

Land and Hold Short Operations Lighting Control Study

January 2008

DOT/FAA/AR-TN07/60

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1. Report No. DOT/FAA/AR-TN07/60		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle LAND AND HOLD SHORT OPERATIONS LIGHTING CONTROL STUDY				5. Report Date January 2008	
				6. Performing Organization Code	
7. Author(s) Renee N. Frierson, Donald W. Gallagher, and Nelson Brown*				8. Performing Organization Report No.	
9. Performing Organization Name and Address Federal Aviation Administration William J. Hughes Technical Center Airport and Aircraft Safety Research and Development Division Airport Technology Research and Development Branch Atlantic City International Airport, NJ 08405				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591				13. Type of Report and Period Covered Technical Note	
				14. Sponsoring Agency Code AFS-400, AJP-6350	
15. Supplementary Notes Dr. Archie Dillard and Mr. Larry Hackler provided input on requirements for this study.					
16. Abstract The International Civil Aviation Organization (ICAO) has suggested using a continuously illuminated bar of red in-pavement lights at Land and Hold Short Operations (LAHSO) locations; however, the United States currently uses a pulsing bar of white in-pavement lights. Since a bar of red lights usually means a go-no-further signal to a subject pilot, the ICAO suggested system would need to be automated to indicate between LAHSO and non-LAHSO operations. The purpose of this effort was to determine the critical flight situations, from the subject pilots viewpoint, under which the LAHSO red light bar must be on and off during high-capacity operations at an airport. The objectives of the evaluation were to (1) determine the appropriate clearance distance, 1 nautical mile (nm) versus 2 nm, under which the LAHSO red light bar should be turned on and off; (2) determine if there were any differences in the landing distance when clearance to land was given at 1 or 2 nm; (3) determine the subject pilot's reaction under malfunction(s) of the LAHSO red light bar; and (4) determine if subject pilots considered the LAHSO red light bar to be an effective visual presentation for communicating a go-no-further boundary. The evaluation was conducted at the Federal Aviation Administration Mike Monroney Aeronautical Center using the Boeing 737-800 simulator. Twenty-five subject pilots that were rated in a B-737-800 aircraft and familiar with the simulator participated in the study. Each subject pilot was presented with ten different scenarios alternating between LAHSO and non-LAHSO clearances, with eight reflecting normal operations and two reflecting malfunctions deviant from normal operations. Malfunction scenarios were added to test any potential mishaps that may be encountered with an automated system. All test scenarios were conducted in visual flight rule conditions during dusk and night. The entire setup and testing of the system took approximately a year and a half to complete. The results indicated that 44% of the subject pilots expressed concern about not receiving clearance during 1-nm clearance scenarios with a possible conflicting state of the LAHSO red light bar. All subject pilots were comfortable with the 2-nm clearance scenarios regardless of the state of the LAHSO red light bar. There were no significant differences between 1- versus 2-nm clearance and landing distances. Regarding the malfunction scenarios, all subject pilots viewed the illumination of the automated LAHSO red light bar and considered the change of state as a change of clearance from non-LAHSO to LAHSO. When the LAHSO red light bar was off, all subject pilots maintained that they were still under a LAHSO clearance and were able to come to a complete stop prior to the hold short line. All subject pilots considered the LAHSO red light bar to be effective, with 72% rating it as very effective.					
17. Key Words Land, Hold short, Lights, Operations			18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 36	22. Price

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LIST OF ACRONYMS

ATC	Air Traffic Control
BOS	Boston Logan International Airport
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
LAHSO	Land and Hold Short Operations
nm	Nautical miles
R&D	Research and Development
U.S.	United States
VFR	Visual Flight Rule

EXECUTIVE SUMMARY

The purpose of this study was to determine the critical flight situations, from the viewpoint of the subject pilot, under which Land and Hold Short Operations (LAHSO) red light bar must be illuminated and extinguished during high-capacity operations at an airport.

Development of the Federal Aviation Administration (FAA) LAHSO location identifier was conducted in 1991 at the FAA William J. Hughes Technical Center. The LAHSO system consists of a pulsing transverse line of in-pavement white lights that remain on at all times. It serves to identify the point on the landing runway where the aircraft must stop if the subject pilot accepts a land and hold short landing clearance issued by the air traffic controllers. Although red lights are the standard visual cue for identifying the end of the usable runway, white lights were chosen to alleviate the necessity for the air traffic controllers to turn these lights on and off for each landing operation.

The objectives were to determine (1) the appropriate clearance distance, 1 versus 2 nautical miles (nm) at which the LAHSO red light bar should be turned on or off; (2) if there were any differences in the landing distance when clearance to land was given at 1 or 2 nm, (3) the subject pilot's reaction under malfunction(s) of the LAHSO red light bar; and (4) if the subject pilots considered the LAHSO red light bar to be an effective visual presentation communicating a go-no-further boundary.

This study was limited to the subject pilot's evaluation of the LAHSO red light bar. The development of an automated control system to control these lights was not within the scope of this study.

The study was conducted at the FAA Mike Monroney Aeronautical Center using the Boeing 737-800 simulator. Twenty-five subject pilots who were rated in a B-737-800 aircraft and familiar with the simulator participated in the study. Each subject pilot was presented with ten different scenarios, alternating between LAHSO and non-LAHSO clearances, with eight reflecting normal operations and two reflecting malfunctions deviant from normal operations. Malfunction scenarios were added to test any potential mishaps that may be encountered with an automated system. All test scenarios were conducted in visual flight rule conditions during dusk and night. The entire setup and testing of the system took approximately a year and a half to complete.

The results indicated that 44% of the subject pilots expressed concern about not receiving clearance during 1-nm clearance scenarios with a possible conflicting state of the LAHSO red light bar. All subject pilots were comfortable with the 2-nm clearance scenarios regardless of the state of the LAHSO red light bar. There were no significant correlations between the 1- and 2-nm clearance and landing distances. Regarding the malfunction scenarios, all subject pilots viewed the illumination of the automated LAHSO lights and considered the change of state as a change of clearance from non-LAHSO to LAHSO. When the LAHSO lights were off, all subject pilots maintained that they were still under a LAHSO clearance and were capable of coming to a complete stop prior to the hold short line. All subject pilots considered the LAHSO red light bar to be effective, with 72% rating the LAHSO red light bar as very effective.

INTRODUCTION

PURPOSE.

The purpose of this study was to determine the critical flight situations, from the subject pilot's viewpoint, under which a Land and Hold Short Operation (LAHSO) red light bar must be illuminated and extinguished during high-capacity operations at an airport. This research project was undertaken by the request of the Federal Aviation Administration (FAA) Flight Technologies and Procedures Division, funded through the Terminal Area Safety Research Program.

BACKGROUND.

Development of the Federal Aviation Administration (FAA) LAHSO location identifier was conducted in 1991 at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey. The LAHSO system consists of a pulsing transverse line of in-pavement white lights that remain on at all times. It serves to identify the point on the landing runway where the aircraft must stop if the subject pilot accepts a "land and hold short" clearance issued by air traffic control (ATC). Additional tests were conducted at Boston Logan International Airport (BOS), which culminated in the adoption of the present standard FAA LAHSO visual identifier for use throughout the United States (U.S.).

One of the first concerns that arose in the developmental effort was the use of the color red. Red was initially proposed since it would present a bold, unmistakable indication of a point past which the subject pilot should not continue. It was immediately recognized that this would achieve the desired result of causing the subject pilot to safely halt the aircraft short of possible traffic on the intersecting (non-LAHSO) runway. It became evident, however, that this same go-no-further signal would prevent (ATC) from clearing the same aircraft across the intersecting runway while the LAHSO red light bar was displayed. Subject pilots have a natural disinclination to pass over or through a location with a LAHSO red light bar, as evidenced by the effectiveness of the ATC-controlled Stop Bar systems installed as part of the Surface Movement Guidance and Control System at many major airports in the U.S. and overseas. The use of a LAHSO red light bar is further complicated by a decision that, in the U.S., ATC would not turn on and off the LAHSO for clearance of individual aircraft.

The issue of red versus white lights was addressed during simulator tests of proposed International Civil Aviation Organization LAHSO lighting system configuration changes that were introduced in 1997. The results indicated that red lights would not be appropriate for the current LAHSO lighting system intended for mixed LAHSO operations. For the color red to work, an automatic lighting system would need to be implemented to reduce the problem of having the LAHSO red light bar turned on during non-LAHSO operations. There is some concern, however, over potential hazards associated with an automated system, since such a system has not been built or tested. For example, when is it appropriate to illuminate the LAHSO red light bar when mixed operations are conducted on the same runway? At what point should a subject pilot be able to see the LAHSO red light bar? These and other issues were evaluated during this study.

OBJECTIVES.

The objectives were to determine:

- What subject pilots consider to be the appropriate clearance distance, 1 versus 2 nautical miles (nm), at which the LAHSO red light bar should be turned on or off.
- If there were any correlations between the distances an aircraft landed and distances a clearance was issued.
- Subject pilot reaction under certain malfunction(s) of the LAHSO red light bar, specifically:
 - How subject pilots react to the automated lights illuminating on a non-LAHSO clearance.
 - If subject pilots are willing to cross the LAHSO red light bar, if non-LAHSO clearance is reaffirmed when the automated lights incorrectly illuminate.
 - How subject pilots react to the automated lights extinguishing on the LAHSO clearances.
- If the subject pilots consider the LAHSO red light bar to be an effective visual presentation communicating a go-no-further boundary.

SCOPE.

The scope of this study was limited to subject pilot evaluation of the LAHSO red light bar. Development of an automated control system was not within the scope of this study.

DISCUSSION.

The FAA Airport Safety Technology Research and Development (R&D) Branch undertook this study because recent Aviation Safety Reporting System reports have indicated that the current white pulsing bar used to identify the land and hold short point caused some confusion with subject pilots due to the bar constantly being illuminated during LAHSO and non-LAHSO operations. This effect may be exacerbated by the fact that runways are not perfectly flat. Small rises and dips in the runway may obscure the pulsing lights. In one case, a subject pilot was startled when the LAHSO red light bar suddenly appeared during a takeoff. Subject pilots have also warned that it is dangerous to condition crews to roll through a pulsing LAHSO red light bar, as they would be required to do during a non-LAHSO operation, particularly if there was an urgent requirement to clear the runway.

To address these and other issues, it was decided that a simulation would be necessary to create different scenarios. Starting in February 2005, members from the FAA Airport Safety Technology R&D Branch went to the FAA Mike Monroney Aeronautical Center, Oklahoma

City, Oklahoma, where the Boeing 737-800 simulator is located. During these visits, members from the Airport Safety Technology R&D with support from Hi-Tec Systems (hereby known as the Team) gained insight into the simulators capabilities, talked to key personnel about the study, and developed scenarios for the test.

The FAA Airport Safety Technology R&D Branch provided information to the software engineers in order to develop the test scenarios used throughout the tests. Different features were added to the scenarios such as an in-trail aircraft to give it a real-world experience. Malfunction scenarios were added in order to test any potential mishaps that may be encounter with an automated system. All test scenarios were conducted in visual flight rule (VFR) conditions during dusk and night.

The entire setup and testing of the system took approximately a year and a half to complete, with 3 weeks of actual formal testing. Practice sessions were also held during this time period.

RELATED DOCUMENTATION.

The following documents are related to this study:

- Katz, Eric S., “Simulator Evaluation of Land and Hold-Short Operation (LAHSO) Lighting Configurations,” FAA report DOT/FAA/AR-TN97/86, December 1998.
- Katz, Eric S. and Paprocki, Thomas H., “Prototype Runway Hold-Short Lighting System,” FAA report DOT/FAA/CT-TN91/43, September 1991.
- FAA Order 7110.118, Land and Hold Short Operations, February 2001.

EVALUATION APPROACH

METHOD.

The following is a brief description of the equipment and participants used throughout the study.

- Equipment Description
 - FAA B-737-800 simulator. This simulator meets the performance standard of Title 14 Code of Federal Regulations (CFR) Part 121, Appendix H (Level D), in accordance with FAA Advisory Circular AC 120-40C.
- Evaluation Subjects and Participants
 - Twenty-five B-737-800 certificated subject pilots who were familiar with the operation of the simulator were recruited for this test. Several subject pilots were from various commercial air carrier companies and military branches.

- Members from the FAA Airport Safety Technology R&D Branch (supported by Hi-Tec Systems research personnel) and FAA members from the Flight Operations Simulation and Analysis Branch participated in the evaluation.

Before each test, a preliminary briefing sheet was given to each subject pilot describing the overall test, which included discussing the current LAHSO white light bar and the simulated LAHSO red light bar. In addition, the simulated position and approach configuration information was discussed. A demographic sheet was also given to each subject pilot to gather information about their background including commercial or military experience, type ratings, aircraft flown, total flight hours and hours, specific to the B-737-800. Table 1 shows the subject pilots flight experience. The preliminary briefing sheets can be found in appendix A.

Table 1. Statistics of Subject Pilot Experience

	Mean	Median	Minimum	Maximum
Total Flight Hours	9468	8000	1700	30,000
Specific Flight Hours	2145	650	0	14,000

TEST SCENARIOS.

The scenarios presented to subject pilots simulated approaches into BOS to runway 22L from the runway threshold to the hold short line. There was 6400 ft of available landing distance. There was 1200 ft of remaining distance to the opposing runway 22L threshold past the hold short line. Subject pilots were placed on a 5-nm direct approach alignment to runway 22L. Figure 1 shows a diagram of BOS with runway 22L circled in red.

During the test, the subject pilot was given one of two types of clearances: either LAHSO (they could not pass the hold short line) or non-LAHSO (they had the full length of the runway) to bring the airplane to a safe and controlled stop.

A proceeding simulated aircraft was placed approximately 3 nm on direct approach alignment with runway 22L. This aircraft alternated between LAHSO and non-LAHSO clearances. For instance, if the subject pilot had a LAHSO clearance, the proceeding aircraft would have non-LAHSO clearance.

Ten scenarios were conducted: eight reflected normal operation and two reflected malfunctions that were deviant from normal operations. Four scenarios were conducted as LAHSO, where the LAHSO red light bar illuminated a certain distance prior to reaching runway 22L threshold. Scenarios 1 and 9 set this distance at 1 nm and scenarios 7 and 10 set this distance at 2 nm. All scenarios were conducted in VFR conditions, six were set at night and four set at dusk.

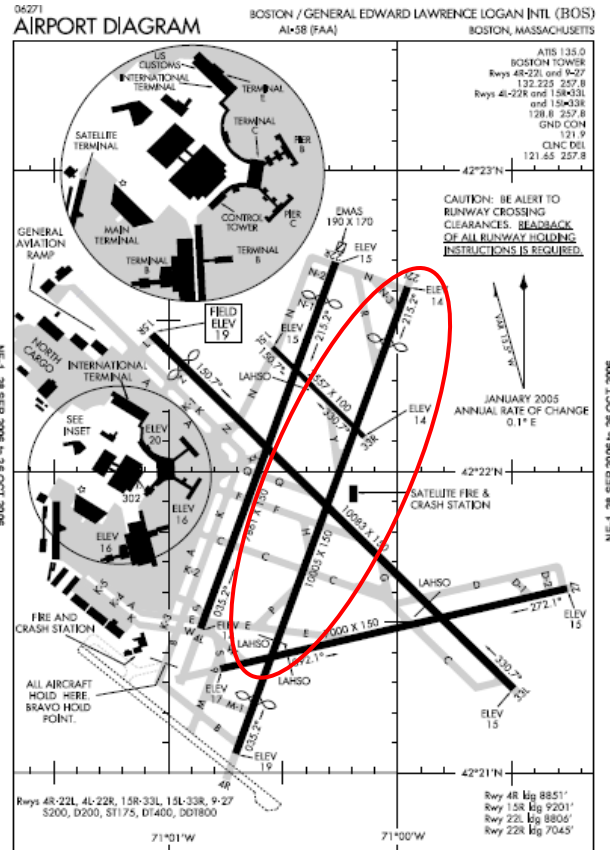


Figure 1. Boston Logan International Airport Diagram

One malfunction (mal) scenario presented to the subject pilots was mal-scenario 11, which presented subject pilots with a LAHSO clearance after the LAHSO red light bar illuminated 1 nm prior to runway threshold. However, after the subject pilot was 0.5 nm past the runway threshold (a distance of approximately 3360 ft before the LAHSO red light bar), the LAHSO red light bar extinguished. Table 2 shows the LAHSO scenarios.

Table 2. Breakdown of LAHSO Clearance Scenarios

Scenario	Description
Scenario 1	Night conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned on.
Scenario 9	Dusk conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned on.
Scenario 7	Night conditions When subject pilot is 2 nm from threshold, LAHSO red light bar turned on.
Scenario 10	Dusk conditions When subject pilot is 2 nautical mile from threshold LAHSO lights turn on.
Mal-scenario 11	Night conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned on. But the LAHSO red light bar also extinguished at 1.5 nm past threshold.

The four other scenarios presented to subject pilots were non-LAHSO clearances. The 1-nm scenarios were named scenarios 4 and 6. The 2-nm scenarios were named scenarios 2 and 5.

In similar fashion to LAHSO clearances, non-LAHSO clearances had an associated malfunction scenario named mal-scenario 12. In this scenario, the LAHSO red light bar extinguished when the subject pilot reached 1 nm prior to runway 22L threshold, and illuminated 1.5 nm after touchdown. Table 3 describes the non-LAHSO scenarios.

Table 3. Breakdown of Non-LAHSO Clearance Scenarios

Scenario	Description
Scenario 2	Dusk conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned off.
Scenario 5	Night conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned off.
Scenario 4	Dusk conditions When subject pilot is 2 nm from threshold, LAHSO red light bar turned off.
Scenario 6	Night conditions When subject pilot is 2 nm from threshold, LAHSO red light bar turned off.
Mal-scenario 12	Night conditions When subject pilot is 1 nm from threshold, LAHSO red light bar turned off. But LAHSO red light bar also illuminated at 1.5 nm past threshold.

If the subject pilot chose to contact tower regarding either malfunction, they were told that the clearance they had initially been given was still in effect. For instance, on mal-scenario 11, the subject pilots who queried tower about the malfunction were told to hold short of the hold short line, even though there was no LAHSO red light bar indicating their position. One main objective of the study was to examine the subject pilot’s reaction of the change of state, and the response after the clearance was reaffirmed.

During the test, data collectors simulated ATC radio traffic using a scripted sequence, provided in appendix A. Engineers monitored each subject pilot’s reaction to visual stimulus by recording general and specific comments that the subject pilot made in reference to the LAHSO red light bar or simulated environment. In addition, a questionnaire and a verbal postbriefing were given to the subject pilots after the test. See appendix A for the questionnaire.

DATA COLLECTION.

SUBJECTIVE RESULTS. This study was a measure of the subject pilot’s reaction to the visual stimulus that was presented to them without creating a true gauge on subject pilot performance, and so, the realism of a typical environment was of key concern. A true performance metric would have to take into account multiple aircraft types, landing configurations, and human stress and reliability factors that lie outside the scope and objective of this study. Subjective data was collected using audio devices in the simulator, as well as postbriefing questionnaires. The subjective results are shown in appendix B.

OBJECTIVE RESULTS. The simulator produced data files from each scenario, as well as distinct timestamps from the beginning to the end of the scenario, which had associated measurements including ground speed, latitude, and longitude.

The objective results are separated into three parts:

- Distribution of stopping distances within each scenario and possible correlations to the timing of (1) when landing clearances were issued and (2) when the LAHSO red light bar transitions from LAHSO to non-LAHSO.
- Subject pilot reaction within mal-scenario 11, where the automated LAHSO red light bar extinguished at an established distance after touchdown from the hold short point.
- Subject pilot reaction within mal-scenario 12, where the automated LAHSO red light bar illuminated at an established distance after touchdown from the hold short point.

In this study, stopping distances were defined as the subject pilot's ability to bring the aircraft to a controlled speed of less than 60 knots (kts) ground speed. The considerations that mandated the adoption of this approach were the unrealistic nature of full stops during the ground roll portion of a landing. This is especially true of non-LAHSO landings, where the taxiways are available for use past the threshold. The objective results are shown in appendix C.

SUMMARY.

SUBJECTIVE RESULTS SUMMARY.

The tests revealed that 11 out of 25 (44%) of the subject pilots requested clearance just prior to the 1-nm mark for 1-nm clearance scenarios. In postbriefings, subject pilots also commented that the 1-nm clearance were too close to the runway to be effective.

There was a dramatic difference between mal-scenario 11 and mal-scenario 12 in the percentage of subject pilots who verbally acknowledged a possible malfunction and hesitated to contact the tower. The word hesitated was defined as a delay greater than 10 seconds from verbal acknowledgement. Even though the percentage of subject pilots who acknowledged a malfunction was the same in both scenarios, (76% acknowledged, 24% failed to acknowledge) the malfunction percentage of those who hesitated to contact is drastically lower in mal-scenario 11 (28%) compared to mal-scenario 12 (48%) as evidenced in tables C-1 and C-2, respectively.

OBJECTIVE RESULTS SUMMARY.

In table C-3, the most significant correlation is that scenarios 9 and 10 are related by similar range. This pair of LAHSO scenarios has opposing 1- and 2-nm distances when a clearance was given, indicating that there was no strong correlation between landing distance of the aircraft and the distance at which the clearance was issued. No distinct conclusion relating 1- and 2-nm clearances can be drawn from the non-LAHSO statistics in table C-4.

LAHSO scenarios 9 and 10 have similar light conditions. Subject pilots generally landed further apart from one another (greater range of stopping distances) in LAHSO scenarios during night conditions than during twilight conditions.

Recall that in mal-scenario 11 subject pilots on a LAHSO clearance landing could no longer observe the LAHSO red light bar because they had extinguished by malfunction 3360 ft prior to the LAHSO red light bar location. Operators allowed for subject pilots to come to a complete stop in most instances, and to a very low taxi speed (<25 kts) in others. A detailed list of end distances and velocities for mal-scenario 11 can be found in C-12.

Table C-5 shows that the mean velocity on mal-scenario 11 was 4 kts with 95% of the data falling within ± 3 kts of the mean. All scenarios that ended within 750 ft of the hold short line were full stop. For this reason, the distance measurements for mal-scenario 11 are reliable performance statistics. Table C-5 shows that the common average distance of 951 ± 181 ft is fairly representative of the subject pilots during this scenario. The minimum, or closest, distance to the hold short line was 87 ft, as shown in table C-12.

All subject pilots had very similar performance-related reactions when compared to each other and to their own LAHSO landings. No subject pilots had exceptional increases in deceleration during their landings. Figure C-1 shows distance versus velocity for all subject pilots under mal-scenario 11.

Recall that in mal-scenario 12, subject pilots on a non-LAHSO landing observed the LAHSO red light bar that had illuminated by malfunction 3360 ft before the LAHSO red light bar location. The reaction to mal-scenario 12 was varied in contrast with mal-scenario 11, in which subject pilots reacted to the absence rather than the presence of an illuminated object.

During postbriefings, all subject pilots who noticed the LAHSO red light bar interpreted the visual cue as a change of clearance from non LAHSO to LAHSO. All subject pilots who noticed the malfunction tried to hold short of the LAHSO red light bar with greater decelerations. However, subject pilots who did not notice the malfunction did not share this reaction.

There were some subject pilots whose regular non-LAHSO and LAHSO landing distances were very comparable. Of these subject pilots, there was a subgroup that had two common traits. The first common trait was that they neither noticed nor mentioned that the malfunction occurred. The second common trait was that the closer the subject pilots came to the LAHSO red light bar, the more noticeable the lights became. For this reason, instead of presenting all curves as done in figure C-1 for mal-scenario 11, the mal-scenario 12 distances versus velocity graphs are divided into four different subsets of subject pilots based on end distances from the LAHSO red light bar. The data from these four subsets are presented in figures C-1 through C-5.

The point where the vertical line intersects with the curve that corresponds to each subject pilot's performance represents the point where the malfunction occurred, as shown in figures C-2 through C-5. This is not to say that this point is where subject pilots did or did not notice the malfunction.

Figure C-2 shows subject pilots from group A who stopped 800 ft or more before the LAHSO red light bar. Some subject pilots either did not notice or mention the LAHSO red light bar. This was the case for the subject pilot (P06 in figure C-2) who landed the furthest distance from the LAHSO red light bar (1752 ft) as referenced in table C-12. All statistics for the reaction of these subject pilots is available in table C-6.

Figure C-3 shows subject pilots from group B1 who stopped between 400 and 800 ft before the LAHSO red light bar. All statistics for the reaction of these subject pilots is available in table C-7.

Figure C-4 shows subject pilots from group B2 who also stopped between 400 and 800 ft before the LAHSO red light bar. However, the subject pilots in this group also exhibited a unique leveling effect characteristic in the curve that described their distance from LAHSO red light bar versus their velocity. Specifically, for a set distance, their velocity remained constant and then resumed deceleration, which is attributed to one of two reasons.

The first reason is that a particular subject pilot who never initiated communication with the tower had a hesitation to react. The second reason may be due to the subject pilot initiating and engaging in communication with controllers and then being given a reaffirmed non-LAHSO clearance. This reaction time may be the subject pilot simply taxiing the distance being given by the non-LAHSO clearance. Still other unknown reasons may exist for this result, but this group is the one that showed evidence of this leveling, or constant velocity, characteristic.

All statistics for the reaction of these subject pilots is available in table C-8.

Figure C-5 shows subject pilots from group C who either stopped within 400 ft of the LAHSO red light bar or crossed over them. All subject pilots who crossed over the LAHSO red light bar were given clearance to go through the runway intersection, except one who had not acknowledged the malfunction and came to a complete stop prior to the LAHSO red light bar. Of the six subject pilots who came close enough to the LAHSO red light bar to cross them, three held short and three consciously chose to cross. The reaction data of this last group of subject pilots can be seen in table C-9.

CONCLUSIONS

1. Forty-four percent of subject pilots verbalized concern about not receiving clearance on 1-nautical mile (nm) clearance scenarios with possible conflicting state of the land and hold short operations (LAHSO) red light bar. All subject pilots were comfortable with 2-nm clearances regardless of the state of the LAHSO red light bar.
2. There were no significant correlations between 1- versus 2-nm issued clearances and aircraft landing distances.

3. Regarding the malfunction scenarios:
 - a. All subject pilots viewed the illumination of the LAHSO red light bar and considered the change of state as a change of clearance from non-LAHSO to LAHSO.
 - b. Given a reaffirmation of non-LAHSO clearance, some subject pilots crossed the LAHSO red light bar. Of the six subject pilots who approached the LAHSO red light bar and were given clearance to cross it on a malfunction scenario, three held short and three crossed. This 50% percentile score, however, was based on only 6 of the 25 subject pilots. Only these six subject pilots were presented with this choice within the malfunction scenario.
 - c. All 25 subject pilots who viewed the extinguished lights maintained that they were still on a LAHSO clearance, and all subject pilots were capable of coming to a complete stop prior to the hold short line.
4. All subject pilots considered the LAHSO red light bar to be effective, with 72% of them rating it as very effective.

APPENDIX A—SUBJECT PILOT EVALUATION MATERIAL

This appendix contains examples of the evaluation material that was given to each subject pilot.

LAND AND HOLD SHORT OPERATIONS (LAHSO) PILOT BRIEFING SHEET

In the United States, airports currently utilize a pulsing bar of in-pavement “white” lights as a visual aid for land and hold short operations (LAHSO). This bar identifies the point along the length of the landing runway at which a pilot must stop the aircraft if he/she accepts a “Land and Hold Short” landing clearance issued by Air Traffic Control (ATC). The International Civil Aviation Organization (ICAO) has suggested a “red” bar of in-pavement lights should be used at the LAHSO location for the same purpose. The Federal Aviation Administration (FAA) has been tasked with researching this idea. Since a line of red lights usually means a “Go-No-Further” signal to a pilot this system would need to be automated in order to reduce the problem of having the LAHSO bar turned on during non-LAHSO operations. The intent of this testing effort is to preview the situations and conditions that may be expected in the event a decision is made that LAHSO hold short-indicator lights must be controlled (turned on and off) for each approaching aircraft.

This evaluation will be conducted at Boston Logan International Airport (BOS); all approaches will be to runway 22L and will take approximately 1 hour to complete.

- 1) You will be conducting both LAHSO and non-LAHSO landings in a Boeing 737-800 simulator. An Air Traffic Controller will provide you with instructions and information.
- 2) A total of ten (10) scenarios will be conducted each in Visual Flight rule conditions during dusk or night.
- 3) You will have a co-subject pilot that will perform all pre-flight tasks.
- 4) At the beginning of each scenario you will start out at a 5-mile final to runway 22L, at this point you may choose to either fly the aircraft or use auto pilot.
- 5) For each approach there will be an aircraft 3 or more miles ahead of you, you will be the in-trail (second) aircraft in line for landing.
- 6) During each approach either the “pilot” in the first aircraft or you will be given a Land and Hold Short clearance. If ATC gives you a Land and Hold Short clearance please verbally verify whether you accept the clearance or not, then land accordingly.
- 7) It is important that we record your comments concerning the LAHSO lights during each landing. Therefore, we ask that you vocalize your thoughts (“think out loud”). A data collector/observer will be in the cockpit with you to record your response.
- 8) After completion of the test you will be asked to fill out a post-session questionnaire. We ask that you take this opportunity to give us feedback on any concerns you may have.

Thank you for your assistance and cooperation!

LAND AND HOLD SHORT OPERATIONS (LAHSO) SIMULATOR TEST

SUBJECT PILOT DATA SHEET

We would like to have the following information so that we may analyze the test results according to experience, position, etc. A Subject pilot Number will identify all questionnaires only, so that no individual can be specifically identified in the event that data is shared with other organizations. Please note that providing your name and telephone number is optional, although we would like to have this information in the event that we need to contact you for further clarification of your evaluation responses. **This information is also needed if you would be interested in participating in future simulator and/or actual flight test efforts.**

Thank you for your cooperation!

PILOT'S NAME: _____

POSITION (Capt/1st Off): _____ AIRLINE: _____

TYPE RATINGS: _____

TOTAL FLIGHT HOURS: _____ BOEING 737-800 HRS: _____

TELEPHONE NUMBER: _____

APPROXIMATE DATE OF LAST SIMULATOR TIME: _____

Have you ever performed a Land and Hold Short Operation? _____

ASSIGNED SUBJECT PILOT NUMBER: _____

ATC COMMAND SCRIPT FOR LAHSO EVALUATION

SCENARIO 1- (Scenario # 2, 4, 5, 6, 12)

Aircraft 1. "BOS Tower, This is United 101, 3 miles out."

Tower: "United 101, this is BOS Tower, you are number one on final, cleared to land runway 22L, hold short of runway 27, acknowledge."

Aircraft 1 "Roger tower, United 101 is cleared to land 22L, hold short of runway 27."

Aircraft 2 "BOS Tower, this is Southwest 202, final approach fix inbound."

Tower: "Southwest 202, this is BOS Tower you are 5 miles out, number 2 for runway 22L, behind a United 737. Expect landing clearance at 2 or 1 mile."

Aircraft 2: "Southwest 202, roger."

Tower: "Southwest 202, cleared to land 22L (or go-around)"

Aircraft 2: "Southwest 202 roger cleared to land."

SCENARIO 2- (Scenario # 1, 7, 9, 10, 11)

Aircraft 1. "BOS Tower, This is United 101, 3 miles out."

Tower: "United 101, this is BOS Tower, you are number one on final, cleared to land runway 22L."

Aircraft 1 "Roger tower, United 101 is cleared to land 22L."

Aircraft 2 "BOS Tower, this is Southwest 202, final approach fix inbound."

Tower: "Southwest 202, this is BOS Tower you are 5 miles out, number 2 for runway 22L, behind a United 737. Expect to land and hold short of runway 27 and expect landing clearance at 2 or 1 mile."

Aircraft 2: "Southwest 202, roger."

Tower: "Southwest 202 cleared to land runway 22L, hold short of runway 27, acknowledge."

Aircraft 2: "Southwest 202 roger cleared to land Runway 22L, hold short of runway 27"

AUTOMATED LAHSO LIGHTING CONTROL STUDY

POST SESSION SUBJECT PILOT QUESTIONNAIRE

Having just completed your simulated flight session, we would like you to answer a few questions that we hope will help us to assess the validity of this simulator technique. Please bear in mind that we are attempting to anticipate the problems that will be encountered when, and if, automated operation of Land and Hold Short (LAHSO) lights is developed and implemented so as to permit use of Red lights in place of the present standard White LAHSO lights.

Pilot's Name: _____ Airline: _____ Date: _____

1. Did you feel that the external visual presentations (airport and runway depictions, visual aids, etc.) were realistic and contributed to the overall environmental situation?

Very realistic:____ Semi-realistic:____ Unrealistic:____

Comments:_____

2. Did you feel that the situations to which you were exposed (i.e. LAHSO light operation, point at which clearances were given, etc.) were realistic and typical of those that you would encounter during real-world LAHSO operations?

Very realistic:____ Semi-realistic:____ Unrealistic:____

Comments:_____

3. Do you feel that the LAHSO visual aid presented was an adequate cue for performing Land and Hold Short Operations?

Very effective:____ Effective:____ Not effective:____

Comments:_____

THANK YOU FOR YOUR ASSISTANCE!

APPENDIX B—SUBJECTIVE POSTBRIEFING DATA RESULTS

Appendix B contains actual comments made by the subject pilots during postbriefing. Tables B-1 through B-3 show subject pilot responses to the Post Session Subject Pilot Questionnaire found on page A-4.

Table B-1. Postbriefing Question One

Question #1: External Visual Representations			
Did you feel that the external visual presentations (airport and runway depictions, visual aids, etc.) were realistic and contributed to the overall environmental situation?			
	Very Realistic	Semi-Realistic	Unrealistic
Participants	24	1	0 out of 25
Percentages	96%	4%	0%

Comments made by subject pilots in response to Question #1:

- Little difficulty identifying preceding aircraft.
- Excellent visual and simulator environment. It looks and feels quite realistic.
- Not having flown into red LAHSO before I believe it was realistic based on other airport lighting.
- I've always felt that this simulator had great visuals. Very conducive to training.
- Lights can be seen at 5 miles – Red stands out better than white.
- LAHSO lights blended in with R/W end lights in flare.
- As expected in a LVL B simulator.
- The stop lights seemed brighter than the rest of the runway lights.
- The simulator depicts realistic visual presentation.
- I would like runway lights a little brighter.

Table B-2. Postbriefing Question Two

Question #2: Realistic Situations			
Did you feel that the situations to which you were exposed (i.e. LAHSO light operation, point at which clearances were given, etc.) were realistic and typical of those that you would encounter during real-world LAHSO operations?			
	Very Realistic	Semi-Realistic	Unrealistic
Participants	21	4	0 out of 25
Percentages	84%	16%	0%

Comments made by subject pilots in response to Question #2:

- Scenario was set up realistically. Some confusion developed when lights (LAHSO) malfunctioned. Also, I liked to hear tower voice whether or not to “expect” full length or LAHSO prior to being cleared for landing.
- Having us positioned right behind another aircraft is very typical of what I see at airports.
- I liked the mixture of light/clearance usable. Even some last minute landing clearances very “real world”.
- Solid LAHSO scenario.
- When we were told to expect LAHSO, while out on final, I thought that would be typical.
- Landing clearance at one mile at busy airports is unrealistic. Subject pilots would be stepped on by others in radio traffic; others will build up in cue.
- The lights coming on and going off as aircraft landing are very obvious.
- Good as you get closer to runway, it is important to stay in contact with tower to ensure you get direction.
- Seldom have I experienced alternating LAHSO Ops – Either they are or are not holding short.
- One-mile clearance to land happened often (when I was working @ SWA) so it did not seem unreasonable.
- Usually there are more distracting factors i.e. ATC chatter / Traffic in the pattern. Maybe to make it more realistic, have ATC forget to provide landing clearance.
- It seemed the clearance to land was given much later than I’m used to. Most of the time, if waiting for a landing clearance, it’s given right after the first plane clears the runway.
- I would like clearance sooner if possible.

- Occasional controller “mistakes” are a reality, and it’s good to incorporate them into the scenario.

Table B-3. Postbriefing Question Three

Question #3: Effective Presentation			
Do you feel that the LAHSO visual aid presented was an adequate cue for performing Land and Hold Short Operations?			
	Very Effective	Effective	Not Effective
Participants	18	7	0 out of 25
Percentages	72%	28%	0%

Comments made by subject pilots in response to Question #3:

- Personally, the lights, on or off, were superfluous, given landing conditions; If the plane was heavier, or it was not, or if we had some significant tailwind, then I would have brought the lights into my situational awareness more strongly.
- Effective means of identifying LAHSO point. Limited difficulty experienced with mixing runway edge (red) lights and LAHSO lights.
- I would require red stop bar type lighting for all LAHSO ops.
- The light bar being turned on and off based on the clearance given is a “warm fuzzy” to me as to what my clearance was.
- The red lights are great, but I feel there should be more of them spaced closer together on the runway as well as some sort of sign on the side of the runway for daylight ops. This way I know what the distance from the intersecting runway for the LAHSO line.
- I like the red stop bar a lot. It is more identifiable to subject pilots than the present lighting.
- Really thought red LAHSO lights were very effective.
- Preceding aircraft lights did occasionally block out the LAHSO lights.
- The lights were very easy to see and sent a clear message on where to be stopped by.
- Rather see red. Lighting and air traffic engineers should be aware that subject pilots on a short, one mile final are:
 - Awaiting instruction for clearance
 - Thinking about holding short

- Thinking about taxiing off – back [to terminals from the runway
 - Looking for aircraft ahead
 - What is my FOM status?
- Lights were very visible from marker in.
 - At night with little depth perception the lights tend to rush up a little quick at the end of the landing roll. Verbalizing distance remaining helps.
 - Good system! The last malfunction [scenario 12, in which the red LAHSO bars come on when full clearance is given] is the most critical.
 - I really liked the red stop lights!!
 - Comment on “automated system” – what determines if lights come on automatically? Aircraft on runway, aircraft on x- [cross]-ing runway, etc.
 - ATC voice to confirm is nice.
 - Red lights are easy to understand. The most dangerous scenario would be when the lights fail and you are cleared to LAHSO.
 - Red lights are much better than white lights.
 - Yes, it was, but if it was displayed when it was not supposed to be there, it adds confusion in the cockpit.
 - Semi-effective. It’s very subtle during rollout if the LAHSO lights are reconfigured. The current flashing ones are more distinctive and easier to keep cognizant of. The red steady LAHSO lights, in my opinion, would be tremendously more effective if they were flashing.
 - I prefer the red as opposed to the white. I always questioned why they used white strobes all these years.
 - If normal ops will include the lights being turned on in conjunction with landing clearance, then the presentation was right on.
 - I’m a little concerned about losing sight of the LAHSO red light bar in the touchdown zone.

APPENDIX C—OBJECTIVE DATA RESULTS

Appendix C contains objective data results. Tables C-1 and C-2 show postbriefing statistics for each subject pilot.

Table C-1. Reaction Statistics Within Mal-Scenario 11, All Participants

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	19%-76%	6%-24%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	7%-28%	18%-72%
Did the subject initiate communication with tower?	16%-64%	9%-36%

TABLE C-2. Reaction Statistics within Mal-Scenario 12, All Participants

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	19%-76%	6%-24%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	12%-48%	13%-52%
Did the subject initiate communication with tower?	18%-72%	7%-28%

Tables C-3 through C-5 and figure C-1 show statistics on end distances from the Land and Hold Short Operations (LAHSO) red light bar and ground velocities on malfunction (mal)-scenario 11 and mal-scenario 12.

Table C-3. Descriptive, Univariate Statistics for End Distance From LAHSO Red Light Bar on LAHSO Scenarios

	Scenario 1	Scenario 7	Scenario 9	Scenario 10
Mean	1010	1058	1071	1107
Standard Error	100	89	93	103
Median	1103	988	1048	1185
Standard Deviation	490	434	467	516
Range	1562	1581	1731	1886
Minimum	144	455	199	151
Maximum	1705	2036	1930	2037
Count	24	24	25	25
Confidence Level (95.0%)	207	183	193	213

Table C-4. Descriptive, Univariate Statistics for End Distance From LAHSO Red Light Bar on Non-LAHSO Scenarios

	Scenario 2	Scenario 4	Scenario 5	Scenario 6
Mean	599	773	849	561
Standard Error	95	108	113	131
Median	677	756	903	520
Standard Deviation	477	540	551	656
Range	2411	1909	2106	3069
Minimum	-757	-260	-194	-873
Maximum	1655	1649	1912	2196
Count	25	25	24	25
Confidence Level (95.0%)	197	223	233	271

Table C-5. Descriptive, Univariate Statistics for End Distance From LAHSO Red Light Bar and Ground Velocity on Mal-Scenario 11 and Mal-Scenario 12

	Mal-Scenario 11		Mal-Scenario 12	
	Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)
Mean	951	4	624	7
Standard error	88	2	100	2
Median	935	0	586	0
Standard deviation	439	8	499	9
Range	1573	26	2068	31
Minimum	87	0	-316	0
Maximum	1660	26	1752	31
Count	25	25	25	25
Confidence Level (95.0%)		3	206	4

LAHSO Malfunction 11

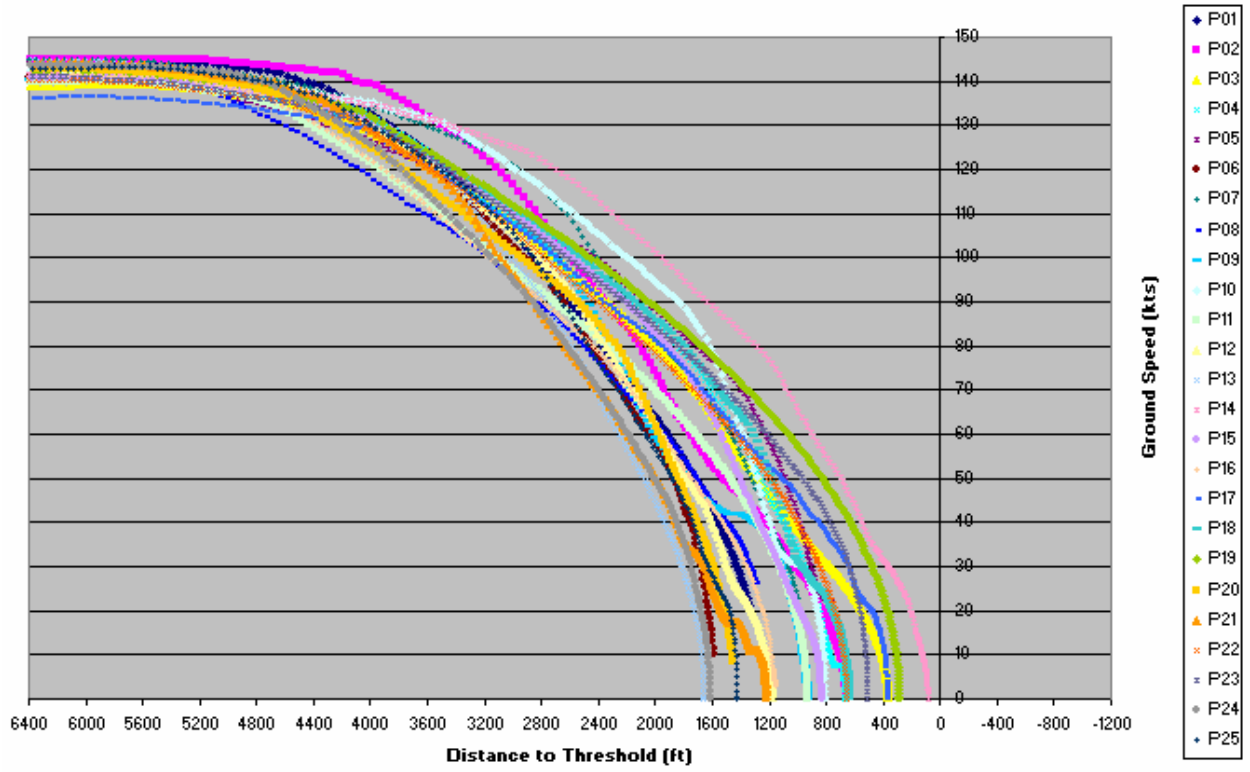


Figure C-1. Mal-Scenario 11 Distance Versus Velocity

Figure C-2 shows subject pilots in group A who stopped 800 ft or more short of the hold short point. Table C-6 are reaction statistics for group A during mal-scenario 12.

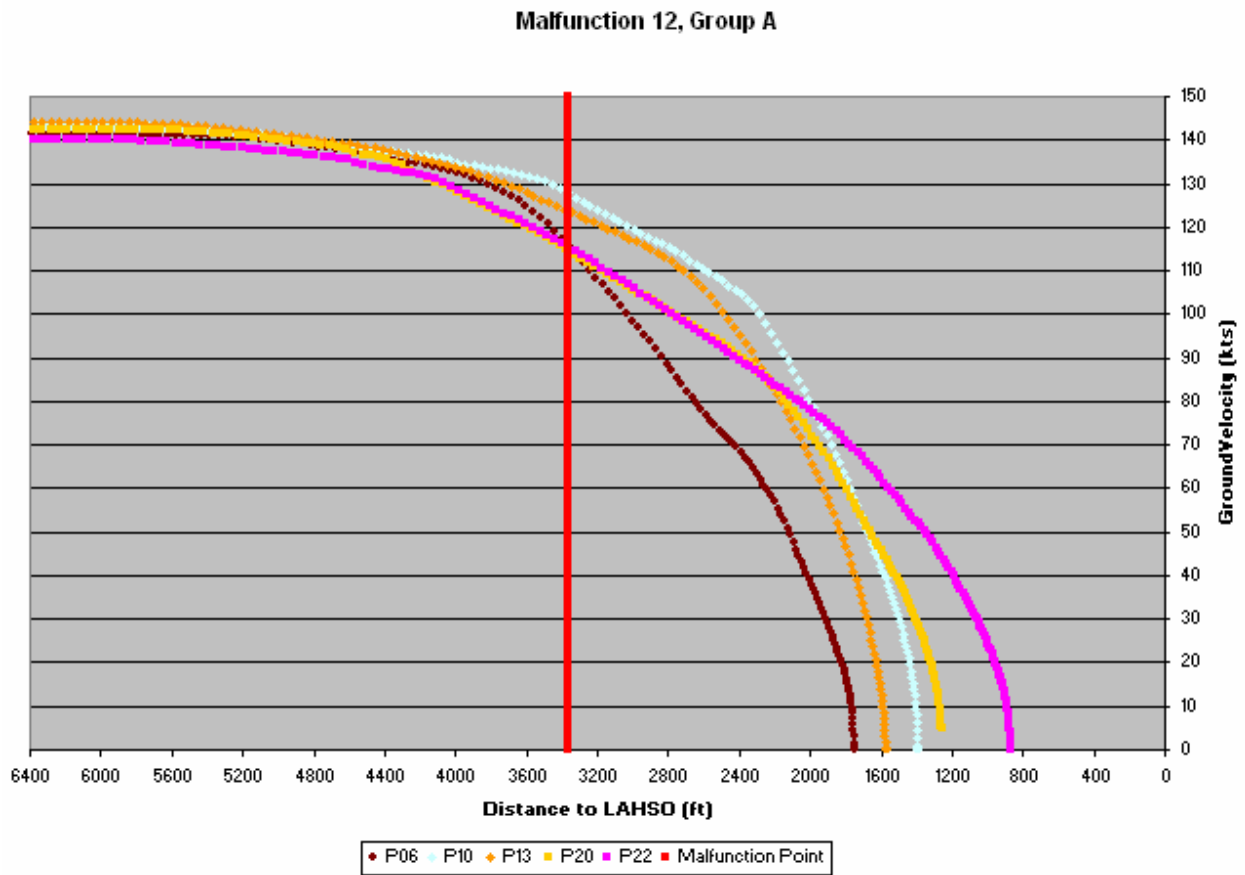


Figure C-2. Mal-Scenario 12, Group A

Table C-6. Statistics Within Mal-Scenario 12, Group A Subset

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	2%-40%	3%-60%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	1%-10%	4%-80%
Did the subject initiate communication with tower?	2%-40%	3%-60%

Figure C-3 shows subject pilots in group B1 who stopped within 400 to 1200 ft short of the hold short point. Table C-7 are reaction statistics for group B1 during mal-scenario 12.

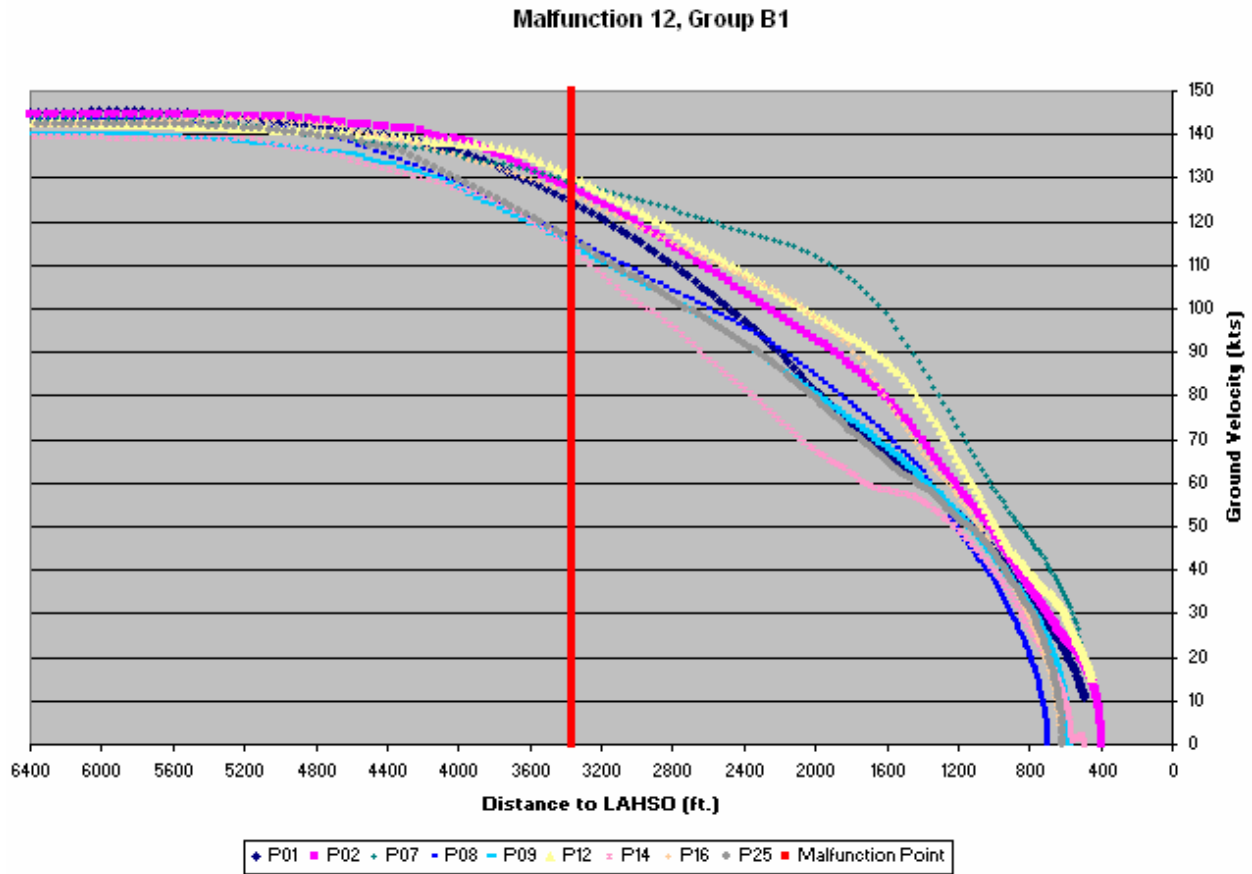


Figure C-3. Mal-Scenario 12, Group B1

Table C-7. Statistics Within Mal-Scenario 12, Group B1 Subset

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	7%-78%	2%-22%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	4%-44%	5%-56%
Did the subject initiate communication with tower?	7%-78%	2%-22%

Figure C-4 shows subject pilots in group B2 who stopped within 400 to 1200 ft short of the hold short point with level velocity effect. Table C-8 are reaction statistics for group B2 during mal-scenario 12.

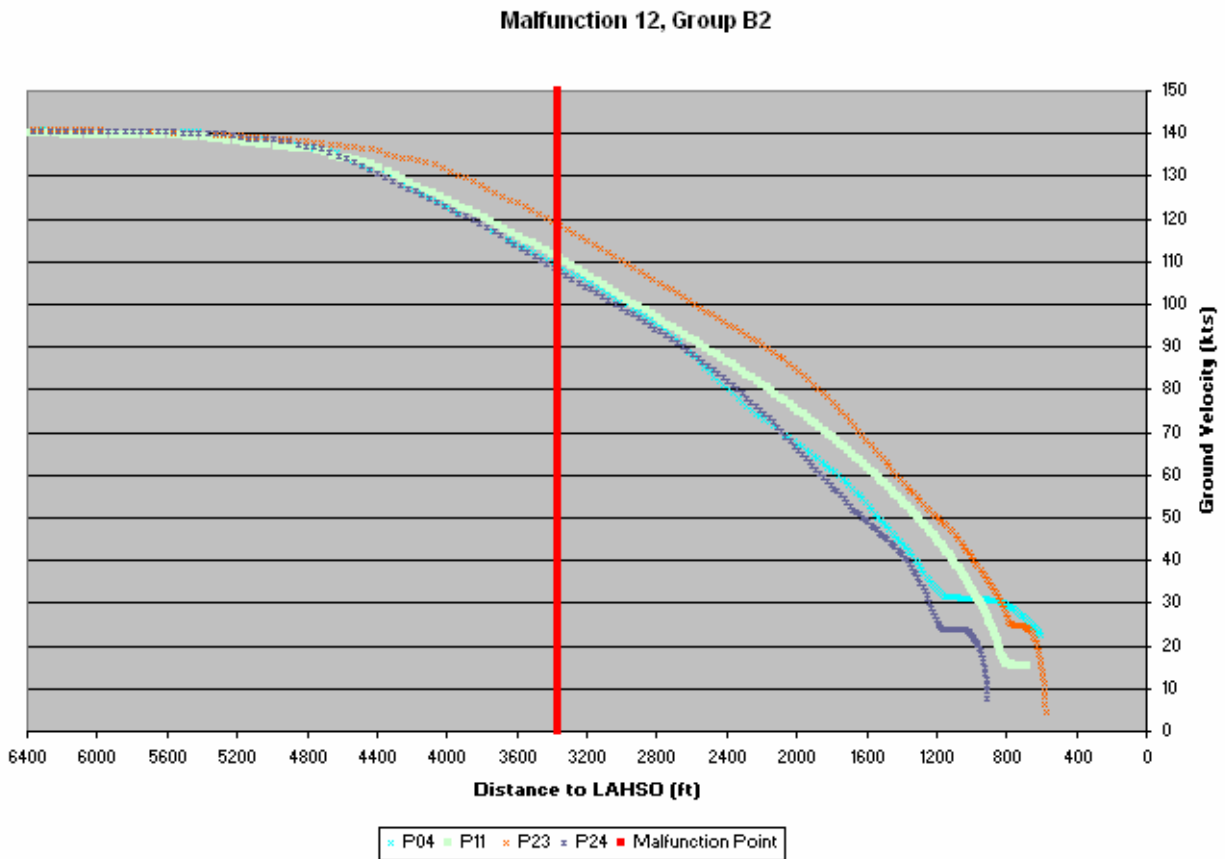


Figure C-4. Mal-Scenario 12, Group B2

Table C-8. Statistics Within Mal-Scenario 12, Group B2 Subset

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	4%-100%	0%-0%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	3%-75%	1%-25 %
Did the subject initiate communication with tower?	3%-75%	1%-25%

Figure C-5 shows subject pilots in group C who came to within 400 ft or crossed the hold short line. Table C-9 are reaction statistics for group C during mal-scenario 12.

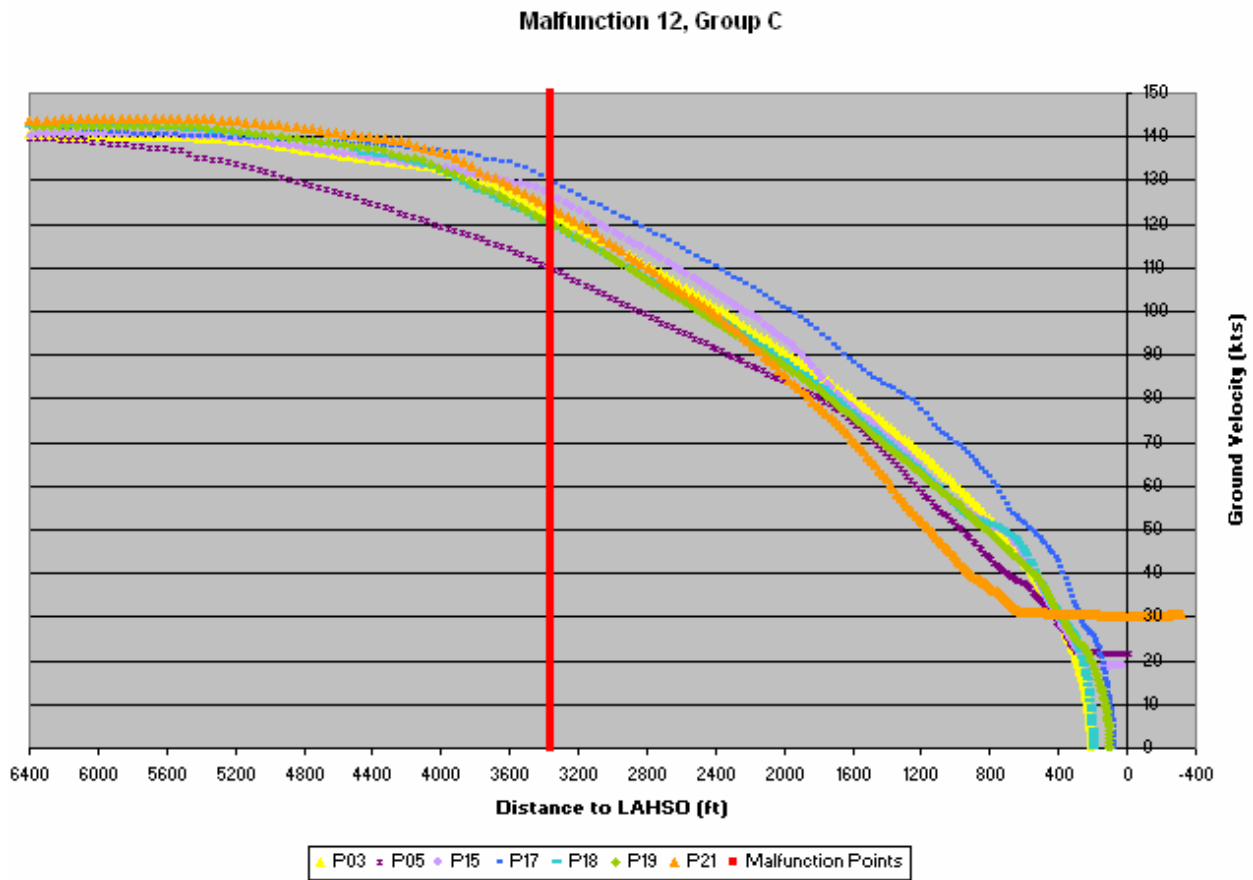


Figure C-5. Mal-Scenario 12, Group C

Table C-9. Statistics Within Mal-Scenario 12, Group C Subset

Condition	Yes	No
Did the subject verbally acknowledge the light malfunction?	6%-85%	1%-15%
Did the subject initiate communication with tower without hesitation? (Less than 10 seconds within verbal acknowledgement)	4%-57%	3%-43%
Did the subject initiate communication with tower?	6%-85%	1%-15%

Tables C-10, C-11, and C-12 show the LAHSO, the non-LAHSO, and the malfunction end scenarios stopping distance and ground velocities, respectively.

Table C-10. The LAHSO End Scenarios Stopping Distance and Ground Velocities

Scenario 1		Scenario 7		Scenario 9		Scenario 10	
Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)
1705	0	2036	2	1930	27	2037	21
1651	0	1990	37	1690	0	1795	9
1587	1	1614	13	1633	6	1767	25
1580	37	1542	7	1627	56	1742	21
1480	13	1394	21	1568	14	1647	44
1445	38	1308	15	1536	30	1589	38
1440	23	1300	9	1458	23	1447	43
1360	0	1161	23	1378	20	1422	27
1299	23	1126	15	1326	16	1263	16
1271	12	1126	118	1186	15	1250	24
1199	28	1101	29	1133	29	1200	30
1114	26	993	4	1067	29	1196	0
1092	29	983	22	1048	0	1185	42
903	21	971	31	1006	0	1067	26
878	0	940	16	988	0	1037	30
816	38	897	1	979	28	1022	28
670	27	735	6	823	29	865	0
664	32	727	0	814	28	861	2
654	33	701	0	786	30	811	36
548	9	672	0	783	13	720	0
401	0	558	29	693	20	671	6
244	0	551	11	504	3	451	13
155	17	520	25	358	5	298	0
144	0	455	23	264	19	183	12

Table C-11. Non-LAHSO End Scenarios Stopping Distance and Ground Velocities

Scenario 2		Scenario 4		Scenario 5		Scenario 6	
Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)
1655	26	1649	25	1912	29	2196	20
1216	0	1588	23	1830	19	1415	43
1116	25	1553	0	1464	28	1301	0
1064	17	1489	13	1435	10	1138	23
841	19	1297	33	1361	29	999	16
815	46	1254	40	1161	26	986	33
778	33	1219	43	1155	5	857	0
766	35	1207	29	1073	38	817	36
745	0	1087	33	1025	46	811	0
740	47	860	28	1024	33	737	2
707	7	858	31	1016	31	646	22
688	24	850	31	908	33	528	27
677	27	756	21	897	32	520	5
640	31	619	24	814	41	469	34
609	0	597	38	797	0	468	16
557	0	520	42	681	40	432	0
555	0	426	37	622	33	432	29
446	6	420	24	461	16	426	29
433	38	411	28	327	10	376	42
372	28	394	26	281	0	368	0
351	35	359	12	224	1	77	10
188	6	78	30	54	35	14	46
80	7	67	4	50	24	-269	56
-302	37	17	12	-194	13	-846	41
-757	29	-260	41	—	—	-873	34

Table C-12. Malfunction End Scenarios Stopping Distance and Ground Velocities

Mal-Scenario 11		Mal-Scenario 12	
Distance (ft)	Velocity (kts)	Distance (ft)	Velocity (kts)
1660	0	1752	0
1610	0	1577	0
1585	10	1396	0
1450	8	1255	5
1424	0	1013	0
1327	19	908	8
1302	26	871	0
1221	0	713	0
1180	0	682	15
1156	3	629	0
1006	0	612	0
971	19	605	23
935	0	586	0
930	0	576	4
832	0	500	0
808	0	492	11
759	22	481	17
671	0	447	15
661	0	396	11
657	0	209	0
510	0	102	0
383	0	91	0
365	0	25	19
286	0	5	22
87	0	-316	31