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Simulator Evaluation of Land and Hold-Short Operation (LAHSO) Lighting Configurations

PB99-126906

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December 1998

DOT/FAA/AR-TN97/86

U.S. Department of Transportation

Federal Aviation Administration

NOTICE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/AR-TN97/86		

4. Title and Subtitle	5. Report Date
SIMULATOR EVALUATION OF LAND AND HOLD-SHORT OPERATION (LAHSO) LIGHTING CONFIGURATIONS	December 1998
	6. Performing Organization Code: AAR-410

7. Author(s)	8. Performing Organization Report No.
Eric S. Katz	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Federal Aviation Administration Airport Technology Research and Development Branch William J. Hughes Technical Center Atlantic City International Airport, NJ 08405	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Federal Aviation Administration Office of Aviation Research Washington, DC 20591	Technical Note
	14. Sponsoring Agency Code: AAS-200

15. Supplementary Notes

16. Abstract

The Federal Aviation Administration (FAA) evaluated several proposed Land and Hold-Short Operation (LAHSO) lighting configurations using a flight simulator. The configurations are designed to indicate to the pilot of a landing aircraft the location of the hold-short point. Subject pilots flew approaches and takeoffs to each LAHSO configuration under simulated visual flight rules (VFR) weather conditions and completed evaluation questionnaires. In addition to subjective questionnaire responses, pilot and aircraft performance data, such as speed at touchdown, length of rollout, etc., were recorded.

The evaluation was directed specifically towards identifying which lighting pattern(s) would effectively indicate to the pilot of a landing aircraft the location of the hold-short point. Configurations containing red in-pavement and elevated holding point lights, along with pulsing-white in-pavement taxi-speed warning lights, were determined to be most appropriate for installations using control tower operation of the lights for each landing or takeoff. If air traffic control does not control the LAHSO lights, the FAA proposal of pulsing-white in-pavement lights located at the hold-short point appeared to be most appropriate.

17. Key Words	18. Distribution Statement
Land and hold-short operations, Lighting configurations, Boeing 727 Simulator	This document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	51	

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EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) evaluated several proposed Land and Hold-Short Operation (LAHSO) lighting configurations using a flight simulator. The configurations are designed to indicate to the pilot of a landing aircraft the location of the hold-short point. The configurations, suggested by various participants in an International Civil Aviation Organization (ICAO) Visual Aids Panel working group meeting, were displayed for evaluation by experienced B-727 captains from U.S. air carriers and the FAA. Each subject pilot flew approaches and takeoffs under simulated visual flight rules (VFR) weather conditions and completed evaluation questionnaires upon finishing each group of scenarios involving a particular LAHSO lighting configuration. In addition to subjective questionnaire responses, pilot and aircraft performance data, such as speed at touchdown, length of rollout, etc., were recorded for subsequent analysis to determine whether configuration differences influenced flight performance.

The evaluation was directed specifically towards identifying which lighting pattern(s) would effectively indicate to the pilot of a landing aircraft the location of the hold-short point. Configurations containing red in-pavement and elevated holding-point lights, along with pulsing-white in-pavement taxi-speed warning lights, were determined to be most appropriate for installations utilizing control tower operation of the lights for each landing or takeoff. If air traffic control does not control the LAHSO lights, the FAA proposal of pulsing-white in-pavement lights located at the hold-short point appeared to be most appropriate.

INTRODUCTION

PURPOSE.

In support of the International Civil Aviation Organization (ICAO), the Airport Technology Research and Development (R&D) Branch, AAR-410, at the Federal Aviation Administration (FAA) William J. Hughes Technical Center evaluated several Land and Hold-Short Operation (LAHSO) lighting configurations using a flight simulator. The configurations evaluated included proposals from the FAA, the International Civil Aviation Organization (ICAO) Visual Aids Panel (VAP) working group, and the International Federation of Airline Pilots Association (IFALPA).

This technical note describes the evaluation of the proposed LAHSO lighting configurations and presents the results obtained. Conclusions are also included.

BACKGROUND.

LAHSO and the requirement for visual aids to support such operations have been presented for discussion and action at the ICAO VAP working group meeting in Montreal, Quebec. The need for a standard lighting configuration to clearly and boldly indicate the hold-short point was recognized, and a decision was made to evaluate proposed lighting, marking, and sign arrangements using a flight simulator. A resulting information paper briefly stated the LAHSO lighting system evaluation objective and requirements.

It is an operational requirement that the lighting pattern provide a visual signal to the pilot that enables the aircraft to be operated safely using normal landing and roll-out procedures. The LAHSO lighting configuration shall also be compatible with the requirements of air traffic control procedures and shall be useable under all visual flight rules (VFR) weather conditions.

To meet the requirements, the United States (U.S.) member of the ICAO VAP suggested the use of an FAA prototype runway hold-short lighting system, since it had been tested and used in the U.S. for a number of years. Other ICAO VAP members felt that the FAA system did not adequately fulfill the need and offered a number of changes and additional components to improve the system effectiveness. In all, a total of six different configurations, each to include the standard sign and marking array, were recommended.

Depictions of the lighting configurations proposed for testing are provided as figures 1 through 6. Each lighting configuration was displayed with the standard sign and marking array. One configuration consisted of signs and markings only.

OBJECTIVE.

The evaluation was directed specifically towards identifying which lighting pattern(s) would effectively indicate the location of the hold-short point to the pilot of a landing aircraft.

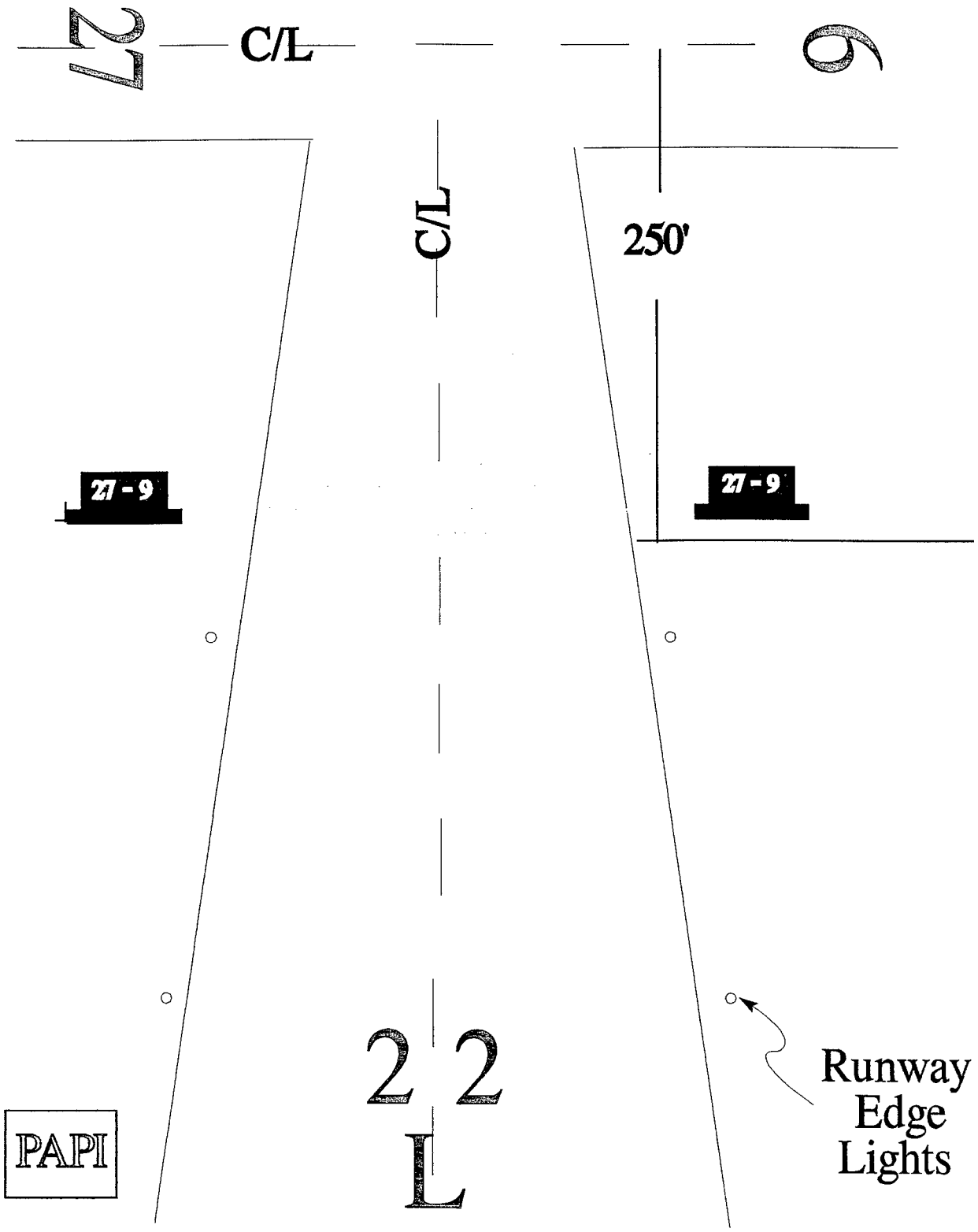


FIGURE 1. STANDARD MARKINGS AND SIGNAGE

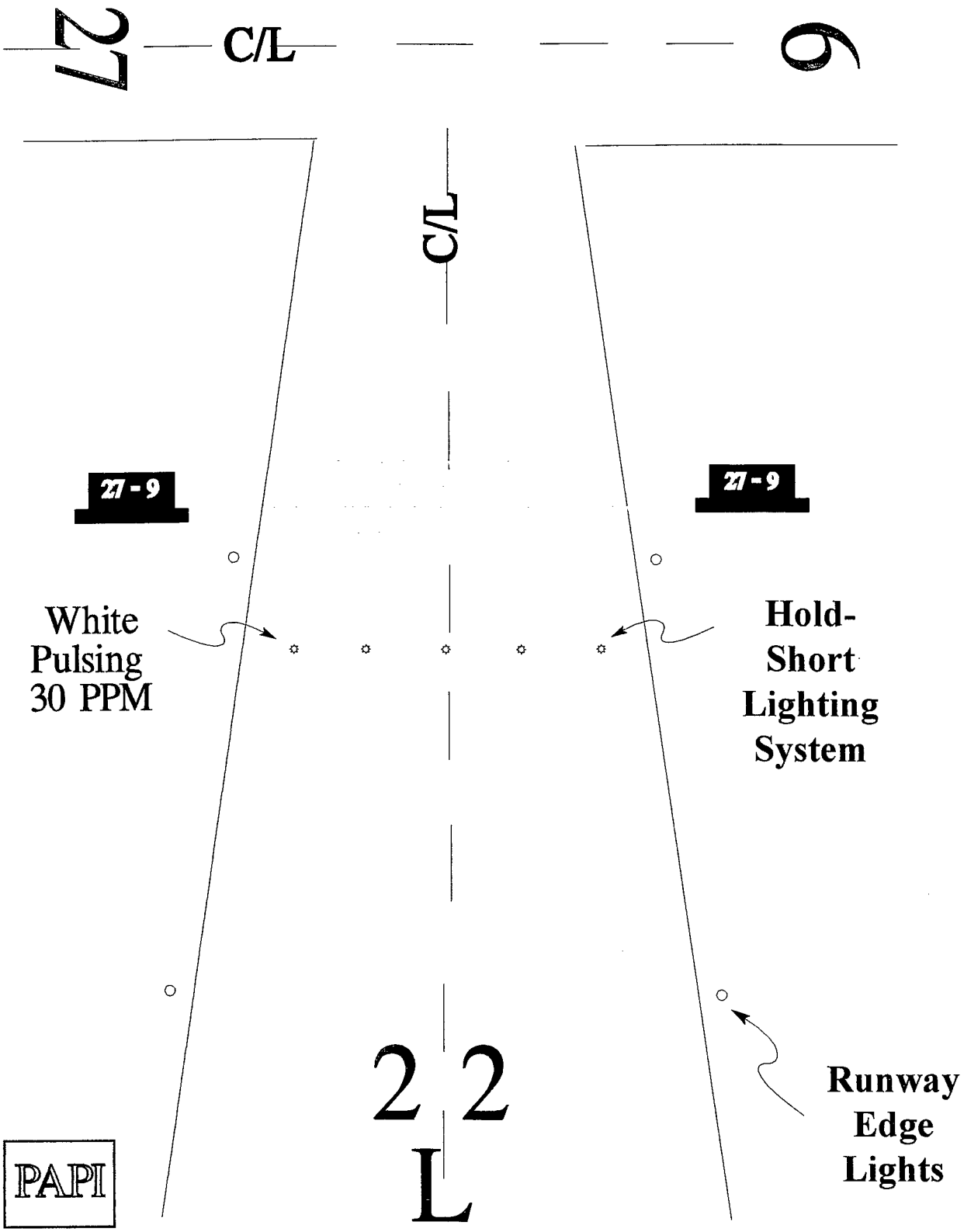


FIGURE 2. FAA PROPOSAL

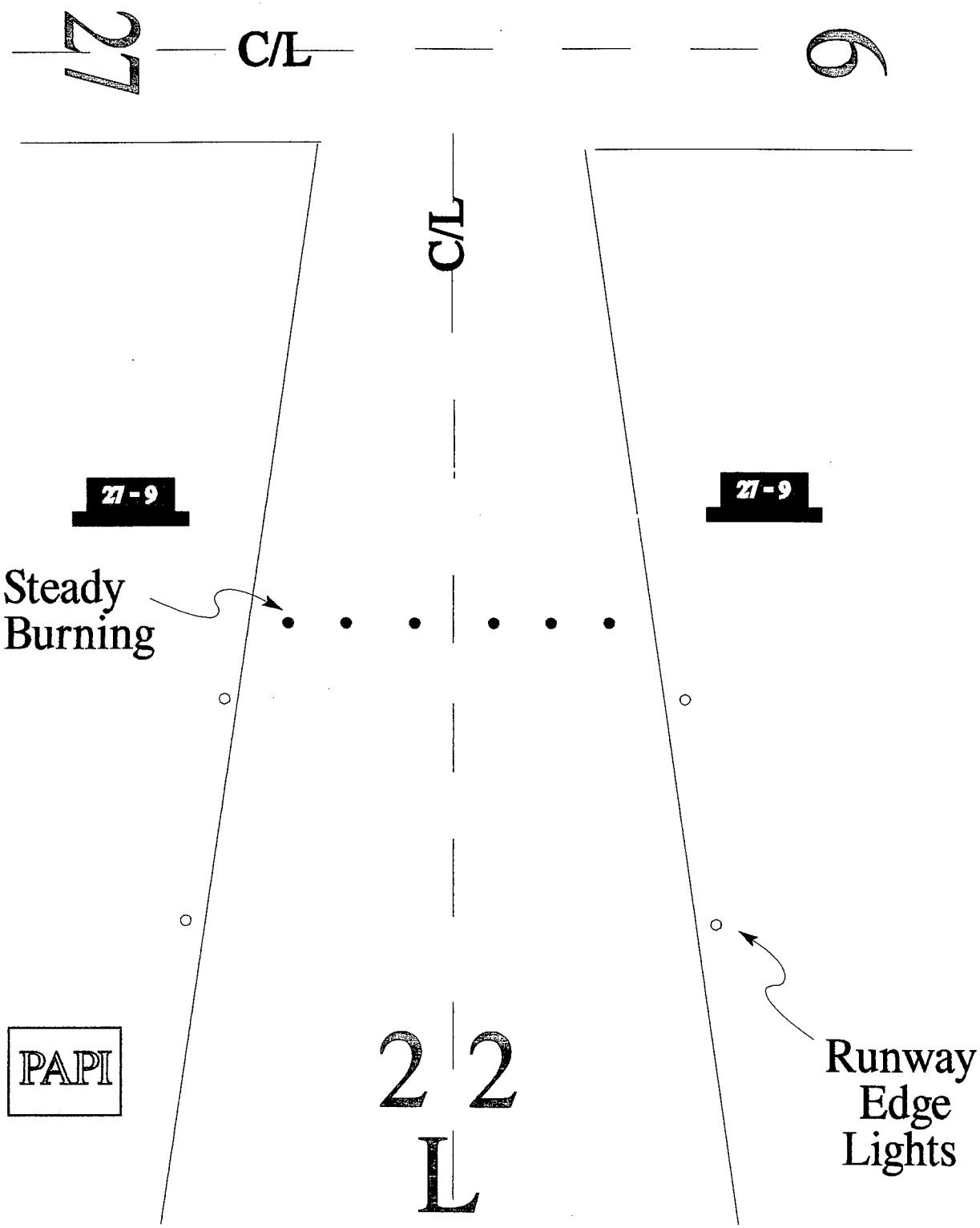


FIGURE 3. ICAO VAP WORKING GROUP PROPOSAL

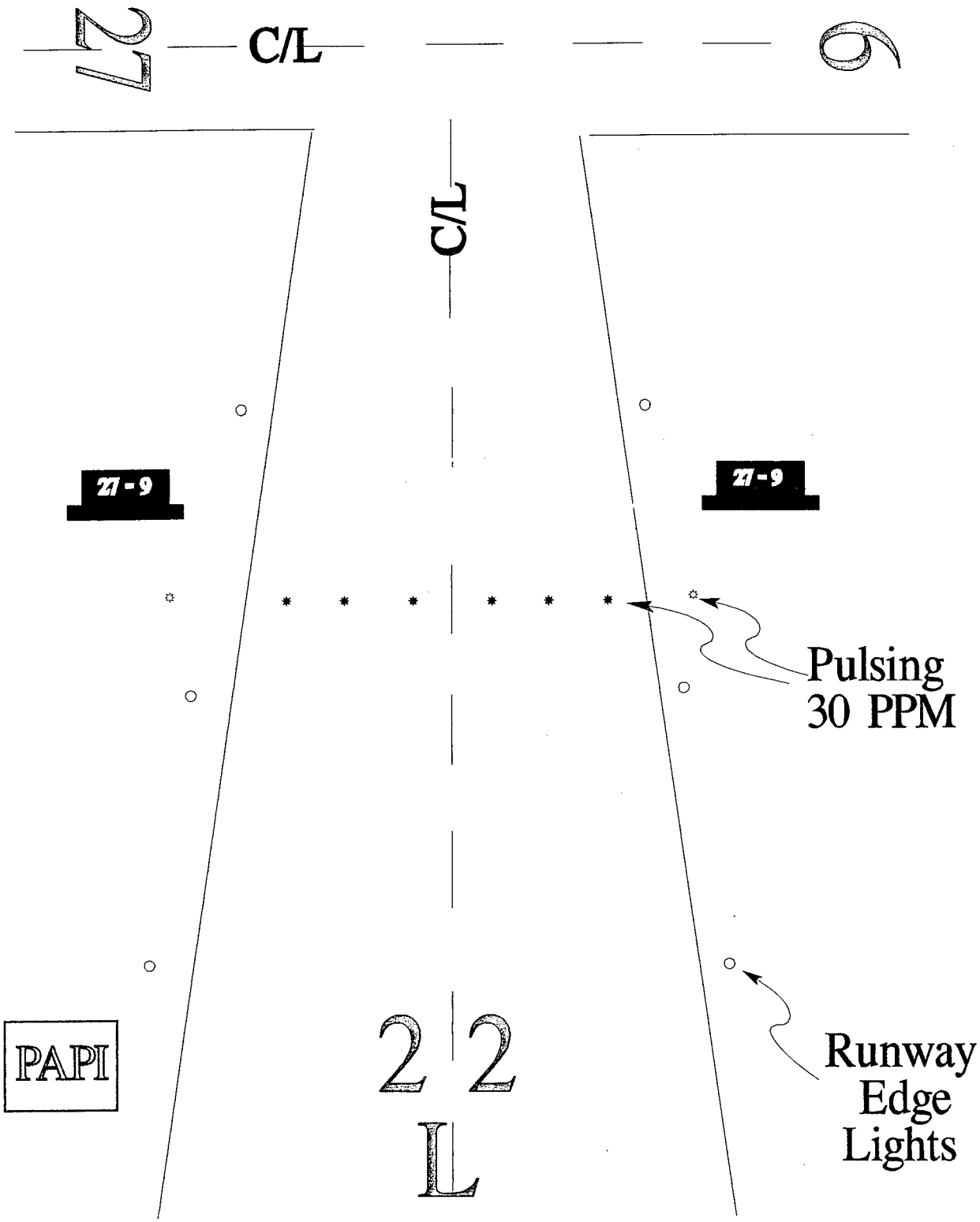


FIGURE 4. MODIFIED ICAO VAP WORKING GROUP PROPOSAL

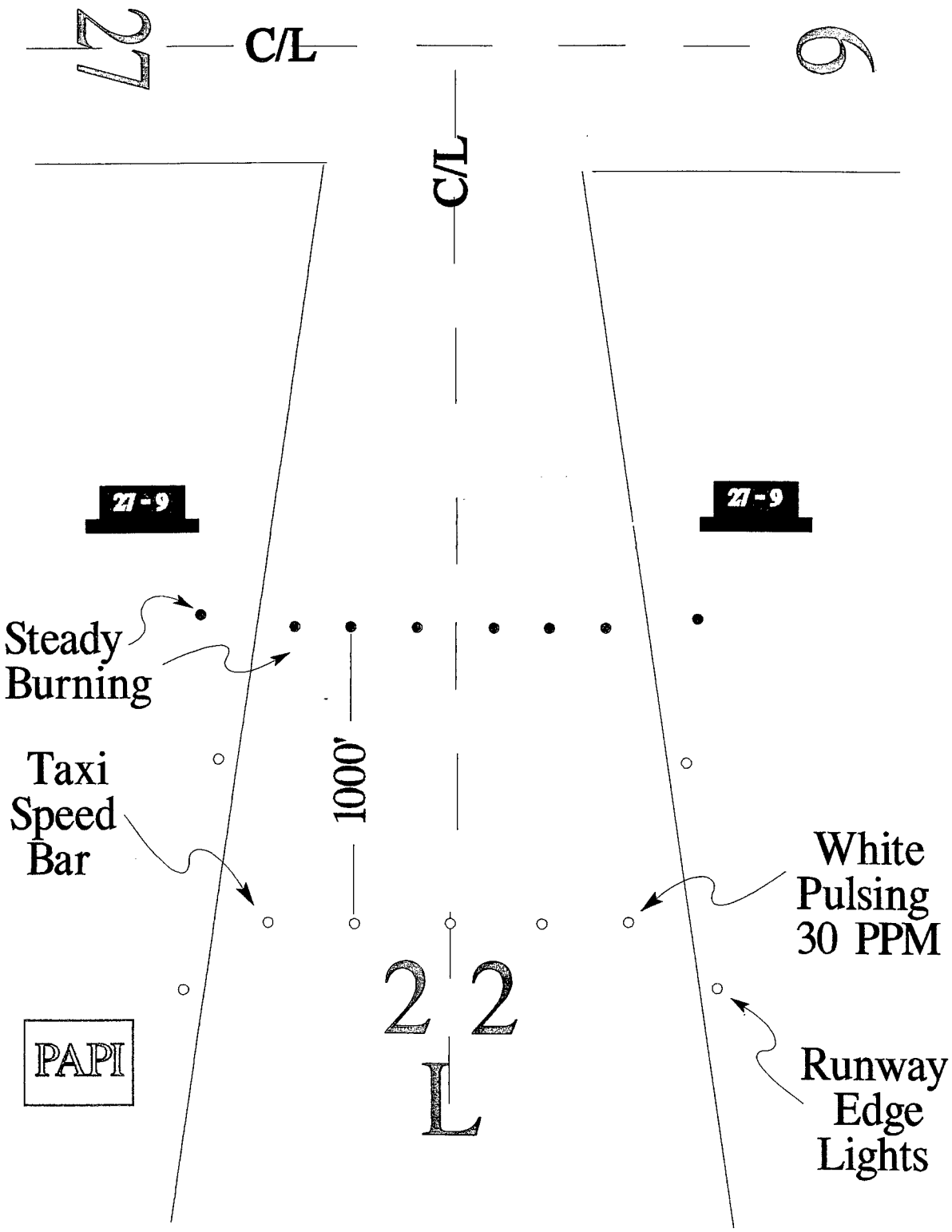


FIGURE 5. IFALPA PROPOSAL NO. 1

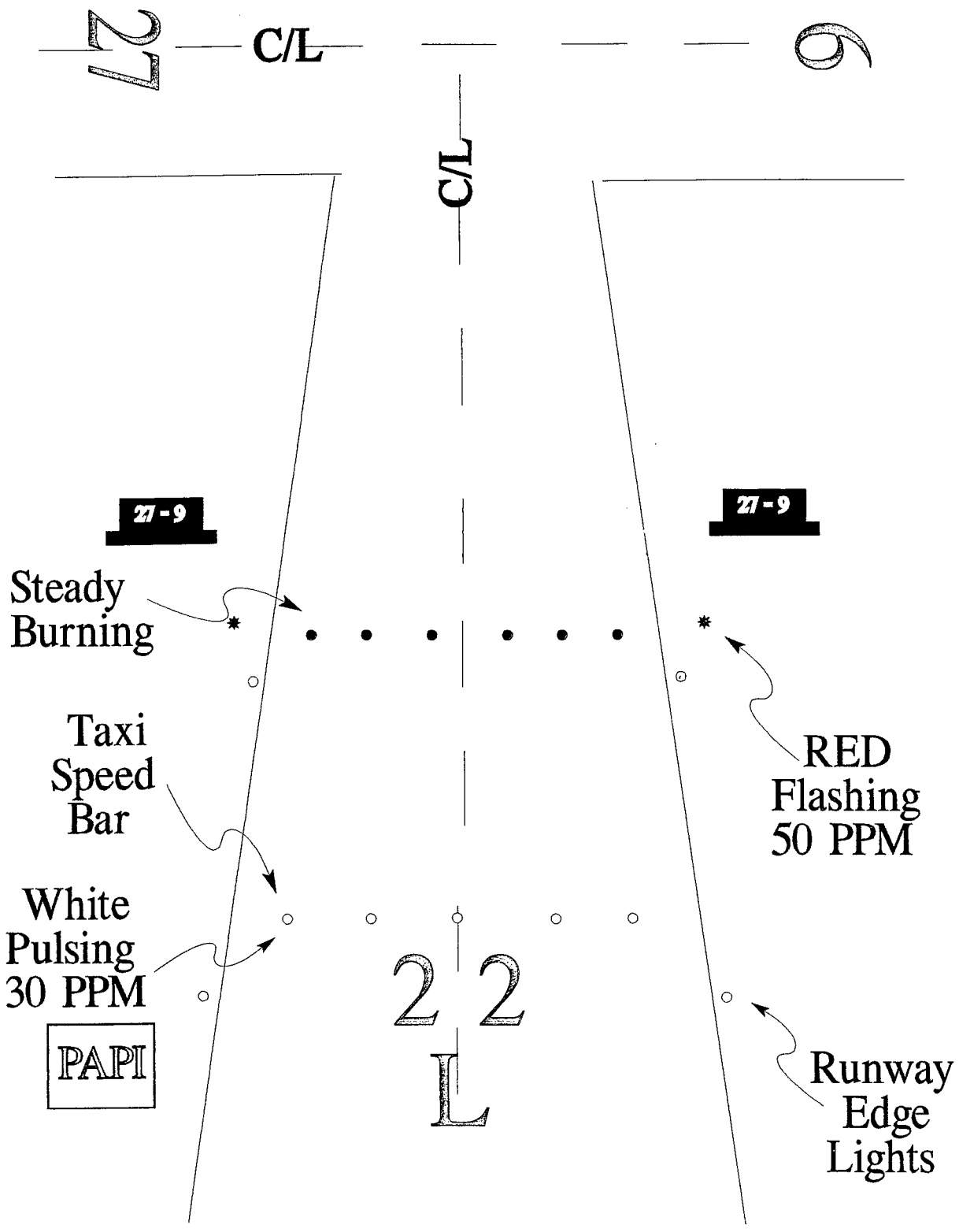


FIGURE 6. IFALPA PROPOSAL NO. 2

DISCUSSION

Although the U.S. had earlier initiated LAHSO at commercial air carrier airports, it did not recognize the need for unique visual aids to support that type of operation until 1990. At that time the Visual Aids R&D group at the FAA Technical Center was tasked with developing the necessary runway lighting configuration that would identify the exact location of the hold-short point to the landing pilot. Various red and white in-pavement lighting patterns were initially tested, using both steady-burning and pulsing modes of operation. Ultimately a pulsing array of five high-intensity white inset lights was installed for in-service evaluation at the Boston Logan International Airport. The use of red lights was considered at first, but later discarded when Air Traffic Control (ATC) requirements indicated that pilots might, at times, be authorized to taxi, roll-out, or takeoff through a LAHSO system containing red lights. Since red lights imply stopping, it would be undesirable to have pilots continue past such a system. Technical Note DOT/FAA/CT-TN91/43, "Prototype Runway Hold-Short Lighting System," describes this effort in detail.

EVALUATION APPROACH

METHOD.

To evaluate several different LASHO lighting configurations, experienced air carrier pilots conducted approaches, landings, and takeoffs using the FAA Boeing 727 Flight Simulator located at the Oklahoma City Aeronautical Center. The visual display component of the flight simulator was upgraded and calibrated to significantly enhance the lighting system presentation and to better suit it to visual aid evaluations. The simulator is equipped with an SP-1T texturized dusk/night visual display, with a full range of visual weather effects available.

PILOTS.

While the preliminary test procedures and simulator displays were being developed by FAA test pilots and visual guidance engineers, industry B-727 type-rated pilots from various airlines were used in the final evaluation. The flight sessions were approximately 2 1/2 hours in length, with the subject pilot participating as Captain (Pilot-in-Command). Breaks were offered as necessary.

A total of 12 volunteer subject pilots participated from the following organizations: American Airlines, Federal Express, Delta Airlines, Southwest Airlines, Continental Airlines, United Airlines, and the Federal Aviation Administration. The average total flight hours were 9,818 and the average B-727 flight hours were 3,036.

SCENARIOS.

Approximately 50% of the landing operations included receipt of Automatic Terminal Information Service (ATIS) indicating LAHSO in progress, along with the associated appropriate information. ATC clearances were issued via simulated radio transmissions and were appropriate for the specific operation being evaluated, either land and hold short or full length (available). At least 5% of landing operations were issued a non-LAHSO ATIS accompanied by

a clearance stating simply "cleared to land" without mention of holding short when a lighting configuration intended for hold-short operations was presented. Additionally, at least 5% of hold-short landing clearances were issued very late (on final approach between 1 and 2 miles from the runway threshold), with LAHSO configuration lights not illuminated in some instances and illuminated in others. Takeoff scenarios were included to assess pilot reaction to the sudden appearance of each of the five LAHSO lighting configurations during the takeoff roll.

Appropriate signs and markings specified in ICAO Annex 14 and FAA Advisory Circular 150/5340-18C were depicted (holding-position markings and mandatory signs on each side of the runway) along with a Precision Approach Path Indicator (PAPI) system for all configurations evaluated.

The scenario matrix is provided in table 1. Further procedural details are provided in the following Evaluation Implementation section.

Since all evaluations were conducted under simulated 7-mile visibility conditions, the approaches were flown manually with the subject pilot, acting as Captain in the left seat, completing the landing visually. A qualified test team member occupied the right seat in the simulator and performed such duties as would normally be assigned to the first officer.

EVALUATION IMPLEMENTATION

GENERAL PROCEDURES.

The volunteer subjects were informed that they were participating in an evaluation of LAHSO visual aids, particularly lighting. They were not informed of what configurations to expect on each approach or takeoff but were informed of the configuration and purpose of each particular aid being evaluated, i.e., the purpose of the white pulsing lights for the specific evaluation (whether it's used as a taxi speed bar as in the IFALPA configurations or an indication of the end of available landing distance as in the FAA configuration).

Subject pilots were briefed on test procedures prior to each simulated flight session and given an opportunity to familiarize themselves with the nature of the postflight questionnaire that they were required to complete. Postflight questionnaires were completed in the simulator immediately after each lighting configuration was evaluated. Typical questionnaire forms are shown in figures 7 and 8.

TABLE 1. SCENARIO MATRIX

Scenario Number	Display (Configuration)						Clearance			ATIS		T/O***	Remarks
	1	2	3	4	5	6	Clear to Land	No H/S*	Late H/S*	LAHSO**	NO LAHSO**		
1	X						X		X		X		
2	X							X			X		
3	X							X		X			
4		X					X				X		
5		X					X			X			
8		X						X			X		
6		X					X		X		X		
9		X						X		X			
7		X					X		X	X			
10		X								X		T/O	
11			X				X				X		
12			X				X			X			
15			X					X			X		
13			X				X		X		X		
16			X					X		X			
14			X				X		X	X			
17			X								X	T/O	
18				X			X				X		
19				X				X		X			
20				X						X		T/O	
21					X		X				X		
22					X		X			X			
25					X			X			X		
23					X		X		X		X		
26					X			X		X			
24					X		X		X	X			
27					X						X	T/O	
28						X	X				X		
29						X		X		X			
30						X				X		T/O	

* Hold short
** Land and hold-short operation
*** T/O = Takeoff Scenario

SIMULATED FLIGHT SESSION QUESTIONNAIRE
LAHSO LIGHTING EVALUATION
APPROACH AND LANDING SCENARIOS

CONFIGURATION PRESENTED: "1"

VISIBILITY COND: VFR, 7-Mile Visibility

SUBJECT PILOT:_____ DATE:_____

Please place a check in the appropriate square to indicate the relative effectiveness of this lighting configuration in providing the following forms of guidance.

1. INDICATION THAT LAHSO IS IN USE:

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)

2. LOCATION OF THE HOLD-SHORT POINT:

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)

Please answer the following four questions from your experience.

3. DO YOU FEEL THAT THIS CONFIGURATION CAN REMAIN DISPLAYED EVEN WHEN FULL RUNWAY LENGTH IS AVAILABLE FOR LANDING AND ROLLOUT? (I.E., ATC NEED NOT TURN OFF FOR FULL-LENGTH LANDINGS)

   YES:_____ NO:_____

   IF NO, PLEASE EXPLAIN WHY NOT:_____

   _____

   _____

FIGURE 7. SAMPLE APPROACH/LANDING SCENARIO QUESTIONNAIRE

4. AT WHAT POINT DURING YOUR APPROACH/LANDING OPERATION DID YOU FIRST ACQUIRE AND IDENTIFY THE LASHO LIGHTS?

LONG FINAL:____ SHORT FINAL:___ THRESHOLD:___ TOUCHDOWN:___

COMMENTS:_____

_____

_____

5. WAS THE ACQUISITION DISTANCE ADEQUATE TO PERMIT YOU TO USE THE INFORMATION?

YES:_____ NO:_____

COMMENTS:_____

_____

_____

6. COULD THE HOLD-SHORT LIGHTS POSSIBLY BE CONFUSED WITH ANY OTHER EXISTING LIGHTING SYSTEMS ON THE AIRPORT?

YES:_____ NO:_____

COMMENTS:_____

_____

_____

FIGURE 7. SAMPLE APPROACH/LANDING SCENARIO QUESTIONNAIRE (Continued)

SIMULATED FLIGHT SESSION QUESTIONNAIRE
LAHSO LIGHTING EVALUATION
TAKEOFF SCENARIOS

CONFIGURATION PRESENTED: "2"

VISIBILITY COND: VFR, 7-Mile Visibility

SUBJECT PILOT:_____ DATE:_____

Please answer the following questions, bearing in mind the visual LAHSO lighting configuration just displayed during your simulated takeoff roll.

1. DID YOU EXPERIENCE ANY CONFUSION OR BECOME CONCERNED WHEN UNEXPECTEDLY ENCOUNTERING A DISPLAYED LAHSO LIGHTING CONFIGURATION DURING THE TAKEOFF ROLL?

   YES:_____ NO:_____

   IF YES, PLEASE EXPLAIN WHY:_____

   _____

   _____

2. IN YOUR OPINION, WOULD IT BE ACCEPTABLE FOR ATC TO INTENTIONALLY LEAVE THE LAHSO LIGHTING CONFIGURATION DISPLAYED WHILE CLEARING AIRCRAFT FOR TAKEOFF?

   YES:_____ NO:_____

   IF NO, PLEASE EXPLAIN WHY NOT:_____

   _____

   _____

3. AT WHAT POINT IN THE TAKEOFF ROLL DID YOU NOTICE THE LAHSO LIGHTS?

   BEGINNING:_____ HALFWAY:_____ AT THE END_____

FIGURE 8. SAMPLE TAKEOFF SCENARIO QUESTIONNAIRE

The following data were recorded for approaches:

1. Conspicuity range (Number)
2. Adequacy of conspicuity range (Rating)
3. Touchdown point, velocity and deceleration rate (Number)
4. 25-knot achievement point and average percentage of braking used (Number)

Test team members were present in the simulator cockpit during each evaluation session to record pertinent subject pilot comments. They also noted any unique occurrences, such as abrupt maneuvering and/or inadvertent crossing of the hold-short point.

In addition, subject pilots were informed that cockpit discussions and comments were being tape recorded to facilitate subsequent analysis. Identification of the participants is confidential.

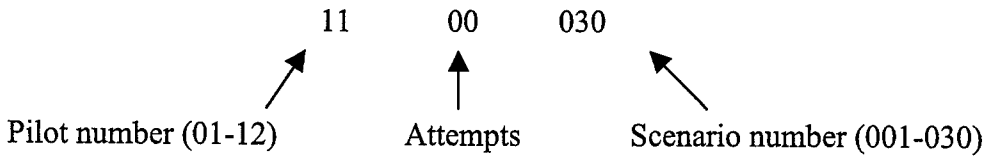
DATA COLLECTION AND ANALYSIS.

Data variables were collected at five samples per second and saved to disk files in the FAA's off-line data collection facility. Variables collected during this LAHSO lighting system evaluation included:

1—Test/Scenario Number
2—Indicated Airspeed
3—Radio Altitude
4—On-Ground Flag
5—Ground Distance from Threshold
6—Ground Speed
7—25-Knot Achievement Point
8—Deceleration Rate
9—Average Percentage of Braking Used

The real-time data files were saved automatically to disk files for later retrieval and analysis. Data collection was monitored to ensure proper acquisition.

To insure clear identification of each test run, a six-digit test number was used on each scenario run. The number was formatted as follows:



The test number was entered by the operator at the simulator control panel and was collected on all data samples as a variable.

WEATHER SIMULATION.

Weather simulation was established at 7-mile visibility with unlimited ceilings.

INITIAL AIRCRAFT CONDITIONS.

Initial conditions were as follows:

Initial Conditions	For Landing	For Takeoff
Gross Weight	154,500 lbs.	172,000 lbs.
Center of Gravity	25%	25%
Fuel Freeze	Set	Set
Visual Control	CRT	CRT
Visibility	7 miles	7 miles
Ceiling	Unlimited	Unlimited
Turbulence	8%	8%

PILOT OPERATING PROCEDURES.

As previously discussed, the simulator test program was automated as much as possible to expedite test runs and ensure repeatability with different test pilots.

The operator initiated each scenario from the simulator control panel. When an approach/landing scenario number was entered and activated, the aircraft was repositioned to a point 4.6 nm from the runway threshold and approximately 100′ below glide path.

As soon as the aircraft was stabilized at the approach position, the pilot established the following initial conditions:

Stab Trim	5.5
EPR's	1.5
First Officer Flight Director	Disengaged
Capt. Flight Director	As desired
Auto Throttle	As desired
Flaps	30°
Gear	Down
Autopilot	Disengaged
Spoilers	Stowed

When a takeoff scenario number was entered and activated, the aircraft was repositioned at the takeoff runway threshold. As soon as the aircraft was stabilized at the takeoff position, the pilot established the following initial conditions:

Stab Trim	6.0
EPR's	2.10/2.12
F.O. Flight Director	Disengaged
Capt. Flight Director	As desired
Auto Throttle	Disengaged
Flaps	15°
Gear	Down

When the operator was ready to initiate the run, and the pilot concurred, "Flight Freeze" was released and the pilot flew the visual approach or takeoff manually as directed in the briefing.

Test runs, from operator initialization until test complete, averaged approximately 3 minutes.

TEST RESULTS

SUMMARY AND ANALYSIS OF QUESTIONNAIRE RESPONSES.

The following section provides a complete summary of subject pilot effectiveness ratings, specific question answers, and evaluation comments on the hold-short lighting configurations. The summary for each question is followed immediately by an analysis of the subject responses and comments for that question.

The summaries and analyses are arranged in order of questions posed for the landing scenarios, followed by those for the takeoff scenarios. Within each specific question area, ratings, answers, and comments are arranged in order of configuration number (1 through 6).

Note: Questions 1 and 2 were configured to obtain subject pilot ratings on the effectiveness of each lighting configuration. These questions did not request comments.

For convenience, the configuration descriptions are repeated here:

Configuration

1—Standard Markings and Signage
2—FAA Proposal
3—VAP Proposal
4—Modified VAP Proposal
5—IFALPA I Proposal
6—IFALPA II Proposal

Landing Question 1—Data Summary

Please place a check in the appropriate square to indicate the relative effectiveness of this lighting configuration in providing the following form of guidance:

INDICATION THAT LAHSO IS IN USE:

Configuration 1

Note: For configuration 1, which did not include any of the proposed lighting arrays, this question was not included.

Configuration 2

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
1	6	3	2	0

Configuration 3

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
2	2	4	4	0

Configuration 4

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
1	4	2	4	1

Configuration 5

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
5	3	2	1	1

Configuration 6

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
7	3	1	1	0

Landing Question 1—Data Analysis

HOW UNIQUE IS THIS CONFIGURATION FOR THE PURPOSE INTENDED?

Subject pilots showed a preference for: (In order of preference)

Configuration 6	E =58%, G=25%, A=8%, AA=8%, U=0%
Configuration 5	E =42%, G=25%, A=17%, AA=8%, U=8%
Configuration 2	E =8%, G=50%, A=25%, AA=17%, U=0%

Configurations 6, 5, and 2 received an average judgment of "Good" effectiveness, which was the second highest of the five possible ratings that could be selected.

Configuration 3	E =17%, G=17%, A=33%, AA=33%, U=0%
Configuration 4	E =8%, G=33%, A=17%, AA=33%, U=8%

The two configurations that displayed either steady-burning or flashing-red lights only (configurations 3 and 4) were judged to have only adequate uniqueness, and in fact were thought to be only "almost adequate" (actually inadequate) by 4 of the 12 subjects. This lower rating of the red-only lighting configurations can most likely be explained by subsequent subject pilot comments that frequently mentioned the possibility of confusing these configurations with the red end-of-runway lighting system component.

Landing Question 2—Data Summary

Please place a check in the appropriate square to indicate the relative effectiveness of this lighting configuration in providing the following form of guidance:

LOCATION OF THE HOLD-SHORT POINT:

Configuration 1

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
0	0	2	8	2

Configuration 2

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
2	6	4	0	0

Configuration 3

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
1	3	7	1	0

Configuration 4

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
1	3	4	3	1

Configuration 5

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
7	2	2	1	0

Configuration 6

Excellent (E)	Good (G)	Acceptable (A)	Almost Acceptable (AA)	Absolutely Unacceptable (U)
7	3	1	1	0

Landing Question 2—Data Analysis

HOW EFFECTIVE IS THIS CONFIGURATION AS A HOLD-SHORT LOCATION IDENTIFIER?

Configuration 5 E =58%, G=17%, A=17%, AA=8%, U=0%
Configuration 6 E =58%, G=25%, A=8%, AA=8%, U=0%
Configuration 2 E =17%, G=50%, A=33%, AA=0%, U=0%

Configurations 5 and 6 were rated nearly equal on this question, although a single subject did rate both of them as "Almost Acceptable" or, in other words, less than acceptable. Configuration 2 was not rated quite as highly as configurations 5 and 6 overall, but also was not rated less than acceptable by any of the subjects.

Configuration 3 E =8%, G=25%, A=58%, AA=8%, U=0%
Configuration 4 E =8%, G=25%, A=33%, AA=25%, U=8%

The steady-burning red barrette (configuration 3) was slightly favored over the flashing-red array (configuration 4). In fact, the flashing array (configuration 4) was judged as less than acceptable as a locator by 4 of the 12 subject pilots.

The "sign and marking only" (configuration 1) was judged to be almost acceptable by 8 of the 12 pilots (67%) and felt to be "absolutely unacceptable" by another 2 subjects (17%). Subsequent comments supported this evaluation.

Landing Question 3—Data Summary

DO YOU FEEL THAT THIS CONFIGURATION CAN REMAIN DISPLAYED EVEN WHEN THE FULL RUNWAY LENGTH IS AVAILABLE FOR LANDING AND ROLLOUT? (i.e., ATC need not turn off for full-length landings)

Configuration 1:

Note: This question was not included on the configuration 1 questionnaire since no LAHSO lighting configuration was displayed (basic signs and markings only).

Configuration 2:

Yes: 5 No: 7

Comments-

- Strongly prefer it be turned off. I might ignore when I shouldn't.
- Tougher choice because it's white lights, not red—less alarming to a pilot.
- Do not provide what might be an ambiguous signal to a pilot.
- Should be turned off to preserve uniqueness.
- It's a distraction in the landing roll. Might loose impact if left on all the time.
- Distraction.
- (This) configuration—easy to determine distance remaining.
- (Can leave on) only because lights are white, not red.
- (Leave on), but only if the tower states they will be on. Concern is that the lights will be at different runway remaining point (?).

Configuration 3:

Yes: 1 No: 11

Comments-

- I'll possibly think it's the end of the runway and blow tires trying to stop.
- White lights are more indicative of unique purpose than red.
- Possible confusion with red end-of-runway lights.
- Red traditionally means don't go, stop, danger, etc.
- Red means end of runway.
- Should be turned off to retain uniqueness.
- (Turn off) since it would require crews to roll through red lights, and goes counter to previous conditioning.
- Red hold-short (H/S) lights, in conjunction with amber edge lights, might be confused with a lighted overrun.
- Red appears as two ends of the runway.
- Definitely like white better. Red means end of runway to me.
- Configuration should agree with clearance (don't display in no H/S landing).
- Easy to see, easy to read. Red sense of urgency induced without problem with this system.
- Might be confusion with end-of-runway lights.
- Could be confused with end-of-runway lights.

Configuration 4:

Yes: 4 No: 8

Comments-

- Red, and could be mistaken for runway end. Might cause me to hold-short because of uncertainty.
- Can be confused with red end of runway.
- Still don't like red lights, but blinking better than steady burning.

- I like the flashing red. No doubt that there's more runway.
- (Leave on) but blinking red lights are still distracting during landing maneuver.
- Still a distraction during landing if not needed.
- Need consistency. Configuration displayed should agree with the clearance.
- Causes confusion as to whether I have H/S limitation.
- (I like) much more than the other (steady-burning red).

Configuration 5:

Yes: 2 No: 10

Comments-

- Should be turned off due to potential for confusion and distraction. Possible unnecessary maximum braking.
- Red across runway means end of runway to me.
- Getting two pieces of information, red and white lights, to provide unique visual picture.
- If full runway available, I don't want anything to provoke question in my mind about it.
- Saw white (taxi-speed lights) first. Thought they were LAHS limit until saw two red bars.
- It is uncomfortable to cross red lights, no matter why. Don't like white taxi-speed lights.
- Still think should be turned off. Lack of flashing-red lights make turnoff more needed.
- (Turn off) because I have a real problem with going through steady-burning red lights.
- Configuration with flashing-red lights is better.
- Two rows—you're left guessing which governs.
- Need to turn off.
- Configuration leaves question mark as to landing clearance limitation.

- That's a nice little system. White lights very useful in judging rate of closure with red H/S lights.
- I want it turned off for unrestricted landings.
- That one had me confused. First saw end-of-runway lights as H/S lights. Then thought white lights were H/S (location), and finally perceived correct H/S (location) on landing rollout.
- If you leave on all the time, possibility of mistaking end-of-runway lights for hold-short (into the woods).

Configuration 6:

Yes: 3 No: 9

Comments-

- Overpowering. Demands, draws all attention to it. Mandates that you stop.
- My assumption is that the red line across the runway is to indicate the end of the runway.
- Good information, but too busy.
- Effectiveness would diminish with "leave on" policy, due to becoming used to seeing it all the time. Might even be aircraft on the runway.
- Configuration must dictate same action all the time.
- It's a distraction. Don't like two bar systems.
- Turn off if LAHSO is not in effect.
- Too strong a hold-short indication to be left on if H/S not required.
- You're going to try to hold short with the red bar there, no matter what the clearance.
- "We don't cross red lights"—this would seem to be in opposition to that.

Landing Question 3—Data Analysis

DO YOU FEEL THAT THIS CONFIGURATION CAN REMAIN DISPLAYED EVEN WHEN FULL RUNWAY LENGTH IS AVAILABLE FOR LANDING AND ROLLOUT?

Although none of the five lighting configurations received a majority of Yes responses, the configurations having only pulsing or flashing lights (configurations 2 and 4) had the most nearly

even (42%:58% and 33%:67% respectively, 5:7 and 4:8 respectively) division of Yes/No votes. The two configurations displaying both white and red lights (configurations 5 and 6) and the red steady-burning array (configuration 3) were judged to be virtually unsuitable for such operational use.

In general, however, the subjects felt strongly that it would be most undesirable to have any hold-short lights displayed while full runway length landing clearances are being issued. Besides being a distraction, comments indicated that uniqueness would be lost by allowing passage over hold-short lights. Several pilots compared these lights to "stop-bar" lights, and indicated that they should always mean the same thing: "hold short at this point." Several comments indicated that white lights would be more appropriate if the system would not be turned off for full-length landings and stressed the fact that red lights are normally associated with an end-of-runway situation. The feeling seemed to be that red is the best color for a display to be used only for hold-short landings but certainly not a suitable choice for unrestricted landing situations. The flashing-red configuration seemed to be preferred, at least by inference from comments, over the steady-burning red array since it was less like the end-of-runway lights.

The multicolor configurations were noted as being very distinctive and unique but perhaps also promoting confusion as to the exact location of the hold-short point. Several pilots thought it was overkill and a somewhat unnecessarily busy signal, especially when the red-flashing elevated side lights were added (configuration 6) to the dual-color array. Comments on these configurations expressed a significant aversion to rolling over any red lights.

Landing Question 4—Data Summary

AT WHAT POINT DURING YOUR APPROACH/LANDING OPERATION DID YOU FIRST ACQUIRE AND IDENTIFY THE LAHSO LIGHTS?

Note: No comments were received in connection with this question.

Configuration 1:

Long Final: 1 Short Final: 2 Threshold: 1 Touchdown: 8

Configuration 2:

Long Final: 11 Short Final: 1 Threshold: 0 Touchdown: 0

Configuration 3:

Long Final: 10 Short Final: 2 Threshold: 0 Touchdown: 0

Configuration 4:

Long Final: 5 Short Final: 7 Threshold: 0 Touchdown: 0

Configuration 5:

Long Final: 10 Short Final: 2 Threshold: 0 Touchdown: 0

Configuration 6:

Long Final: 11 Short Final: 1 Threshold: 0 Touchdown: 0

Landing Question 4—Data Analysis

AT WHAT POINT DURING YOUR APPROACH/LANDING OPERATION DID YOU FIRST ACQUIRE AND IDENTIFY THE LAHSO LIGHTS?

Subjects were asked to estimate the point, during the approach and landing maneuver, at which they first acquired and identified the hold-short lights. In addition, the cockpit project observer also noted, during each approach, the distance measuring equipment (DME) distance at which the subject vocally indicated that he saw the lights.

With the exception of the "signs and marking only" configuration (1), subject pilots estimated their acquisition and identification point as either long final or short final for all configurations. Estimates for configurations 2, 3, 5, and 6 were predominantly long final, while those for configuration 4 (flashing-red bar) were predominantly short final.

Estimates of the acquisition/identification distance for configuration 1 included 9 out of 12 at or after threshold.

Recorded verbal calls of lights provided average acquisition/identification DME-to-threshold distances of:

Configuration 1—Data not obtained due to no lights.
Configuration 2—3.0 Nautical Miles
Configuration 3—3.4 Nautical Miles
Configuration 4—2.6 Nautical Miles
Configuration 5—3.5 Nautical Miles
Configuration 6—3.6 Nautical Miles

These two sets of results (estimates and recorded DME) appear to be mutually supporting and indicate that subjects had no trouble acquiring and identifying any of the hold-short lighting systems.

Landing Question 5—Data Summary

WAS THE ACQUISITION DISTANCE ADEQUATE TO PERMIT YOU TO USE THE INFORMATION?

Configuration 1:

Yes: 8 No: 4

Comments-

- (Yes) Except when you really need the information (on R/W), it disappears.
- Would like more than signs.
- For first encounter, only marginal.
- Information not in time to adjust approach and landing.
- (Yes) but marginal.
- (Yes) but need more.
- Too late.
- Nothing to judge by.
- I'm using intersecting runway lights.
- Signs acquired only because I'm aware of the H/S operation.

Configuration 2:

Yes: 12 No: 0

(No comments were received for this configuration.)

Configuration 3:

Yes: 12 No: 0

(No comments were received for this configuration.)

Configuration 4:

Yes: 11 No: 1

- Not Really.

Configuration 5:

Yes: 12 No: 0

(No comments were received for this configuration.)

Configuration 6:

Yes: 12 No: 0

(No comments were received for this configuration.)

Landing Question 5—Data Analysis

WAS THE ACQUISITION DISTANCE ADEQUATE TO PERMIT YOU TO USE THE INFORMATION?

Subject pilots were asked to indicate by Yes or No answers whether the acquisition and identification range provided by each configuration allowed sufficient time for them to use the location information in setting up their landing.

Subjects were unanimous 100% (12:0) in stating that the range of configurations 2, 3, 5, and 6 was sufficient for use. Configuration 4 (flashing-red lights) was judged only slightly less favorably 92%:8% (11:1), while the signs and marking only configuration (1) was only marginally acceptable 67%:33% (8:4) in visual acquisition/identification range.

These results are completely in accord with the results of the previous question and support the conclusion that pilots feel the need to acquire and identify the hold-short lighting configuration at least during the short final portion of the approach.

Landing Question 6—Data Summary

COULD THE HOLD-SHORT LIGHTS POSSIBLY BE CONFUSED WITH ANY OTHER EXISTING LIGHTING SYSTEMS ON THE AIRPORT?

Configuration 1:

Note: This question was not included on the configuration 1 questionnaire since no LAHSO lighting configuration was displayed (basic signs and markings only).

Configuration 2:

Yes: 2 No: 10

Comments-

- Blinking light might be confused with vehicle on the runway.
- White lights could be interpreted as edge lights of other (intersecting) runway—a good feature.
- Flashing (lights) could be confused with strobes, REILs, etc.

Configuration 3:

Yes: 10 No: 2

Comments-

- Only on long final, they tend to blend in with other lights.
- With red end-of-runway lights.
- Possible confusion with amber last 2,000′ edge lights and end-of-runway red lights.
- Red could be either hold-short or end of runway.
- Being steady (burning), initially might be mistaken for end-of-runway lights. When close, more distinguishable.
- End-of-runway lights. (five subjects)
- Could possibly confuse with end-of-runway lights if unfamiliar with airport. Additional airport reference (?) would clear this up.

Configuration 4:

Yes: 5 No: 7

Comments-

- So dim and similar to construction lights.
- End-of-runway lights. (two subjects)
- Could be emergency or other vehicle.
- (No) Since they flash.
- With flashing mode, should not be confused with end-of-runway lights. However not as prominent.
- (Yes) but not as much as steady burning.

Configuration 5:

Yes: 7 No: 5

Comments-

- Red end-of-runway lights. Possibly use alternating colors (red/white, red/yellow, etc.).

- Red LAHSO lights look like end-of-runway lights until close in. On approach, taxi-speed bar lights could be thought of as LAHSO (location) lights.

- Without red flashing, easier to mistake for end-of-runway lights.

- Steady reds could be confused with end-of-runway lights.

- Red for end-of-runway lights. Two rows (bars) confusing.

- Red lights acquired first, could then be confused with end-of-runway lights. White lights (acquired) later identified as hold-short lights.

- They mean the same thing as the end of runway (lights).

Configuration 6:

Yes: 3 No: 9

Comments-

- Might overpower, but not confuse.

- End-of-runway lights. (two subjects)

- Red LAHSO lights appear brighter and sooner than end of runway (lights), and thus might be mistaken for end-of-runway lights.

Landing Question 6—Data Analysis

COULD THE HOLD-SHORT LIGHTS POSSIBLY BE CONFUSED WITH ANY OTHER EXISTING LIGHTING SYSTEM ON THE AIRPORT?

The pulsing-white light configuration (2) and the combined pulsing white and steady-burning red with elevated flashing-red light configuration (6) were judged to be least likely to be confused with other airport lighting systems. Both configurations received favorable ratios of No to Yes votes (83%:17% and 75%:25%, 10:2 and 9:3 respectively) showing that pilots felt the possibility of confusion to be low. The red flashing light configuration 4 also received a relatively favorable response with more "no confusion" answers than "yes" (58%:42%, 7:5).

More difficult to understand is the fact that the other white/red configuration (5), which differs from configuration 6 only in not having additional red elevated flashing lights, was not judged nearly so favorably by the subjects. It would appear that the supplementary flashing-red lights add considerably more to the display than one would expect. In fact, one subject mentioned that configuration 6 could possibly be mistaken for runway end lights were it not for the red flashing lights. This is the only difference between configurations 5 and 6.

Subjects were much less favorably inclined toward the steady-burning red configuration (3), with a ratio of (83%) 10 Yes to (17%) 2 No confusion answers. The comments received very clearly indicated that the pilots were concerned with possibility that the lights could easily be mistaken for the red end-of-runway lights.

Takeoff Question 1—Data Summary

DID YOU EXPERIENCE ANY CONFUSION OR BECOME CONCERNED WHEN UNEXPECTEDLY ENCOUNTERING A DISPLAYED LAHSO LIGHTING CONFIGURATION DURING THE TAKEOFF ROLL?

Configuration 1:

Note: Since no LAHSO lighting was displayed (basic signs and markings only), no takeoff scenarios were conducted with configuration 1.

Configuration 2:

Yes: 4 No: 8

Comments-

- (No) But in real world I might experience some concern.
- (Yes, because of) unexplained flashing light across my active runway.
- Blinking lights could be something on the runway.
- Lights suddenly appearing did cause a distraction.
- Confusion as to why the lights came on during takeoff roll.
- (No) But I don't like it.
- No concern with lights. Didn't bother me.

Configuration 3:

Yes: 7 No: 5

Comments-

- Because it was red and looked like the end of the runway.
- Confusion with red lights across my runway, other than end of runway (i.e., two sets of end-of-runway lights).
- As takeoff roll started, red lights suddenly appeared across my runway and caused concern. Almost aborted takeoff.

- Those red lights are terrible. If tower displays red lights, you would think that an abort is necessary. Another point for white lights.

- I expected lights, with (H/S) clearance for other aircraft. Still don't like taking off through red lights.

- Both confused and concerned.

- Did not expect LAHSO lights to intrude into my visual picture.

- Required too much concentration to conclude that LAHSO lights were not end-of-runway lights.

- (No) but the landing clearance mention of landing traffic did prompt concern—not the lights.

- (No) except late in the takeoff roll, concentrating on hold-short lights rather than the end-of-runway lights.

Configuration 4:

Yes: 4 No: 7

Comments-

- Flashing-red lights across runway create confusion. Typically they indicate construction areas.

- (No) However, it is a distraction that should be avoided.

- Couldn't determine, at first, purpose of lights.

- Thought the lights were white, not red. Confused me.

- Flashing lights, a lot going on, can distract crew during takeoff.

Configuration 5:

Yes: 4 No: 8

Comments-

- My impression was that the red lights were runway end, especially appearing past white lights. This configuration more disconcerting than previous others.

- Initial red, followed by immediately sighting white, identified system right away.

- (Yes) because I expect a clear runway on takeoff roll.
- Combination of landing aircraft clearance heard and hold-short lights prompted inclination to abort. Too much diversion of attention during takeoff.
- Flashing lights, in this case before any landing clearance heard, caused concern.
- I knew what it was from past experience (previous runs in the simulator).

Configuration 6:

Yes: 4 No: 8

Comments-

- (No) but because of repetitive simulator situations. Might be concerned with isolated real-world takeoffs.
- I knew what it was. System nice, but perhaps overkill.
- I'm getting used to LAHSO lights. (After 2 hours doing LAHSO evaluations)
- Momentary hesitation over possibility that red lights are end-of-runway lights (slight distraction).
- (No) but concerned about landing clearance.
- White bar glaring. It's a distraction you don't need.
- Flashing lights more disconcerting than steady burning and thus more likely to induce concern.
- For a second, thought it was end-of-runway lights.

Takeoff Question 1—Data Analysis

DID YOU EXPERIENCE ANY CONFUSION OR BECOME CONCERNED WHEN UNEXPECTEDLY ENCOUNTERING A DISPLAYED LAHSO LIGHTING CONFIGURATION DURING THE TAKEOFF ROLL?

Note: The lights were activated when the subject pilot's takeoff speed reached approximately 40 knots. At about the same time, a simulated hold-short landing clearance was issued to an imaginary aircraft on long final for the same runway. The clearance mentioned, as traffic, another aircraft about to land on or depart the intersecting runway.

Yes or No results for all lighting configurations except that using steady-burning red lights only (configuration 3) were virtually identical, with No answers outnumbering the Yes answers by a 2:1 ratio (8:4). For configuration 3, the ratio of No to Yes answers was 5:7.

Configurations 2, 5, and 6	No = 67%, Yes = 33%
Configuration 4	No = 58%. Yes = 33%, one abort with no answer
Configuration 3	No = 42%, Yes = 58%

The majority of comments voiced by the subject pilots mentioned a distraction or uncertainty caused by sudden appearance of the lights. Many indicated that the period during the takeoff roll was no time to introduce changes to the visual scene; i.e., they wanted a clear takeoff runway. Some stated that seeing any array with red lights in it might lead a pilot to abort the takeoff.

Six instances of aborted takeoffs were encountered; four with configuration 4, and one with each of configurations 5 and 6. In each instance, however, the subjects stated immediately that the aborts were prompted by hearing the hold-short landing clearance for an aircraft on final rather than by suddenly seeing the LAHSO lights. The hold-short clearance mentioned traffic about to depart or land on the intersecting runway.

Takeoff Question 2—Data Summary

IN YOUR OPINION, WOULD IT BE ACCEPTABLE FOR ATC TO INTENTIONALLY LEAVE THE LAHSO LIGHTING CONFIGURATION DISPLAYED WHILE CLEARING AIRCRAFT FOR TAKEOFF?

Configuration 1:

Note: Since no LAHSO lighting was displayed (basic signs and markings only), no takeoff scenarios were conducted with configuration 1.

Configuration 2:

Yes: 5 No: 7

Comments-

- (Yes) maybe, and provided some information as to this situation is given (Automatic Terminal Information Service (ATIS), etc.)
- Creating confusion.
- Need lots of training. Lights on only for LAHSO landings. Must be turned off for takeoffs and non-LAHSO landings.
- (Yes) because the LAHSO doesn't apply to me (taking off).

- Configuration should agree with the clearance.
- I had no confusion.
- (Yes) if so stated by the tower. Not acceptable if runway hump masks the end-of-runway lights.

Configuration 3:

Yes: 1 No: 11

Comments-

- (Yes) because it was red and looks like the end of the runway.
- Possible confusion.
- (No) most definitely.
- Question arises as to how much runway really remains for rejected takeoff. Don't want white either, but doesn't cause as much confusion.
- Still believe it should be off to avoid distraction.
- (No) absolutely.
- (Yes) but don't turn on during takeoff roll.
- Possible confusion with end-of-runway lights.
- Might prompt rejected takeoff unnecessarily.

Configuration 4:

Yes: 5 No: 6

Comments-

- (No) predicated on my not being told to ignore them.
- Red lights = don't go. Also, red lights mimic end-of-runway red lights.
- (Yes) but only if ATIS contains hold-short mention.
- (Yes) but only minimally.

Configuration 5:

Yes: 3 No: 9

Comments-

- Confusion with other lights, i.e., end of runway.
- (No) because I expect a clear runway on takeoff roll.
- Don't like the idea.
- (No) Absolutely.
- Still think it's a distraction.
- Too much diversion of attention during takeoff.
- (Yes) if hold-short operations noted on ATIS.
- Confusion about where end of runway is and possible abort or over rotation.

Configuration 6:

Yes: 3 No: 9

Comments-

- Additionally, would prove distracting during abort for other reasons.
- Not without training. Once I know what it means it doesn't bother me.
- I want a clear runway.
- I would prefer not.
- Lights should mandate an (identical) action every time.
- Might be confused, in the real world, to see these hold-short lights.
- Too much confusion and distraction. Might confuse with end-of-runway lights.
- I don't like looking at that for takeoff. Takeoff the most critical maneuver. Pilot must be in confident Go or No-Go mode.

Takeoff Question 2—Data Analysis

IN YOUR OPINION, WOULD IT BE ACCEPTABLE FOR ATC TO LEAVE THE LAHSO LIGHTING CONFIGURATION DISPLAYED WHILE CLEARING AIRCRAFT FOR TAKEOFF?

Here again, subject pilot opinion strongly suggests that hold-short lighting configurations, regardless of color or characteristics, should not be displayed while pilots are executing any maneuver other than the basic hold-short approach and landing. In fact, the results of this question concerning the takeoff situation parallel almost exactly the results of landing question 3, which concerned the approach landing situation.

Subjects were almost unanimously 92%:8% (11:1) opposed to displaying the steady-burning red configuration 3 at any time during takeoffs. They cited distraction and possible confusion with the red end-of-runway lights, resulting in aborted takeoffs, as the principle reason for rejecting the concept of leaving the LAHSO lights on. Several subjects stated that white lights might be more acceptable, as they should cause less confusion.

Opposition to other configurations was somewhat less vehement but still mostly negative. Opinion on the display of the flashing-red configuration (4) was almost evenly divided 42%:50% (5:6), while display of the pulsing-white only lighting configuration (2) was only somewhat less favorably considered with a Yes/No ratio of 42%:58%, 5:7. The remaining two pulsing-red/steady-white configurations (5 and 6) were rejected even more strongly with identical Yes/No ratios of 25%:75%, 3:9.

Several subjects also commented that the display of LAHSO lights during takeoffs might be less objectionable if controllers (ATC) specifically mentioned why the lights were being turned on (i.e., for subsequent landings) and/or if mention of LAHSO was included in the ATIS provided to departing pilots. Each pilot qualified this, however, with a statement to the effect that they still did not like the procedure.

A number of subject pilots stressed that, regardless of the configuration selected as standard or the mode of operation adopted, the issue of training and dissemination of LAHSO procedures is paramount.

Takeoff Question 3—Data Summary

AT WHAT POINT DURING THE TAKEOFF ROLL DID YOU NOTICE THE LAHSO LIGHTS?

Note: No comments were solicited or received in connection with this question.

Configuration 1:

Note: Since no LAHSO lighting was displayed (basic signs and markings only), no takeoff scenarios were conducted with configuration 1.

Configuration 2:

- Beginning: 6 Halfway: 6 At the End: 0

Configuration 3:

- Beginning: 8 Halfway: 4 At the End: 0

Configuration 4:

- Beginning: 7 Halfway: 4 At the End: 0

Configuration 5:

- Beginning: 9 Halfway: 3 At the End: 0

Configuration 6:

- Beginning: 10 Halfway: 2 At the End: 0

Takeoff Question 3—Data Analysis

AT WHAT POINT IN THE TAKEOFF ROLL DID YOU NOTICE THE LAHSO LIGHTS?

Responses showed that virtually all of the subject pilots noticed the lights just as soon as they were illuminated, with opinion split as to whether it happened at the beginning or at the middle of the takeoff roll. In fact, most of the pilots used the term "end of the beginning" as their judgment of the distance involved, and their choice of beginning/halfway blocks to be checked appears to be inconsequential. The significant result is that none of the subjects checked "at the end" for the point of acquisition, indicating that the lights were prominent and very noticeable.

OBJECTIVE DATA RESULTS—AIRCRAFT (PILOT) PERFORMANCE.

From the data recorded it was possible to extract and to subsequently calculate the following values for each approach:

1. Distance from the touchdown point to the hold-short point.
2. Distance from the hold-short point when 25 knots achieved.
3. Velocity (Speed) of aircraft at touchdown.
4. Rate of deceleration from touchdown point to 25-knot speed point.

Detailed data is provided, sorted according to scenario and pilot number, in table 2 on page 42. Only data collected on approaches for which a hold-short landing clearance had been given to the subject pilot is included here in the body of the report. Average distances for values 1 and 2 above were calculated and are presented below.

SUMMARY AND ANALYSIS OF RECORDED DATA.

TOUCHDOWN/HOLD-SHORT POINT DISTANCE—DATA SUMMARY. The following data averages are for distance from the touchdown point to the hold-short point. They are sorted by scenario and lighting configuration.

Lighting Configuration	Scenario Number	Average Distance (ft.)	Configuration Average (ft.)
Markings and Signs Only	01	3667	
	02	3567	
	03	3575	
	All		3603
FAA Proposal	04	3567	
	05	3500	
	06	3756	
	07	3456	
	08	3867	
	09	4067	
	All		3702
VAP Proposal	11	3456	
	12	3650	
	13	3810	
	14	3320	
	15	3770	
	16	3820	
	All		3638
VAP Proposal (Modified)	18	3620	
	19	3210	
	All		3415
IFALPA Proposal Number 1	21	3590	
	22	3590	
	23	3860	
	24	3300	
	25	3800	
	26	3920	
	All		3678
IFALPA Proposal Number 2	28	3890	
	29	3370	
	All		3630

TOUCHDOWN/HOLD-SHORT POINT DISTANCE—DATA ANALYSIS. Configurations are ranked in order of decreasing distances as follows:

1. FAA Proposal 3,702 feet
2. IFALPA No. 1 Proposal 3,678 feet
3. VAP Proposal 3,638 feet
4. IFALPA No. 2 Proposal 3,630 feet
5. Signs and Markings Only 3,603 feet
6. Modified VAP Proposal 3,415 feet (3,566 if corrected)

There is only a variation of plus or minus 50 feet among the first five configurations, which has little to no significance from the pilot performance aspect. If one single very questionable data point for scenario 19 (a Modified VAP Proposal configuration approach) is eliminated, it would change the distance average from 3,415 feet to 3,566 feet as indicated in parentheses above. It still would not, however, change the order of ranking.

25-KNOT/HOLD-SHORT POINT DISTANCE—DATA SUMMARY. The following averages are for distance from the 25-knot point to the hold-short point. They are sorted by scenario and lighting configuration.

Lighting Configuration	Scenario Number	Average Distance (ft.)	Configuration Average (ft.)
Markings and Signs Only	01	729	
	02	686	
	03	433	
	All		616
FAA Proposal	04	633	
	05	420	
	06	800	
	07	967	
	08	650	
	09	878	
	All		725
VAP Proposal	11	360	
	12	429	
	13	814	
	14	580	
	15	637	
	16	760	
	All		597

Lighting Configuration	Scenario Number	Average Distance (ft.)	Configuration Average (ft.)
VAP Proposal (Modified)	18	500	
	19	780	
	All		640
IFALPA Proposal Number 1	21	500	
	22	533	
	23	725	
	24	833	
	25	614	
	26	300	
	All		584
IFALPA Proposal Number 2	28	820	
	29	640	
	All		730

25-KNOT/HOLD-SHORT POINT DISTANCE—DATA ANALYSIS. Here again with a range of approximately 140′ among the various configurations, there appears to be little significance from the pilot performance aspect. Configurations are once more ranked in order of decreasing distances as follows:

1. IFALPA No. 2 Proposal 730 feet
2. FAA Proposal 725 feet
3. Modified VAP Proposal 640 feet
4. Signs and Markings Only 616 feet
5. VAP Proposal 597 feet
6. IFALPA No. 1 Proposal 584 feet

TOUCHDOWN VELOCITY—DATA SUMMARY. The following averages are speeds (velocities) at the moment of touchdown. They are sorted by scenario and lighting configuration. Due to problems with data extraction, only touchdown speeds for the following scenario approaches were recoverable.

Lighting Configuration	Scenario Number	Average T/D Speed (kts)
Standard Signs and Markings	02	Not Received
	03	Not Received
FAA Proposal	08	143
	09	140

Lighting Configuration	Scenario Number	Average T/D Speed (kts)
VAP Proposal	15	141
	16	142
VAP Proposal (Modified)	19	141
IFALPA Proposal Number 1	25	142
IFALPA Proposal Number 2	29	141

It should be noted that, while the averages shown above are very close in value (140-143 knots), individual touchdown speeds as recorded by scenario approach varied from 130 to 151 knots.

TOUCHDOWN VELOCITY—DATA ANALYSIS. As mentioned earlier, the touchdown speeds, averaged for each lighting configuration scenario set, are very close in value (140-143 knots) independent of the lighting configuration displayed, indicating that the LAHSO lighting configuration had very little affect upon pilot performance. It should also be noted that speeds within a scenario set showed a much wider variation, as is revealed by a detailed breakdown of speeds attained by various pilots for scenario 16 (Modified VAP Proposal):

Pilot	Touchdown Speed	
1	136	
2	130	(Lowest)
3	136	
5	146	
6	147	
7	147	
8	151	(Highest)
9	139	
11	145	
12	145	

AIRCRAFT DECELERATION RATE—DATA SUMMARY. Individual scenario data is provided in table 2.

TABLE 2. DECELERATION RATE OF AIRCRAFT

Touchdown to IAS of 25 Knots				
	Test Number	IAS Difference	Time Difference	Knots Per Second
Scenario 08	20008	106.6	24.5	4.35
	30008	110.8	20.0	5.54
	50008	119.8	26.0	4.61
	60008	122.3	21.5	5.69
	70008	119.8	21.0	5.70
	80008	125.4	22.5	5.57
	90008	117.0	44.0	2.66
	110008	118.6	19.5	6.08
	120008	120.0	22.0	5.45
			Average:	5.07
Scenario 09	10009	108.1	19.5	5.54
	20009	104.5	19.5	5.36
	30009	111.1	22.0	5.05
	50009	121.6	24.5	4.96
	70009	117.3	21.0	5.59
	80009	119.4	23.5	5.08
	90009	119.1	29.0	4.11
	110009	117.4	20.0	5.87
	120009	118.1	25.0	4.72
			Average:	5.14
Scenario 15	10015	110.2	20.5	5.38
	20015	107.7	25.0	4.31
	30015	109.2	21.0	5.20
	50015	119.3	21.0	5.68
	60015	121.5	21.0	5.79
	70015	119.0	21.0	5.66
	80015	119.5	29.0	4.12
	90015	114.7	26.5	4.33
	110015	119.5	20.0	5.98
	120015	119.7	21.0	5.70
			Average:	5.22
Scenario 16	10016	110.7	20.0	5.54
	20016	105.3	19.0	5.54
	30016	110.8	20.5	5.40
	50016	121.1	25.5	4.75
	60016	122.1	20.5	5.96
	70016	121.5	22.0	5.52
	80016	126.3	25.5	4.95
	90016	113.9	26.0	4.38
	110016	119.9	19.5	6.15
	120016	119.4	23.5	5.08
			Average:	5.32

TABLE 2. DECELERATION RATE OF AIRCRAFT (Continued)

Touchdown to IAS of 25 Knots				
	Test Number	IAS Difference	Time Difference	Knots Per Second
Scenario 19	10019	110.5	28.5	3.88
	20019	103.7	19.0	5.46
	30019	114.1	20.0	5.71
	50019	118.9	26.5	4.49
	60019	121.7	22.0	5.53
	70019	117.4	22.0	5.34
	80019	118.3	19.5	6.07
	90019	112.2	22.0	5.10
	110019	119.2	19.5	6.11
			Average:	5.29
Scenario 23	10023	107.7	20.0	5.89
	20023	108.4	26.5	4.09
	30023	107.7	18.5	5.82
	50023	119.9	19.0	6.31
	60023	121.8	21.0	5.80
	70023	120.7	20.5	5.89
	90023	117.8	25.0	4.71
	110023	115.2	18.5	6.22
	120023	117.4	23.5	4.99
			Average:	5.52
Scenario 25	10025	106.6	19.5	5.58
	20025	107.8	24.5	4.40
	30025	111.8	20.0	5.59
	50025	118.5	18.5	6.30
	60025	120.0	21.0	5.71
	70025	120.9	20.0	6.04
	80025	126.9	27.0	4.70
	90025	119.0	27.0	4.40
	110025	118.7	21.0	5.65
	120025	117.2	21.0	5.58
			Average:	5.40
Scenario 29	10029	108.8	19.5	6.22
	20029	109.9	24.5	4.49
	30029	110.4	21.5	5.13
	50029	116.7	16.5	6.42
	70029	119.1	19.5	6.11
	80029	120.1	33.5	3.59
	90029	119.3	24.0	4.97
	110029	116.6	20.0	5.93
	120029	120.4	25.5	4.72
			Average:	5.28

OBJECTIVE DATA ANALYSIS CONSIDERATIONS.

Analyzing the collected data to determine the relative effectiveness of the proposed LAHSO lighting configurations presents somewhat of a problem. All of the data reflects pilot performance and the manner in which he executed the approach, landing, and rollout maneuver. Assuming that all other factors remain constant, the characteristics of each individual lighting configuration should influence the efficiency with which the pilot brings the aircraft to a stop, or fails to stop, at the required location. This is to say that the most effective array should allow for a nearly uniform deceleration to a smooth stop at or before the hold-short point. Visual guidance provided by an inadequate array could, conversely, result in a less uniform deceleration and, in the extreme case, a violation of the runway area supposedly protected by the hold-short system.

Unfortunately, all of the other factors do not remain constant. Pilot techniques, such as selection of a desired approach speed, adherence to the desired (PAPI projected) approach path, and execution of the final flare for landing, will dramatically affect the control inputs (braking action, spoiler deployment, reverse thrust application, etc.) used to bring the aircraft to a stop in time. These additional variables are introduced not only due to the individual preference of each pilot, but even as variations in each pilot's performance on consecutive approaches to the same lighting configuration.

As an example, the project member acting as first officer throughout the evaluation observed that approach speeds varied significantly from pilot to pilot. While a speed of Vref + 10 knots (135 + 10 knots) was recommended initially to each subject, based on simulated aircraft weights, some pilots consistently used only Vref (135 knots) while others just as consistently used higher speeds (150+ knots) than that suggested. The resultant higher or lower touchdown velocities must, of course, drastically affect the rollout distances and/or braking action necessary.

Further, and again as observed repeatedly by the right seat project member, the landing techniques used during the last portion (approximately one half mile) of the approach and during the flare varied considerably from pilot to pilot and even between approaches with the same lighting array and pilot.

Some pilots flew the final approach segment somewhat low (3 red/1 white PAPI signal) so as to perform a noticeable "duck under" maneuver prior to touchdown in anticipation of having to stop at the hold-short point. Touching down early, they had little trouble stopping in time. Others crossed the runway threshold on glide path (2 red/2 white PAPI signal), but then flared to extend the touchdown distance considerably, with a resultant loss of runway distance available for rollout before reaching the hold-short point. They, of course, had to apply heavier braking application to stop in time. Occasional high final approaches (1 red/3 white PAPI signal) likewise resulted in heavier braking and longer thrust reversal applications.

While none of the pilot technique variations were so extreme as to prevent stopping the aircraft prior to the hold-short point, with two exceptions, these piloting technique differences may well have affected the data (distances, decelerations, etc.) more than any differences in LAHSO lighting configurations.

CONCLUSIONS

From the results of this simulator evaluation, we can conclude that:

- Pilot opinion supports the use of configurations containing the dual taxi-speed and hold-short light bar combinations if the LAHSO lights are only displayed during land and hold-short landings.

- The configuration containing only white pulsing lights will provide adequate identification of the hold-short point with the least possibility of misinterpretation if the LAHSO lights are to be displayed during full length landings and routine takeoffs in addition to land and hold-short landings.