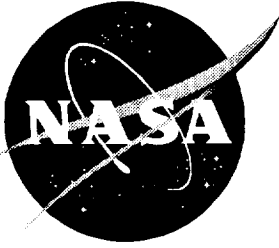


Pilot Evaluations of Runway Status Light System

Steven D. Young, Robert W. Wills, and R. Marshall Smith

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Abbreviations

a/c	aircraft	F/O	First Officer
ALPA	Air Line Pilot's Association	IFR	instrument flight rules
AMASS	Airport Movement Area Safety System	ILS	Instrument Landing System
AOPA	Aircraft Owners and Pilots Association	LaRC	Langley Research Center
arr.	arrival	ops	operations
ASMA	airport surface movement area	PAPI	precision approach path indicator
ASTA	Airport Surface Traffic Automation	REL	runway entrance lights
ATC	air traffic control	RVR	runway visual range
ATIDS	Aircraft Tagging and Identifier System	RWSL	Runway Status Light System
ATIS	Automatic Terminal Information System	sim.	simulator
ATP	airline transport pilot	SMA	Surface Movement Advisor
CAMAC	Computer Automated Measurement and Control	SMEL	single and multiengine license
CGI	computer-generated image	SMGCS	Surface Movement Guidance Control System
C/O	Commanding Officer	TAP	Terminal Area Productivity
CRDS	calligraphic raster display system	TCAS	Traffic Alert and Collision-Avoidance System
dep.	departure	THL	takeoff hold lights
DGPS	Differential Global Positioning System	TSRV	Transport Systems Research Vehicle
EADI	electronic attitude display indicator	VASI	visual approach slope indicator
EHSI	electronic horizontal situation indicator	VFR	visual flight rules
FAA	Federal Aviation Administration	VIOP	VME Input/Output Processor
F/E	Flight Engineer	vis.	visibility
		VMC	visual met conditions

Abstract

This study focuses on use of the Transport Systems Research Vehicle (TSRV) Simulator at the Langley Research Center to obtain pilot opinion and input on the Federal Aviation Administration's Runway Status Light System (RWSL) prior to installation in an operational airport environment. The RWSL has been designed to reduce the likelihood of runway incursions by visually alerting pilots when a runway is occupied. Demonstrations of the RWSL in the TSRV Simulator allowed pilots to evaluate the system in a realistic cockpit environment.

1. Introduction

Air traffic is expected to increase significantly in the 21st century. With geographical, environmental, and zoning restrictions placed on most major U.S. airports, expansion is severely constrained. Therefore, action must be taken to increase the capacity and safety of existing airport facilities. One area of focus is the airport surface movement area (ASMA). The Federal Aviation Administration (FAA) has established Airport Surface Traffic Automation (ASTA) programs to enhance safety and to optimize the flow of traffic on the airport surface. These programs include the Surface Movement Advisor (SMA), the Airport Movement Area Safety System (AMASS), the Aircraft Tagging and Identifier System (ATIDS), and the Runway Status Light System (RWSL). These programs address the various ASTA issues by providing air traffic controllers, airline personnel, and airfield management with positive identification of surface targets on the movement area; providing pilots with airfield safety alerts; providing controllers with automated warnings of potential and actual runway incursions; providing a surface traffic planning capability; and providing an automated method of sending instructions (e.g., taxi route clearances) to aircraft.

Similarly, the National Aeronautics and Space Administration (NASA) Terminal Area Productivity (TAP) program is focused on providing technology and operating procedures for safely achieving clear-weather capacities in instrument-weather conditions. In cooperation with the FAA, NASA's approach is to develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management, reduce controller workload, improve low-visibility landing and surface operations, and integrate aircraft and air traffic systems.

Because of LaRC's history of high-fidelity flight simulation tests (refs. 1-3), realistic cockpit environments, and common interests in safely improving terminal area productivity under the TAP program, the FAA and the Volpe National Transportation Systems Center (Volpe Center) requested that LaRC conduct a flight simulation study that would implement a conceptual proto-

type and also allow for pilot evaluations of the RWSL. This paper describes the simulation effort conducted as part of the FAA's RWSL program and the NASA LaRC TAP program.

The primary goal of the study was to obtain pilot opinion of the potential usefulness of this lighting system for reducing the likelihood of runway incursions on the airport surface. To accomplish this, several incursion situations were introduced, as well as normal operational situations, to allow pilots to observe the behavior of the system under various conditions. No attempt was made to acquire statistical data that would quantify the effectiveness of the RWSL.

Secondary goals were to (1) determine the impact of the system in a *realistic cockpit environment* (e.g., Is the system confusing? Does it add to pilot workload?); (2) provide suggestions on design issues such as light size, directionality, and location; and (3) acquire suggestions for operational procedures and areas of improvement.

2. Runway Status Light System

The Runway Status Light System (RWSL) has been developed by the FAA in cooperation with MIT Lincoln Laboratory. (See ref. 4.) As described in reference 4, the objective of the RWSL is to improve airport safety by preventing runway incursions by both aircraft and ground vehicles. Most runway incursions are caused by human error usually brought about by a lack of situational awareness, failure to communicate properly, and navigational errors. The RWSL is intended to minimize the effect of human errors by providing an independent source of information for pilots about the status of a runway. Currently, pilots obtain information about the status of the runway from visual scans or from air traffic control (ATC).

The RWSL operates by conveying the *status* of individual runways indicating whether or not runways are unsafe to occupy. The RWSL is not intended to convey clearance to proceed onto a runway or down a runway. The RWSL is intended for use at all times of the day or night.

Functionally, the RWSL is a system of lights automatically controlled through use of surface radar data. Two types of lights make up the RWSL. (See fig. 1.) Takeoff hold lights (THL's) are positioned to warn pilots who are ready to take off that the runway is presently not clear or that other aircraft are projected to enter the runway in front of the takeoff. The THL's are positioned on either side of a runway ahead of the takeoff hold position. Runway entrance lights (REL's) are designed to inform pilots (or ground vehicle operators) when a runway is unsafe to enter. The REL's are positioned on either side of taxiways just prior to the intersection of the taxiway and the runway. Both THL's and REL's are bright red when "on."

A prototype of the RWSL was installed at the Boston Logan International Airport by the Volpe Center in the summer of 1995. This prototype system is being used for extensive trials so that the RWSL can be fine-tuned in an operational airport environment. Prior to this set of trials, the FAA and the Volpe Center determined the need to allow pilots to evaluate a prototype of the RWSL concept in a simulated environment. Feedback from the pilot community during the early stages of system development could provide support, not only for the trial system in Boston, but also for an eventual operational implementation of the system that would evolve from the Boston Logan prototype.

3. Simulation Environment

3.1. Simulation Facility

Initial pilot opinion of the proposed RWSL has been obtained through a series of flight simulations performed with the Transport Systems Research Vehicle (TSRV) Simulator at the Langley Research Center. The TSRV Simulator consists of a modified Boeing 737 cockpit that contains an "all-glass" instrument panel, dual sidearm controllers, Boeing 737 throttle quadrant and center aisle stand, and a four-window display configuration that provides crew members with a 150° field of view of the out-the-window scene. (See ref. 5.) A block diagram of the simulator (fig. 2) shows several systems that are required to operate the simulation. Control inputs to the simulation are made through dual McFadden sidearm control loaders, rudder pedals, and a tiller for nose wheel steering. The input is read at 32 Hz and sent over a fiber-optic highway to a Convex minisupercomputer. (See ref. 6.) The Boeing 737 simulation executed on the Convex accurately simulates the flight dynamics experienced during all phases of flight and taxi. The pilot receives aircraft state information from the instrument panel and out-the-window scenes from the computer-generated image (CGI) system. The CGI used in the study was an Evans and Sutherland CT6, which is a high-performance

system capable of rendering day and night scenes with complex environmental special effects (e.g., fog, storms, and clouds). The CGI-generated visual scenes accurately depicted a three-dimensional view of the Denver, Colorado, area (200 n.mi × 200 n.mi) from a Denver database. The Denver Stapleton International Airport (fig. 3) is modeled at the center of the database. The lights, which made up the RWSL system, were included in the database used by the CT6 to generate the out-the-window scenes at the Denver Stapleton International Airport. (See fig. 3.) The real-time system emulates Boeing 737 flight dynamics during all phases of flight. Further, the CT6 image generator can simulate other aircraft and show their movement in the fields of view of the test subjects. The pilot receives instrumentation information from the monitors mounted in the cockpit panel. The calligraphic raster display system (CRDS) provides an electronic attitude display indicator (EADI), an electronic horizontal situation indicator (EHSI), and other required information on the eight monitors mounted in the cockpit.

3.2. RWSL Implementation

To perform the evaluations described previously, REL and THL fixtures had to be depicted in the computer-generated image (CGI) of the Denver Stapleton airport (Denver database). The lights that make up the RWSL were constructed in the Denver database. Because of the limitation of the number of lights that can reside in the CGI database, lights were located only on runways 26L/8R and 26R/8L and the associated taxiways leading to and from the terminal building. These are the two parallel runways on the south side of the Denver Stapleton airport. (See fig. 3.) The light fixtures were specified as 12- by 24-in. rectangular boxes placed on the surface. In areas where acute angles occur between the taxiway and the runway, multiple lights were modeled in multiple locations. This permits movement of lights to determine the best locations so that pilots will be able to see the lights. Each of these fixtures could be turned on and off independently by the host computer. Each fixture contained two circular lights 6 in. in diameter and centered in the box. The lights were red and the box enclosing them was black. Side and top fins were added to allow the host computer to set the necessary directionality and beam width. These variables were added to the specific on-field light fixture because the on-line operational characteristics were still to be determined during the suitability assessment demonstration.

3.3. Experiment Design

Pilots were briefed on the purpose and limitations of the RWSL-simulated demonstrations and were given the opportunity to become familiar with the flight simulator

environment. The pilots were then asked to operate the simulated aircraft during ten different scenarios. The scenarios included arrivals and departures that permitted taxiing to and from runways. (See appendix A.) These tests allowed the pilots to evaluate the RWSL under various operational and situational conditions. Pilots were asked to answer several questions both before and after the simulation sessions. The questionnaires are listed in appendix B. The responses have been accumulated and are presented in appendixes C and D. The results of this study were based on these responses as well as on comments made by the pilots during their visits.

Departure scenarios started after pushback, on the initial taxiway, in the controlled area, and ended just after takeoff. Arrival scenarios started on final approach and ended at the ramp. Crews were asked to perform normal operational activities during each scenario (e.g., checklists and radio communications). Several of the scenarios placed pilots in incursion situations through controller misdirections.

An air traffic controller (acting as both the ground controller and the tower controller) was situated at a remote location and had real-time displays of the traffic being simulated. This controller not only communicated with the test subjects during the scenarios, but also emulated voice traffic of other aircraft in the field of view of the test subjects.

Cockpit time for the RWSL demonstration scenarios was 2 hr for each crew. All cockpit audio and video were recorded as well as a top-level animated view of the airport activity. These recordings allowed for playback of any test, if necessary.

Twenty-one pilots participated in the simulation test and completed the evaluation of the RWSL as demonstrated in the TSRV simulator. These pilots represented commercial airline pilots from USAir, United, and America West Airlines, as well as pilots from NASA and the general aviation community. Of the 16 commercial airline pilots, 12 were captains, and 4 were first officers, of which 13 were members of the Air Line Pilot's Association. Average pilot experience was nearly 10 000 hr of flight time.

4. Pilot Responses

Subjects were asked to evaluate the RWSL in the following three categories: (1) general comments, (2) specific design issues, and (3) suggested improvements. Responses to each of these categories are presented in the following discussion. Tabulated data, along with all questionnaire responses, are included in appendixes C and D.

4.1. General Comments

4.1.1. Viability. Responses reveal that test subjects unanimously support the concept of the Runway Status Light System. Further, they feel the status lights will, in fact, reduce the likelihood of runway incursions on the airport surface movement area. Test subjects frequently referred to the system independence as being the most attractive characteristic. By having a passive, independent source of status information to support the information pilots get from controllers and visual scans, little doubt will exist about the situation with respect to active runways. On the other hand, if they receive conflicting information about the runway status, this independent source can be used as a backup to prevent possibly proceeding into an incursion situation.

4.1.2. Workload. Seventy-six percent of the subjects felt that the RWSL would not add to pilot workload in an operational environment. This is based on the comment that inclusion of one more item in your visual scan is not a noticeable increase. However, the remaining 24 percent did point out that the system will increase workload initially because of unfamiliarity and insufficient training. Until the system becomes commonplace (i.e., part of the user's habit) in the airport environment, additional work will be required to understand this new system. Pilots felt that, once the habit is formed, additional workload would be negligible.

4.1.3. Situational awareness. Seventy-six percent of subjects felt the RWSL would improve their situational awareness to a degree. The remaining 24 percent felt it would not. The difference in opinion here can be attributed to different definitions of situational awareness. Some of the 24-percent group are referring to positional awareness (e.g., "The RWSL will not help me determine my location."). The 76-percent group is referring to the fact that the RWSL will improve their awareness of the other activity currently taking place on the active runways which, in a manner, improves their awareness of the situation.

4.1.4. Clutter. All subjects felt that the RWSL would not add an unreasonable amount of clutter to their visual scene at airports assuming the lights are hooded and pointed correctly.

4.1.5. Confusion. Ninety percent of the test subjects felt that the RWSL would not be confusing to pilots once it is fully operational. Confusion may occur in three situations: (1) during the training period for new users, (2) during any conflict between information received (e.g., between the controller and the lights), and (3) during the time that the RWSL is not working properly.

Each of these situations must be addressed to minimize the confusion that may occur.

4.1.6. Integration with taxiway lighting system. Ninety-five percent of the test subjects were comfortable with the appearance of the RWSL in conjunction with the Surface Movement Guidance Control System (SMGCS) lights. One subject felt that these two systems could be integrated functionally. Conceptually, the green taxiway centerline lights that guide pilots onto the runway would be triggered by the information received from the RWSL logic as well as from the controller. These lights would be driven by a logical "And" between the controller and radar information indicating the status of the runway. The lights would only be off (or green) if both the controller has given clearance *and* the RWSL determines that the runway is safe to enter. This concept would eliminate the cost of additional light fixtures necessary for the status lights.

4.1.7. Runway incursion experiences. Eighty-one percent of the test subjects were aware of incursions that could have been prevented with the RWSL in place. Most often mentioned were the accident in the Canary Islands (Tenerife) in the late 1970's (ref. 7) and the accident in Detroit in 1990 (refs. 8 and 9).

Also of note is the fact that the vast majority of test subjects felt the RWSL would help them feel safer if an incursion situation became likely. An incursion could become more likely if a pilot questioned or doubted the aircraft location or a taxi instruction. Subjects felt that the RWSL would decrease the likelihood of an incursion in these situations.

4.2. Specific Design Issues

Because of the nature of flight simulation environments, several design-implementation issues could not be adequately addressed. Examples of these issues include light intensity, glow effects, and beam widths. These system attributes can only be effectively specified based on real-world observations. However, a few specific questions regarding the RWSL design were answered by pilots who observed the RWSL in the simulated environment.

4.2.1. Conflicting information. With respect to operations, 81 percent of the subjects felt that, whenever conflicting information is received in the cockpit (e.g., the controller says "go" and the lights say "stop"), pilots should always hold their position and verify with the tower how to proceed. Fourteen percent explicitly stated that you should never cross a red light. The remaining 5 percent represents the opinion of the pilot who suggested the integration of SMGCS and the RWSL, which

would conceivably eliminate the possibility of receiving conflicting information. Of importance with respect to discrepancies, note that this is only *pilots'* opinion. The design must also consider the controller's opinion on this issue. Adequate consideration of this issue is critical to the success of the RWSL.

4.2.2. In-pavement lights. Subjects were divided with respect to installation of RWSL's in rows of in-pavement lights. Of the test subjects, 33 percent liked the idea, 49 percent did not, and 9 percent suggested having both in-pavement lights and peripheral lights. The remaining 9 percent did not have any opinions. All candidates agreed that the cost may make in-pavement lights prohibitive, but certainly situations exist where in-pavement lights become necessary (e.g., extremely wide taxiway intersections).

4.2.3. Acute angle intersections. Taxiways (as well as runways) that intersect runways at acute angles present a unique problem. The REL on the opposite side of the taxiway (the obtuse angle side) may be much farther from the pilot's eye reference point than the REL on the acute angle side. Conceivably, by the time a pilot sees the distant REL, the aircraft may have already incurred the runway or may not be stopped in time. When asked about this situation, 76 percent of the subjects suggested placement of the distant REL closer to the hold line along a line perpendicular to the taxiway centerline and in line with the opposite REL. Further, pilots suggested that there be three REL's at this type of intersection; the first two should be at the normal location and the third at the point closer to the hold line. (See fig. 4.) Lastly, one pilot who had suggested the integration approach mentioned earlier also noted that this problem would be eliminated if the same lights were used for the RWSL that are used for the SMGCS, which are already located in the centerline.

4.2.4. Cockpit display of runway status. When asked if a status information display in the cockpit would be preferred to lights on the airfield, 43 percent responded positively, but 33 percent responded that a cockpit display of status should only be used as a backup or in low-visibility situations. In low-visibility situations, the lights may not be visible until a runway incursion becomes inevitable. The remaining 24 percent said a cockpit display would not be preferred. The trade-off here seems to be protection versus cost. A cockpit display of status could reduce much of the cost of the system; however, many vehicles would not be protected from runway incursions because of lack of equipage (e.g., ground vehicles). Also, the question of increased heads-down time arose, which could lead to additional

incursions. Cockpit display of status information would seem most useful in low-visibility situations.

4.3. Suggested Improvements

Pilot concerns with the Runway Status Light System have focused on the type and location of the status lights. Future deployment of these lights on airport surfaces must ensure that they are sufficiently conspicuous to catch pilots' attention in all weather conditions. Several suggestions to improve the light system have been made by the test subjects.

4.3.1. THL conspicuousness. The most frequent suggestions were related to the conspicuousness of the takeoff hold lights (THL's). As pilots begin their takeoff roll, they tend to get tunnel vision. Their visual scan includes their instruments, but the focus of their attention is directly down the centerline of the runway. They may not even notice peripheral activity. Activation of THL's must be conspicuous enough to get their attention so that they can avoid a potential incursion. Most subjects suggested a flashing light fixture for the THL's. Some even suggested this for the REL's, although this would not be as important. Pilots had no problems monitoring the state of the REL's because pilots are more apt to do an out-the-window scan in all directions during taxi.

Another frequent suggestion for improving the conspicuousness of the THL's was to add an in-pavement light near the centerline of the runway in line with the two THL's on either side of the runway. This would allow pilots to continue to focus on the centerline during takeoff roll and still observe activation of the status light.

4.3.2. Series of THL's. To give pilots every opportunity to avoid an incursion while on takeoff roll, subjects suggested a series of THL pairs located every 500 ft down the runway where possible. This configuration would cover two incursion situations not covered by the current design: (1) the first THL pair has been activated after the aircraft on takeoff roll has passed them and (2) the pilot did not see the first THL pair even though they were on. This added coverage is not necessary if users always see and obey the lights, but it would protect against someone inadvertently "running" a red light.

4.3.3. Maintaining capacity. Subjects felt that the algorithm that activates the THL's based on the traffic sequencing at specific airports also needs modification. In the simulation, THL's came on when the nose of an aircraft got within 50 ft of the runway edge, and the THL's went off after the tail of the aircraft crossed a line 50 ft on the other side of the runway. Pilots suggest that this could potentially impede the flow of traffic at some airports. Often, if an aircraft is crossing the runway at a

long distance from the takeoff hold point, the departing aircraft will be cleared to take off prior to the taxiing aircraft clearing the runway. Obviously, if the departing aircraft has to wait for the THL to go off, a delay of possibly several seconds could occur.

Pilots have suggested two options for resolving this problem: (1) move the trigger point so that the THL's go off before the taxiing aircraft is actually clear of the runway (projecting that it will be clear soon) or (2) have the controllers acknowledge the light state in their instructions (e.g., "NASA515, runway 8R, fly runway heading, cleared for takeoff pending status lights.>").

4.3.4. RWSL operational status. Some pilots suggested the need for an indication that the RWSL is working. This could be part of the Automatic Terminal Information System (ATIS) services, but pilots would prefer an indication on the light itself. Another suggestion was to have the status lights be either red or yellow, but never off (unless they've failed or are being serviced). The yellow indication would relate "proceed with caution," whereas the red indication would be the same "stop." If the RWSL's are down for any reason, the users must be aware of this. Eventually, pilots may come to depend on these lights to keep them out of trouble on the airfield surface. Note, pilots stated that a "green" light indication would not be effective because a pilot may assume that it is an indication of clearance to go.

4.3.5. THL height. Pilots suggested raising THL's 2–3 ft off the ground. The light fixtures used in the simulation sat on the ground and were occasionally occluded by runway edge lights, which also sit on the ground. This occlusion only occurs from some viewing angles, but a raised THL would correct this problem.

4.3.6. REL's. Only two suggestions were made with respect to improving the REL's. The first is for situations where wide areas of pavement intersect a runway. At these locations, a number of in-pavement lights should be installed between the side REL's that also denote runway status. Because of locations where aircraft await clearance while sitting side by side on a taxiway, crews may not be able to see the REL pair at the intersection.

Secondly, the use of the SMGCS taxiway centerline light fixtures to denote runway status (in place of the REL fixtures) could significantly reduce the cost of this system at airports where SMGCS lights are operational. Pilots have suggested that the centerline lights proceeding from a hold line out onto a runway could be forced to turn "red" if either (1) they are not cleared onto the runway or (2) the RWSL logic declares the runway unsafe to enter.

5. Observation

One observation with respect to the incursion scenarios that the test subjects were put through should be noted as follows. Nearly all crews (either one- or two-man) passed an illuminated THL pair after being cleared incorrectly to take off. In these situations, an aircraft was crossing the runway somewhere down the runway in front of the takeoff position (but hidden because of low visibilities) thus illuminating the THL's. Crews, not expecting an ATC misdirection, focused their attention on takeoff duties and did not observe the THL activation. After they had passed the THL's, ATC would issue an abort for the takeoff to avoid a collision.

Most subjects remarked that because their attention is mainly focused on the centerline at a point down the runway during takeoff, they normally do not look peripherally. This caused pilots to suggest that THL's be more conspicuous either by including an in-pavement THL near the centerline or flashing THL's that would catch the attention of pilots.

6. Concluding Remarks

The RWSL demonstrations performed at LaRC have produced data from a unique perspective—the pilot's. As the most frequent users of the RWSL, pilots must support its implementation. Further, the pilot community's inputs should be seriously considered when implementing the RWSL in an operational airport environment. Several pilots were enthusiastic about this system because of the fact that they (the pilot community) were being involved in the design process prior to implementation. Subjects suggested that if their input had been solicited for other developmental systems, more effective systems could have resulted.

Keep in mind that the opinions expressed in this document are solely those of the test subjects who participated. Their opinions are based on a simulated demonstration of the RWSL. The authors recognized that several specific questions about the RWSL could not be answered in a simulated environment with present day technology. These include issues such as required light intensity, luminescence, and beam width. These questions can only be answered at an actual airport facility busy with aircraft and ground activity where image resolution is no longer limited to a fixed number of pixels.

These demonstrations have shown that these pilots unanimously support the concept of the Runway Status Light System. Further, they feel that the RWSL will reduce the likelihood of runway incursions on the airport surface. Subjects were concerned with some of the specifications of the light fixtures—they must catch your attention, light locations for some specific types of intersections (wide areas and acute angles), and timing of the light state changes with respect to maintaining airport capacity.

The authors believe that the most important aspect to address beyond implementation is pilot training. Users must understand precisely how the system works, and its operation must become part of the culture in the airport environment. Part of this training must ensure that users will not become totally dependent on the RWSL to protect them. The system must also ensure that users will not misinterpret the state of the lights to denote clearance. The previous factors could prove fatal to the RWSL effectiveness and conceivably cause additional incursion situations.

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Appendix A

Simulated Flight Scenarios

The simulated flight scenarios are given in the following table:

No.	Conditions	Type	Taxi route	Traffic movement
1	VFR-day	Dep.-8L	B4-B-B3-C3-8L	1. Arr.-8R 2. Dep.-8. 3. Arr.-8L 4. Taxi along B4 to ramp
2	VFR-day	Dep.-8R	C4-C-C1-8R	1. Arr.-8L 2. Dep.-8R 3. Arr.-8R 4. Taxi along B4 to ramp
3	VFR-night	Dep.-26L	C6-C-C12-26L	1. Arr.-26R 2. Dep.-26L 3. Arr.-26L 4. Taxi along B4 to ramp
4	RVR = 600 ft	Dep.-8R	B4-B-B1-8R	1. Dep.-8R 2. Arr.-8R 3. Taxi along B4 to ramp
^a 5	RVR = 800 ft	Dep.-8R	C4-C-C1-8R	1. Arr.-8L 2. Dep.-8R 3. Arr.-8R 4. Taxi along B4 to ramp
^b 6	RVR = 600 ft	Dep.-8R	C4-B4-B-B1-8R	1. Arr.-8R
7	VFR-night	Dep.-26R	B4-B-B5-C6-C-C11-26R	1. Arr.-26L 2. Dep.-26R 3. Arr.-26R 4. Taxi along B4 to ramp
^c 8	RVR = 1200 ft	Dep.-26L	C6-up 26L-C9-C-C12-26L	1. Dep.-26L 2. Backtaxi up 26L
^d 9	VFR-night	Arr.-26L	26L-C6-ramp	1. Arr.-26R
^d 10	RVR = 600 ft	Arr.-26L	26L-C8-C-	1. Arr.-26R

^a Pilot is misdirected by ATC to take off while there is an a/c taxiing across 8R. Crew cannot see this a/c because of reduced visibility.

^b Pilot is misdirected to cross runway 8R as an a/c is landing on 8R. REL's illuminate prior to own ship incurring the runway but after the hold line. Crew cannot see the arriving a/c because of reduced visibility.

^c Similar to Tenerife accident. Pilot misdirected to take off on 26L while another a/c is backtaxiing up 26L toward him. Crew cannot see backtaxiing a/c because of reduced visibility.

^d Pilot misdirected to expedite across 26R to ramp while a/c lands on 26R. REL's illuminate prior to own ship incurring 26R but after own ship has crossed the hold line.

Appendix B

Pilot Questionnaires

Preflight Questionnaire

1. Name
2. Date
3. Affiliation:
 - a. Air Line Pilot's Association (ALPA)
 - b. Aircraft Owners and Pilots Association (AOPA)
4. Employer
5. Job title
6. Flight ratings
7. Approximate flight hours experience
8. Approximate flight hours in glass cock pits
9. Have you flown approaches/takeoffs in Category III conditions? Where?
10. Experience with similar flight simulators (yes/no)? Where?
11. Were you familiar with the FAA's ASTA program prior to today?
12. Were you familiar with the Runway Status Light System prior to today?
13. Were you familiar with the Surface Movement Guidance Control System (SMGCS) light system before today?

Postflight Questionnaire

1. Do you feel that the Runway Status Light System is a viable concept?
2. Do you feel that the Runway Status Light System will reduce the likelihood of runway incursion?
3. Do you feel the Runway Status Light System will add to pilot workload?
4. Do you feel that the Runway Status Light System will improve your situational awareness?

5. Do the runway status lights add an unreasonable amount of clutter to your visual scene during taxi operations (day/night)?

6. Do you feel the runway status lights will be confusing to pilots?

7. In low-visibility situations, were you comfortable with the integration of the runway status lights and the Surface Movement Guidance Control System (SMGCS) lights (wigwags and stop bars)?

8. How would you improve the Runway Status Light System?

9. How would you resolve a situation where the controller and the status lights disagree?

10. Would you prefer that the runway entrance lights be an in-pavement row of lights? How about the takeoff hold lights?

11. Positioning runway entrance lights on taxiways that intersect runways at acute angles still has to be determined. Where would you suggest they be located at these types of intersections? Closer to the runway or closer to the hold line?

12. Would you prefer to have runway status displayed in the cockpit in an electronic format (e.g., on an electronic taxi-map display)? Would this be useful to you?

13. Are you aware of any runway incursions that could have been avoided if the Runway Status Light System had been in place?

14. (Optional) Have you ever questioned (or doubted) a taxi clearance given to you? If so, would the Runway Status Light System have helped you feel safe?

15. (Optional) Have you ever questioned (or doubted) your location at an airport? If so, would the Runway Status Light System have helped you feel safe?

16. Any other general comments, criticisms, or support for the Runway Status Light System?

17. Finally, do you feel the TSRV simulator facility provides adequate realism to evaluate the Runway Status Light System concept?

Appendix C

Tabulated Pilot Responses

The numbers in this appendix correspond to the question numbers in the postflight questionnaire in appendix B. Two questions were omitted because the answers were not easily tabulated, but those answers are included in the responses in appendix D.

General Questions

	Y/N
1. Do you feel that the RWSL is a viable concept?	21/0
2. Do you feel that the RWSL will reduce the likelihood of runway incursions?	21/0
3. Do you feel the RWSL will add to pilot workload?	5/16
4. Do you feel that the RWSL will improve your situational awareness?	16/5
5. Does the RWSL add an unreasonable amount of clutter to your visual scene?	0/21
6. Do you feel the RWSL will be confusing to pilots?	2/19
7. In low-visibility situations, were you comfortable with the integration of the RWSL and the Surface Movement Guidance Control System (SMGCS) lights?	20/1
13. Are you aware of any runway incursions that could have been avoided if the RWSL had been in place?	17/4
14. Have you ever questioned (or doubted) a taxi clearance given to you?	19/2
If so, would the RWSL have helped you feel safe?	17/4

15. Have you ever questioned (or doubted) your location at an airport?	20/1
If so, would the RWSL have helped you feel safe?	15/6

Specific Questions

9. How would you resolve a situation where the controller and the status lights disagree?

Verify with controller: 17
 Never cross a red light: 3
 Integrate with SMGCS: 1

10. Would you prefer that the REL's be an improvement row of lights? THL's?

Yes: 7
 No: 10
 Both: 2
 Don't know: 2

11. Positioning REL's on taxiways that intersect runways at acute angles has yet to be determined. Where would you suggest they be located at these types of intersections? Closer to the runway or closer to the hold line?

Hold line: 16
 Runway: 2
 Both: 1
 Integrate with SMGCS: 1
 Don't know: 1

12. Would you prefer to have runway status displayed in the cockpit in an electronic format?

Yes: 9
 No: 5
 As backup for low vis.: 7

17. Do you feel that the TRSV simulator facility provides adequate realism to evaluate the RWSL concept?

Yes: 21
 No: 0

Appendix D

Pilot Responses to Questionnaires

This appendix contains the written responses provided by the test pilots. The pilots have been assigned identification letters a–u, and their responses to each question are listed together.

Preflight Questionnaire Responses

5. Job title:

- a. Pilot
- b. Captain
- c. Research Pilot
- d. Pilot
- e. -----
- f. -----
- g. Captain, Boeing 737-200
- h. Captain
- i. Check Airman-Captain
- j. First Officer
- k. Captain
- l. Captain Boeing 737-300/400
- m. F/O
- n. Electronic Engineer (Private Pilot)
- o. Aviation Safety Inspector
- p. First Officer
- q. Captain
- r. Captain
- s. First Officer
- t. C/O
- u. Lead Engineer

6. Flight ratings:

- a. Boeing 737, 757, 767; DC-9; IA-JE7
- b. ATP (airline transport pilot)
- c. SMEL, glider, rotorcraft
- d. ATP
- e. DC-9; FK-28; Boeing 737, 757, 767
- f. Boeing 737
- g. ATP Boeing 757, 767, 737
- h. ATP
- i. F28; F100; Lear jet; Boeing 737, 727
- j. ATP G-IV type
- k. ATP-LRJET, Boeing 737-AMEL-COMM ASEL; CFI-ASE, instrument; F/E-turbojet
- l. FIC-28; DC-9; Boeing 737, 757, 767
- m. DC-9
- n. Private
- o. ATP-Boeing 727; Citation
- p. ATP-F/E Boeing 737; EC-9; Boeing 757, 767
- q. ATP-Boeing 737; DC-9; F/E, COMM/INST R/W
- r. Boeing 767, 757, 737; F-28; F-100
- s. Boeing 727, 767, 757

- t. F-100; Boeing 737; DC-9
- u. Airplane single and multiengine commercial license with instrument, commercial helicopter

7. Approximate flight hours experience:

- a. 10 000
- b. 12 000
- c. 6 500
- d. 9 500
- e. 12 750
- f. 1 100
- g. 8 000
- h. 17 000
- i. 4 500
- j. 5 300
- k. 12 000 +
- l. 1 200
- m. 12 000
- n. 100
- o. 5 000
- p. 9 000
- q. 11 600
- r. 9 400
- s. 6 000
- t. 9 000
- u. 1 700

8. Approximate flight hours in glass cockpits:

- a. 3000
- b. 0
- c. 20 in flight (NASA C-402 in mid-1980's—part of the single-pilot IFR program).
- d. 50
- e. 1200
- f. 100
- g. 800
- h. 3000
- i. 1000
- j. 275
- k. 0
- l. 1000
- m. 0
- n. Not applicable
- o. 0
- p. 1500
- q. 0
- r. 500
- s. 2000
- t. 100
- u. 0

9. Have you flown approaches/takeoffs in Category III conditions? Where?

- a. Yes. CLT, LAX, LGW, FRA
- b. Yes. Various places.

- c. No.
- d. Yes. BOS, PIT, ATL, BWI
- e. Yes. PIT, CLT, LAX, SEA
- f. Yes. TSRV sim.
- g. Yes. CLT, BOS
- h. No.
- i. Yes. ORD, PIT, BOS, IND, CLT, and others
- j. Yes. Pittsburgh, Charlotte
- k. Yes, formerly Piedmont. I flew the Boeing 737-300 at Category IIIA.
- l. Yes. USAir—Domestic and International (London, Gatwick, Paris, Orly)
- m. No.
- n. No.
- o. Yes. Oklahoma City, FAA sim.
- p. Yes. BWI, LGW, PHL
- q. No.
- r. Yes. USAir
- s. Yes. Germany, France, England, Seattle
- t. Yes. BOS
- u. No.

10. Experience with similar flight simulators (yes/no)?
Where?

- a. Yes. NASA, USAir, Piedmont
- b. Yes. USAir
- c. Yes. HL-20 in TSRV and a few other brief programs in TSRV.
- d. Yes. USAir, PIT, CLT
- e. Yes. SEA, Boeing 767-300
CLT, USAir Boeing 737-300/200
PIT, USAir Boeing 737-300/200, 757
TPA, Reflection; USAir FK-28
- f. NASA Langley
- g. Yes. USAir, Piedmont, Boeing
- h. Yes. PHX
- i. Yes. USAir Check Airman Simulator Instructor F28, F100
- j. Yes. USAir sim., NASA
- k. Yes. Airline
- l. USAir Flight Operations
- m. USAir sim., Flight Safety St. Louis
- n. No
- o. Yes. FAA and Military (Navy)
- p. Yes. USAir PIT, CLT, INT; Boeing SEA; Am West PHX; Southwest DAL
- q. Yes. Airline to USAir
- r. Yes. NASA, Navy, USAir
- s. Yes. Denver training
- t. Yes. USAir
- u. Yes, at Mitre.

11. Were you familiar with the FAA's ASTA program prior to today?

- a. No.

- b. No.
- c. Vaguely.
- d. Yes, somewhat.
- e. No.
- f. Yes, somewhat.
- g. No.
- h. Yes.
- i. No.
- j. Somewhat.
- k. No.
- l. Yes.
- m. Vaguely.
- n. Yes.
- o. Yes.
- p. Somewhat.
- q. No.
- r. No.
- s. No.
- t. No.
- u. Yes.

12. Were you familiar with the Runway Status Light System prior to today?

- a. No.
- b. No.
- c. No.
- d. No.
- e. No.
- f. No.
- g. No.
- h. Yes.
- i. No.
- j. No.
- k. No.
- l. No.
- m. Vaguely.
- n. Yes.
- o. Yes.
- p. No.
- q. No.
- r. No.
- s. No.
- t. Yes.
- u. Yes.

13. Were you familiar with the Surface Movement Guidance Control System (SMGCS) light system before today?

- a. Yes.
- b. No.
- c. No.
- d. Somewhat.
- e. Yes.
- f. No.
- g. Somewhat.

- h. Yes.
- i. No.
- j. No.
- k. Yes.
- l. Yes.
- m. No.
- n. Yes.
- o. Yes.
- p. Yes.
- q. No.
- r. Yes.
- s. Yes.
- t. Yes.
- u. Yes.

Postflight Questionnaire Responses

1. Do you feel that the Runway Status Light System is a viable concept?

- a. Yes.
- b. Yes.
- c. Absolutely, the primary challenge, I think, is to find good locations on the airfield for them.
- d. Yes.
- e. Yes.
- f. Yes, I especially like independence from the controller.
- g. Yes.
- h. Yes.
- i. Yes.
- j. Extremely viable because it is passively tied to the ground surface radar and does not require human activation. See comments on question 6.
- k. Absolutely!!
- l. Yes. It does have a potential to enhance safety. It does need refinement.
- m. Viable concept yes. Needs improvement in the type of warning lights.
- n. Yes.
- o. Yes.
- p. Yes. As I mentioned earlier, though, I wonder about reliability. However, if it had some sort of monitor and this whole system could be shut down manually for "glitches" or failures, I suppose it would be okay.
- q. Yes, definitely.

r. Yes. It would be a definite aid in avoiding runway incursions.

- s. Yes.
- t. Yes.

u. Yes, if some of the physical characteristics of the lights can be worked out.

2. Do you feel that the Runway Status Light System will reduce the likelihood of runway incursions?

- a. Yes.
- b. Yes; however, at busy airports where a/c's are cleared onto the runway while a landing a/c is still rolling out, I see a potential problem where pilots could become accustomed to ignoring the lights.
- c. Yes. But it's essential that a habit of checking and interpreting them be acquired by flight crews. In effect this action should become part of the taxi and take-off checklists
- d. Yes.
- e. Yes. This will allow pilots to have a backup if there is aircraft movement in the vicinity of their aircraft.
- f. Yes.
- g. Yes.
- h. Yes.
- i. Yes. This system creates better situational awareness for the pilot as well as the controllers and that equates to a safer operation.
- j. Yes! They will definitely increase pilot's situational awareness and act as a good backup system for controller errors.
- k. Yes. This is a great idea, long over due. I especially like it because the system operates independently of controller-pilot actions.
- l. Yes. It was helpful, but I had to take the caution and resist depending on the system too much. My normal pattern of scanning for traffic and incursions was slightly affected when I relied on this technology.
- m. Yes. If properly interpreted by the pilot. The "THL" lights could be missed on low-vis. takeoffs.
- n. Yes.
- o. Yes.
- p. Yes. I hope the current system is "good enough" but feel as if the RWSL will provide an independent backup. I do wonder about how much of an incremental reduction in runway incursions the system

will provide and how that reduction will be affected by system reliability, i.e., will a breakdown of the system possibly cause some other problem through a chain reaction.

q. Yes, definitely.

r. Yes!! To do so, however, it would need to be incorporated into training programs. To be effective, the pilots would need to be aware of the lights until they and we pass them.

s. Yes.

t. Yes.

u. Yes. It's another step added to the chain of events that work to stop runway incursions.

3. Do you feel the Runway Status Light System will add to pilot workload?

a. No, provided pilots understand the system and aren't confused by this display when it is seen against all other airport runway light displays, such as ICS hold signs, in-ground taxi light systems, etc.

b. Not at all.

c. No. They are easily interpretable and are either off or red. It is important that their positioning be standard so that pilots know where to look for them and don't miss a red light by looking in the wrong place.

d. No. Red or red flashing lights during "heads-up" operation would be easily responded to.

e. No. Not overall. During the initial stages of acclimation to the new system there may be an increase (slight) in workload but only until the system becomes second nature to the pilot's external scan.

f. No. Pilot workload is not necessarily high during taxi. Might decrease workload by insuring safer taxi ops.

g. No.

h. No.

i. No. The lights should aid the pilot and actually lessen the workload by allowing for a safer operation.

j. No. They will initially take pilots some getting used to looking for them but would quickly become part of his habit pattern.

k. Initially, yes, to a small extent. However, once the system is installed at most-all airports and it becomes standard, the pilots will treat this the same as any other lighting system. And it will become second nature. Once everybody is used to the system, I don't feel there will be any increase in workload.

l. No.

m. Not a concern with me. In the simulator, I used the additional input to make decisions about runway and taxiway traffic.

n. Very little. It adds one more thing to watch for, although the alternative is to completely trust the controller. In low visibility it added a tremendous amount of comfort.

o. Somewhat. Another set of lights to watch for.

p. Yes. I think the additional workload is rather small, but I do feel it is there. Maybe it is because I knew what this test was for, but I found myself consciously looking for the lights and trying to anticipate potential conflicts that the lights would illuminate for. Whereas the anticipation of conflicts would not be there day to day, I feel as if the "looking for the lights" would be there.

As an aside I reread this and feel I need to explain that pilots try to "anticipate conflicts" always. I just felt as though I were looking harder at this today (in the context of this study).

q. It will add very slightly to the workload. Pilots will develop the habit of looking for the lights, but it will be well worth it.

r. If one considers glancing at a light an increase in workload, then yes. If it will save my behind, then no. Basically, no.

s. No.

t. No.

u. Yes and no. It's another detail to look for in airport operations, but it's fairly easy to spot once accustomed to their presence. However, wide taxiways connecting to a runway may present a problem.

4. Do you feel that the Runway Status Light System will improve your situational awareness?

a. Yes. It will improve my situational awareness in relation to areas where an incursion could occur but not to overall airport awareness.

b. Yes.

c. Yes, in a gross sense. At least runway incursions should be less likely.

d. I don't think so. Only in the area of avoiding wrongful incursions onto a taxiway or runway in the immediate area. Would not help in determining your position on the airport.

e. Yes. It will allow backup information from the controller that there is no crossing traffic downfield.

f. Not really. Not any more than a stoplight does on the highway.

g. Yes.

h. Yes.

i. Yes. See response to question 1.

j. Definitely, as long as the reliability and visibility remains useful.

k. Probably not. Under the present system of taxiway-runway markings and lights, a pilot has many cues relative to situational awareness. The REL-THL's really don't provide, *per se*, information that the pilot didn't already have regarding aircraft location. They do provide "conflict" information, however.

l. Yes. It also seems to provide another safety net in areas of high-density operations. However, one can not be sure what the obstruction really is.

m. We know that somethings there, but we don't know what (e.g., aircraft, truck, etc.) or where (e.g., which taxiway).

n. Yes.

o. Yes.

p. Yes. I don't think it will improve my positional awareness, but I do feel it will improve my awareness of situation (e.g., low visibility, aircraft on approach). The situation I describe may be impossible to detect from the cockpit because we usually taxi with the Traffic Alert and Collision-Avoidance System (TCAS) off. In good weather you can look up and see the approaching aircraft. This is frequently not possible in foggy conditions.

q. No, it will not really help me to locate myself.

r. Yes, especially in low-visibility situation and at night.

s. Yes.

t. Yes.

u. Yes. It should be as much of a benefit in visual met conditions (VMC) as in low-vis. conditions, especially, because operations are usually pushed a little tighter in VMC a lot of times.

5. Do the runway status lights add an unreasonable amount of clutter to your visual scene during taxi operations (day-night)?

a. No, but possibility of confusion where runway signs might exist.

b. No. However, there were times (during the sim. session) where I could only see one light or saw both lights but one brighter than the other. Ex.: one scenario

involved a high-speed turnoff which then crossed an active runway. I noticed the right "REL" but could not see the left one (it was farther away and initially blocked by a taxi light). I think the REL's would stand out more if they were perpendicular to the taxi centerline (may be connected by a printed line). This would eliminate the possibility of seeing one light and not the other.

c. No, either day or night. However, the status lights should not be closely surrounded by a mass of other ground lights.

d. No.

e. No.

f. No. Visual, day/night scene is not normally cluttered on an airport. In fact, sometimes one has to look for signage to help find one's way.

g. No.

h. No.

i. No. During night ops the lights might possibly be a little harder to discern if not placed correctly or in a location where they will not be confused with other lights on the surface.

j. Not at all. There are already a lot of lights on the airfield but having these lights lets the pilot know exactly what the status is of the runway the pilot may be crossing or taking off from.

k. No. If anything, they need to be more eye-catching.

l. No. However, depending on the pilot's eye position in the cockpit, I did not like the picture I saw when the red RWSL was blocked by the white runway edge identifier lights.

m. Didn't seem to in the simulator.

n. No (for day or night).

o. If their physical positioning to other lights or features is complicated, then the status lights would be more difficult to discern.

p. No. There is probably some clutter at night (particularly if the lights were very bright), but I did not feel as though there was any "clutter" in the day visuals. Also any clutter in the night scene was definitely acceptable.

q. They don't add much to clutter. The real issue is: will they stand out from the clutter when illuminated? (See no. 8.)

r. No, for daytime. Yes, to some degree, at night when there are many other lights out there, all having a meaning.

s. No.

t. Day, no. Night, no.

u. Not as depicted in the simulation (question remains of visibility from all aircraft types).

6. Do you feel the runway status lights will be confusing to pilots?

a. Not as long as pilots understand the blank sign means clear (and not broken) and do not confuse lights with verbal clearance given by controller.

b. No. Except as noted by question 4. Also, how will you address large "run-up blocks," e.g., TPA runway 18.

c. No. They convey a simple message. Any subtypes of meaning or reasons for their illumination would have to be clarified by talking to the controller.

d. No.

e. No, not once the pilot has become conditioned to their meaning. The only problem I can foresee is that the pilot may subconsciously interpret the light being turned off as "clearance for takeoff."

f. No, should be natural situation, i.e., red means stop.

g. No.

h. No.

i. No.

j. No. I'm sure 90 percent of the time they will be off, especially the intersection lights. At many airports (e.g., Philadelphia), takeoffs and landings involve crossing an active runway on both events. These lights would be very valuable at those airports.

k. No, not if they're colored red and plainly visible. The color "red" tells it all.

l. Yes. As stated in question 4. Also, I take caution for I think a two-bar visual approach slope indicator (VASI) system may be confused with these lights. Round VASI precision approach path indicator (PAPI) lights would not be confused with this concept.

m. The steady red lights could be missed on low-vis. taxi conditions. Perhaps blinking lights could reduce the confusion.

n. Pilots who are educated on their operation should not find them confusing. Although I did not find them confusing, I can see potential for confusion, especially in conjunction with stop bars and wigwags.

o. Not if adequate training to all pilots is conducted.

p. No. I like the simplicity. I have two small children and very early on they knew "Green for Go, Red for Stop." This system is even simpler because we can delete the "Green."

q. No. (See no. 8.)

r. No.

s. No.

t. No, but a priority must be that status lights are first and ATC clearance second.

u. No. However, they might make pilots question the controllers more (hopefully only when needed).

7. In low-visibility situations, were you comfortable with the integration of the runway status lights and the Surface Movement Guidance Control System (SMGCS) lights (wigwags and stop bars)?

a. Very comfortable, but is this overkill? Perhaps too much information. Would be nice if systems were combined somehow to eliminate any confusion from so many lights.

b. No problem.

c. Not familiar to me.

d. I'm sure I would be comfortable with this system.

e. Yes. I feel this is a must. I found the European System at London's Gatwick for taxiing to be quite helpful.

f. Yes. Wigwags are necessary to preclude missing the red lights.

g. Yes.

h. Yes.

i. Yes. Consideration needs to be given to placement of the lights at the most optimum point as well as the height of the lights above the ground. Flashing lights would also be more readily visible to the pilots.

j. Yes. Although redundant in their intent, I liked the concept that the RWSL was not controller activated because, if the same controller clears you to cross in error, the controller will also turn off the SMGCS in error, but the RWSL should override an erroneous clearance.

k. Yes. I found that to be a much better system integrated as it was.

l. I was very comfortable with this system. When in use, these lights offer a protective measure of safety that is unquestionable.

m. Yes.

n. Because of my previous knowledge of both subjects, I did not find the combination confusing; otherwise, I probably would have. I did note that I was paying far more attention to the RWSL than to the stop bar.

o. Yes.

p. Yes. I felt as if they were complementary. In rethinking the scenarios, I know that I waited for the SMGCS lights to go out at least during one scenario but do not know if I taxied over any illuminated SMGCS lights. I may not have. I just don't remember whether I did or not.

q. No. I thought there was lightbulb overload. These need to be better integrated.

r. Yes.

s. Yes.

t. Yes.

u. Yes. As depicted, they were different enough not to be a problem.

8. How would you improve the Runway Status Light System?

a. (1) Large displays.

(2) Distance from hold short line to display bars might be difficult to see in extremely low vis., i.e., 0-0.

(3) Include some indication that system is working when blank.

b. As noted in question 4. Also, the REL's would be more effective if they blinked in the scenario with the SMGCS; I think it would be more effective to have the yellow SMGCS warning lights steady (less important) and the red REL's blinking (more important).

c. See following comments.

d. Study and implement this system in the already established centerline system.

e. Make the light boxes bigger. Might even consider placing another set of red lights about 1000 ft beyond the first set to allow pilots a "secondary view" in case an aircraft or truck began crossing the runway downfield after brake release and takeoff roll had been initiated. Must be careful not to confuse them with VASI lights.

f. Need to see them in real life to see brightness, size, etc. Might need to be brighter. Especially in bright daylight conditions.

g. Wide taxiways need more indicators. Burbank airport has an unusually wide paved area. Would prefer flashing lights. Modify on/off time for THL's. The THL's must catch your attention. Perhaps a series of them.

h. Flashing lights, at least in daytime. Need to modify the on/off timing of the THL's to ensure that capacity is not affected.

i. (1) Flashing lights versus steady lights.

(2) Raising the height of the lights to make them more visible.

(3) Making sure the lights will not be confused with any other surface lights.

j. I would raise them 2 1/2-3 ft above the ground. This elevation would give a better line of sight from most cockpits because they would be well above any taxiway-runway lights. Also, in winter this elevation will limit effects of snow accumulation which might otherwise obscure visibility of the lights. I would also make the THL flashing instead of steady. Pilot workload at power up for takeoff is higher than during taxi and flashing THL would get their attention better.

k. The REL lights should be placed (perhaps in conjunction with existing REL lights) along the hold short line. Perhaps in the concrete.

l. I would alternately blink these lights, in the same manner as the SMGCS. There would be little confusion on their purpose. Most of the lights we see burn steady. Blinking lights would be a definitive cue of a runway incursion.

m. Perhaps a blinking red light would be more distinguishable than a simple steady red light. At present we have many steady red lights on the airport: red nav. lights, red VASI lights, and red approach lights. A red light in the middle of the runway may improve interpretation of the THL lights.

n. ----

o. (1) Initial intensity of lights should be sufficiently conspicuous to pilots and vehicle operators.

(2) Time to turn on and turn off should be slightly greater. A landing aircraft generates a quick on, then off, indication. Pilots may want to know of landing aircraft situations a little sooner.

(3) After crossing the hold short line and about to enter a runway, the lights could be triggered to come so abruptly that an average pilot may not be able to stop his aircraft soon enough without entering a part of the runway. See question 11.

p. Light placement seems okay. They are sort of marginally bright currently as pointed out in the briefing. I would be careful of making them so bright as to interfere with vision down the runway or taxiway. This particularly applies to night operations.

q. I would make them more conspicuous and more unique: that is, house them in a unique cabinet or use an array of lights which makes them more distinguishable from other lights. I would consider having lights both at hold lines and at the runway edges to give advance warning in low-vis. conditions and then last-ditch warning when past the hold line.

r. Larger lights. Blinking lights. Move lights down the runway. The system needs to be able to "reach out and grab you" to get your attention. A system that may or may not get your attention would be no good.

s. No improvement that I can think of now. Appears to be an excellent idea and probably should have been incorporated years ago!

t. For takeoff and landing, I do not like the lights on the side of the runway. A bar in the center would work fine.

u. Is there any way to know the difference between a broken light (or cable run) and one that is off?

9. How would you resolve a situation where the controller and the status lights disagree?

a. Pilot must call controller for verification of situation. This is currently done in Europe when taxiing using ground taxi light systems.

b. The most restrictive should apply until clarified by verbal communication.

c. Follow the most conservative consequence while calling ground/tower for clarification.

d. I would like to see status lights incorporated with centerline lighting in taxiways and runways. Changing from green to red would be very effective and recognizable.

e. Obey the status lights unless the pilot in command can obey controller instructions or if the pilot has the conflicting traffic in sight and believes it poses no threat or hazard.

f. Until it could be proven that lights were faulty, they must be honored. Controller may not have all the necessary info.

g. Verify with ATC.

h. Verify with ATC.

i. The pilot and a/c should hold position until both lights and controller agree no conflict exists.

j. Pilots are taught early on to query the controller if there is any doubt on their clearance. If there is still a disagreement and the pilots have seen strong reliability with the RWSL, they should believe the lights first and question the controller again.

k. The procedure should be to adhere to the lights while checking with the controller and informing him of the status of the REL's or THL's.

l. Stop the aircraft and obtain qualification of instructions. At the same time (from a pilot's point of view), never place the aircraft in a position of ambiguity or harm.

m. Utilization of airport ground radar to confirm a disagreement.

n. Exactly as we did during the simulation: (1) stop, (2) inform controller of illuminated runway status lights, and (3) await further instructions.

o. Turn off the system. Pilot should not taxi past any illumination red lights, such as the case with stop bars.

p. I suppose I alluded to this earlier with my comment about a manual shutoff. As a pilot, I would not enter a runway with red lights or take off with red take hold lights without a substantial discussion with a controller. This presumes very low visibility. Obviously, if I can also see no traffic, I would probably go with the controller even if the RWSL did disagree. If the controller knows she/he is right and the status lights are wrong, the RWSL should be shut down.

q. Pilots should be trained to stop for a light until getting a verbal confirmation from a controller to proceed.

r. Status lights rule until an actual condition is confirmed by other V's.

s. Talk to ground-tower about disparity.

t. Status lights must be controlling.

u. Pilot asks the controller for clarification. After confirmation that everything is ok with the controller and visually verifying the area to the best of his/her ability, then the pilot can proceed. Shutdown rules and criteria should be established.

10. Would you prefer that runway entrance lights be an in-pavement row of lights? How about takeoff hold lights?

a. Runway entrance lights and takeoff hold lights could both be in the ground. This would allow a pilot

during extremely low-vis. conditions to be able to look out of cockpit windows directly down and see lights, because forward visibility is sometimes limited by cockpit height, e.g., Boeing 747, 767, and DC-10.

b. The REL's in the pavement would be more noticeable but I don't think the added cost is necessary. However, connecting the two edge lights with a painted line (perhaps a red broken line) would be an effective substitute. As for the THL's on takeoff, the flying pilot is initially focused on the runway centerline thereby making it possible to overlook the edge lights.

c. The main consideration is making the lights easy to see. This means that they should be visible from positions away from runway lights. Also, they should be visible from positions some distance and angle off the normal entrance and/or hold positions. These factors may or may not favor in-pavement lights.

d. Yes. Takeoff hold lights would almost eliminate unauthorized taxiing onto an active runway.

e. No. Because during snowy or icy conditions, the lights will be covered over and not visible to the cockpit. Be placed only in pavement as change backup.

f. Runway entrance lights with wigwag okay. Takeoff hold lights may need some more work. A row of lights might be good at night, maybe not so good in daytime.

g. No, because of snow problem. Perhaps could integrate with SMGCS.

h. No, because of snow problem.

i. I feel the runway entrance lights could actually use both systems. When the taxiways or airport surfaces are contaminated, the in-pavement lights could be covered up. The takeoff hold lights are fine the way I tested them considering that, possibly, they should be elevated and should flash.

j. During winter ops, the in-pavement row of lights might have some limitations. Under normal taxi conditions, the in-pavement lights are very effective. I would not prefer in-pavement for THL because most people look downfield for takeoff roll not down in front on the pavement.

k. Ref. REL's; yes. (See question 8.)

Ref. THL's; I'm not sure yet, how to do that. The present THL display is not optimal and needs to be modified but at this point, I'm not sure exactly how to handle that.

l. I would suggest that these lights be left as they are except for the following recommendations:

(1) Place a third round red light in the centerline of the taxiway.

(2) Wigwag these lights to get the pilot's attention.

m. Yes, for both.

n. For most of the intersection, the elevated lights worked fine. The wide throats and places where a pilot approaches the lights from an angle probably needs inset lights. At times during the simulation (physically), I could not see the runway status lights. The THL's should be enhanced in some way. Insets may have some problem with bumps on runways.

o. In all cases but very low visibility (less than 600-ft RVR), the above-ground version is acceptable. Below 600-ft RVR operations, require that all information to the pilot be on or near the taxiway center line.

p. The REL's might be better this way. That might help with the next question. I don't feel it is necessary for the THL's, but it might make them harder to miss. If they were installed, I feel it would become almost automatic to look for them though. (You would be unlikely to miss them.)

q. No. Snow, ice, or even heavy rain contamination could render them ineffective.

r. In the pavement would be nice, but weather phenomenon (e.g., snow, ice, sand) would probably make it unrealistic.

s. No. The two lights on the side of the taxiway are certainly sufficient. The in-pavement row of lights would also do the job. Regarding the THL's, once we were used to them, they were also very sufficient.

t. I would like to see all the lights in the pavement.

u. These are the physical characteristics of the lights that need to be resolved. If they are in the pavement, what happens with a little snow? Will pilots in all heights of cockpits be able to see them? How are they kept from shining all over the airport?

11. Position of runway entrance lights on taxiways that intersect runways at acute angles still has to be determined. Where would you suggest they be located at these types of intersections? Closer to the runway or closer to the hold line?

a. Closer to the hold line. Currently pilots look for hold short lines in an effort to determine position relative to runway, this light should probably be close to the lines to stop further incursions toward the runway in an effort to see REL system in low-vis. conditions.

b. Close to the runway but perpendicular to the taxi centerline. See question 4.

c. Close to the hold line. Rationale: this information is most important to you when you are at the hold line and should be most easily interpretable there.

d. Here again, centerline placement solves this problem. Green to red activation of these lights could take place at anytime and at a longer distance.

e. Closer to the hold line. Maybe place two sets of lights: one at the hold line and one at the runway.

f. -----

g. Closer to hold line.

h. Not sure.

i. Closer to the hold line and also in the pavement.

j. Close to the hold line especially on the captain's side (left); closer to the hold line is where you expect to stop so. If the red lights are where you are looking, chances are better that you'll see them.

k. I'm a proponent of having the REL's at the hold line with the REL's at the runway, possibly, as a backup.

l. At intersections, they could be installed flush with the ground. In winter, the heat from the lights would more than likely warm any precipitation falling on them. Closer to the hold line.

m. Closer to the hold short line or in the pavement at the hold short line.

n. The REL's were more conspicuous when both could be seen at the same time. They should probably be on a line perpendicular to the taxiway.

o. Closer to the hold line, which gives the pilot more time to react.

p. Lights beside the taxiway should probably be by the hold line. Lights in the pavement should probably form a "do not cross line" parallel to the runway centerline.

q. Both. Closer to the runway to give pilots a "last chance" to stop and at the hold line for advance warning.

r. Closer to the runway for last-ditch opportunity to prevent an incursion.

s. Closer to the hold line so they can be easily detected and observed in low-vis. situations.

t. The hold line.

u. Intuitively, I'd say closer to the runway. If the aircraft is positioned right at the hold line, the aircraft crew may have difficulty seeing lights at the hold line.

12. Would you prefer to have runway status displayed in the cockpit in an electronic format (e.g., on an electronic taxi-map display)? Would this be useful to you?

a. Yes, it would be useful, but I would be concerned with the possibility of an aircraft system failure so I would probably want this only as a backup to the ground system.

b. Based on today's a/c configuration, outside lights are the way to go.

c. This would be good supplemental information but not a primary source. Because the airplane is taxied by looking outside the cockpit, having the lights outside makes sense. The electronic display might have some utility in depicting the runway status before you could see it from the cockpit.

d. I don't think so. The flight crew could use an airport taxi map in the cockpit incorporated with glass cockpit displays. The flight crew must be "outside" during critical taxi phases of operation. Airport taxi-map displays in the cockpit should be used for situational or positional reference only.

e. Yes. Unfortunately, if this equipment broke, the company would certainly defer repair. I believe fixtures on the airport environment to be our best bet.

f. Yes, would preclude getting "lost", taking wrong route, missing a turn, etc. Electronic taxi map is highly desirable.

g. Yes, as long as it doesn't increase workload in the cockpit.

h. My preference depends on how the equipment is integrated.

i. Absolutely. Any input given to the flight crews to increase situational awareness and increase the level of operating safety would be of great use.

j. I'm not sure if that would be cost-effective because very little time is spent looking inside during taxi out. It might be a good backup under extremely low-vis. ground ops especially if the copilot was instructed to monitor the a/c progress on the map display.

k. This would be great.... but how far down the road this technology would be and how expensive are the main factors to consider. You have to remember, that unless revenue is enhanced, airlines are typically reluctant to buy new gadgets. Quite frankly money is the primary consideration among airline executives today.

Also, if a display were to be put in the cockpit, it needs to be visible by all pilots in the cockpit and not just by the Captain. So, you'd need a screen that all can see or more than one screen.

l. Not really. To keep on schedule, our workload would be increased and cause us possibly to miss other important items. To a pilot, these items (outside of the cockpit) are more useful in their place outside than in our scan inside the cockpit.

m. No. We already have our heads and eyes in the cockpit too much now. We need to be looking outside to use logic and thinking skills.

n. I prefer them to be lights on the airfield; however if a moving map is installed, the RWSL indication should probably be duplicated on the map.

o. No. Taxiing procedures call for good external visual scanning, not focused in one area.

p. No. I think 99 percent of the time this would not be that helpful. During that other fractional percentage, it would probably be very helpful. This question gets me thinking about reliability of the equipment again. With another layer of data link or whatever, what are we setting ourselves up for when it does break down. Also it brings up the vision of taxiing with your "head down" in the cockpit. I was thinking about a ground radar system "broadcasting" to the cockpit. If the system was more of a TCAS-type system, it might take away some of my objections, but I still think I would not like it.

q. I would prefer it in addition to outside lights, as long as only the lights appropriate to my position on the taxi map came on. Otherwise, such lights could sucker me into believing I were somewhere else.

r. I would not prefer this. I believe that the more pilots can be outside the cockpit, the safer the operation will be.

s. Yes. Any additional tool would be helpful, especially while taxiing at busy airports (e.g., O'Hare).

t. Yes. A electronic taxi-map display would be useful.

u. Yes, I believe it would, especially once taxi clearances are given and displayed electronically causing more heads-down time in the cockpit anyway. This would potentially offset the heads-down time. However, a continual outside scan is still going to be of vital importance.

13. Are you aware of any runway incursions that could have been avoided if the Runway Status Light System had been in place?

a. Yes.

b. Personally, no, but obviously DTW and Canary Is.

c. Not personally familiar.

d. Yes.

e. Perhaps the Northwest flights in Detroit, PanAm and KLM in the Canary Islands, Delta and Flying Tigers in Chicago, and Delta and North Central Convair 580 in Chicago. These are the immediate ones that come to mind.

f. Not really.

g. Yes, Detroit and Tenerife.

h. Detroit and Tenerife.

i. Yes. Two incursions come to mind right away. Detroit and the accident several years ago in the Canary Islands (Tenerife). Also I had a situation of my own in LGA a couple of years ago; we were cleared for takeoff when another a/c was cleared for takeoff on an intersecting runway.

j. I'm sure that the Tenerife and Detroit accidents would have been prevented. That would have saved about 500 lives right there. It's definitely worth the cost.

k. Yes! You have to remember that pilots have been known to take off or land on a runway other than the one that they were cleared for. This is another reason why the idea of this system is so great!

l. Possibly the Northwest Orient incursion at DTW. Possibly the KLM-PanAm accident in Tenerife.

m. Detroit. Could the L.A. accident have been avoided? Where an a/c was on the runway and another a/c was cleared to land on the same runway.

n. Detroit 1990 for the aircraft taking off.

o. Yes

p. Yes. Tenerife, Detroit.

q. I am aware of a near-runway incursion which would have been stopped sooner if such a system had been installed.

r. Personally, no.

s. Sure. Detroit accident with Northwest Airlines. Also, Tenerife!

t. ----

u. Yes, if they would have been visible. Detroit accident.

14. (Optional) Have you ever questioned (or doubted) a taxi clearance given to you? If so, would the Runway Status Light System have helped you feel safe?

a. Yes. Yes. It would have validated the controller or caused me to question his instruction.

b. Yes. Yes.

c. Yes; yes, in the short term, but I would clear up any uncertainty by asking the ground controller.

d. Yes. Red "do not continue warning lights" would have been helpful.

e. Yes. Yes.

f. Rarely do controllers make errors, e.g., taxi clearances. When I am in doubt when at a strange airport, I ask for "progressive taxi", which means the controller will call all turns.

g. Yes and yes.

h. Yes and yes.

i. Yes. If the clearance were to cross an intersecting runway, I would feel much more comfortable crossing that runway if this system were in place.

j. I always question myself before crossing an active runway. If I have the slightest doubt, I query the controller. I do the same thing on takeoff clearance versus position and hold. I've caught a couple of errors in my 20 years of flying military and civilian.

k. Yes, I have doubted-questioned a clearance. Safety and legality are two factors. The REL system (also THL) would help me feel safer, but a query to the controller makes me feel legal.

l. Yes, many times. Would an animal trigger these lights? Feel safe? No. Just because the lights are off does not mean there is no danger.

m. Yes. The system would allow me to resolve the disagreement with the controller.

n. Yes. I have been told to hold position after crossing the hold line. The REL's would have helped if the controller didn't catch the mistake.

o. No. The status system would seem to be very useful in those areas of low visibility.

p. I have questioned or doubted a clearance. Whereas the light system would help, I think I would still have to query the controller to "sort it all out."

q. Yes I have. Such a system definitely would have helped me feel safer.

r. Yes for both questions.

s. Yes. If I were truly in doubt, I would stop and talk to ground/tower regarding the clearance-position on the field.

t. Yes. I have questioned many taxi clearances, but the status lights will not replace asking the controller the clearance one more time.

u. Yes I have. Well, I'm not sure they'd make me feel safe, but at least they would make for an easy intro for me to talk with the controller about it.

15. (Optional) Have you ever questioned (or doubted) your location at an airport? If so, would the Runway Status Light System have helped you feel safe?

a. Yes, yes, but only in the sense that I might be safe from taxiing onto the active runway, not necessarily safe on the airport as a whole.

b. Yes. Yes.

c. Yes. The Runway Status Light System would be of some help in preventing runway incursions. But position uncertainty should be cleared up by stopping taxi and determining position before proceeding.

d. Yes. Yes.

e. Yes. No. It was temporary disorientations due to snow and fog. We had missed a taxiway sign obscured by a snow drift.

f. Absolutely. No. RWSL would give me assurance that runway incursions are not going to occur, but RSS will not tell me anything about location.

g. No, but yes.

h. No, but yes.

i. Yes. I feel most, if not all, pilots at some point and time have felt uncomfortable with their position. This system would certainly help remove any doubts as to whether or not you are cleared to cross a runway or cleared onto a runway.

j. Some airports are definitely confusing to taxi around. The RWSL would make anyone feel safer.

k. Yes, absolutely.

l. Yes. The RWSL would not make me feel safe, but maybe feel better. Painted letters on the taxiway would give me a cue as to my location.

m. Feel safe? NO. Feel better? YES. Reliance on lights for safety without using one's brain creates complacency. One could be lulled into not observing the surroundings.

n. Yes. Critical cases are double parallels on the same side of a runway and a parallel sandwiched between runways.

o. Yes. It would help if I have accidentally entered an active runway.

p. ----

q. Yes, I have doubted my position. The runway status system would have helped me feel safe in a last-ditch sense.

r. Yes for both.

s. Yes. Landing at some European fields in Category-III conditions (fortunately, a "follow me" van provides some help).

t. Yes. I have questioned my location at an airport, but I do not think the runway status lights would help me feel safe. I would stop the aircraft and ask the controller.

u. Yes. Again, I'm not sure about making me feel safe, but they might keep me from making a bigger mistake! Best help for location on the airport might be a Differential Global Positioning System (DGPS) with a moving map.

16. Any other general comments, criticisms, or support for the Runway Status Light System?

a. Good system, provided human factors (pilots) can be integrated successfully into this system and training is adequate.

b. I think it is a worthwhile program.

c. The light intensity for the RWSL components is good as it is. Too bright a light can cause too much glare, decreasing visibility at night through a scratched window; also, an annoyingly bright light can cause a pilot to "tune it out" to pursue other cockpit tasks. For the present size and brightness, it is important for the pilot to know just where to look to find the lights

d. A good idea. I would suggest that this system be used in conjunction with the already established centerline lighting system (even added to or additional centerline lighting would be good.)

e. I feel that it is a great system that is long overdue. The pilots must be made aware that the extinguishing of the light does not provide clearance for crossing or for takeoff unless the controller states so (i.e., "after landing Northwest DC-9 and the extinguishing of the status light, you are cleared to cross RWY 26L," which is similar terminology to European clearances).

f. Would like to see it in real life to check brightness, ease of seeing, etc.

g. ----

h. ----

i. None other than those listed previously and the fact that we as pilots all would have this type of system

installed yesterday to increase the safety factor of our operating environment!

j. I think it's a great idea-system if it proves reliable. At first, pilots will not trust the RWSL system, but if it is consistently correct, pilots will quickly learn to believe and trust the lights. I would make the THL flashing and elevate all of the light boxes above the taxiway-runway light level. Make sure it stays passive (not tied to controller input).

k. This system, along with the new taxiway-marking system, should eliminate 90 percent or more of the current runway incursion problems.

l. The concept is good and useful. I would support this system with pilot input and reforms.

m. I like the concept. I don't believe we have the final product. We need (1) light improvements and (2) light position improvement.

n. ----

o. See question 17 also. Based on recent requirements-improvements to airports such as signs, markings, lighting, SMGCS procedures, etc., this system may be too expensive if goals-tasks are too complicated to achieve.

p. I think it is an excellent idea. I like the fact that it requires no input from the controller and therefore acts as a backup system to him-her. I also like its very simplicity from a user standpoint.

q. I believe it is worth pursuing at airports with ground radar.

r. ----

s. Great idea! Let's install them to make the airports safer!

t. A good system and would be a great asset.

u. Installation costs will be high. In the actual implementation, you might want to talk with controllers before the final steps are taken. Also, given the timing that the controllers may want for lights to come on, does this leave enough time for reaction in a highly dynamic situation?

17. Finally, do you feel the TSRV simulator facility provides adequate realism to evaluate the Runway Status Light System concept?

a. Yes.

b. Yes.

c. Yes, with the exception that the "frame" separating the front windshield panel and the side panel can, in the real airplane, easily be looked around by small

pilot head position changes; these position changes do not work as well in the simulator.

d. Yes, I do.

e. Yes. This is the best simulator visual that I have experienced including:

- USAir MD-80 in Pittsburgh

- Piedmont Boeing 737-300/200 in Winston-Salem and Charlotte, NC

- Boeing 767-300 in Seattle

- Republic DC-9 in Minneapolis

- Federal Falcon 10, DC-10 in Memphis.

f. Yes, it's a good evaluation of procedure, probably as close to the real thing as can get.

g. Yes.

h. Yes.

i. Yes.

j. Yes, except in the 26L hold line, the captain's RWSL was not visible because of a break in the screen.

k. Yes, actually, overall, I like the sim. It's a nice sim.!!!

l. Yes!!

m. Yes, very much so.

n. For the most part. Backs of signs should be black. Backs of RWSL's should be yellow. Location signs were missing. Poor resolution made reading signs from a distance difficult.

o. Yes. It could use more external clutter to the test program. Ex. communication from other aircraft, aircraft taxiing on the airport surface, etc. The test is spring-loaded for the evaluator to "look for" the lights. Normally, a pilot may be busy elsewhere on the cockpit. Need to interface with normal traffic flow using departures/arrivals from ATC.

p. ----

q. Yes. Actually, I was pleased with the fidelity of the simulator visuals. Of course, evaluation of real hardware with real aircraft needs to be done.

r. Yes.

s. Yes, very adequate. Excellent visual by the way!

t. Yes.

u. Concept, yes. Actual lights, no.

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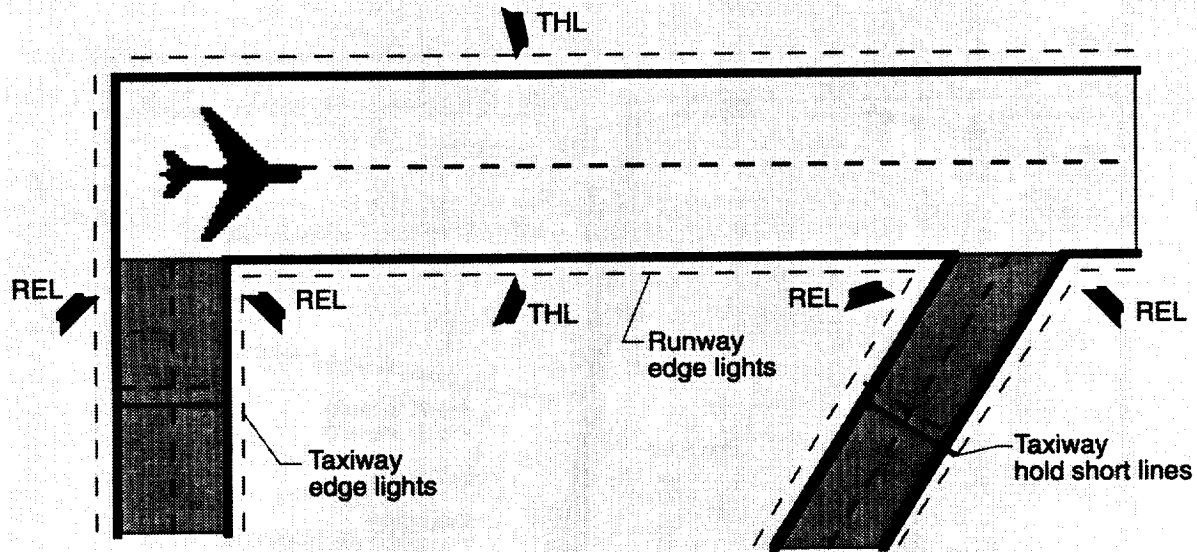


Figure 1. Runway Status Light System (RWSL).

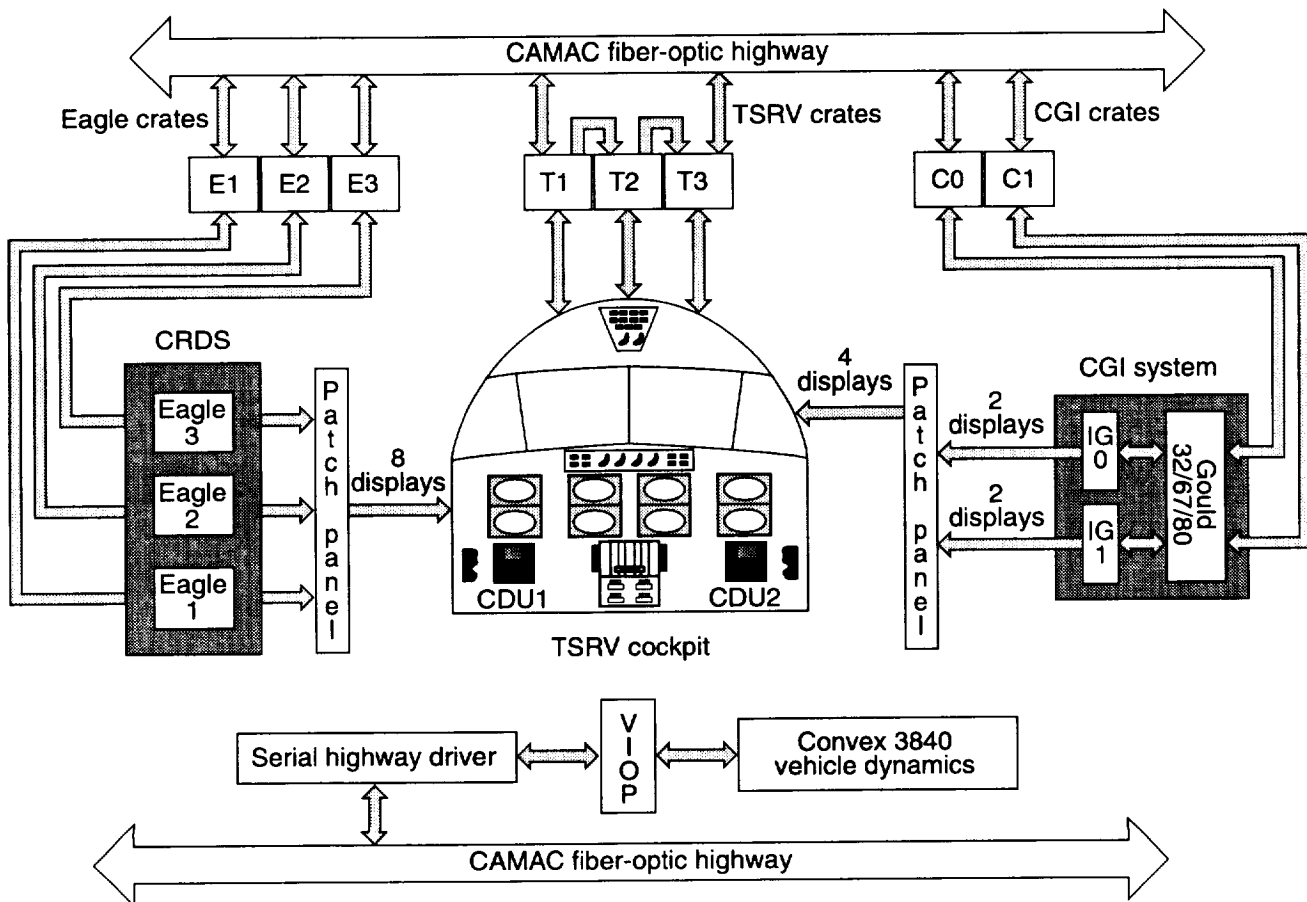
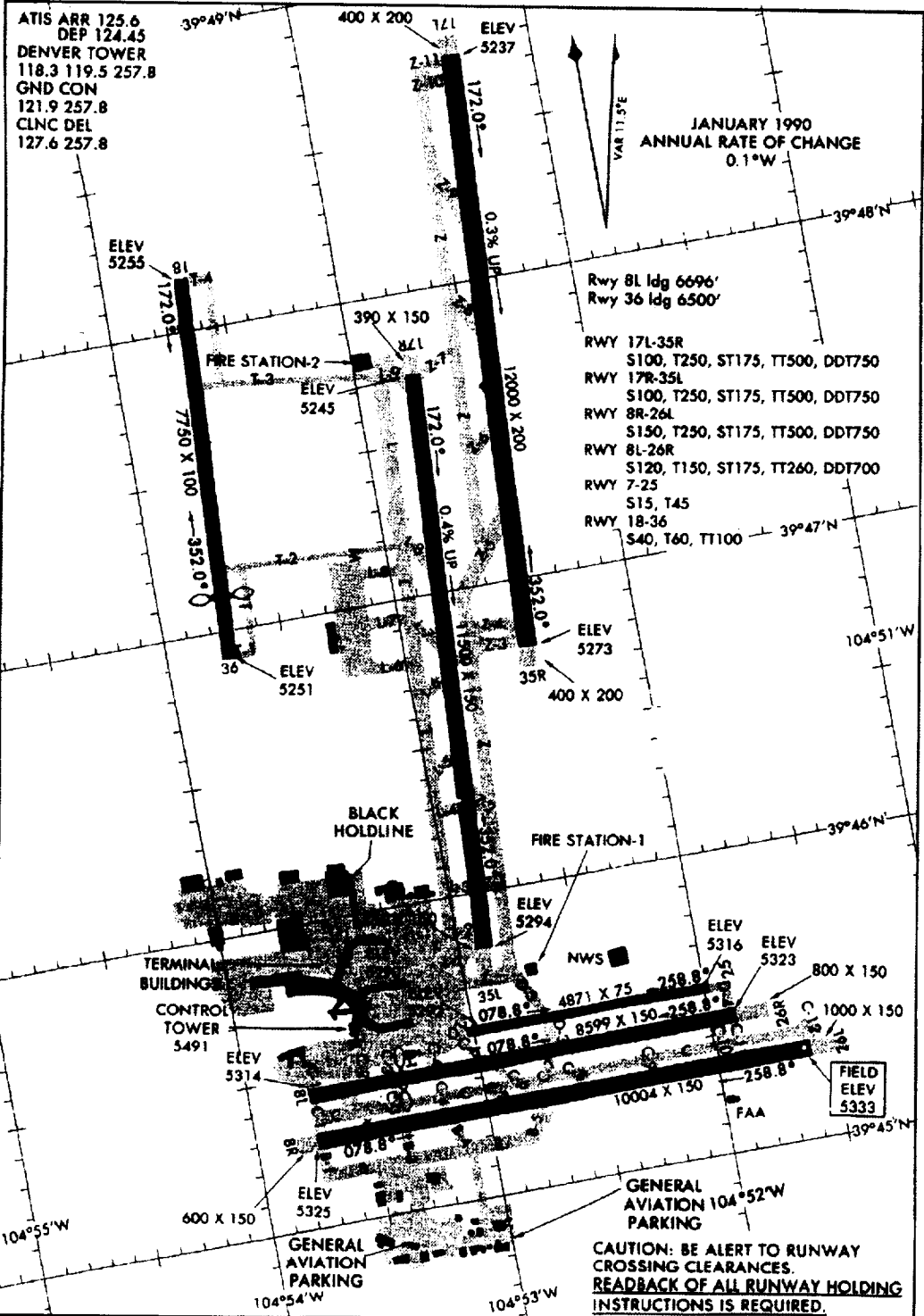


Figure 2. Transport Systems Research Vehicle (TSRV) Simulator at Langley Research Center.

92177
AIRPORT DIAGRAM

78
 AL-114 (FAA)

DENVER/STAPLETON INTL (DEN)
 DENVER, COLORADO



AIRPORT DIAGRAM

DENVER, COLORADO
 DENVER/STAPLETON INTL (DEN)

Figure 3. Denver Stapleton International Airport.

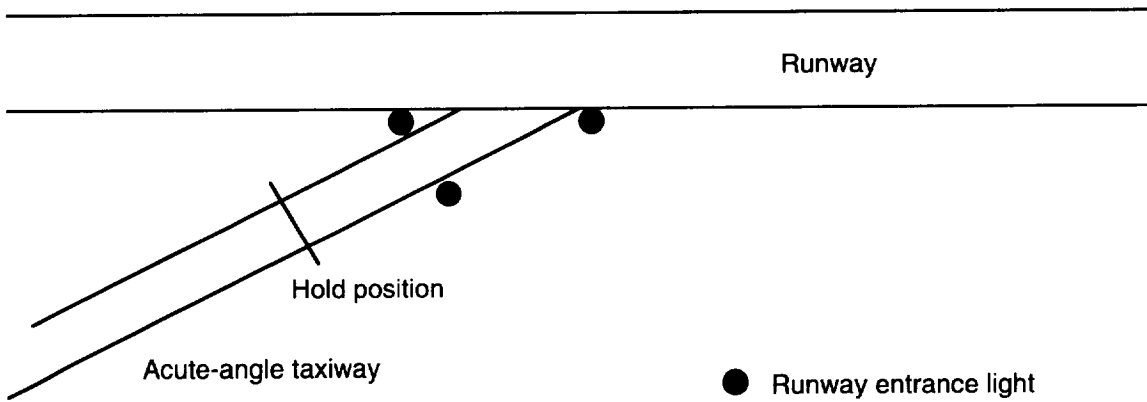


Figure 4. Suggested acute-angle runway entrance light configuration.

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