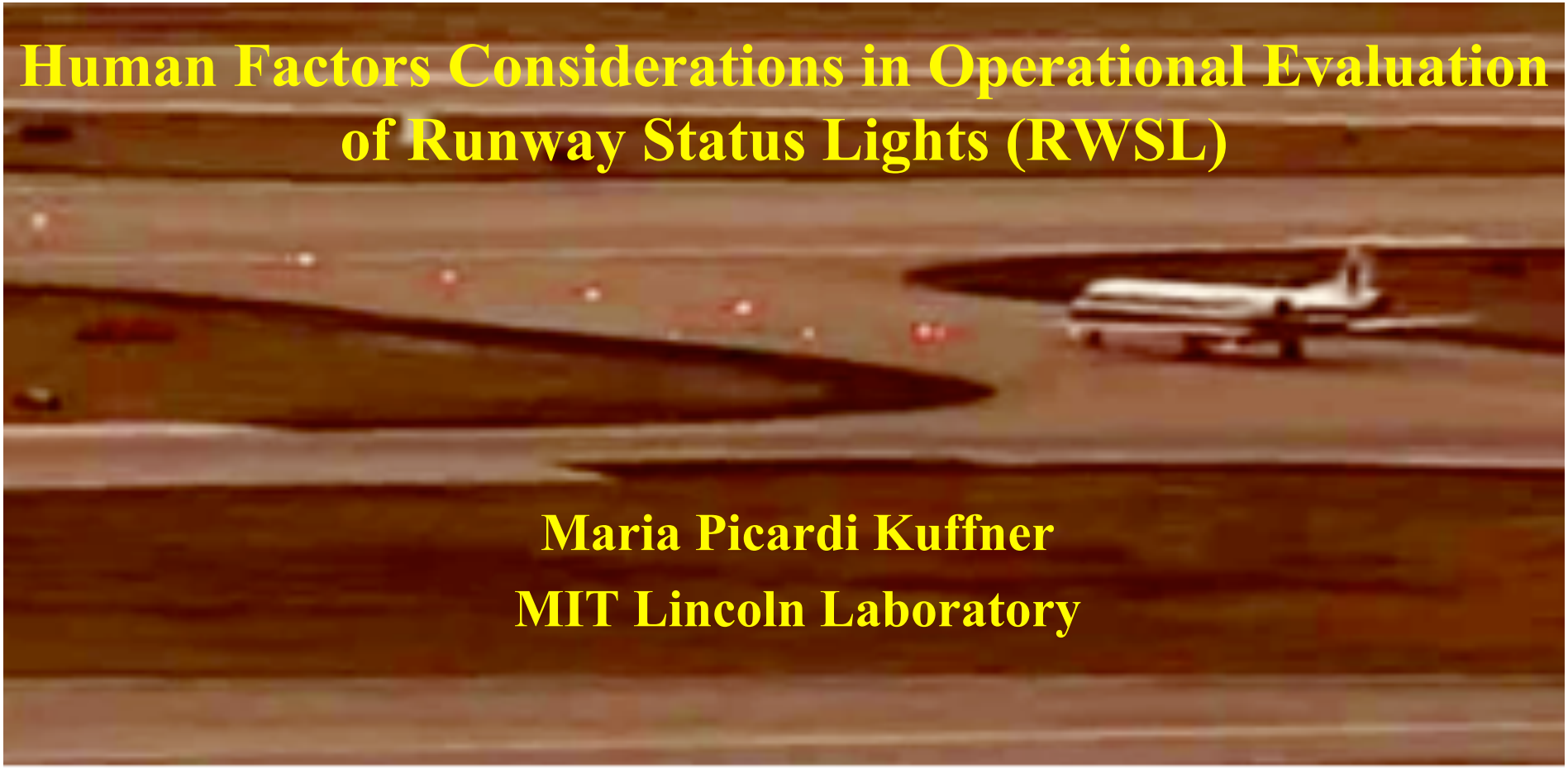
* This work is sponsored by the Federal Aviation Administration under Air Force Contract #FA8721-05-C-0002. Opinions, interpretations, recommendations and conclusions are those of the author and are not necessarily endorsed by the United States Government.

Human Factors Considerations in Operational Evaluation of Runway Status Lights (RWSL)



Maria Picardi Kuffner

MIT Lincoln Laboratory

Outline

Milestone achieved May 31, 2005: RWSL Operational Evaluation completed at DFW,* now *24/7 until December 2005

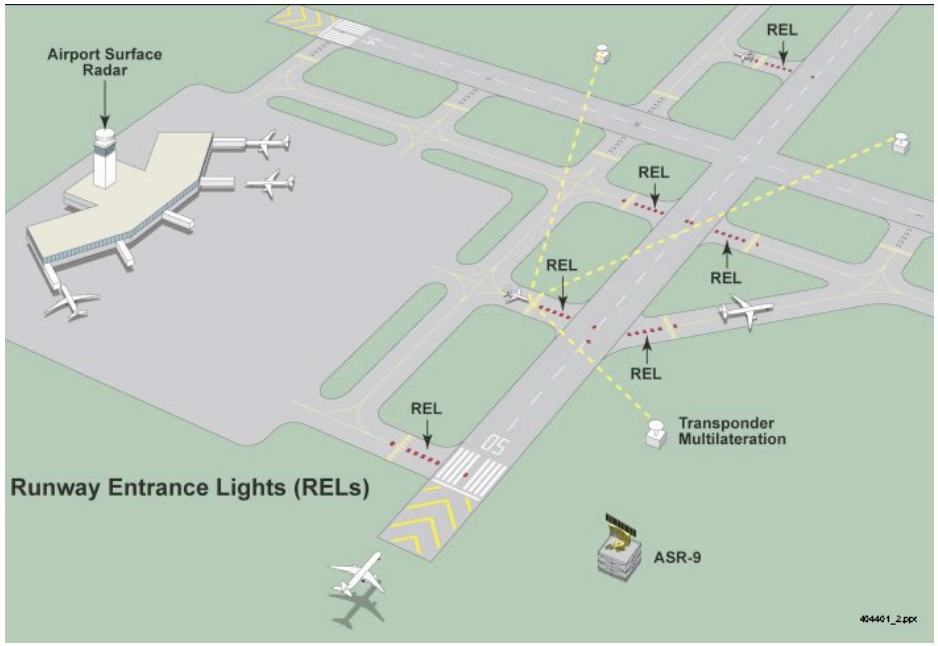
- MIT/LL Human Factors
  - Study of runway incursion problem and RWSL solution
  - Scope of Effort: Trained and Surveyed Users on Runway Entrance Lights (RELs)
  - Directed Test From DFW West Tower and Reported Results
- Training Method and Materials
- Human Factors Survey
  - Method, Data Collection and Analysis
  - Summary of Survey Findings
  - Lessons Learned and Next Steps
- Summary of Human Factors Contributions

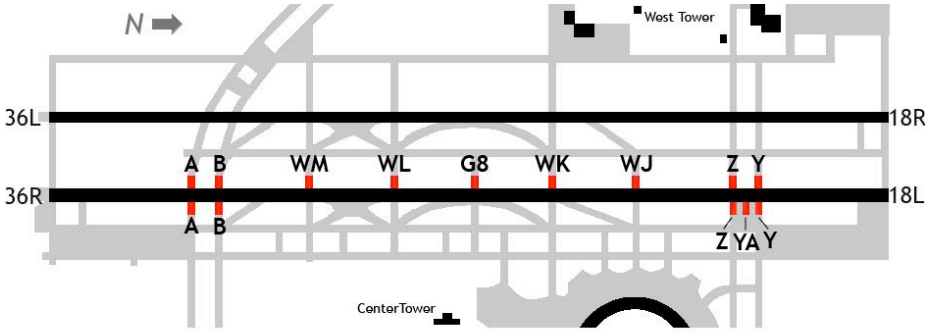
Runway Incursion Problem

- FAA Administrator recently expressed concern:
  - "I have worried all along that the next major collision will be on the ground."*
- Future close calls may be prevented by RELs
- Example: Kennedy Airport runway incursion last month (July, 2005)**
- Preliminary data reported by several news sources
  - About 2 a.m. DC-8 was cleared for takeoff on Runway 22R and began to roll
  - Israir Boeing 767 taxied across same runway, failing to turn left as instructed
  - Pilot in the DC-8 said, **"Somebody's crossing the runway"**
  - Israir pilot yelled, **"Somebody's taking off!"**
  - Airborne Express pilot rotated steeply to fly over the 767
  - FAA reported the DC-8 cleared the 767 by 75 feet.
- Reason RELs could help
  - RWSL uses fused data from different surveillance sources to turn RELs red and warn pilots not to cross runway in use

* Reference: The Monitor Breakfast, July 27, 2005. ** Newsday, Inc. 2005.

DFW Runway Entrance Lights Evaluation

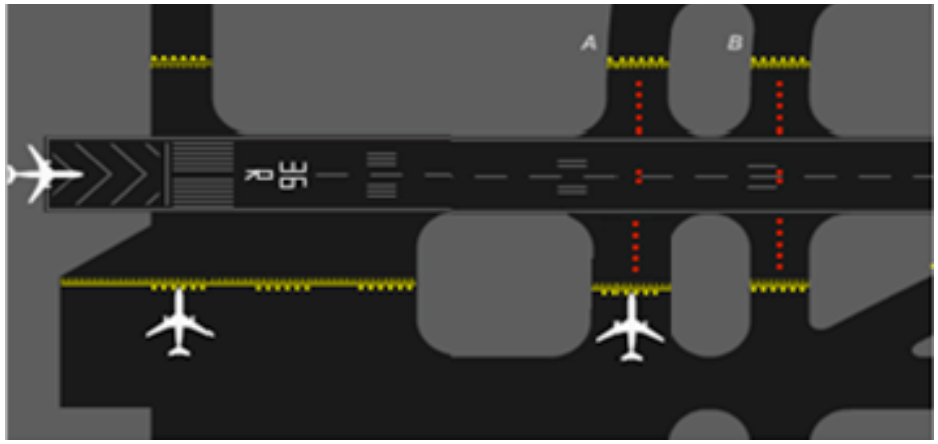


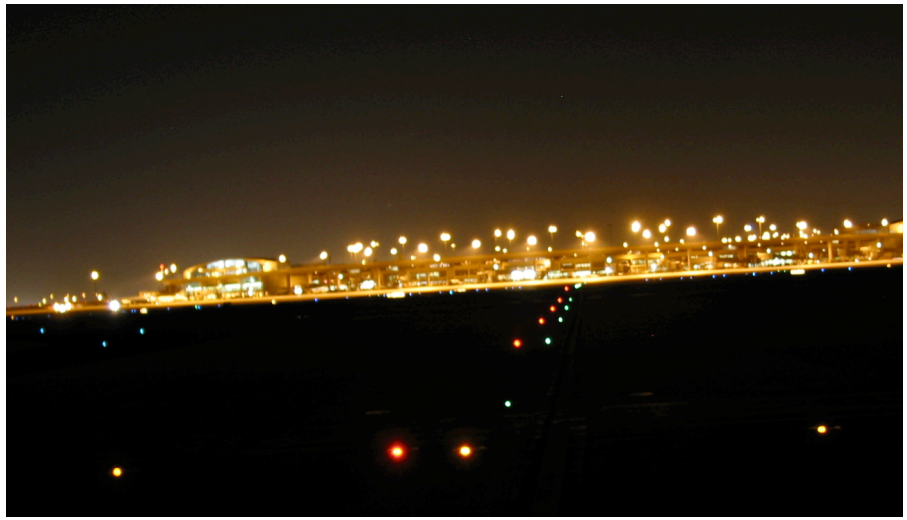


RELs have been installed and tested on RWY 18L/36R
- East side: TWYs A, B, Z, YA, and Y
- West side: TWYs A, B, WM, WL, G8, WK, WJ, Z, and Y

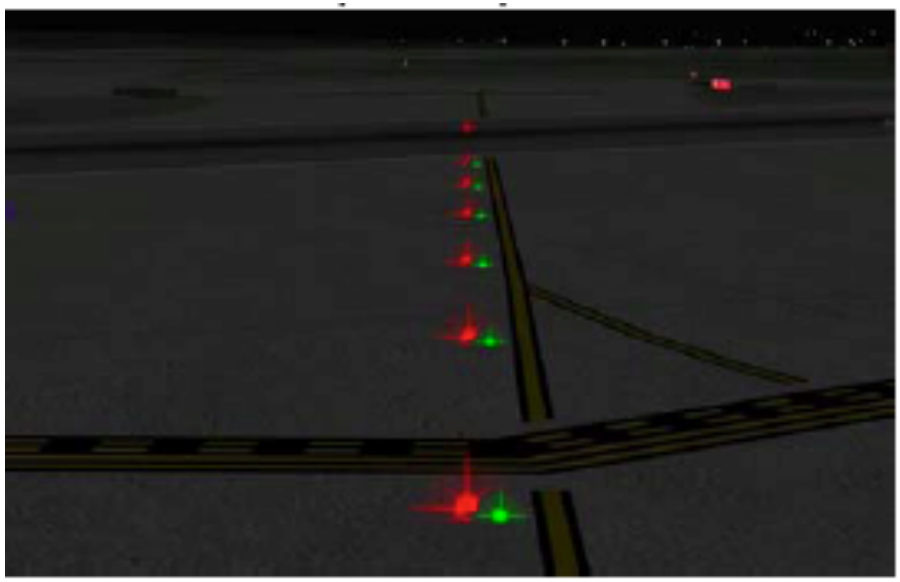
RELs red if unsafe, otherwise off.

Lights are dynamically driven by surveillance





Scope of Effort:
RWSL comprises two types of lights, RELs evaluated first



Runway Entrance Lights (RELs)

Takeoff Hold Lights (THLs)

- Both RELs and THLs configured longitudinally for unique and consistent appearance to pilots, intensity varied for day and night
  - Human factors studied by FAA and MIT/LL with pilots at Atlantic City airport and during two flights tests at DFW and in simulations at MITRE
- Both RELs and THLs aim to reduce runway incursions
  - THLs to be installed for both intersection and full-length departures

MIT/LL's Human Factors Role: Training Method and Materials

- Massive outreach effort to introduce new concept and technology before RELs exposed to flying public
  - Developed briefings, scripted animations and recorded data movies
    - Coordinated with FAA Academy and SAN program
  - Trained 50 air traffic controllers and 7 tower supervisors
  - Materials sent to numerous airlines for pilots and DFW airport
  - Briefing to DFW airlines managers (American and Eagle)
    - Briefing to FAA pilots safety meeting
  - Coordinated with airline pilots unions throughout
  - Participated in two pre-OpEval Flight tests at DFW
  - Developed website: RWSL.net
    - Links from APA and ALPA pilots unions websites
  - Directed test from West tower
    - Used new display with identified targets and red RELs
    - Viewed live traffic out the window and listened to clearances

Training materials developed with pilots

Milestone achieved: American Airlines has added RWSL information to their recurrent training for DFW pilots

- MIT/LL Human Factors led development of training material with pilots and FAA HF and flight standards
  - Jeppesen 60-8 and 60-8a pages inserts
  - Notices to Airmen (NOTAMs) on FAA.gov
  - RWSL website, including survey access
  - CDs of briefings and DFW recorded data movies delivered to over 70 contacts at DFW and SAN
  - Posters and laminated cards delivered to Airlines Operations Centers at DFW

Jeppesen Pages: color and glossy paper

JEPPESEN 28 JAN 05 (60-8) DALLAS-FT WORTH, TEXAS
DALLAS-FT WORTH INTL

PILOT GUIDE TO RUNWAY STATUS LIGHT SYSTEM (RWSL)
DALLAS/FORT WORTH INTERNATIONAL AIRPORT (DFW)

The FAA has initiated a project to reduce the frequency and severity of runway incursions through the use of a new automatic, surveillance-driven lighting system at DFW. DFW was chosen because of its early implementation of ASDE-X radar surveillance. The Runway Status Light System (RWSL) uses surveillance to monitor runway usage and automatically illuminates the appropriate red Runway Entrance Lights (RELs) to indicate to pilots when the runway is unsafe for entry or crossing at that location. RELs turn on and off with every landing and departure on Runway 18L/36R (see Figure 1).

Red RELs are illuminated when it is unsafe to enter or cross the runway on which an aircraft is about to land or take off. RELs are turned off 1) when a landing aircraft has slowed, 2) when a departing aircraft is airborne, and 3) just prior to when an aircraft on the runway will enter the intersection. RELs are not controlled by ATC. To preclude confusion with red stop bar lights, RELs are placed longitudinally along the taxiway centerline instead of in a "stop bar" configuration. An ATIS message will indicate to pilots when the RELs are operational.

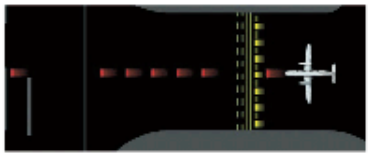


Figure 1 Runway Entrance Lights (RELs).

RELs are a series of five red, in-pavement lights spaced evenly along the taxiway centerline from the taxiway hold line to the runway edge. One REL is just before the hold line and one REL is near the runway centerline. RELs 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.

Project Overview

In-pavement RELs have been installed on Runway 18L/36R only, and only at high traffic intersections (see red bars representing RELs in Figure 2.) Please provide feedback online at www.RWSL.net or by calling toll free 1-877-339-7975 (DFW-RWSL).

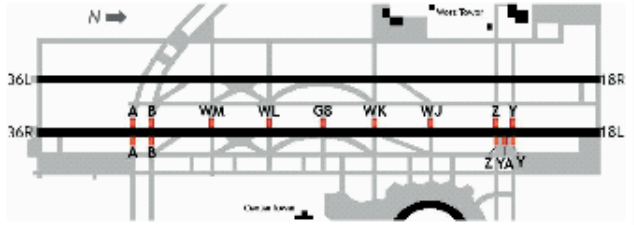


Figure 2 DFW west side with REL alignment and locations on 18L/36R taxiway intersections.

(CONTINUED ON REVERSE SIDE)

Supplied by Jeppesen Sanderson

JEPPESEN 28 JAN 05 (60-8A) DALLAS-FT WORTH, TEXAS
DALLAS-FT WORTH INTL

Operational Evaluation of Runway Status Lights

RED MEANS STOP!

Figure 3 RWSL Operational Concept.

As shown in Figure 3, the RWSL system is designed to provide a direct status indication to pilots that a runway is unsafe to enter or cross. Note: **RELs TURNING OFF DOES NOT CONSTITUTE A CLEARANCE TO CROSS OR ENTER A RUNWAY!** Pilots should be familiar with the RWSL operational concept and REL phraseology before the DFW RWSL operational evaluation commences.

Remember:

- **When the RELs illuminate, the flight crew should remain clear of the runway.**
- **If cleared onto or across the runway, and RELs are illuminated, STOP the aircraft and communicate to ATC that you are holding with red lights and then wait for further clearance.**
- **If the aircraft crosses the hold line and the flight crew subsequently observes illuminated lights, then if practical the flight crew 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 RELs indicate the runway is unsafe to cross or enter) and contact ATC at the earliest opportunity.**

www.RWSL.net

MIT Lincoln Laboratory DFW RWSL

Supplied by Jeppesen Sanderson

RWSL Website: Successful HF Initiative

- MIT/LL Human Factors developed website per FAA request
  - Coordinated with FAA to standardize format
    - MIT/LL provided RWSL Backgrounder document
  - Training materials and surveys operational
    - Easy access to surveys for user feedback
    - Briefings and poster artwork files
    - Graphics and animations of operational concept
    - DFW and SAN Runway diagrams with REL locations
    - Recorded data movies with scripted audio of REL operations
    - Airport Traffic Information Service (ATIS) text
    - Contact information and relevant links provided

RWSL website: RWSL.net

Runway Status Light System

Runway Status Lights

Home
Pilot/Vehicle Operator Survey
ATC Survey
Training Briefing
How It Works ››
Notice to Airmen
Airport Traffic Information Service
About Us
Contact

This site is hosted by MIT Lincoln Laboratory in support of the FAA/ATO-P RWSL DFW Operational Evaluation. MIT Lincoln Laboratory has been tasked by FAA/ATO-P, to implement the evaluation system at DFW, design and execute the Operational Evaluation, and develop an assessment of the operational suitability of Runway Status Lights (RWSL).

Runway Status Light System

Created on November 29, 2004

RWSL is a fully automatic, advisory safety system designed to reduce the number and severity of runway incursions and thus prevent runway accidents while not interfering with airport operations. RWSL is compatible with existing procedures.

The Problem

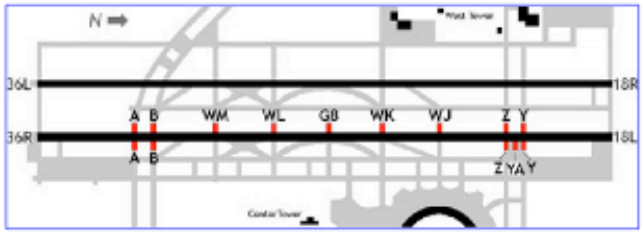
Most runway incursions are caused by a lack of situational awareness.

The Solution

Runway Entrance Lights (RELs) illuminate red when a runway is unsafe to enter or cross due to a high-speed operation on the runway. [More...]

As part of an ongoing effort to explore new technologies, the FAA's Runway Incursion Reduction Program (RIRP) has developed the Runway Status Light System (RWSL). RWSL aims to improve crew and vehicle operator situational awareness through accurate and timely indication of runway usage.

RELs have been installed at two test sites, Dallas/Fort Worth International Airport (DFW) and San Diego International Airport (SAN), and will undergo operational evaluations in 2005.



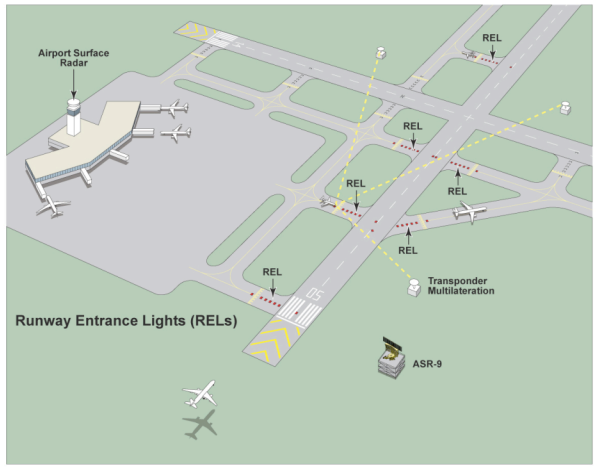
MIT/LL Human Factors Liaison with Users

- Airline pilots unions
  - Allied Pilots Association (APA)
  - Airline Pilots Association (ALPA)
- Demonstrations of RWSL Operational Concept and recorded data from DFW Shadow Operations with RELs on screen
  - ALPA Annual Safety Forum, 2004 and tbd 2005
  - National Business Aviation Association, 2004
  - FAA Airventure at Oshkosh, 2004
  - Air Traffic Controllers Association, tbd 2005
- RWSL articles published
  - Airline Pilot (ALPA magazine), March 2005, cover story coming soon
  - ATCA Bulletin, January 2005
  - American Airlines Flight Bulletin
- APA and ALPA email reminders to pilots
  - Effective at increasing survey response rate

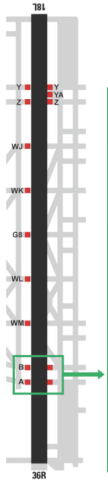
Posters used to communicate and motivate

Runway Status Lights

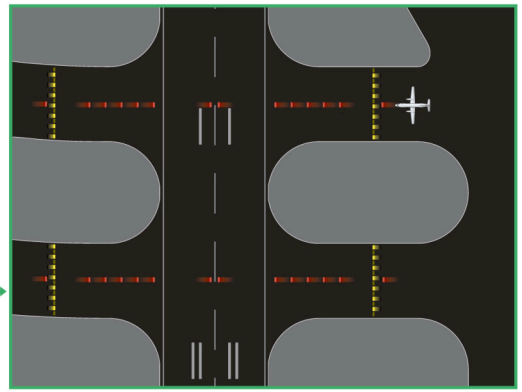
Purpose: Reduce Runway Incursions and Airport Surface Collisions



Surveillance-Driven RELs Provide Direct Indication That Runway is Unsafe



If RELs are RED, stop. RELs are RED if runway is not safe to enter.
Remember: Lights indicate *status only*, never clearance!
Surveillance-driven lights turn on/off to increase situational awareness.
RELs at selected intersections as shown.

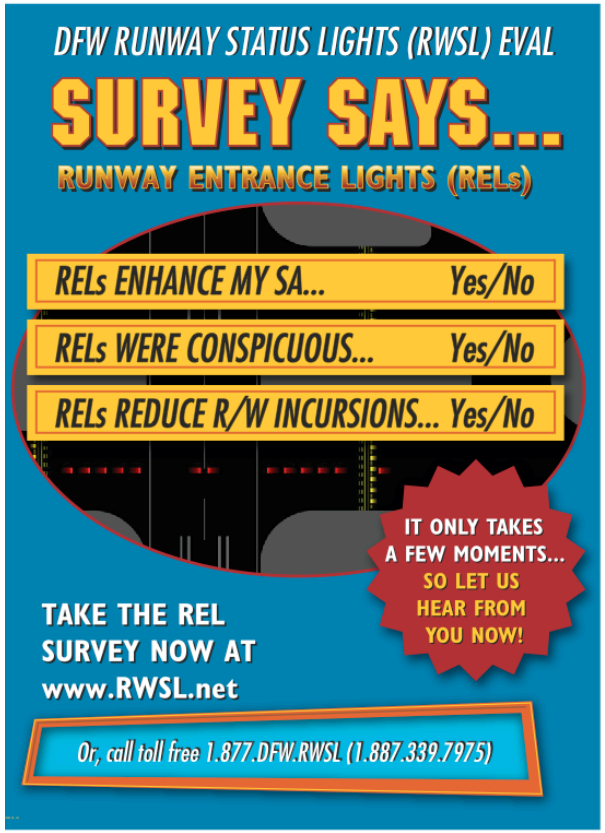


DFW Operational Evaluation on Runway 18L/36R
February – May 2005

MIT Lincoln Laboratory

www.RWSL.net

414401_1.ai



Placed in Airlines Operations Centers and GA Lounge at DFW and FBOs in coordination with FAA, Airlines and DFW Airport

American Airlines Flight Bulletin, Jan. 2005

Flight Operations Informational Bulletin

January 2005 — Number 2005-02

DFW RUNWAY STATUS LIGHT SYSTEM (RWSL) TEST

Project Overview

Beginning February 14, 2005 the FAA will conduct an operational evaluation of a new, fully automatic, surveillance-driven lighting system installed on taxiways intersecting Runway 18L/36R at DFW. The Runway Status Light System (RWSL) uses Airport Surveillance Detection Equipment (ASDE-X) radar to monitor runway usage. When the system determines the runway is unsafe to cross / enter, appropriate red Runway Entrance Lights (RELs) are illuminated. The RWSL was designed to reduce the frequency and severity of runway incursions. DFW was chosen for the test because of its early implementation of ASDE-X.

Runway Entrance Lights (RELs)

RELs are a series of five, in-pavement red lights spaced evenly along the taxiway centerline from the taxiway hold line to the runway edge. Additionally, one REL is located just before the hold line and one REL is near the runway centerline (see Figure 1). RELs 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.

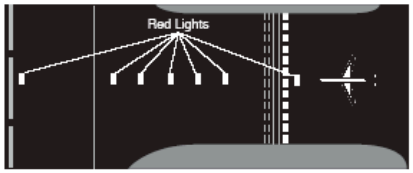


Figure 1
Runway Entrance Lights (RELs)

RELs have been installed only at high traffic taxiways intersecting Runway 18L/36R (see Figure 2).

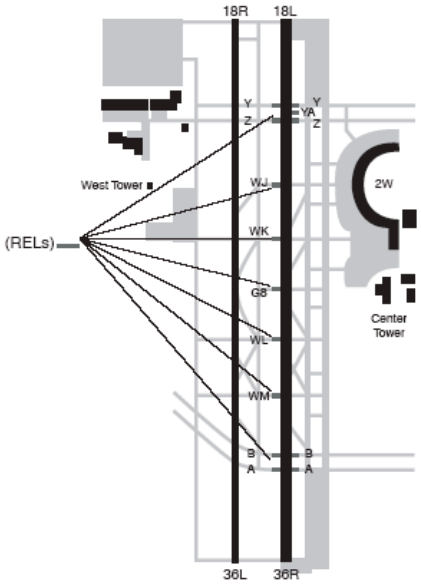


Figure 2
DFW west side with REL alignment and locations on Runway 18L/36R taxiway intersections.

RWSL Funtionality

The RWSL system is designed to provide a direct status indication to pilots that a runway is unsafe to cross / enter (see Figure 3).

Arrivals

- All RELs are simultaneously illuminated when an aircraft on final approach is within 3/4 NM of the runway. RELs progressively turn off at lighted taxiways approximately 3 seconds prior to the landing aircraft passing the taxiway. All RELs turn off as the landing aircraft reaches taxi speed (34 kts).

Departures

- All RELs illuminate when a departing aircraft accelerates beyond 20 kts. All RELs are turned off when the departing aircraft transitions to airborne status (wheels off ground and positive rate of climb).

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

RED MEANS STOP!

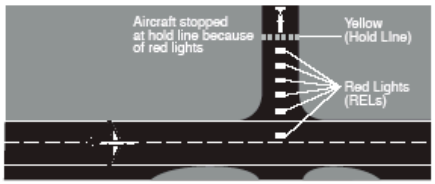


Figure 3
RWSL Operational Concept

Pilot Procedures for Operational Evaluation of Runway Status Lights

- When the RELs illuminate remain clear of the runway.
- Whenever cleared on to the runway (i.e. cleared for takeoff, position and hold, cleared to cross etc.), and RELs are illuminated; stop the aircraft and notify ATC that you are stopped with red lights. Wait for further clearance.
- If the aircraft crosses the hold line and the flight crew subsequently observes illuminated lights, then if practical, the flight crew should stop the aircraft and notify ATC that they are stopped across the hold line because of red lights.
- If remaining clear of the runway is impractical for safety reasons, the flight crew should proceed according to their best judgment (understanding that the illuminated REL indicates the runway is unsafe to cross / enter) and contact ATC at the earliest opportunity.

Summary

The RWSL system is a good tool for providing pilots an indication that the runway is unsafe to cross / enter. **It is not a clearance to cross / enter a runway.**

The operational evaluation of the Runway Status Light System is scheduled to commence on February 14 and will last through May 13, 2005. An ATIS message will indicate to pilots when the RELs are operational. Pilots must maintain a high state of positional and traffic awareness and comply with ATC clearances, whether the system is operating or not.

For this program to be successful, pilot feedback is necessary. Pilots can provide feedback via the website www.RWSL.net. A link to this site will also be available on www.aapilots.com under the links section.

ATCA Bulletin, March 2004

FAA Tests Runway Status Lights System at Dallas-Fort Worth

FAA has begun a three-month operational evaluation of the Runway Status Lights (RWSL) at DFW. The DFW RWSL system is fully automated and intended to provide direct warning to aircrews and vehicle operators on the airport movement area when it is unsafe to enter a runway. The system combines inputs from Airport Surface Detection Equipment Model 3 (ASDE-3) surface radar, Airport Surveillance Radar Model 9 (ASR-9) terminal radars and ASDE-X multilateration technology through safety logic that commands runway entrance lights (RELs) deployed along DFW runway 18L/36R to illuminate red when there is high speed traffic on or approaching the runway. The RELs consist of in-pavement incandescent red lights deployed at taxiway/runway intersections between the hold short position and the runway edge.

The development of RWSL addresses the National Transportation Safety Board (NTSB) recommendation A-00-66, calling for a ground movement safety system that provides direct pilot warning capability. The FAA has specified RWSL development as a strategic initiative to support the runway incursion safety objectives in the agency's Flight Plan 2005-2009. A recent study of runway conflicts in the United States concluded that a RWSL system would be the best defense for more than 60% of high hazard runway incidents.

The development of RWSL is funded through the FAA's Runway Incursion Reduction Program (RIRP). Non-operational tests using live surveillance data at DFW were conducted during 2003-2004 to obtain operational feedback from DFW air traffic personnel. During January 2005, the FAA conducted flight tests at DFW to demonstrate end to end performance of the system in preparation for the formal operational evaluation tests. Limited operational testing of the system was initiated February 14, 2005 and is ongoing.

The FAA will collect RWSL data during formal operational evaluation from March 1 - May 31, 2005.

Human Factors Data Analysis

- Survey data collected from pilots and vehicle operators
- Verbal testimonials from controllers and supervisors in West tower
- Review of recorded surveillance and audio replays, especially of anomalies
  - Pilots crossing over red RELs
- Review of REL intensity levels used during both day and night
  - Balance conspicuity for pilots and vehicle operators with acceptance by tower ATC

Human Factors Surveys

- Survey composition for pilots
  - 18 yes/no response statements, counterbalanced
  - Additional comments encouraged
- Survey methods supplied
  - Web site (pilots survey and password protected ATC survey)
  - Telephone (toll free number)
  - Paper (placed near posters in Operations Centers)
- Survey methods used
  - **Most pilots used website**
  - Most vehicle operators used paper
  - Phone rarely used

Pilots Survey Statements

#	Statement	Yes	No
1.	If cleared to cross the runway, I will proceed through illuminated red Runway Entrance Lights.		
2.	I interpret Runway Entrance Lights turning off as clearance to proceed.		
3.	I have observed Runway Entrance Lights activate in response to traffic at least once.		
If response to #3 = Yes go to #4; Otherwise go to #14.			
4.	I have seen Runway Entrance Lights activate on more than five occasions.		
5.	I found the Runway Entrance Lights were conspicuous.		
6.	Runway Entrance Lights operation was consistent with my clearance.		
7.	My verbal response time to clearances increased due to Runway Entrance Lights.		
8.	My ability to complete normal cockpit duties was impeded by Runway Entrance Lights.		
9.	Runway Entrance Lights enhanced my situational awareness.		
10.	I thought that the Runway Entrance Lights were not functioning.		
11.	The Runway Entrance Lights were *on* when they should have been off.		
12.	The Runway Entrance Lights were *off* when they should have been on.		
13.	The Runway Entrance Lights were conspicuous even in low visibility.		
14.	I know of runway conflicts that Runway Entrance Lights would have helped.		
15.	I have at times been uncertain of my location on the movement area of an airport.		
16.	Runway Entrance Lights can be confused with Runway Guard Lights.		
17.	Runway Entrance Lights will help to reduce the number of runway incursions.		
18.	I would recommend additional implementations of Runway Entrance Lights.		

Second Page of Pilot Survey

Any additional comments you have will be very helpful and much appreciated.

_____

_____

_____

_____

_____

_____

_____

_____

Providing the following information for each flight or ground operation will help us make better use of your feedback, but is optional. If you are willing to leave this information, please fill in the spaces below.

Employer (please specify): _____

Total number of hours logged: _____

Date: _____

Time: _____

Flight ID: _____

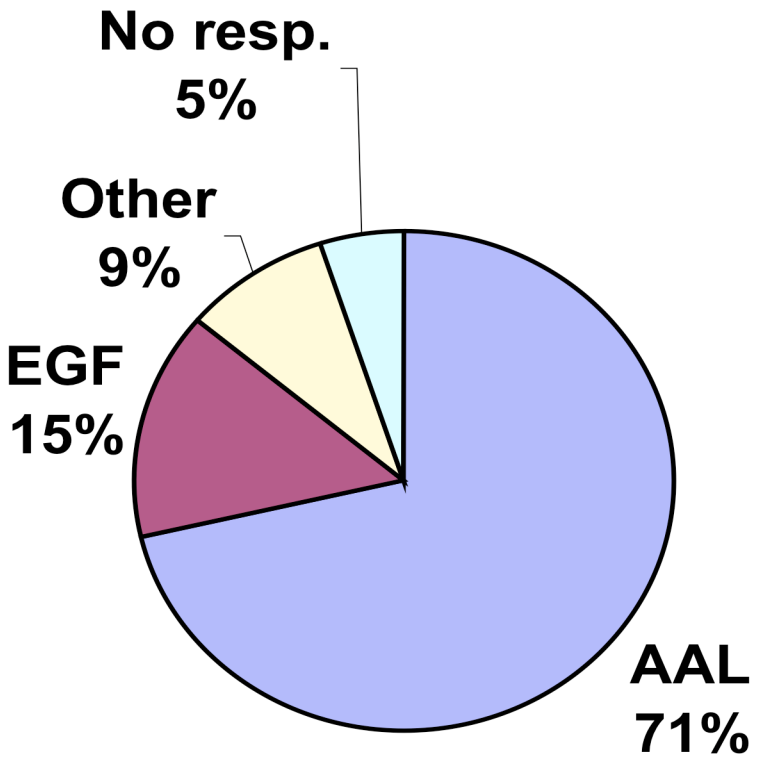
Role (please circle one): Pilot Co-pilot Vehicle operator

Thank you for responding. **Your feedback is important to us!** For further information or to provide additional feedback, please visit www.RWSL.net. You are welcome to respond again after each experience with Runway Entrance Lights.

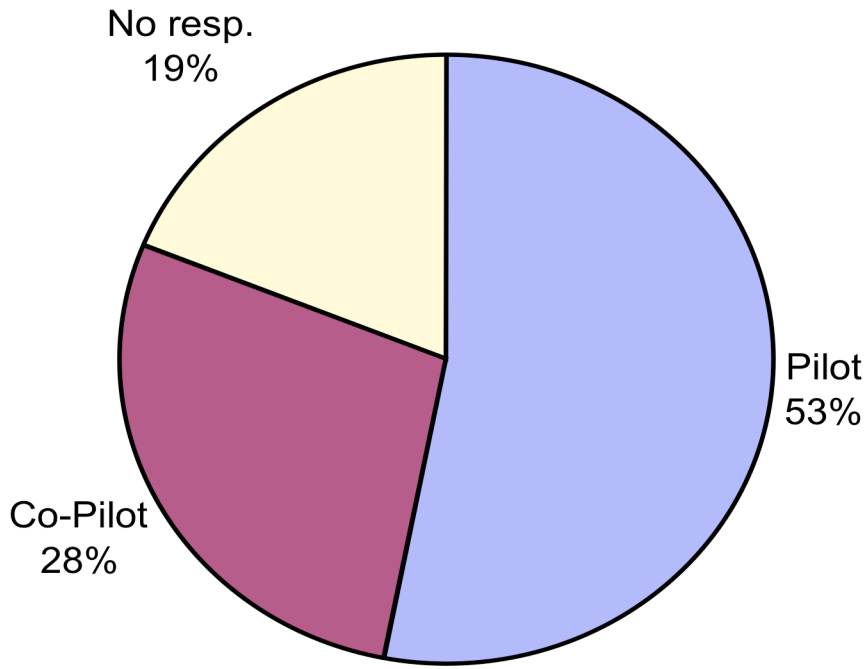
Pilots Results: employer and role

Total of 181 pilots responses

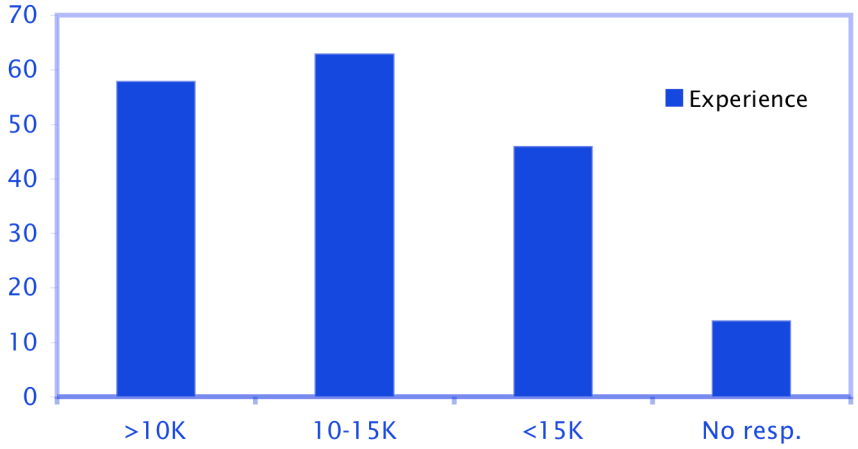
Employer

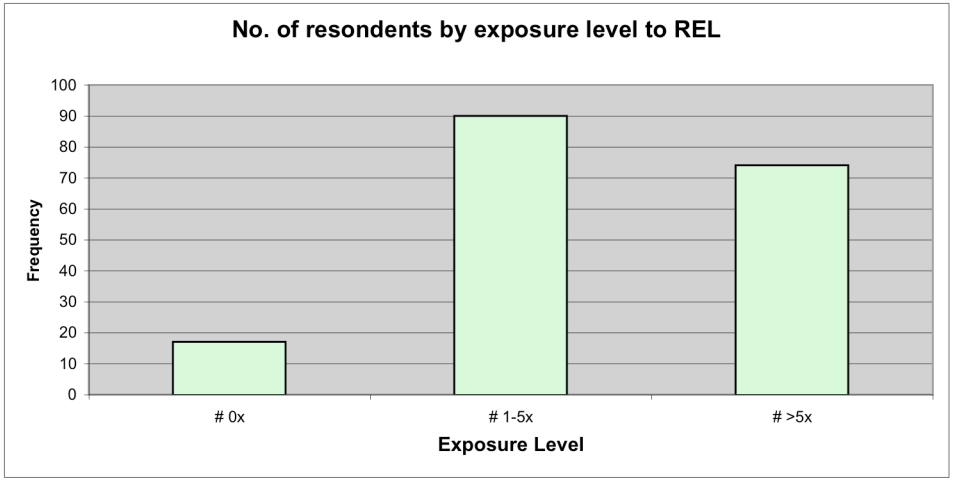


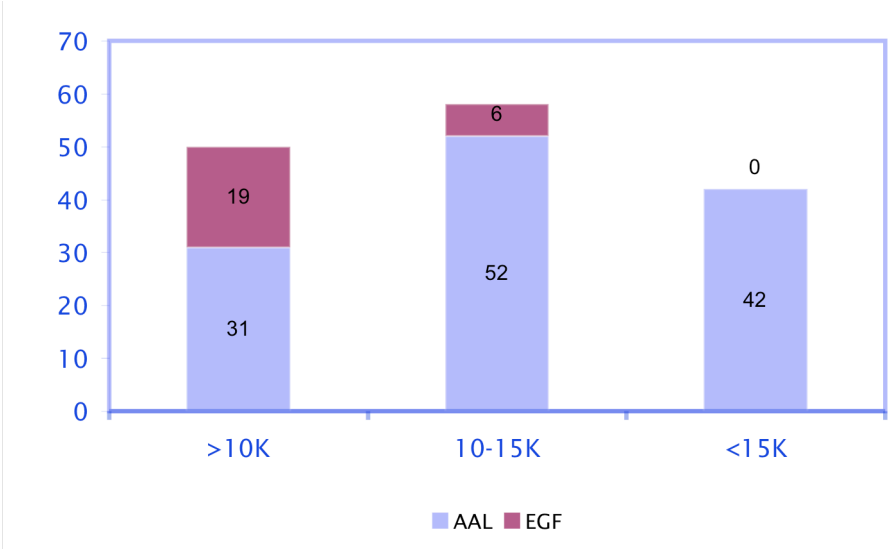
Role



Pilots Results: pilots' experience and REL exposure

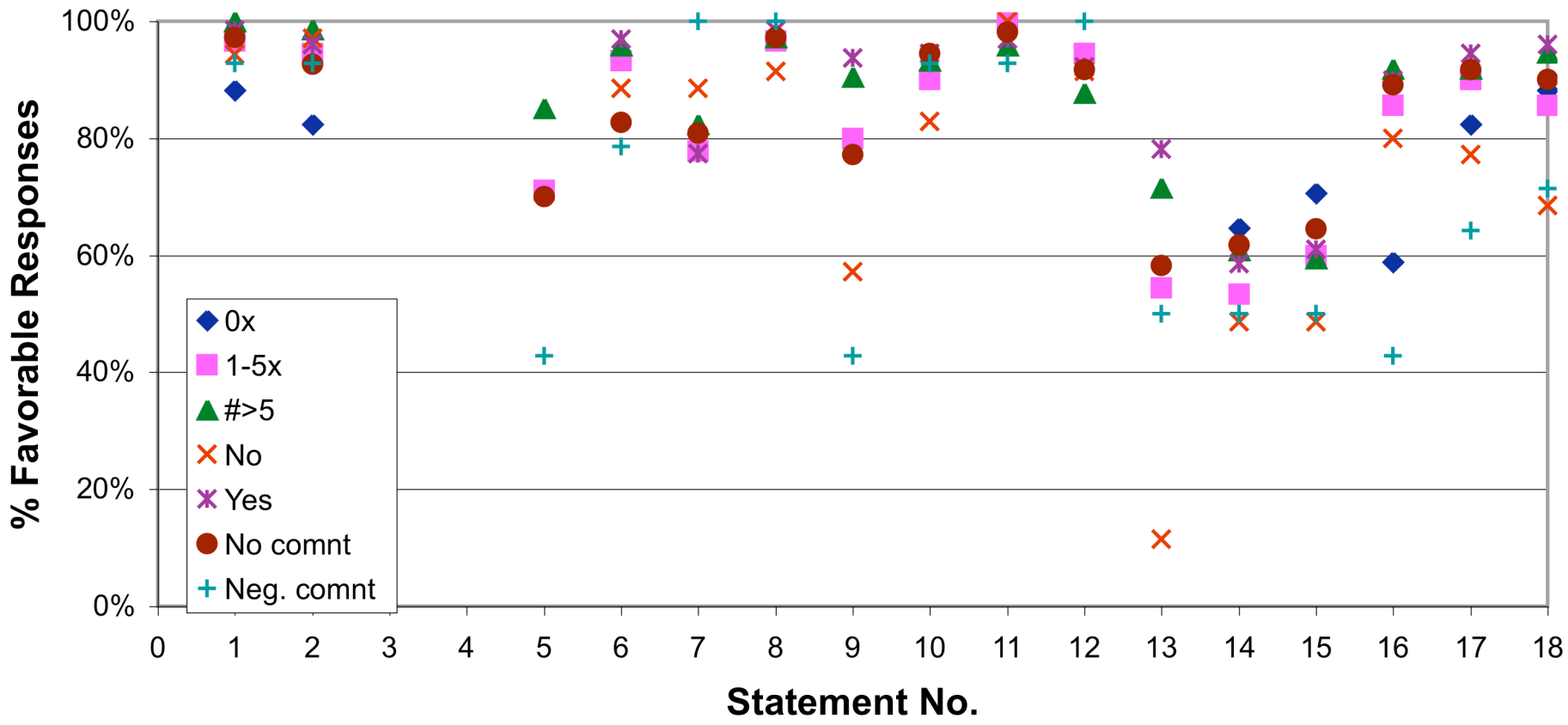






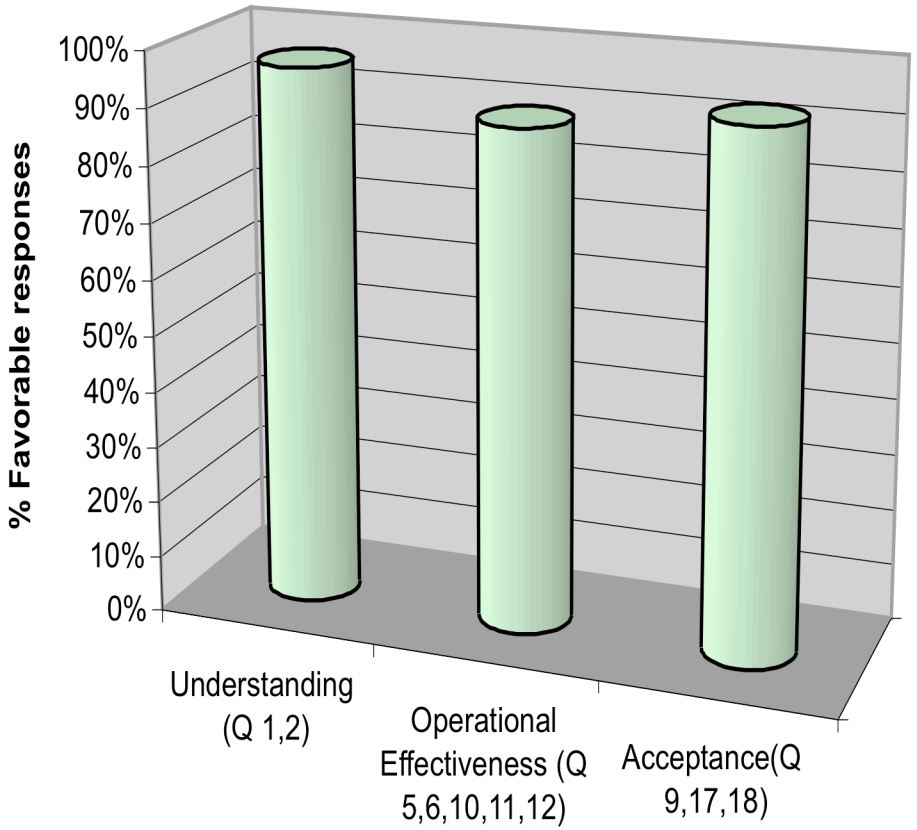
- Most pilots have >10K flight hours
- American airlines pilots have most hours of flying experience
- Most pilots were exposed to RELs between 1 and 5 times
- Responses did not differ much with pilots experience level

Pilots Results: REL exposure, conspicuity, configuration



- More REL exposure = more favorable response overall, also better understanding
- Overall results positive: ratings, comments and response rate (about 200, March - May)
- Some specific negative ratings when REL conspicuity and configuration were concerns

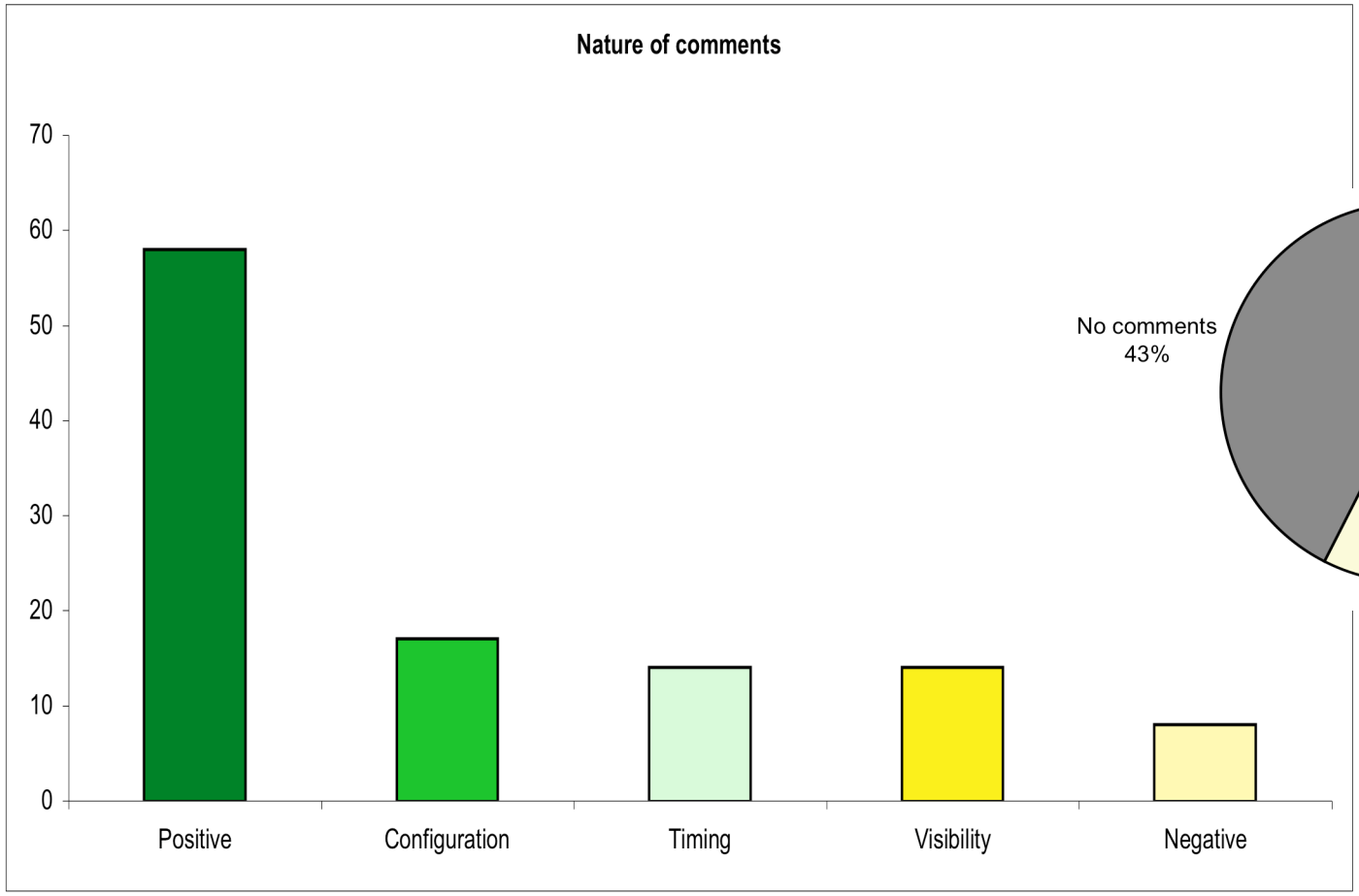
Pilots Results: three key categories

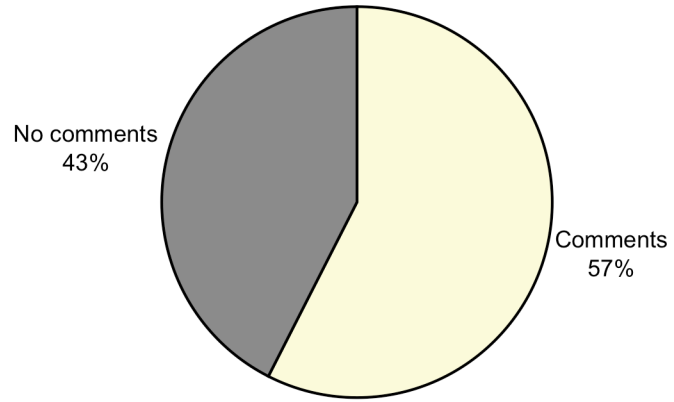


- **Understanding**
  - ***Do not cross*** red RELs
  - REL off is ***not*** clearance
- **Effectiveness**
  - RELs functioning, visible, consistent with clearances
- **Acceptance**
  - Situational awareness enhanced, RELs valuable and valid

Results indicate our successful design

Pilots Results: key comments





- Number and nature of comments received (104/181)
- Most comments positive, many *very* supportive

Example comments from pilot survey

- **Negative:**
  - *They too closely resemble Lead-in Lights (FDX Co-Pilot 3/15/05)*
  - *I was disappointed that they were so "inconspicuous" during daylight operations (AAL Pilot 04/29/05)*
- **Positive:**
  - *I thought that they worked great and it is an incredible idea. (NWA Co-Pilot 3/12/05)*
  - *If it saves one Tenerife type accident, they have paid for themselves forever (AAL Pilot 03/31/05)*
  - *It is a good system that will enhance safety (AAL Pilot 4/22/05)*

Example comments from pilot survey (continued)

- **Positive:**
  - *Great system that will save lives. (AAL Co-Pilot 4/06/05)*
  - *Good system. We should have this system at all large airports. (AAL Pilot 04/09/05)*
  - *Great system, very easy to understand. (AAL Pilot 4/19/05)*
  - *Great low cost alternative to prevent runway incursions. (AAL Co-Pilot 4/22/05)*
  - *System is working well and WILL reduce incursions. (AAL Co-Pilot 5/28/05)*
  - *"An excellent tool" (EGF Pilot 4/14/05)*
  - *"Good system" (EGF Pilot 6/2/05)*

Pilots Results: important benefits

- Most pilots expressed their opinion that:
  - RELs functioned appropriately
  - RELs enhanced situational awareness
  - Workload was unaffected by RELs
  - ATC clearance was consistent with RELs
  - RELs will help reduce runway incursions
  - Implementations of RELs should continue
- Note: overall very positive feedback from pilots
  - Operational suitability revealed by near or above 90 percent favorable response to measures of understanding, effectiveness and acceptance

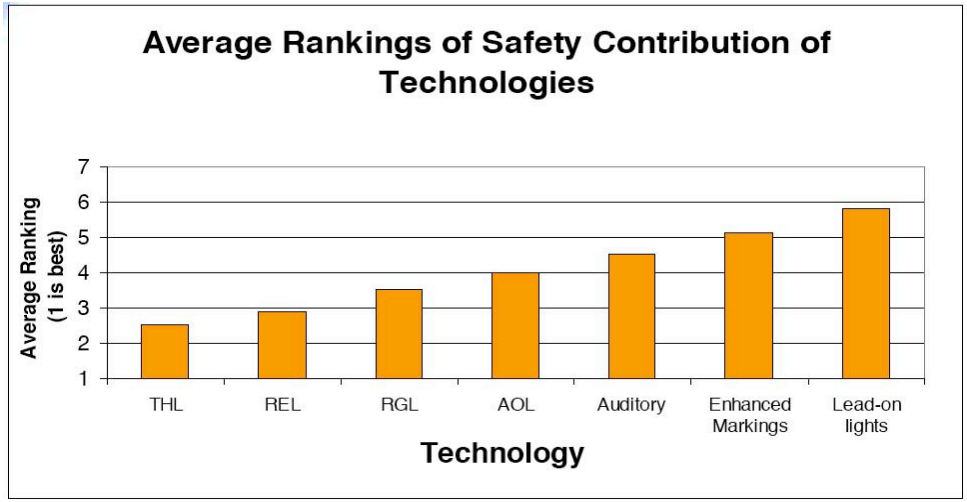
Lessons learned from pilots results

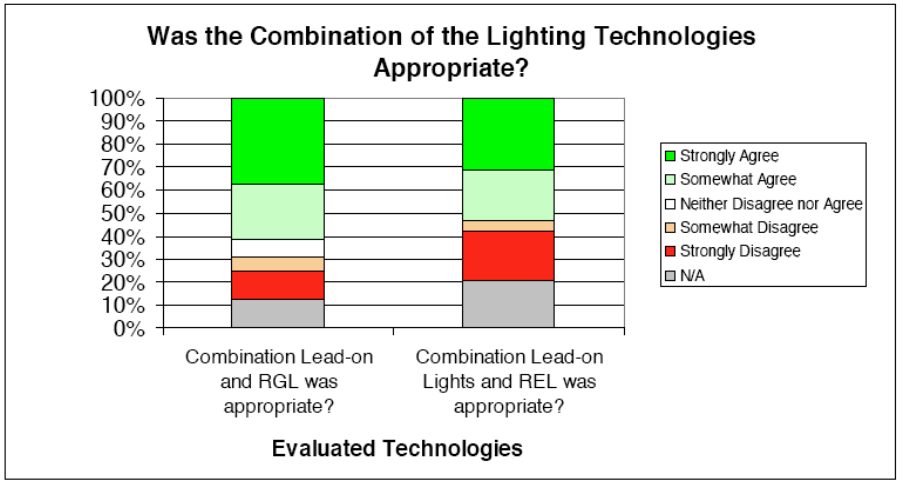
- Training concept and procedures
  - More meetings with airlines training management
  - Improve presentation for recurrent training
- Communication to crews
  - Jeppesen pages best, e-mail reminders useful
- Survey methods to use in future
  - Website best for pilots
- Improvements to survey statements
  - Focus on understanding, effectiveness, acceptance
- Next steps for survey administration
  - Re-issue once DFW REL exposure increases (11/05)

MIT/LL Human Factors post-hoc analysis of inter-statement correlations

- Validates survey statements used when assessed with Pearson correlations at $p<.01$ level of significance
  - Strongest correlations for statements on *acceptance* followed by perception of operational *effectiveness*
  - Attitude about RWSL concept is overwhelming positive
    - Correlates with favorable responses to all key statements
      - SA enhanced, workload unaffected, RELs visible, RELs distinct from RGLs, RELs will help reduce incursions and should be further implemented
  - Attitude about RWSL concept rarely negative (8/104 comments)
    - Correlates with unfavorable responses to consistency with clearance
  - No correlation between two statements on *understanding*
    - Implied training or learning to **not** cross red RELs, even if cleared
  - No correlations with flight experience or role or airline (aircraft)
    - Positive indication of consistent reaction from pilot population
    - Supports REL design efficacy

MITRE's Integrated Direct Pilot Warning Simulation*





- Average rankings of safety contribution
  - THLs and RELs ranked best
- Recommendations
  - "Implement RELs to significantly reduce safety incidents related to runway crossings"
  - "Continue R&D for take-off hold (and) arrival occupancy lighting system"
- About half the pilots thought that RGL's, REL's and lead-on lights were appropriately combined

* Reference: Results of an Integrated Direct Warning Simulation, Peter Mortl, MITRE, July 2005 Draft

Summary of Human Factors (HF) contributions to DFW RWSL operational evaluation

- Training and survey methods established
- Human Factors survey results support proof of RWSL operational concept
  - Operational suitability high enough that DFW FAA has continued use of RELs
  - FAA has directed continuation of RWSL with phased evaluation of THLs to begin next month at DFW
    - ***All DFW pilots welcome to participate at DFW Center Tower***
    - Operational evaluation of THLs will follow on DFW west side
- Future plans for RWSL at other NAS airports
- The bottom line: RWSL provides a direct indication of an unsafe runway, as per NTSB and FAA goals