hold short of 35L, REL come on; CAASD 19 lands:

ATC: **"**CAASD 49, Runway 35L, taxi into position and hold"

Participant: **"**Taxi into position and hold Three-Five Left, CAASD Forty-Nine"

After participant has TIPH 35L; THL illuminate

ATC: CAASD 19, turn right at B6, taxi to the ramp

<u>CAASD 19:</u> Right on Bravo six and taxi to the ramp, CAASD Nineteen.

<u>CAASD 39</u>: Tower, CAASD 39 ready to taxi

ATC: "CAASD 39, taxi to runway 29 via Foxtrot, Altimeter 29.92."

<u>CAASD 39</u>: "Roger, taxi to runway 29 via Foxtrot, roger on the Altimeter."

ATC: "CAASD 49, Runway 35L, cleared for takeoff."

Participant: **"**Cleared for takeoff 35L, CAASD 49"

END SCENARIO

Familiarization Scenario 2 (SDF)

Visibility: Day, low

AC1= CAASD 19
AC2= Participant/ CAASD 49

AC3= CAASD 29 (no visual)
CAASD 87 (no visual)
CAASD 95 (no visual)

Participant: Louisville Tower, CAASD 49 8 miles out for 35R

ATC: CAASD 49, Louisville tower, Runway 35R, cleared to land.

Participant: Cleared to land 35R, CAASD 49.

CAASD 19: Tower, CAASD Nineteen holding short of Runway Three-Five Right

ATC: CAASD 19, Runway 35R, taxi into position and hold.

CAASD 19: Position and hold on Runway Three-Five Right, CAASD Nineteen.

CAASD 29: Louisville tower, CAASD 29 ready to taxi.

ATC: CAASD 29, runway 35L via bravo, position and hold Altimeter 29.92.

<u>CAASD 29</u>: Runway Two-Five Left via bravo, position and hold, altimeter two niner, niner two, CAASD 29

ATC: CAASD 29, runway 35L, cleared for takeoff.

<u>CAASD 29</u>: Cleared for takeoff on Two-Five Left, CAASD 29

<u>CAASD 87:</u> Tower, CAASD eighty-seven ready to taxi

ATC: CAASD 87, taxi to runway 35L via Delta, Foxtrot and Bravo, Altimeter 29.92.

<u>CAASD 87:</u> Three-five left via Delta, Foxtrot and Bravo, CAASD eight seven

<u>CAASD 95</u>: Louisville Tower, CAASD ninety-five, ready to taxi

ATC: CAASD 95, taxi to runway 35L via Delta, Altimeter 2-9-9-2

<u>CAASD 95</u>: Taxi to runway three-five left via Delta, Altimeter 2-9-9-2 CAASD 85.

ATC: CAASD 87, runway 35L, climb 3000 feet, maintain runway heading, cleared for take off.

<u>CAASD 87:</u> Runway heading, 3000, cleared for take off, CAASD eighty-seven

AWL come on

ATC: CAASD 49, go around, fly runway heading, maintain 3,000

Participant: Tower, roger, initiating go around, maintain runway heading CAASD 49

END SCENARIO

Familiarization Scenario 1 (LAX)

Visibility: Day, high

AC1= CAASD 89 **CAASD 58 (no visual)**
AC2= Participant/ CAASD 49 **CAASD 56 (no visual)**
AC3= CAASD 39 **CAASD 97 (no visual)**

Participant: **"**LA ground**,** CAASD 49 on Bravo for 25R"

ATC: **"**CAASD 49, LA ground, taxi to runway 25R, via Bravo."

Participant: "Taxi to runway 25R via Bravo, hold short of 25R, CAASD 49"

CAASD 89: "Los Angeles Tower, CAASD Eight-Nine, eight out for Runway Two-Five Right"

ATC: **"**CAASD 89 Los Angeles Tower, Runway 25R, cleared to land"

CAASD 89: **"**Cleared to land on Runway Two-Five Right, CAASD Eighty-Nine"

CAASD 58: Los Angeles tower, CAASD five-eight ready to taxi

ATC: CAASD 58 taxi to runway 24 L via Echo, Altimeter 2-9-9-2

CAASD 58: Taxi to runway 2-4 Left via Echo, Altimeter 2-9-9-2, CAASD five-eight

CAASD 56: Tower, CAASD five six in position and holding runway 24L

ATC: CAASD 56, runway 24L, cleared for takeoff, climb to 3000, maintain runway heading.

CAASD 56: Cleared for takeoff runway two-four Left, climb to 3000, maintain runway heading, CAASD five six

As participant comes around corner, REL illuminate; CAASD 89 lands

CAASD 39: "Tower, CAASD Thirty-Nine, ready to taxi"

ATC: **"**CAASD 39, taxi to runway 25R via Alpha and November."

CAASD 39: **"**Taxi to Runway Two-Five Right via alpha and November, CAASD Thirty-Nine."

Immediately after CAASD 89 Lands:

ATC: CAASD 49, runway 25R, taxi into position and hold.

Participant: Position and hold, runway 25R, CAASD 49.

CAASD 97: Los Angeles tower, CAASD nine-seven ready to taxi

ATC: CAASD 97 taxi to runway 24 L via Echo, Altimeter 2-9-9-2

CAASD 97: Taxi to runway 2-4 Left via Echo, Altimeter 2-9-9-2, CAASD nine seven

ATC: **"**CAASD 49, Runway 25R, climb 3000 feet, maintain runway heading, cleared for takeoff"

Participant: Runway Two-Five Right, climb 3000 feet and maintain runway heading, cleared for take off, CAASD Forty-Nine.

THL illuminated

Participant: Tower, CAASD 49 aborting take off, runway lights came on.

ATC: CAASD 49, understood, hold position.

END SCENARIO

Familiarization Scenario 2 (LAX)

Visibility: Clear, day

AC1= CAASD 29

AC2= Participant/CAASD 49

CAASD 1020 (no visual)

CAASD 97 (no visual)

Participant: "LA Tower, CAASD 49 with you for two-five left"

ATC: "CAASD 49, LA tower, Runway 25L, cleared to land, wind calm."

Participant: "Roger, cleared for landing 25L, CAASD 49"

CAASD 29: "Tower CAASD twenty-nine, ready on two-five left"

ATC: "CAASD 29, Runway 25L, taxi into position and hold"

CAASD 29 "Taxi into position and hold on runway two-five right left, CAASD twenty-nine"

CAASD 1020: LA tower, CAASD 1020, ready to taxi

ATC: CAASD 1020, LA tower, taxi to runway 25R via Bravo, Altimeter 2-9-9-2.

CAASD 1020: Taxi to runway two-five right via Bravo, Altimeter 2-9-9-2 CAASD 1020.

<u>CAASD 97:</u> Tower, CAASD nine-seven, ready to taxi.

ATC: CAASD 97, taxi to runway 25R via Bravo, Altimeter 2-9-9-2.

<u>CAASD 97:</u> Taxi to runway two-five right via Bravo, Altimeter 2-9-9-2, CAASD nine-seven

ATC: CAASD 1020, runway 25R, climb 3000, maintain runway heading, cleared for takeoff.

<u>CAASD 1020:</u> Runway two-five right, climb 3000, maintain runway heading cleared for take off, CAASD 1020.

AWL illuminate

ATC: **"**CAASD 49, go around; runway occupied; maintain runway heading"

Participant: "Roger, initiating go around, maintain runway heading"

END SCENARIO

<u>Geometry 1 (SDF)</u>

S6-G1

<u>Day, high visibility</u>

AC1= No Audio
AC2= Participant/CAASD 49
AC3= CAASD 42
AC4= CAASD 29

CAASD 86 (no visual)
CAASD 97 (no visual)
CAASD 1020 (no visual)
Tug (no visual)

Participant*:* **"**Louisville Tower, CAASD 49 ready to taxi"

ATC: **"**CAASD 49, Louisville Tower, taxi to 35R via Delta, altimeter 2-9-9-2"

Participant: **"**Taxi to 35R via Delta, CAASD 49"

<u>CAASD 42</u>: **"**Louisville Tower, CAASD Forty-Two, ready to taxi"

ATC: "CAASD 42, Louisville tower, taxi to runway 35L via Bravo, altimeter 2-9-9-2"

<u>CAASD 42</u>: "Three-Five Left via Bravo, twenty nine ninety two, CAASD Forty-Two"

<u>CAASD 29</u>: "Tower, CAASD twenty-nine at Charlie seven, ready to taxi"

ATC: **"**CAASD 29, Louisville Tower, taxi to 35R via Charlie, Foxtrot, Delta, altimeter 2-9-9-2"

<u>CAASD 29</u>: "Taxi Three-Five Right via Charlie, Foxtrot and Delta, CAASD Twenty-Nine."

<u>CAASD 86:</u> Louisville Tower, CAASD eighty-six at UPS seven, ready to taxi.

> **ATC**: CAASD 86, Louisville Tower, taxi to runway 35L via Bravo, altimeter 2-9-9-2.

<u>CAASD 86:</u> Taxi to Runway Two-Five Left via Bravo, altimeter two niner, niner two, CAASD eighty-six.

<u>CAASD 1020:</u> Louisville Tower, CAASD Ten-Twenty on Echo for taxi.

> **ATC**: CAASD 1020, Louisville Tower, cross 35R at Echo and Delta-six, turn left on Delta, taxi to Runway 35R, altimeter 2-9-9-2.

<u>CAASD 1020:</u> CAASD Ten-Twenty is crossing Runway Three-Five Right on Echo, and we'll taxi on Delta to thirty-five right, altimeter two niner, niner two.

<u>CAASD 97:</u> Louisville Tower, CAASD ninety-seven at UPS ramp three, ready to taxi

> **ATC:** CAASD 97, Louisville Tower, taxi to runway 35L via Bravo; follow the company Seven-Fifty-Seven, altimeter 29.92.

<u>CAASD 97:</u> Three-five left via Bravo behind company, altimeter two niner, niner two, CAASD ninety-seven.

<u>Tug</u>: Louisville Tower, Tug 1 requesting a tow from Hotel to Gate 7.

> **ATC**: Tug 1, Louisville Tower, towing operation approved as requested.

REL illuminate as participant approaches 11

Participant: “Louisville Tower, REL came on; holding short of 11, CAASD 49”

ATC: “CAASD 49, thank you, continue to hold short; traffic on approach”

ATC: CAASD 86, runway 35L, taxi into position and hold

CAASD 86: Roger, runway three five left, taxi into position and hold.

END SCENARIO 1

Geometry 2 (LAX)

S1-G2 (Baseline)

S7-G2 (Visual)

Visibility: Clear, day

AC1= No audio
AC2= Participant/CAASD 49
AC3= CAASD 39
AC4= CAASD 19
CAASD 89 (no visual)
CAASD 37 (no visual)
CAASD 56 (no visual)
CAASD 1020 (no visual)
CAASD 97 (no visual)
Airport 1 (no visual)

Participant: “LA Tower, CAASD 49 with you for two-five left”

ATC: “CAASD 49, Los Angeles Tower, runway 25L cleared to land, wind calm.”

Participant: “Roger, cleared for landing 25L, CAASD 49”

CAASD 19: “Tower CAASD Nineteen, ready on two-five right”

ATC: “CAASD 19, Los Angeles Tower, runway 25R , taxi into position and hold.”

CAASD 19 “Position and hold on runway two-five right, CAASD Nineteen”

CAASD 39: "Tower, CAASD thirty nine, pushed off gate Alpha Two, ready to taxi"

> **ATC:** CAASD 39, Los Angeles Tower, taxi to Runway 25L via Alpha. Altimeter 2-9-9-2.

CAASD 39 "Taxi to Two-Five Left via Alpha, CAASD Thirty-Nine"

CAASD 37: Los Angeles tower, CAASD Thirty-Seven, ready to taxi

> **ATC**: CAASD 37, Los Angeles Tower, taxi to runway 24 L via Echo, Altimeter 2-9-9-2

CAASD 37: Roger, taxi to Runway Two-Four Left via Echo

CAASD 56: Tower, this is CAASD Fifty-Six in position on Two-Four Left

> **ATC**: CAASD 56, after departure fly runway heading, maintain 3,000, runway 24L, cleared for takeoff.

CAASD 56: Cleared for takeoff runway two-four Left on a runway heading and climbing to 3000, CAASD Fifty-Six.

CAASD 1020: LA tower, CAASD Ten-Twenty pushed back from Delta 9, ready to taxi

> **ATC:** CAASD 1020, LA tower, taxi to runway 24L via Echo, Altimeter 2-9-9-2.

CAASD 1020: Two-four left via Echo, altimeter twenty nine ninety two, CAASD Ten-Twenty.

Airport 1: Tower, airport one. We need to get to Echo Fourteen, we are at Alpha Alpha.

> **ATC**: Airport one, LA tower; drive AA to Echo, turn right at Echo 14.

Airport 1: Roger, drive Alpha Alpha to Echo, Airport one.

CAASD 97: Tower, CAASD ninety-seven at gate Delta 10, ready to taxi.

> **ATC:** CAASD 97, Los Angeles Tower, taxi to runway 24L via Echo, Altimeter 2-9-9-2.

CAASD 97: Taxi to runway two-four left via Echo, altimeter two niner, niner two, CAASD ninety-seven.

> **ATC:** CAASD 1020, runway 24L, taxi into position and hold.

CAASD 1020: Runway two-four left, position and hold, CAASD Ten-Twenty.

Participant Lands

> **ATC:** "CAASD 49 turn right at Mike, cross 25R, turn left on Bravo, Ground .75; BREAK; CAASD 19, Runway 25R cleared for takeoff"

Participant: "CAASD 49, exiting at Mike"

Immediately after Participant responds:

CAASD 19: "CAASD Nineteen rolling"

Immediately after previous communications:

<u>CAASD 89</u>: “LA Tower this is CAASD Eighty-Nine, requesting taxi”

ATC: **“**CAASD 89, LA Tower, taxi to runway 25R via Charlie”

<u>CAASD 89</u>: “Taxi to Two-Five Right via Charlie, CAASD Eighty-Nine”

ATC: CAASD 1020, runway 24L, climb to 3000, maintain runway heading, cleared for takeoff.

<u>CAASD 1020:</u> Runway two-four left, climb to 3000, maintain runway heading, cleared for takeoff, CAASD Ten-Twenty.

As AC2/Participant turns onto M; REL come on

Participant: Tower, this is CAASD 49 holding short of 25R; the REL came on

ATC: CAASD 49, continue to hold short, departing traffic

END SCENARIO 2

Geometry 3 (LAX)

S2-G3 (Baseline)

S8-G3 (Visual)

Visibility: Night, low

AC1= CAASD 291	**Tower 5 (no visual)**
AC2= Participant/ CAASD 49	**CAASD 53 (no visual)**
AC3= CAASD 39	**CAASD 65 (no visual)**
AC4= CAASD 89	**Airport 1 (no visual)**

Participant: **“**LA tower**,** CAASD 49 on Bravo for 25R”

> **ATC:** **“**CAASD 49, LA tower, taxi to runway 25R, via Bravo, Altimeter 2-9-9-2.”

Participant: **“**CAASD 49, taxi to runway 25R via Bravo, hold short of 25R”

CAASD 89: **“**LA tower, CAASD Eighty-Nine, taxi”

> **ATC:** **“**CAASD 89 LA tower, taxi to runway 25R via Bravo, Altimeter 2-9-9-2”

CAASD 89: **“**Two-Five Right via Bravo, CAASD Eighty-Nine, altimeter twenty nine ninety two”

<u>Tower 5</u>: “Tower five requesting to drive to ramp area Charlie-Four”

ATC: **“**Tower 5, LA Tower, drive via Bravo to ramp area Charlie-four.”

<u>Tower 5</u>: **“**Tower five, roger, drive via Bravo to ramp Charlie-four.”

<u>CAASD 53:</u> LA tower, CAASD fifty-three pushed back from Delta 8, ready to taxi

ATC: CAASD 53, LA tower, taxi to runway 24L via Echo, Altimeter 2-9-9-2.

<u>CAASD 53:</u> Taxi to runway two-four left via Echo, Altimeter 2-9-9-2 CAASD fifty-three.

<u>Airport 1:</u> Tower, airport one. We need to get to the hangar from Sierra.

ATC: Airport one, LA tower; drive S to Echo, turn left on Echo.

<u>Airport 1:</u> Roger, drive Sierra to Echo, Airport one.

ATC: ***AC1 Landing on 25R***

“CAASD 291, turn right on Mike if feasible, ground .75”

<u>CAASD 291</u>: “Right on Mike, Tower point-seven-five, CAASD Twenty-Nine”

ATC: “CAASD 49, taxi into position and hold, runway 25 R”

Participant: “CAASD Forty-Nine, taxi into position and hold runway Two-Five Right”

Immediately after Participant Responds:

<u>CAASD 39</u>: "Tower, CAASD Thirty-Nine on ramp Charlie-Ten requesting taxi instructions

> **ATC:** "CAASD 39, Los Angeles Tower, taxi to 25R via Bravo, Altimeter 2-9-9-2"

<u>CAASD 39</u>: "Two-five Right via Bravo, altimeter twenty nine ninety two, CAASD Thirty-Nine"

<u>CAASD 65:</u> Tower, CAASD sixty-five at gate Delta 9, ready to taxi.

> **ATC:** CAASD 65, LA Tower, taxi to runway 24L via Echo, Altimeter 2-9-9-2.

<u>CAASD 65:</u> Taxi to runway two-four left via Echo, Altimeter 2-9-9-2 CAASD sixty-five.

> **ATC:** CAASD 53, runway 24L, taxi into position and hold.

<u>CAASD 53:</u> Runway two-four left, position and hold, CAASD fifty- three.

> **ATC:** ***As CAASD 291 begins turn onto M***
>
> "CAASD 49, runway 25R, cleared for takeoff without delay"

Participant: **"**CAASD 49, rolling"

> **ATC:** CAASD 53, runway 24L, climb to 3000, maintain runway heading, cleared for takeoff.

<u>CAASD 53:</u> Runway two-four left, climb to 3000, maintain runway heading, cleared for takeoff, CAASD five three.

THL illuminate

Participant: "Tower, CAASD 49 aborting takeoff; THL illuminated"

ATC: "Roger, CAASD 49 exit 35R at Hotel, to taxi back into position at 25R."

END SCENARIO 3

Geometry 4 (SDF)

S3-G4 (Baseline)

S9-G4 (Visual)

Visibility: Day, High

AC1= CAASD 29
AC2= Participant/ CAASD 49
AC3= CAASD 44 (no visual)
AC4= no audio
AC5= no audio
CAASD 85 (no visual)
CAASD 32 (no visual)
Airport 5 (no visual)

Participant: "Louisville tower, CAASD 49 ready for taxi"

> **ATC: "**CAASD 49, Louisville tower, taxi to runway 29 via Echo and Golf, Altimeter 2-9-9-2"

Participant: "CAASD 49, taxi to runway 29 via echo and golf."

CAASD 44: "Louisville Tower, CAASD Forty-Four ready for taxi"

> **ATC: "**CAASD 44, Louisville tower, taxi to 35L via Charlie and Bravo, Altimeter 2-9-9-2"

CAASD 44: "CAASD Forty-Four taxi to Three-Five Left via Charlie and Bravo."

<u>CAASD 29</u>: “Louisville tower, CAASD Twenty-Nine, ready on Runway 35L.”

ATC: **“**CAASD 29, taxi into position and hold 35L”

<u>CAASD 29</u>: **“**Taxi into position and hold Three-Five Left, CAASD Twenty-Nine”

ATC: ***As soon as the participant has turned onto twy G and approaches runway 29***

“CAASD 49, after departure fly runway heading, climb and maintain 3000, runway 29 cleared for takeoff without delay, please, traffic 4 mile final.

Participant: “Cleared for immediate take off runway 29, CAASD 49.”

IMMEDIATELY after participant finishes reply:

<u>CAASD 29</u>: “….rolling”

<u>CAASD 55</u>: “Louisville Tower, CAASD fifty-five, four out for runway two-niner”

ATC: “CAASD 55, Louisville Tower, one departure prior to your arrival, Runway 29 cleared to land, wind calm”

<u>CAASD 55</u>: “Roger Runway Two-Niner cleared to land, CAASD Fifty-Five”

<u>CAASD 85</u>: Louisville tower, CAASD eighty-five at UPS ramp 5, ready to taxi

ATC: CAASD 85, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

CAASD 85: Taxi to runway three-five left via Bravo, altimeter two niner, niner two, CAASD eighty-five.

Airport 5: Tower, airport five, requesting permission to cross three-five right and drive on Delta to UPS ramp 4.

> **ATC**: Airport 5, Louisville Tower, cross 35R and drive Delta to UPS ramp 4.

Airport 5: Roger, cross three-five right and drive Delta to ramp 4, airport five.

CAASD 32: Tower, CAASD thirty-two, ready to taxi.

> **ATC**: CAASD 32, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2. You'll be #3 for takeoff.

CAASD 32: Taxi to runway three-five left via Bravo, altimeter twenty nine ninety two, understand third in line for departure, CAASD thirty-two.

Participant: "CAASD 49 aborting takeoff; lights turned on"

> **ATC: "**CAASD 55 go around, runway occupied, climb runway heading to 3000 feet; BREAK; CAASD 49 right turn at next intersection"

END SCENARIO 4

Geometry 5 (SDF)

S10-G5

Visibility: Day, low

AC1= Airport 1 (vehicle)	**Airport 5 (not seen)**
AC2= Participant/ CAASD 49	**CAASD 45 (no visual)**
AC3= CAASD 29	**CAASD 86 (no visual)**
AC5= CAASD 55	**CAASD 1020 (no visual)**

Participant: Louisville tower, CAASD 49, ready to taxi on Bravo

ATC: CAASD 49, Louisville Tower, taxi to runway 35L via bravo, altimeter 2-9-9-2.

Participant: CAASD 49 to runway 35L via Bravo, 2-9-9-2.

ATC: ***IMMEDIATELY after participant finishes reply:***

CAASD 29, after departure fly runway heading, maintain 3000 runway 35L, cleared for takeoff

CAASD 29: CAASD Twenty-Nine, cleared for takeoff runway Three Five Left

ATC: Airport 5, Louisville Tower, cross runway 35R at Delta 3

Airport 5: Airport 5, roger we are crossing runway three-five Right

CAASD 55: Louisville tower, CAASD Fifty-Five, at gate Bravo Seventeen for taxi

ATC: CAASD 55, Louisville tower, taxi to runway 29 via Charlie and Fox, altimeter 2-9-9-2.

CAASD 55: Charlie and Foxtrot for runway Two-Niner, two-niner-niner-two on the altimeter, CAASD Fifty-Five.

Airport 5: Tower, airport 5 is clear of runway three-five Right, proceeding via golf to north ramp.

ATC: Airport 5, roger.

Participant reaches 35L

ATC: CAASD 49, runway 35L, taxi into position and hold

Participant: CAASD 49, position and hold 35L

***Immediately after*:**

Airport 1: Tower, airport 1, on Foxtrot requesting permission to cross runway three-five Left and drive onto runway one-one for light check

ATC: Airport 1, roger, cross 35L and proceed onto runway 11 for light check

CAASD 45: Louisville tower, CAASD Forty-five, pushed off Bravo fifteen for taxi..

> **ATC: SLOW THE PACE DOWN A LITTLE:** CAASD 45, Louisville tower, taxi runway 35L via Juliet and Charlie, altimeter 29.92.

CAASD 45: Roger, Juliet and Charlie for runway three-five Left, two-niner-niner-two, CAASD forty-five

CAASD 1020*:* Louisville Tower, CAASD ten-twenty, pushed off gate Bravo-5 behind the seven-fifty-seven for taxi.

> **ATC:** CAASD 1020, Louisville tower, follow your company seven fifty seven to runway 35L, via Juliet and Charlie, altimeter 2-9-9-2

CAASD 1020: Following company Seven-Fifty-Seven to runway Three-Five Left, two-niner-niner-two, CAASD Ten-Twenty.

When Participant is in position and holding

Airport 1: Tower, airport 1 is clear of runway three-five Left, on runway one-one.

> **ATC:** Airport 1, roger, clear of 35L. CAASD 49, after departure, turn left heading 320, climb and maintain 3000 feet, runway 35L cleared for takeoff.

Participant: Roger, heading 320, maintain 3000 feet, cleared for takeoff 35L.

CAASD 86: Louisville tower, CAASD Eighty-Six pushed off gate Alpha eight, requesting taxi, we can take runway two-niner

ATC: CAASD 86, Louisville tower, can you take 35L?

CAASD 86: Affirmative, CAASD Eighty-Six

ATC: CAASD 86 taxi to runway 35L via Juliet and Charlie, altimeter 2-9-92.

CAASD 86: Roger, Juliet and Charlie for runway Three-Five Left two-niner-niner-two, CAASD eighty-six.

Participant: Tower, CAASD 49 has aborted takeoff, lights went on

ATC: Roger CAASD 49, exit runway at next intersection; hold short.

Participant: Roger, exit runway and hold short CAASD 49.

END SCENARIO

Geometry 6 (SDF)

S11-G6

Visibility: Night, High

AC1= no audio **CAASD 45 (no visual)**

AC2= Participant/ CAASD 49 **CAASD 25 (no visual)**

AC3= no audio **CAASD 85 (no visual)**

AC4= no audio **CAASD 32 (no visual)**

AC5= CAASD 39

Participant: CAASD 49 ready for departure

ATC: CAASD 49, Louisville Tower, Runway 29, turn left on golf, taxi into position and hold; traffic crossing downfield

Participant: CAASD 49, taxi to runway 29 via golf, position and hold

CAASD 39: Tower, CAASD thirty-nine, ready to taxi

ATC: CAASD 39, Louisville Tower, taxi to runway 29 via Golf, altimeter 29.92.

CAASD 39: Roger, CAASD thirty-nine to runway two-niner via Golf, and we've got the altimeter.

CAASD 45: Louisville tower, CAASD Forty-Five is five out for One-Seven Left

ATC: CAASD 45, Louisville tower, runway 17L cleared to land, wind calm.

DELAY A LITTLE, THEN:

CAASD 45: CAASD Forty-Five cleared to land runway One-Seven Left.

CAASD 25: Louisville tower, CAASD twenty-five is ten miles out for runway one-seven Left.

ATC: CAASD 25, Louisville tower, 6 miles behind a B757, runway 17L cleared to land, wind calm.

CAASD 25: Cleared to land on one-seven Left behind the Boeing, CAASD twenty-five.

CAASD 85: Louisville tower, CAASD eighty-five at UPS ramp 5, ready to taxi

ATC: CAASD 85, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

CAASD 85: Taxi to runway three-five left via Bravo, altimeter two niner, niner two, CAASD eighty-five.

ATC: CAASD 49, after departure turn right heading 080, climb and maintain 3000 feet, runway 29 cleared for take off.

Participant: Roger, CAASD 49 cleared for take off on 29.

CAASD 32: Tower, CAASD thirty-two, ready to taxi.

ATC: CAASD 32, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

CAASD 32: Taxi to runway three-five left via Bravo, altimeter twenty nine ninety two, CAASD thirty-two.

ATC: CAASD 85, runway 35L, climb 3000 feet, maintain runway heading, cleared for takeoff

CAASD 85: Runway three-five left on a runway heading, to three thousand, cleared for takeoff, CAASD eighty-five.

Participant: Tower, CAASD 49 has aborted takeoff, lights came on.

ATC: Roger, CAASD 49, arriving traffic is going around. Hold position.

Participant: CAASD; 49 holding position.

END SCENARIO

Geometry 7 (LAX)

S12-G7

Visibility: Night, low

AC1= no audio	**CAASD 29 (no visual)**
AC2= Participant/CAASD 49	**CAASD 62 (no visual)**
AC3= CAASD 39	**CAASD 53 (no visual)**
AC4 no audio	**Airport 1 (no visual)**

Participant: Tower, CAASD 49, in position and holding at 25R; ready to go.

ATC: Roger, CAASD 49, stand by. I've got traffic to cross downfield prior to your departure.

Participant: Roger, CAASD 49.

CAASD 29: Tower, CAASD 29, ready to taxi

ATC: CAASD 29, Los Angeles Tower, taxi to runway 24L via Echo

CAASD 29: Two-four left via Echo, altimeter two niner niner two, CAASD Twenty-Nine

CAASD 62: Los Angeles Tower, CAASD Sixty-Two ready to taxi

ATC: CAASD 62, Los Angeles Tower, follow company to runway 24L via Echo, you'll be number 2 to depart, altimeter twenty nine ninety two.

<u>CAASD 62</u>: Roger, follow company to runway two-four left via Echo, number two to depart, altimeter twenty nine ninety two, CAASD Sixty-Two.

<u>CAASD 53:</u> Los Angeles Tower, CAASD fifty-three pushed back from Delta 10, ready to taxi

ATC: CAASD 53, LA tower, taxi to runway 24L via Echo, Altimeter 2-9-9-2.

<u>CAASD 53:</u> Taxi to runway two-four left via Echo, altimeter two niner, niner two, number three to depart, CAASD fifty-three.

<u>Airport 1:</u> Tower, airport one. We need to get to the hangar, we are at Sierra.

ATC: Airport one, LA tower; drive S to Echo, turn left on Echo.

<u>Airport 1:</u> Roger, drive S to Echo, Airport one.

ATC: *AC1 lands, departure clearance given as it reaches Hotel*

"CAASD 49, cleared for takeoff on 25R, climb 3000, maintain runway heading"

Participant: Roger, CAASD 49 cleared for takeoff;

<u>CAASD 39</u>: **Los Angeles Tower**, CAASD thirty-nine at Alpha, ready for taxi

ATC: CAASD 39, Los Angeles Tower, taxi to runway 25L via Alpha, altimeter 29.92.

<u>CAASD 39</u>: "Two-five Left via Alpha, altimeter two niner, niner two, CAASD thirty-nine"

ATC: CAASD 29, runway 24L, climb to 3000, maintain runway heading, cleared for takeoff.

<u>CAASD 29:</u> Runway two-four left, climb to 3000, maintain runway heading, cleared for takeoff, CAASD two-nine.

Participant: Tower, CAASD 49 is aborting takeoff, lights came on

ATC: Roger, CAASD 49 aborting takeoff; hold position

Participant: Roger, CAASD 49 holding position

END SCENARIO

<u>Geometry 8 (SDF)</u>

S13-G8 (Visual)

S17-G8 (Auditory)

<u>Visibility: Night, Low</u>

AC1= CAASD 29	**CAASD 56 (no visual)**
AC2= Participant/CAASD 49	**CAASD 32 (no visual)**
AC3= CAASD 39	**CAASD 85 (no visual)**

Participant: "Louisville Tower, this is CAASD 49 with you for three-five right"

> **ATC:** CAASD 49, Louisville tower, runway 35R, cleared to land, wind calm.

Participant: CAASD 49, cleared to land 35R.

<u>CAASD 29</u>: Louisville tower, CAASD twenty-nine ready to taxi.

> **ATC:** CAASD 29, Louisville tower, taxi to 35R via Golf and Delta, Altimeter 2-9-9-2.

<u>CAASD 29</u>: Three-five right via Golf and Delta, CAASD twenty nine.

<u>CAASD 32</u>: Louisville Tower, CAASD thirty-two, ready to taxi.

> **ATC**: CAASD 32, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

<u>CAASD 32</u>: Taxi to runway three-five left via Bravo, altimeter two niner, niner two, CAASD thirty-two.

> **ATC**: CAASD 85, after departure fly runway heading, maintain 3,000, runway 35L, cleared for takeoff

<u>CAASD 85</u>: Runway three-five left, climb 3000 feet maintain runway heading, cleared for takeoff, CAASD eighty-five.

<u>CAASD 39</u>: **"**Louisville tower, CAASD Thirty-Nine is ready to taxi."

> **ATC:** CAASD 39, Louisville Tower, taxi to runway 35R VIA Delta, Altimeter 2-9-9-2. Company will follow you.

<u>CAASD 39</u>: Roger, taxi to three-five Right via Delta and I understand company will follow us.

<u>CAASD 56:</u> Louisville Tower, CAASD Fifty-Six, ready to taxi

> **ATC**: CAASD 56, Louisville tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

<u>CAASD 56:</u> Roger, taxi to runway three-five left via Bravo, altimeter two niner, niner two, CAASD Fifty-Six.

> **ATC**: CAASD 32, runway 35L, taxi into position and hold.

CAASD 32: CAASD thirty-two, position and hold Runway Two-Five Left.

ATC: CAASD 32, after departure, climb runway heading to 3000 feet, runway 35L cleared for take off.

CAASD 32: Roger, cleared for takeoff runway three-five left, CAASD thirty-two

Participant: CAASD 49 initiating go around, warning lights came on

ATC: CAASD 49, roger, go around, fly runway heading, maintain 3000.

END SCENARIO

<u>Geometry 9 (LAX)</u>

S4-G9 (Baseline)

S14-G9 (Visual)

<u>Visibility: Day, low</u>

AC1= Participant/ CAASD 49

AC2= CAASD 29

AC3= CAASD 39

AC4= no audio

Participant: Los Angeles Tower, CAASD 49 5 miles out 25L

ATC: CAASD 49, LA tower, cleared to land 25L, wind calm.

Participant: Roger, CAASD 49 cleared to land 25L.

<u>CAASD 29</u>: Los Angeles Tower, CAASD twenty-nine holding short of runway two-five Right

ATC: CAASD 29, Los Angeles Tower, Runway 25R, taxi into position and hold.

<u>CAASD 29</u>: Taxi to Two-five Right, position and hold, CAASD Twenty-Nine.

ATC: CAASD 39, after departure fly runway heading, maintain 3,000, runway 25L, cleared for takeoff.

CAASD 39: Climb 3000 feet, maintain runway heading, cleared for take off two-five left, CAASD Thirty-Nine

When Participant is about 5.5 miles out:

CAASD 39: Tower, this is CAASD Thirty-Nine, takeoff is aborted, I think we have blown a tire

ATC: CAASD 49, we've got an aircraft stopped on your runway. Can you sidestep to Runway 25R?

Participant: Affirmative.

ATC: CAASD 49, Runway 25R, cleared to land, wind calm.

Participant: Tower, cleared to land runway 25R, CAASD 49

ATC: CAASD 39, can you taxi off the runway?

CAASD 39: CAASD Thirty-Nine, Negative

ATC: Emergency One, drive to runway 25L via S, Bravo and T.

Emergency One: Roger, Tower, driving to runway two-five left via Sierra, Bravo and Tango.

Airport 1: Los Angeles Tower, Airport One requesting clearance to check runway two-five left.

ATC: Airport 1, Los Angeles Tower, cleared to drive to runway 25L via AA, Bravo and U.

Airport 1: Roger, Airport One is cleared onto runway two-five left via Alpha Alpha, Bravo and Uniform

Participant: Tower, CAASD 49 initiating go-around, warning lights came on, there is still an aircraft on 25R.

ATC: Roger, CAASD Forty-Nine, fly runway heading, maintain 3,000

END SCENARIO

Geometry 10 (SDF)

S5-G10 (Baseline)

S15-G10 (Visual)

Visibility: High, day

AC1= CAASD 42	**CAASD 98 (no visual)**
AC2= Participant/CAASD 49	**CAASD 57 (no visual)**
AC3= CAASD 87	**CAASD 85 (no visual)**
AC5= CAASD 1020	**CAASD 32 (no visual)**

Participant: "Louisville Tower, this is CAASD 49 with you for three-five right"

ATC: CAASD 49, Louisville tower, you are 5 miles behind B757, runway 35R cleared to land, wind calm

Participant: Cleared to land on 35R, CAASD 49

ATC: CAASD 1020, are you number 2 or 3 for runway 35R?

CAASD 1020: Tower, CAASD Ten-Twenty is number 2 behind the Seven-Fifty-Seven.

ATC: CAASD 1020 roger, thanks, can you accept a departure from Delta 1? I need you to get out ahead of your company 757.

CAASD 1020: CAASD Ten-Twenty, affirmative.

ATC: CAASD 42, runway 35R, taxi into position and hold

CAASD 42: **P**osition and hold runway Three-Five Right, CAASD Forty-two.

ATC: CAASD 1020, roger, hold short of 35R at Delta 1, you will be number 2 to depart

CAASD 1020: Holding short of Three-Five at Delta one, CAASD Ten-Twenty

CAASD 98: Louisville tower, CAASD ninety-eight, pushed back from gate Bravo seventeen, ready for taxi.

ATC: CAASD 98, Louisville tower, roger, taxi to runway 35L via Juliet and Charlie, altimeter 2-9-9-2

CAASD 98: Juliet and Charlie for runway three-five Left, two-niner-niner-two, CAASD ninety-eight.

When CAASD 87 lands (this may have to be said earlier)

ATC: CAASD 87, turn left at Delta 4, taxi to the ramp.

CAASD 87: CAASD eighty-seven, exiting at Delta Four, cleared to the ramp.

CAASD 85: Louisville Tower, CAASD eighty-five, ready to taxi.

ATC: CAASD 85, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

CAASD 85: Taxi to runway three-five left via Bravo, altimeter twenty nine ninety two, CAASD eighty-five.

When CAASD 87 clears runway:

ATC: "CAASD 42, Runway 35R, cleared for take off without delay, traffic one mile final, wind calm"

IMMEDIATELY AFTER TRANSMISSION:

CAASD 57: Louisville tower, CAASD Fifty Seven, nine miles out for runway Three-Five Right.

ATC: CAASD 57, Louisville tower, number 2 behind a b757, runway 35R cleared to land, wind calm.

CAASD 57: Cleared to land behind the seven-fifty-seven on Three-Five Right, CAASD Fifty-Seven.

CAASD 98: Tower, CAASD Ninety-Eight, confirm we can cross runway Two-Niner at Charlie

ATC: CAASD 98, affirm cross runway 29

CAASD 32: Louisville Tower, CAASD thirty-two, ready to taxi.

ATC: CAASD 32, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

CAASD 32: Taxi to runway three-five left via Bravo, altimeter twenty nine ninety two, CAASD thirty-two.

> **ATC**: CAASD 85, after departure fly runway heading, maintain 3,000, runway 35L, cleared for takeoff

CAASD 85: Runway three-five left, climb 3000 feet maintain runway heading, cleared for takeoff, CAASD eighty-five.

Participant: CAASD 49, going around, climbing runway heading to 3000 feet

> **ATC:** Runway heading, 3000, CAASD 49

END SCENARIO

Geometry 11 (SDF)

S16-G11 (Visual)

S18-G11 (Auditory)

Visibility: Night, High

AC1= CAASD 59
AC2= Participant/ CAASD 49
AC3= CAASD 42
CAASD 22 (no visual)
CAASD 87 (no visual)
Airport 3 (no visual)
CAASD 58 (no visual)

Participant: "Louisville Tower, CAASD 49 with you for three-five right"

ATC: CAASD 49, Louisville Tower, runway 35R cleared to land, wind is calm

Participant: Roger, CAASD 49 is cleared to land runway 35R.

Right after previous communication:

CAASD 59: Louisville tower, CAASD Fifty-Nine, five-and-a-half mile out for runway two-niner.

ATC: CAASD 59, Louisville tower, roger, reduce to minimum approach speed, runway 29, cleared to land, wind calm

CAASD 59: **R**oger, pulling back on the speed, cleared to land runway Two-Niner, CAASD Fifty-Nine.

<u>CAASD 42</u>: Louisville tower, CAASD Forty-Two, ready for taxi at Alpha twelve, requesting runway Three-Five Right.

ATC: CAASD 42, Louisville Tower, taxi to runway 35R via Hotel, November, Foxtrot and Delta, hold short of runway 29, Altimeter 2-9-9-2.

<u>CAASD 42</u>: CAASD Forty-Two, roger, taxi to runway Three-Five Right via Hotel, November, Foxtrot and Delta, hold short of runway two-niner.

<u>CAASD 22</u>: Louisville tower, CAASD Twenty-Two Heavy, Twelve out for runway Three Five Right

ATC: CAASD 22 Heavy, Louisville, roger, 7 miles behind a 757, runway 35R, cleared to land, wind calm**.**

<u>CAASD 22</u>: CAASD Twenty Two Heavy, cleared to land runway Three Five Right, copied the traffic

<u>CAASD 58</u>: Tower, CAASD fifty-eight, ready to taxi.

ATC: CAASD 58, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2

<u>CAASD 58</u>: Taxi to runway three-five left via Bravo, Altimeter 2-9-9-2 CAASD five-eight.

<u>CAASD 42</u>: Tower, CAASD Forty-Two say again taxi instructions—taxi November, Golf Delta to Three Five Right?

ATC: CAASD 42, taxi to Runway 35R via November, Foxtrot, and Delta

CAASD 42: Tower, CAASD Forty-Two is on Golf.

ATC: CAASD 42, proceed on Golf, then turn left on Delta, hold short of 29.

CAASD 42: Okay, Golf, and Delta to Runway Three-Five Right, hold short of Runway Two-Niner, CAASD Forty-Two.

CAASD 87: Louisville tower, CAASD 87, ready to taxi

ATC: CAASD 87, Louisville Tower, taxi to runway 35L via Bravo, Altimeter 2-9-9-2.

CAASD 87: Roger, taxi to runway three-five left via Bravo

Airport 3: Tower, Airport three, requesting clearance to cross runway one-seven on Foxtrot

ATC: Roger, Airport 3, cleared to cross runway one-seven on Foxtrot

Airport 3: Roger, cleared to cross runway one-seven on Foxtrot

CAASD 85: Tower, CAASD eight-five, ready to taxi.

ATC: CAASD 85, taxi to runway 35L via Bravo, Altimeter 2-9-9-2, you are third in line for departure

<u>CAASD 85</u>: Taxi to runway three-five left via Bravo, Altimeter 2-9-9-2, copy third in line for departure CAASD eight-five.

ATC: CAASD 58, runway 35L, climb 3000 feet, maintain runway heading, cleared for takeoff

<u>CAASD 58</u>: Runway three-five left, climb 3000 feet maintain runway heading, cleared for takeoff, CAASD five-eight.

Participant: Tower, we are initiating a go around, the lights came on.

ATC: Roger, fly runway heading maintain 3000 feet.

END SCENARIO

Glossary

AMASS	Airport Movement Area Safety System
AOI	Area of Interest
ARIAS	Arrival Runway Incursion Alerting System
ATC	Air Traffic Control
ATC	Air Traffic Controller
ATCT	Air Traffic Control Tower
ATM	Air Traffic Management
ATO	Air Traffic Organization
ATWIT	Air Traffic Workload Input Technique
AWL	Arrival Warning Lights
CAASD	Center for Advanced Aviation System Development
DFW	Dallas Fort-Worth Airport
FAA	Federal Aviation Administration
FT	Feet
FY	Fiscal Year
KTS	Knots
LAX	Los Angeles Airport
MIT	Massachusetts Institute of Technology
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
ND	Navigation Display
NTSB	National Transportation Safety Board
OTW	Out-the-Window
PAPI	Precision Approach Path Indicator
PFD	Primary Flight Display
REL	Runway Entrance Lights
RWSL	Runway Status Lights System
SA	Situation Awareness

SDF Louisville International Airport

THL Take-Off Hold Lights
TLX Task Load Index

U.S. United States