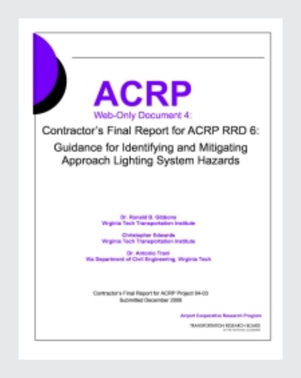

ACRP
Web-Only Document 4:
Contractor's Final Report for ACRP RRD 6:
Guidance for Identifying and Mitigating
Approach Lighting System Hazards

# Contractor's Final Report for ACRP RRD 6: Guidance for Identifying and Mitigating Approach Lighting System Hazards

**DETAILS**

0 pages | null | PAPERBACK
ISBN 978-0-309-43573-4 | DOI 10.17226/23013

**AUTHORS**

# THE NATIONAL ACADEMIES

***Advisers to the Nation on Science, Engineering, and Medicine***

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is one of six major divisions of the National Research Council. The mission of the Transportation Research Board is to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied activities annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation. **www.TRB.org**

**www.national-academies.org**

# TABLE OF CONTENTS

## AUTHOR ACKNOWLEDGEMENTS

The research reported herein was performed under ACRP 04-03 by the Virginia Tech Transportation Institute (VTTI) and the Virginia Tech via Department of Civil Engineering. VTTI is the contractor for this study. The work was undertaken at VTTI under the prime contract.

Dr. Ronald B. Gibbons, Group Leader, Lighting and Infrastructure Technology, Center for Vehicle Infrastructure Safety, VTTI, is the principal investigator. Dr. Antonio Trani, of the Via Department of Civil Engineering at Virginia Tech and Chris Edwards at VTTI, are the co-Principal Investigators on this project.

The authors would like to acknowledge the assistance of the FAA and Airport Operators of the Airports visited during the development of these research results.

## ABSTRACT

This final report presents the results of the research on approach lighting system (ALS) hazard identification and mitigation techniques. This final report contains detailed information for each of the tasks explored in this research project. In addition to this final report a separate and more concise guidebook was also produced that reviews ALS hazard identification and mitigation techniques. A literature review was conducted to identify both current and historical information regarding approach lighting systems. As part of the literature review process, the Federal Aviation Administration (FAA) accident database was also accessed to identify undershoots and overrun ALS incidents. In an effort to gauge current hazards at a variety of airport locations, the research team also conducted on-site interviews with general aviation, reliever, and primary airports. In order to identify specific issues airport and FAA personnel were interviewed. At the conclusion of the interview process, the research team confirmed potential hazard issues and also identified areas needing improvement and mitigation techniques related to approach lighting system incidents. Those issues identified during the interview process were incorporated into an overview of approach lighting system hazards that also included items identified from the database review. Hazards were grouped in this way: acute incidents, hazards occurring during the onset of an incident, and post-incident factors that included electrical, fire, debris, terrain, and other aspects. At the conclusion of identifying these hazards the research team then developed a procedure for airport, ARFF, and FAA personnel to identify potential ALS hazards. The next task took these procedures and integrated the hazards identified from a previous task in order to provide potential ALS hazard solutions. These efforts were combined into a Guidebook and final report as part of the last task for this research project.

# Executive Summary

There are many potential hazards when an aircraft collides with an approach lighting system. Currently, there are no detailed methods for identifying and mitigating hazards associated with approach lighting systems. The severity of the incident is dependent on a variety of factors and also the type of approach lighting system collision, whether the approach is undershot or the aircraft overruns the runway. Given these factors, the present project set out to determine the types of hazards present when an aircraft collides with an approach lighting system. The identification of these factors will then influence appropriate mitigation techniques and associated risks. These elements will then be incorporated into a guidebook for airport and related agency usage.

A series of tasks were undertaken in an effort to identify and review the existing literature on approach lighting systems, review aircraft incident databases, conduct on-site interviews with airport and Federal Aviation Administration (FAA) personnel, and identify hazards and risks when an aircraft collides with an approach lighting system.

The literature and database review provided a background to potential hazards that occur during and after an approach lighting system incident. In particular, the database had varying report details with regard to the type of damage to both the approach lighting system and the aircraft. In most cases, the role of the approach lighting system in further incident complications was not well captured. However, in a few large reports (most often involving commercial airlines), the reports gave specific details about how the structure contributed to further complications. The incident databases also revealed a larger number of aircraft undershooting the runway into the approach lighting system, which are of particular interest, compared to overrun incidents. These factors guided the development of the interview questionnaire in addition to identifying potential hazards.

A total of 15 airports participated in the on-site interview process. The airports chosen varied based on the size and use of the facility; these were categorized into general aviation, reliever, and primary airports. Where possible, various personnel were interviewed at each location, including both airport facility staff and FAA personnel. The interviewees were asked about current procedures, hazards, risks, and automation techniques in the event of an approach lighting system incident. The research team also reviewed the on-site setup of each airport's approach lighting system. The conclusions gathered from the interview process showed that many airport facilities had not considered an approach lighting system incident particularly hazardous beyond basic aircraft evacuation and related fuel fires. When asked about automated mitigation techniques, participants were varied in their acceptance of an additional "system." Furthermore, the site interviews revealed varying relationships between airport facilities and the FAA with respect to the approach lighting system, which can impact the effectiveness of mitigation techniques. Overall, the interview process revealed both procedural and automated techniques that can be used to reduce and in some cases mitigate the hazards.

A large number of hazards were identified using the information gathered from the literature, database, and airport reviews. Each of these hazards was then categorized into a risk type based on the sequence of events when an aircraft collides with an approach lighting system. A risk matrix was constructed in order to determine the level of risk in each of the hazards alone, or in

combination, with regard to influencing the safety of both aircraft and responding personnel. The matrix allows for a determination of risk based on varying factors which may impact each airport differently. Once these factors were determined, the research team was then ready to further analyze the risk.

An outline and sample section for the guidebook was also created as part of the hazard identification and mitigation effort. In addition, the research team has finalized the second phase of the project. The team awaits feedback and suggestions on the updated work plan from the project panel before the next phase continues.

# CHAPTER 1: BACKGROUND

Airports around the country face enormous challenges to protect people and property during regular aircraft operations. Significant encroachment of airports around populated areas has occurred in the past five decades. For the 30 years from 1976–2005, commercial aviation demand – measured in terms of commercial passenger enplanements in the system - has tripled *(1)*. The number of flight operations in the system (i.e., departures and arrivals) has increased from 106 million per year in 1976 to more than 120 million in 2005.

The Federal Aviation Administration (FAA) anticipates an annual growth of 3.1% in the number of enplanements in the National Airspace System *(1)*. The number of operations at commercial airports is expected to grow by a factor of 1.75 between 2005 and 2025, as shown in Figure 1. Other segments of aviation are expected to grow as well. For example, the number of hours flown by general aviation is expected to increase by 7% in the period 2006-2017, according to the FAA. This segment is primarily fueled by higher use of corporate jet aircraft and new business models in the air taxi industry, induced by emerging aircraft technologies such as very light jets *(2)*.

There are the more than 20,400 landing facilities available in the United States *(1)* of which 3,300 are considered critical to the national air transportation system. These are airports included in the National Plan for Integrated Airport Systems (NPIAS). Many of these facilities are equipped with approach lighting systems to provide pilots with a means to transition from instrument flight to visual flight during the landing maneuver. Of the 20,420 airports in the system, 945 runway ends have medium intensity approach lighting systems (designated as Medium Intensity Light System with Flashers [MALSF] or Medium Intensity Light System with Runway Alignment Indicator Lights [MALSR]). These systems are installed at 691 airports nationwide. Another 274 runway ends (or 175 airports) have High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 1)(ALSF-1) or High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 2) (ALSF-2) systems. The number of airports equipped with Omni-Directional Approach Lighting Systems (ODALS) is 95, with 98 runway ends covered nationwide. There are 58 airports with Short Approach Lighting System (SALS) and Short Sequenced Approach Lighting (SSAL) systems. The airports with approach lighting systems in the United States are shown in Figure 2. Superposition of Figures 1 and 2 indicates that in the next 20 years, the number of operations at airports with approach lighting systems is expected to increase by 62% nationwide. This indicates that approach lighting systems will constitute a greater risk to aircraft operations.

The current standards and criteria to implement approach lighting systems are based on the number of aircraft operations, the type of airport operations, and the design criteria of runway operations. These criteria do not address issues such as the safety of passengers and rescue personnel after an aircraft accident/incident. This proposal attempts to bridge the gap between approach lighting system infrastructure provision at airports and protecting passengers and rescue personnel from risks involved with approach lighting systems *(3)*.

The objective of this research project is to develop a guidebook for airport operators to perform risk assessments of the hazards associated with the approach lighting system and develop mitigation techniques to address these risks.

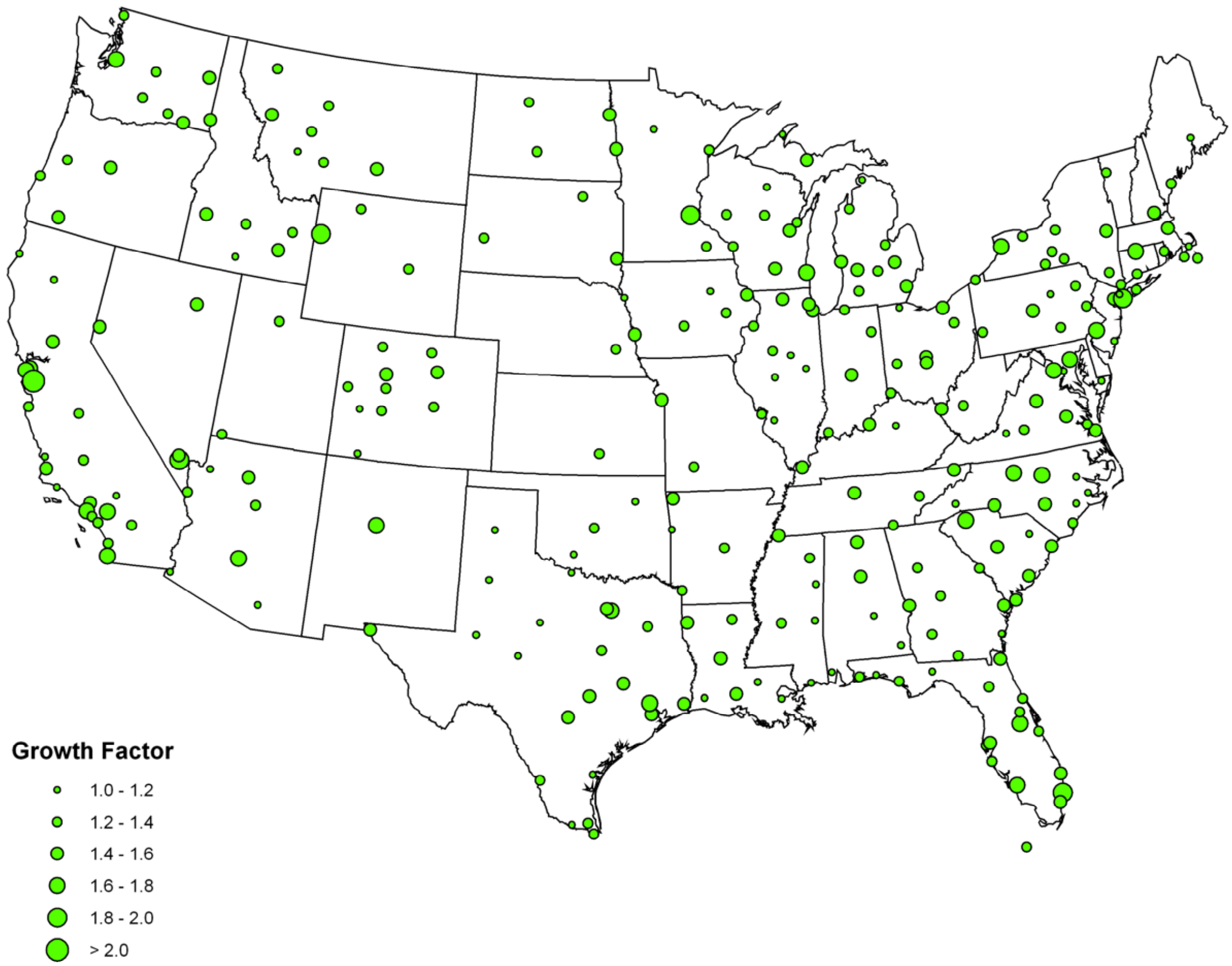



**Figure 1. Predicted airport operations growth factors at the top 287 commercial airports 2005–2025. (Source: FAA Terminal Area Forecast 2006.)**

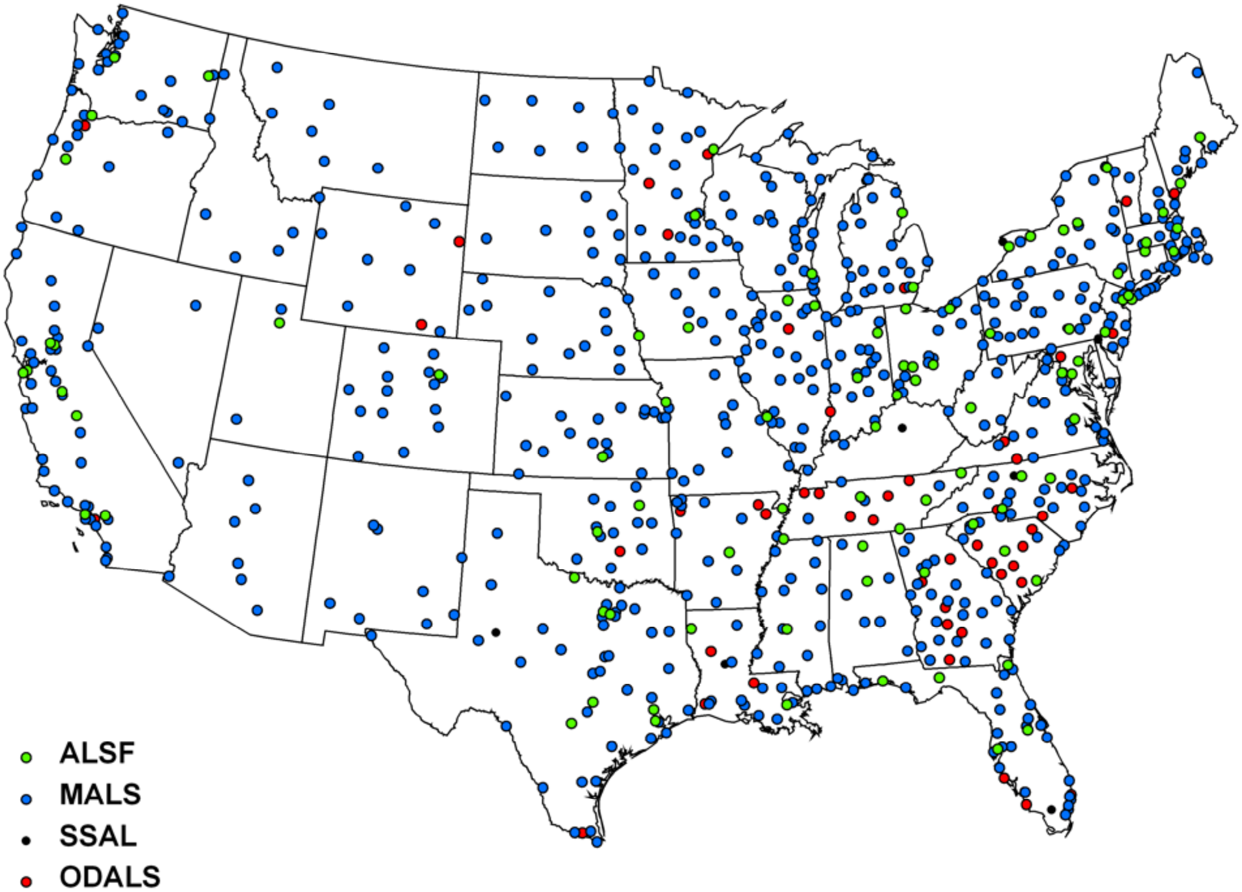



**Figure 2. U.S. commercial airports with Approach Lighting Systems.**

# CHAPTER 2: RESEARCH APPROACH

This research project is designed to investigate the hazards associated with airport approach lighting systems and then develop technological and operational solutions for mitigating those hazards. Risks, best practices, airport size, and operations will all be required to be included in the analysis and development of these solutions.

The objective of this research project is to develop a guidebook for airport operators to:

1) Perform risk assessment of hazards associated with approach lighting systems.
2) Determine measures that can be adopted to mitigate these hazards.

## Research Approach

The research plan consists of two major phases. The first phase is an information-gathering stage where the specifics of the hazards associated with approach lighting systems are determined. The second is a solution development activity where possible mitigation systems and operational guidelines are developed. There are nine tasks to be completed as part of this project.

The proposed research plan is illustrated graphically in Figure 3.

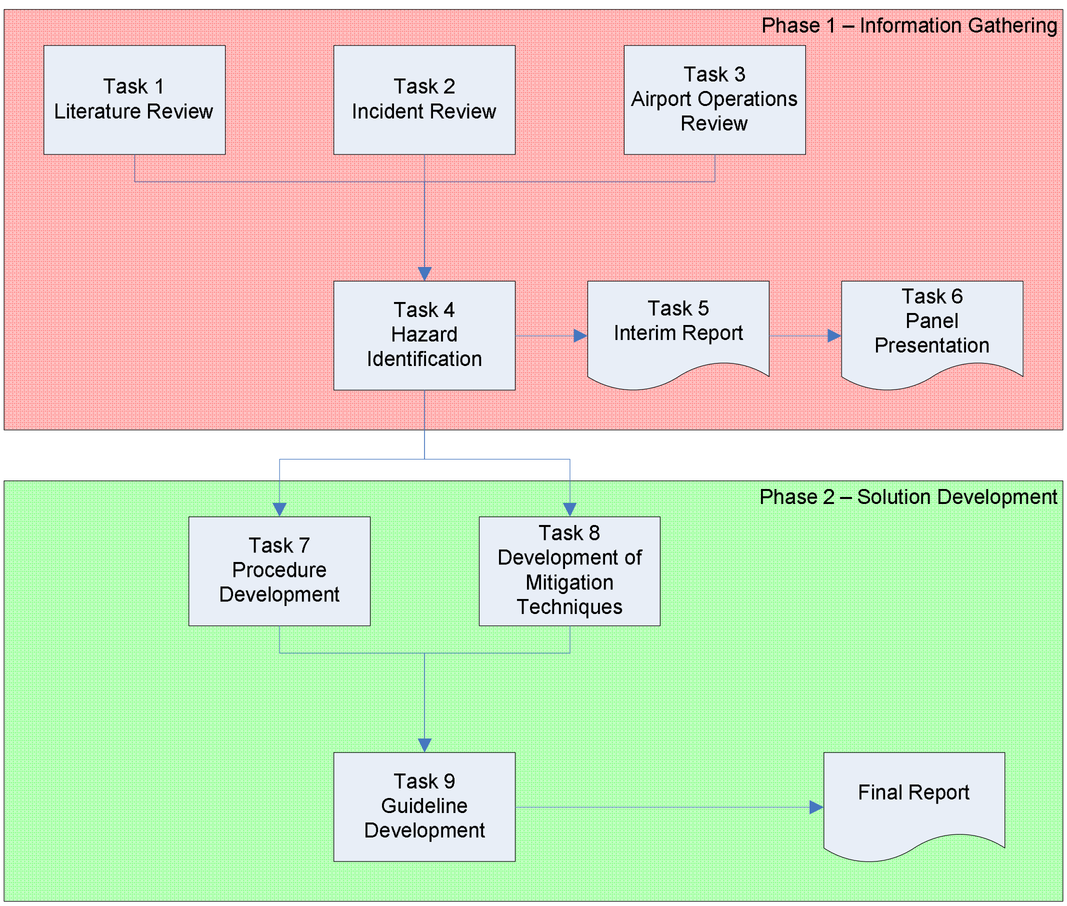



**Figure 3. Elements of the Proposed Research Plan**

## Task Structure

Tasks 1 through 6 of the nine tasks comprise Phase 1 of the project and Tasks 7, 8 and 9 comprise Phase 2.

### *Task 1 – Literature Review*

As a first step in the information-gathering phase of the project, a literature review was conducted that focused on current standards, control and monitoring systems, best practices for operations and accident access, and any other issues as appropriate to the research project. The results of this literature review are documented in an annotated bibliography.

### *Task 2 – Incident Review*

As part of this project, an extensive review of aircraft databases was undertaken to assess the connections (if any) between approach lighting systems and aircraft accidents. The databases used in this project included the National Transportation Safety Board (NTSB) accident database *(4)*, National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) *(5)*, the FAA Aviation Safety Information and Sharing (ASIAS) database *(6)*, and the Aircraft Owners and Pilots Association (AOPA) *(7)*.

### *Task 3 – Airport Operations Review*

In conjunction with Tasks 1 and 2, Task 3 gathered information about current mitigation practices and general techniques by directly interviewing airport operators, FAA officials, Airport Rescue Fire Fighting (ARFF) departments, and mutual aid response groups. The purpose of these interviews was to obtain in-depth site-specific responses regarding current operational procedures and to identify best practices that take system and institutional issues into consideration with respect to the mitigation of approach lighting system hazards. In addition, those interviewed were also asked to provide feedback during the development cycle of the guidebook and mitigation techniques.

### *Task 4 – Hazard Identification*

There are many potential hazards both seen and unseen that can impede the safe evacuation of an aircraft and the safety of first responders. A hazard list was developed based on the results of the information gathering performed in Tasks 1 through 3. The list outlines some of the hazards and risk factors that must be taken into account when constructing mitigation techniques. In addition to the hazard list, a risk table was constructed to identify the potential severity of risks that will be reviewed when considering appropriate mitigation responses. Not every airport is affected by every potential hazard, but reviewing all possible hazards with regard to a variety of airport operations (general aviation, hubs, etc.) can provide a thorough understanding of the mitigation techniques that can be constructed.

### *Task 5 – Interim Report*

An interim report that summarizes the activities in Tasks 1 through 4 was submitted. This report identifies the important factors and the proposed work plan for future tasks.

*Task 6 – Panel Presentation*

Approximately one month after submitting the interim report from Task 5, the research team will meet with the sponsor in Washington, DC at the Keck Center (National Academy of Sciences) to summarize Tasks 1 through 4 and to discuss the work plan of Phase II of the project. Phase II comprises Tasks 7 through 9.

*Task 7 – Procedure Development*

The second phase of the research project is the identification of procedures and technologies which can be used to mitigate the hazards associated with incidents involving approach lighting systems. Task 7 will focus primarily on a set of procedures for airport operators to identify risks associated with the hazards. These hazard items will have been identified (i.e., Task 4) and reviewed (i.e., Task 6) during the interim report process.

*Task 8 – Development of Mitigation Techniques*

Using the hazards identified in Task 4, each hazard will be evaluated in terms of mitigation techniques. These mitigation techniques will either be technological methods or procedural changes.

*Task 9 – Guidelines Development*

All of the previous tasks led to the development of a guidebook. In order to validate the information presented in the guidebook, the research team will present sections of the guidebook and ask for direct feedback from those individuals interviewed in Task 3. The guidebook will follow an iterative development process in which feedback from these key personnel will help shape and tailor the guidebook for real-world applications.

# CHAPTER 3: TASK FINDINGS

## Task 1 – Literature Review

This literature review was designed to investigate all available resources regarding approach lighting systems and the risks associated with them. The specific areas of interest for this review included the current standards applicable to approach lighting systems, control and monitoring techniques, and the best practices for system risk assessment and hazard mitigation.

### *Current Standards*

**Technical Aspects of Approach Lighting Systems.** Approach lighting systems constitute an integral part of runway systems designed to support instrument approach procedures. Approach lighting systems provide a transition between a precision approach and the manual execution of the final landing approach phase. According to the FAA Airport Design Advisory Circular 150/5300-13, approach lighting systems are required for precision approaches with visibility minima of less than ¾ mile *(8)*. These include Instrument Landing System (ILS) Categories I, II and III; approaches using Local Area Augmentation Systems (LAAS) or Wide Area Augmentation (WAAS) and Microwave Landing System approaches (MLS). The FAA recommends certain approach lighting systems for precision approaches with visibility minima of greater than ¾ of a mile. Moreover, some approach procedures with vertical guidance (APV) also require approach lights *(8)*. Finally, some non-precision approaches also require certain types of approach lighting systems. Table 1 summarizes the most current design standards for approach lighting systems according to various types of runway approach procedures.

**Table 1. Federal Aviation Administration Runway Design Criteria for Approach Lighting Systems**

| Runway Design Criteria | Lights | < 3/4 Statute Mile | < 1 Statute Mile | 1 Statute Mile | > 1 Statute Mile | Circling |
|---|---|---|---|---|---|---|
| Precision Instrument Approach | Runway Edge Lights | HIRL / MIRL | HIRL / MIRL | N/A | N/A | N/A |
| | Approach Lights | MALSR, SSALR, or ALSF | Recommended | N/A | N/A | N/A |
| | | | | | | |
| Approach Procedure With Vertical Guidance (APV-RNP) | Runway Edge Lights | HIRL / MIRL | HIRL / MIRL | MIRL/LIRL | MIRL/LIRL | N/A |
| | Approach Lights | ODALS, MALS, SSAL | ODALS, MALS, SSALS | Recommended | Recommended | N/A |
| | | | | | | |
| Non-precision Approach | Runway Edge Lights | HIRL / MIRL | HIRL / MIRL | MIRL / LIRL | MIRL / LIRL | MIRL / LIRL<br><br>(Required only for night minima) |
| | Approach Lights | MALSR, SSALR,<br><br>or ALSF Required | ODALS, MALS, SSALS, SALS | Recommended<br><br>(ODALS, MALS, SSALS, SALS) | Recommended<br><br>(ODALS, MALS, SSALS, SALS) | Not Required |

HIRL = High Intensity Runway Lights, MIRL = Medium Intensity Runway Lights, SSALR = Simplified Short Approach Lighting System with Runway Alignment Indicator Lights, RNP= Required Navigation Performance, LIRL = Low Intensity Runway Lights.

Over the years practical guidelines have been developed on the selection of specific systems for various airport applications *(9)*. While Table 1 provides the minimum requirements of how to satisfy approach lighting system, there are other practical considerations that play a role in selecting specific approach lighting systems. For example, the High Intensity Approach Lighting Systems with Sequenced Flashing Lights (ALSF-1 and ALSF-2) are the preferred configurations installed as part of the ILS with visibility and decision height minima Categories II and III.

Similarly, the primary system used in ILS systems designed for visibility and decision height minima Category I is the MALSR.

As Table 1 indicates, in non-precision approaches it is necessary to provide early runway identification with the provision of an approach lighting system. The Medium Intensity Approach Lighting System (MALS) provides such capability. In airport applications, when local terrain presents a challenge in applications where high ambient lights preclude the quick identification of the MALS system, flashers are added to make a MALSF. In certain applications, a Lead-in Lighting System (LDIN) is sometimes required to provide visual guidance along a specific approach path *(10).* For non-precision approaches with high visibility minima and high decision heights, or to support circling approaches, ODALS may be installed to provide quick identification of the runway. Note that according to Table 1, the family of SALS and SSALS provides similar capabilities and application coverage as that of the MALS.

Many modern approach lighting systems with Sequenced Flashing Lights (ALSF-2) systems can be operated in SSALR mode when the visibility and ceiling permit the use of simpler approach systems.

**Approach Lighting Systems Classes and Installations in the United States.** There are several categories of approach lighting systems recognized by the FAA *(11)* and the International Civil Aviation Organization (ICAO). Figures 4 through 9 present diagrams for the most commonly used approach lighting systems in the United States (note that these diagrams represent the military form of the approach lighting system and that commercial systems are typically 2400 ft rather than 3000 ft as indicated).

Table 2 summarizes the main features of approach lighting systems installed at U.S. airports. Table 3 illustrates the classes of approach lighting systems deployed in the United States. As of February 20th, 2008, there are 1,398 approach lighting systems installed at U.S. airports *(12)*. Maps of the locations of the various installed systems by type are shown in Appendix A.

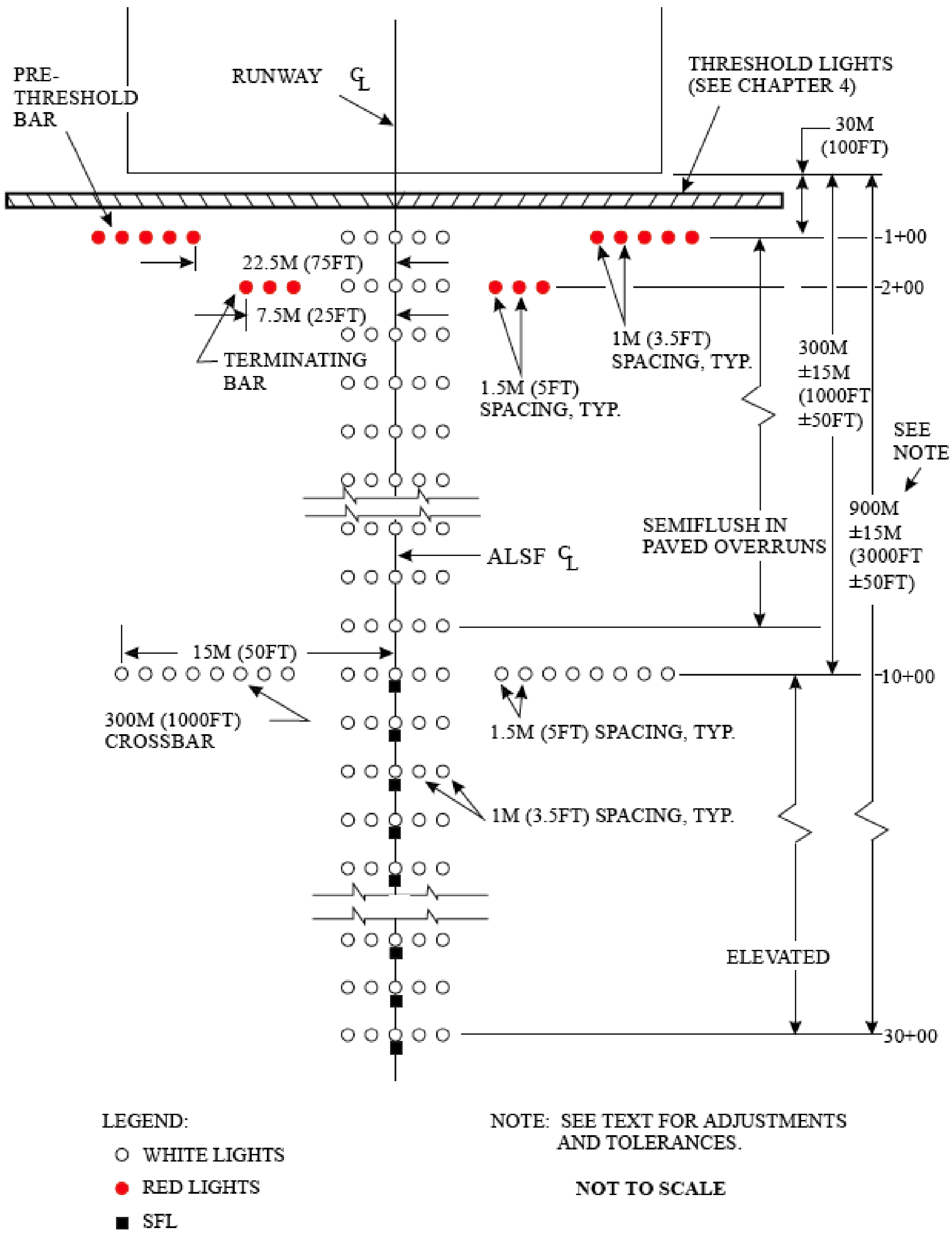



**Figure 4. Typical Installation of an ALSF-1 (Source: Department of Defense, Unified Facilities Criteria: Visual Air Navigation Facilities Document UFC-3-535-01.)**

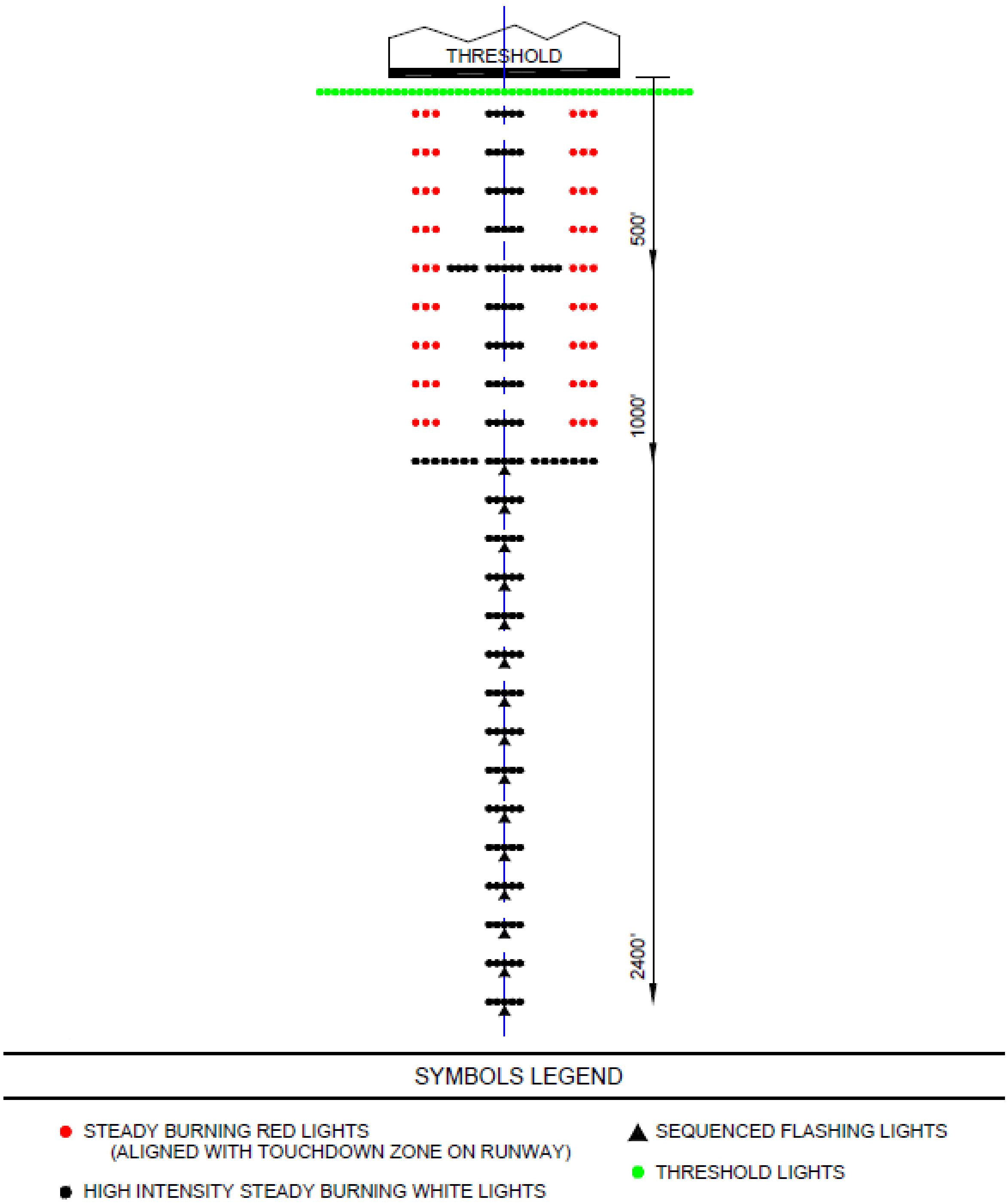



**Figure 5. Typical Installation of an ALSF-2 (Source: General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards. Draft AC 150/5300-18B, U.S. Department of Transportation: Federal Aviation Administration, Page 229.)**

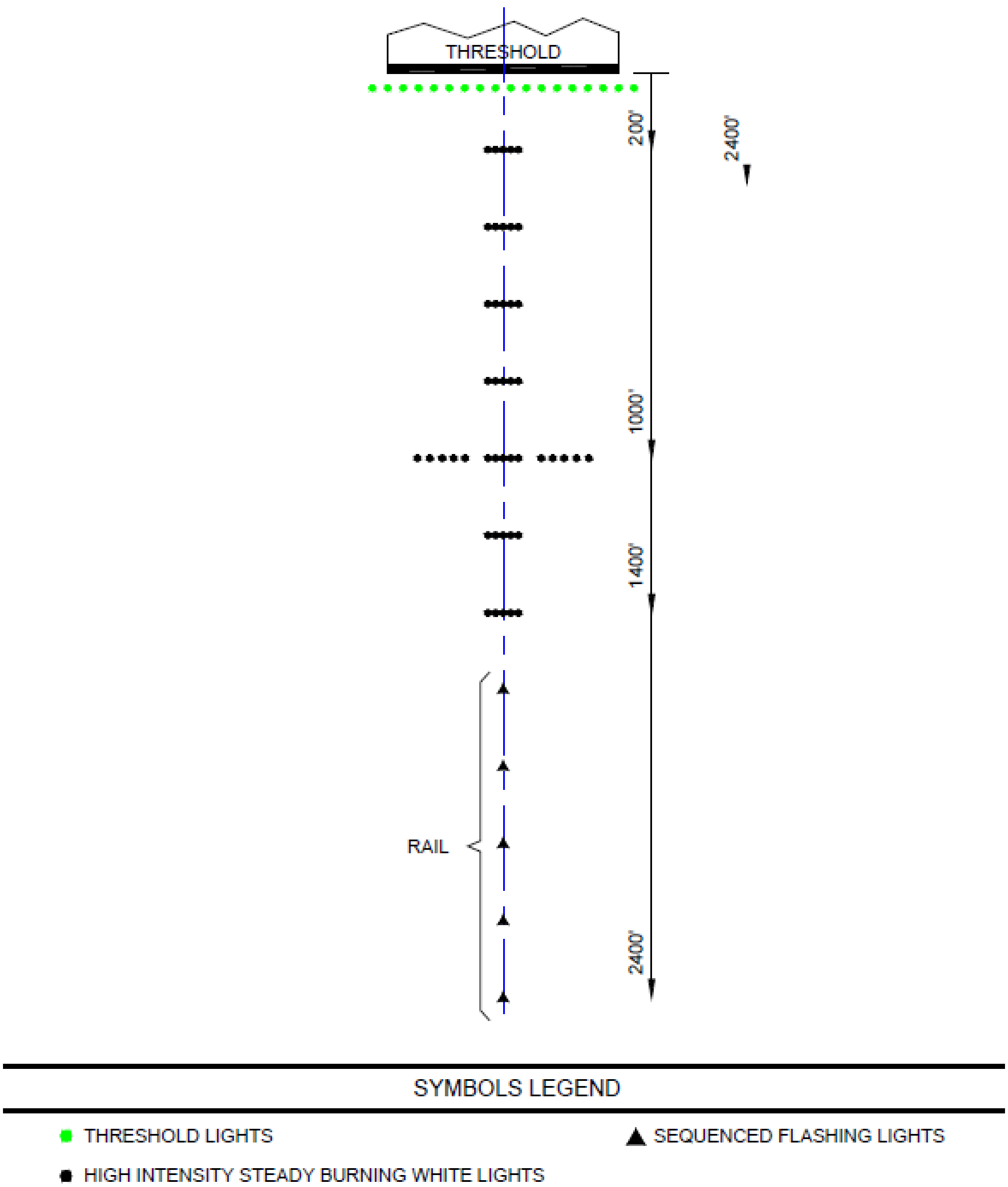



**Figure 6. Typical Installation of an SSALR (Source: General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards. Draft AC 150/5300-18B, U.S. Department of Transportation: Federal Aviation Administration, Page 234.)**

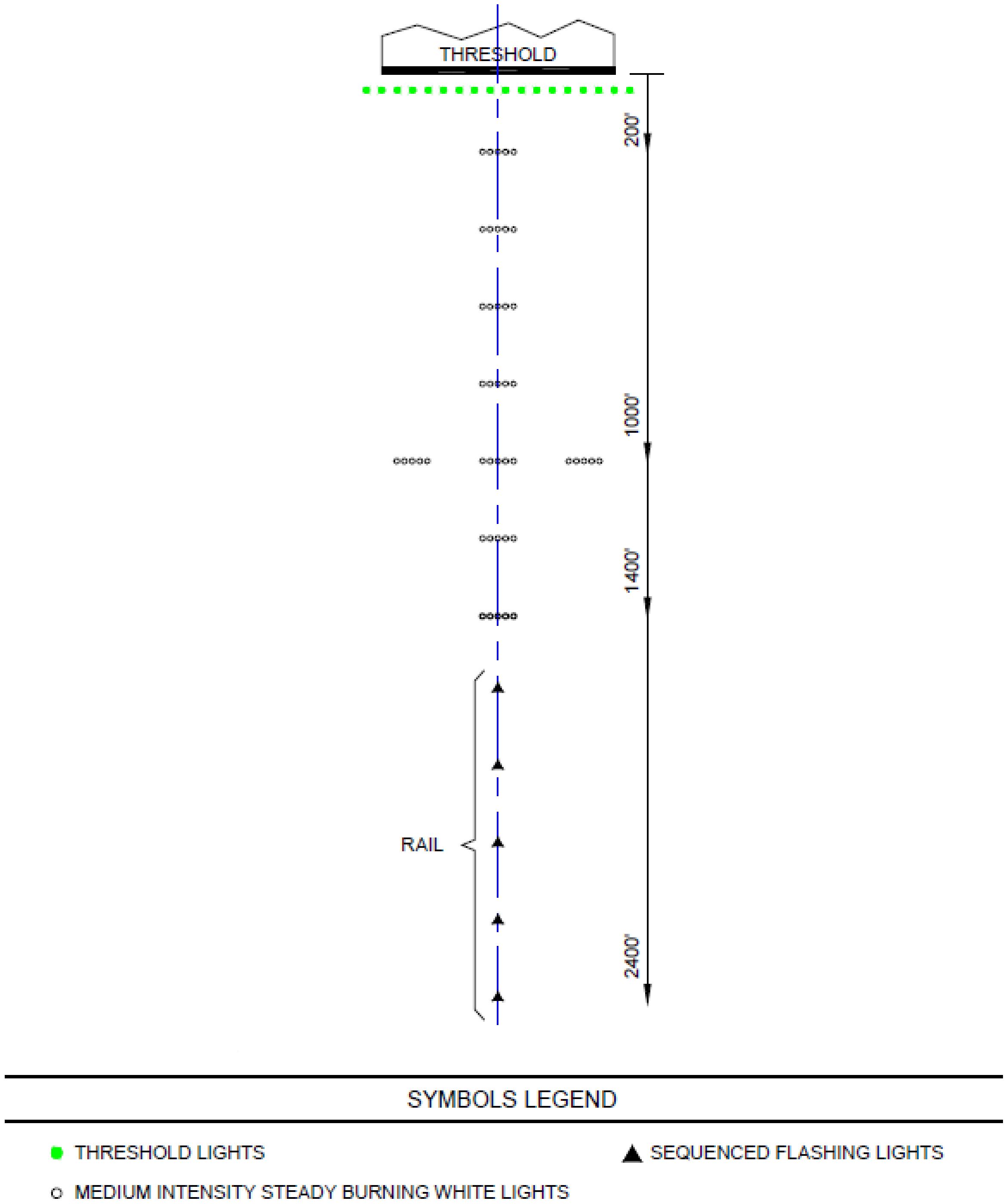



**Figure 7. Typical Installation of a MALSR (Source: General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System (GIS) Standards. Draft AC 150/5300-18B, U.S. Department of Transportation: Federal Aviation Administration, Page 232.)**

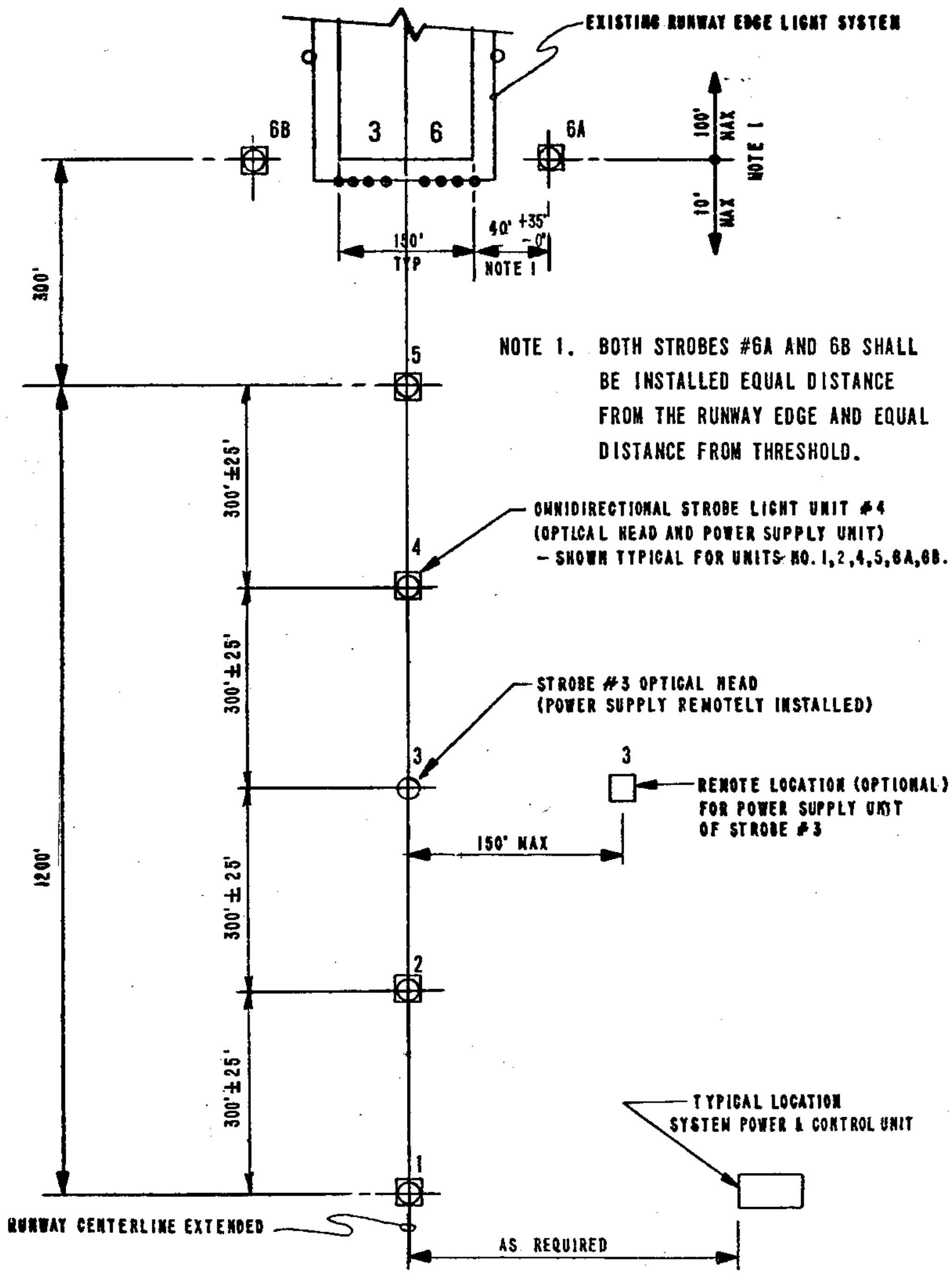



**Figure 8. Typical Installation of an ODALS. (Source: FAA –E-2651.)**

**Table 2. Summary of Approach Lighting Systems (Sources: FAA 2007, New Bedford Panoramex Corporation, Department of Defense, Unified Facilities Criteria: Visual Air Navigation Facilities Document UFC-3-535-01)**

| ALS | Name of the ALS | Characteristics and Basic Configuration |
|---|---|---|
| **ALSF-1** | High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 1) | • Provides information on runway alignment, height perception, roll guidance, and horizontal references for Category II/III instrument approaches.<br>• 2,400 to 3,000 ft from landing runway threshold<br>• Comprised of 205 steady burning lights (49 green threshold lights),144 high-intensity steady burning white lights, and 15 flashing strobe lights<br>• 300 or 500 watt PAR-56 lamps<br>• Limited roll-guidance in the inner 1,000 feet compared with ALSF-2 system<br>• Lights are spaced at 100 feet intervals from the runway threshold |
| **ALSF-2** | High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 2) | • Provides information on runway alignment, height perception, roll guidance, and horizontal references for Category II/III instrument approaches.<br>• 2,400 to 3,000 ft from landing runway threshold<br>• Complete roll guidance in the inner 1,000 ft prior to the runway threshold<br>• Comprised of 247 steady burning lights (277 in the 3,000 ft configuration), Nine rows of 6 red side row-bar lamps, 144 high-intensity steady burning white lights, and 15 flashing strobe lights (21 in the 3,000 ft configuration)<br>• 300 or 500 watt PAR-56 lamps<br>• Lights are spaced at 100 feet intervals from the runway threshold<br>• Flashers discharge twice per second, Time interval between flashes of a single sequence is 16.67 milliseconds<br>• Usually Dual Mode with SSALR system |
| **LDIN** | Lead-in Lighting System | • Variable light sets based on terrain and local ambient conditions<br>• Lead-in flashing lights<br>• 1,600 foot spacing between light elements |
| **MALS** | Medium Intensity Light System | • 7 light stations over 1,400 ft<br>• 63 steady burning lights<br>• 200 foot spacing between light elements<br>• 120 W PAR 38 lights |
| **MALSF** | Medium Intensity Light System with Flashers | • 7 light stations over 1,400 ft<br>• 63 steady burning lights<br>• 200 foot spacing between light elements<br>• 120 W PAR 38 lights<br>• Sequence of flasher lights inside the 1,400 ft steady lights (5 flashers typical) |
| **MALSR** | Medium Intensity Light System with Runway Alignment Indicator Lights | • 12 light stations over 2,400 ft<br>• 63 steady burning lights<br>• 200 foot spacing between light elements<br>• Inner 1,400 foot configuration provides roll guidance<br>• 120 W PAR 38 lights<br>• Sequence of flasher lights in outer 1,000 ft (5 flashers typical) |

| | | |
|---|---|---|
| **ODALS** | Omni-directional Approach Lights | • 5 Omni-directional flashing lights over 1,000 ft<br>• Two Omni-directional lights at runway threshold lateral ends<br>• 200 foot spacing between light elements<br>120 W PAR 38 lights |
| **SALS** | Short Approach Lighting System | • 107 steady burning lights (disposed in 5 light arrays)<br>• 100 foot spacing between light elements<br>• 1,500 foot configuration<br>• Roll guidance bars at 100, 200 and 1,000 feet from runway threshold |
| **SSALS** | Simplified Short Approach Lighting System | Similar to MALS |
| **SSALR** | Simplified Short Approach Lighting System with Runway Alignment Indicator Lights | • 63 steady burning lights<br>• 300 or 500 watt PAR-56 lamps<br>• Sequenced Flashing Lights<br>o 8 active flashers in the 3,000 foot configuration<br>o 5 active flashers in the 2,400 foot configuration<br>• Each unit flashes twice per second. Time interval between flashes of a single sequence is 33.33 milliseconds |
| **SSALSF** | Simplified Short Approach Lighting System with Sequenced Flashers | Similar to MALSF |

**Table 3. Approach Lighting System and Installations in the United States**
**Source: FAA Airport and Runway Facilities Directory (February 2008)**

| ALS | Name of the ALS | Number of Systems Installed at U.S. Airports | Number of Airports with ALS System |
|---|---|---|---|
| **ALSF-1** | High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 1) | 129 | 84 |
| **ALSF-2** | High Intensity Approach Lighting Systems with Sequenced Flashing Lights (Configuration 2) | 154 | 99 |
| **LDIN** | Lead-in Lighting System | 21 | 19 |
| **MALS** | Medium Intensity Light System | 66 | 61 |
| **MALSF** | Medium Intensity Light System with Flashers | 66 | 64 |
| **MALSR** | Medium Intensity Light System with Runway Alignment Indicator Lights | 823 | 633 |
| **ODALS** | Omni-directional Approach Lights | 98 | 94 |
| **SALS** | Short Approach Lighting System | 22 | 18 |
| **SSALS** | Simplified Short Approach Lighting System | 4 | 4 |
| **SSALR** | Simplified Short Approach Lighting System with Runway Alignment Indicator Lights | 11 | 9 |
| **SSALSF** | Simplified Short Approach Lighting System with Sequenced Flashers | 4 | 3 |
| **Total Systems** | | **1,398** | |

Table 3 indicates that 59% of the approach lighting systems in the United States belong to the MALSR class (823 systems installed). The second most common category of approach lighting systems is the family of ALSF-1 and ALSF-2 classes with a combined 20% of the installed systems in the country. MALSFs make up 4.7% of the installed systems whereas MALS also account for 4.7% of the installed systems in the United States. ODALSs account for 7% of the installations in the United States. ODALSs support non-precision approaches and new approach procedures with vertical guidance. LDINs constitute 1.5% of the systems in the country with 21 installations. Finally, the categories of SALS and Simplified Short Approach Lighting Systems (SSALR, SSALS and SSALF) account for the remaining 3% of the approach lighting systems in the country. Appendix A provides more detailed information on all 1,398 installations of various approach lighting systems.

**Frangibility Requirements.** Frangibility requirements are contained in FAA Advisory Circular AC150/5345-45C. The types of mounting structures used in various approach lighting systems do influence the potential damage caused by an aircraft collision with the approach lighting system. Common approach lighting system mounting structures are made of fiberglass lattice, fiberglass tubular poles (see Figure 9), aluminum lattice (Figure 10) and aluminum tubular poles. In some cases, where terrain precludes short pole or lattice installations, non-frangible support structures are needed. Such structures are constructed of steel or wood and could involve existing buildings or piers over bodies of water (Figure 11 and Figure 12).

In general, the frangibility requirements are such that the support must be designed to break away when impacted by a 3000-kg (6613.8-lb) aircraft traveling 140 km/h (75.6 knots) without exerting more than 45 kN (10,116 lbf) on the colliding aircraft. The electrical cabling must disconnect at the base so that the tower and the aircraft do not become entangled with the cabling. The tower must also be able to withstand a wind force of 75 mph with 0.5 in. of ice on all surfaces and 100 mph without ice. The material used to build the tower must also be able to withstand the weather conditions and environmental impact so that corrosion and decay are not an issue.

For structures over 40 ft high, only the top 20 ft need to be frangible. A steel tower is used for the other portion of the light support. As most collisions with the approach lighting system appear to be minor incidents where the system was hit by a low aircraft, this is likely not a problem. This poses a difficulty in the case of a catastrophic incident where an aircraft collides below the frangible structures of the approach lighting system. Here the steel towers may pose a significant threat to the aircraft. It should be noted that the steel tower supports are typically beyond the runway safety area.

**Figure 9. Approach Lights Mounted on Fiberglass Tubular Poles**

**Figure 10. Approach Lights Mounted on Aluminum Lattice Support Structures**

**Figure 11. Approach Lights Mounted on Hybrid Supports (Frangible and Non-frangible): Land Installation**


**Figure 12. Approach Lights Mounted on Hybrid Supports (Frangible Fiberglass Tubular Poles and Non-frangible Wooden Pier Structure): Over-the-water Pier Installation**

### *System Electrical Design, Control, and Monitoring*

The electrical control of the systems varies by the type of approach lighting system being installed. For the ALSF systems, series loop connections powered by constant current regulators are used whereas the other approach lighting systems are powered by more traditional parallel wiring systems. These systems and the control link are well defined by the FAA specifications.

For the ALSF systems (specified in FAA-E-2689a), the series wiring configuration allows for minimum impact on the intensity of the individual lights due to the constant current regulation. Depending on the age and vendor of the system, the ALSF can be powered by three or five current loops and constant current controllers. The current standard is a 5-loop system. Due to the low minima associated with an ALSF approach, the ALSFs are also provided with a backup generator to provide constant power if the input power system should fail. This generator is typically activated by the tower in the case of bad weather. Similarly, five intensity levels are switchable based on the ambient weather and lighting conditions. An isolation transformer, specified in FAA-E-2690a, is required in these systems in order to convert the high voltage in the current loop to usable power for the light source. It is important to note that a failure mode is not specified for the isolation transformer. If the system were damaged, the behavior of the transformer is not determined. The monitoring of the ALSF system is also dependant on age and available resources. New ALSF systems require monitoring at each lamp and light bar to determine the operational mode of the system and to determine failure criteria (Table VI, FAA-E-2689a). This monitor can be remote or local based on the installed system. The older ALSF systems use a differential voltage which can be monitored at the control building that indicates the number of lamps that have failed in each current loop. The FAA personnel must then visually check the system to determine the actual outage. In the case of a catastrophic failure of the system, one where an aircraft damages several components of the system, it is believed that the current regulators will shut down due to current requirements outside of the system specification, but a specification of this behavior was not found in the literature review.

The other approach lighting system configurations use more traditional power. For a MALS, specified in FAA-E-2980, each light bar is hooked to a circuit breaker much like lighting in the home is wired. A control system is used for the flashing sequences and the steady burning system to allow for the intensity switching and the control of the flashers. In the case of a catastrophic failure, the system should be controlled by the individual circuit breakers.

The control for turning the approach lighting system on and off and selecting the intensity level is typically located in the FAA tower. For those airports which do not have a tower, this switching is located in a control cabinet. The connection of the power control to the lighting substation is either a direct cabled link or ground-to-ground radio. For airports without a tower, air-to-ground radio is typically used to activate the system. FAA AC 150/5340-30C allows for the connection of the approach lighting system to the airport's lighting control system and specifies the nature of the control link and off-the-shelf software for the control.

It is important to note that when the approach lighting system is activated, the power to the lighting is flowing from the approach lighting system substation to the lighting system and there is power in the approach area for the runway. When the system is turned off, all of the power is stopped at the substation and no active approach lighting system power is in the runway area. This is important in the case of an incident in that an overshoot situation is not as critical in terms of the approach lighting system as is an undershoot situation. For an overshoot, which is on the non-approach end of the runway, the approach lighting system would not be activated and no electricity would be present in the approach lighting system area. For an undershoot situation, the approach lighting system power is activated and the system would have live electricity in the runway area.

It should be noted that, generally, the airport operator has no responsibility for the approach lighting system. The FAA will install and maintain the system to its specifications. For large airports with 24-hour-per-day FAA support, this is typically not an issue. For smaller airports, and those without a control tower, additional control and monitoring systems may be required to maintain safety and to notify the FAA of the status of the system.

***Airport Emergency Procedures***

FAA AC 5200-31A provides guidance on the development of an Airport Emergency Plan (AEP). It states that "Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended, the elected officials of the communities that own and operate airports are legally responsible for ensuring that necessary and appropriate actions are taken to protect people and property from the consequences of emergencies and disasters." The Federal Emergency Management Agency (FEMA) also provides the *State and Local Guide (SLG) 101: Guide for All-Hazard Emergency Operations Planning*. Here, comprehensive emergency management (CEM) is defined as a process that recognizes four separate but related actions:

- Mitigation
- Preparedness
- Response
- Recovery

For an AEP, the most critical aspect of the plan might be the third and fourth components of the CEM. The AEP must define the response and the recovery aspects of an emergency response. The AEP must assign responsibility and lines of authority for the actions to be carried out in terms of responding to an emergency.

The development of the plan should include a team effort involving all who will be influenced by the plan. FAA AC 5200-31A recommends a wide variety of team members such as the airport management, the FAA, and the air traffic controllers. In terms of incidents involving the approach lighting system, the standard operating procedures (SOPs) for the Air Traffic Control (ATC) and FAA maintenance response, as well as those for the airport operator, must be defined. Simulations and drills to determine the effectiveness of the plan should also be executed.

***Safety Management Systems***

FAA AC 150/5200-37 provides the concept of the safety management system (SMS) for airport operators. This system is a top-down approach to managing system risk at the airport and includes systematic procedures, practices, and policies for the management of risk, safety, and promotion of safety. The important aspect of the SMS in terms of the approach lighting system is the identification of hazards and risks and the design of appropriate mitigation strategies. The five phases of the process are 1) Describe the system, 2) Identify the hazards, 3) Determine the risk, 4) Assess and analyze the risk, and 5) Treat the risk.

The system description should be complete and encompass all of the critical components to the system under concern. For the hazard identification, all threats to the system must be stated and clearly categorized into the conditions which influence the hazard. The risk is then determined based on each hazard. As an example relating to the approach lighting system: the hazard would be debris in the runway safety area, resulting from a frangible approach lighting system tower break, and the risk would be damage to the aircraft and other components of the approach lighting system. The fourth aspect of the task would be to assess and analyze the risks in terms of severity and likelihood. The risk is then determined using the matrix shown in Figure 13. The final aspect of the process is treating the risk through the development of mitigation factors that reduce either the likelihood or the severity of the event.

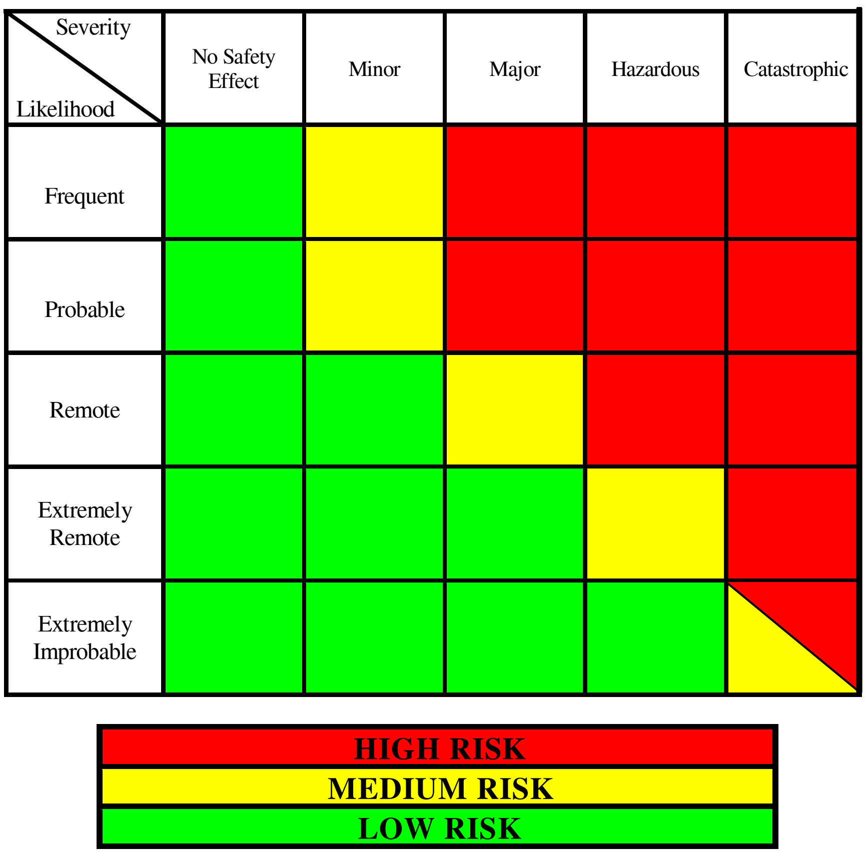



**Figure 13. Predictive risk matrix.**

For this project and the developed guidebook, these five steps will be followed with specific focus on the approach lighting system.

***Summary***

The literature review has developed the basis for the identification and control of the approach lighting system particularly as defined by the FAA specifications. Some oversights, such as the development of criteria for the failure mode of the approach lighting system in terms of a catastrophic failure, were noted. The frangibility requirements for the systems were also reviewed. The final aspect of the literature review was that of safety management systems which identify a procedure for identifying and mitigating hazards and risks in airports. This procedure will be followed throughout the development of the guidebook in the project.

**Task 2 – Incident Review**

An extensive review of aircraft accidents was conducted to understand the risks that approach lighting systems pose to aircraft. In this review of accidents and incidents, the following sources of accident data were consulted:

1) The NTSB accident database (available at http://www.ntsb.gov/ntsb/query.asp)
2) The FAA Aviation Safety Information Analysis and Sharing (ASIAS) database (available at (http://www.asias.faa.gov)
3) NASA's Aviation Safety Reporting System (ASRS) database (http://asrs.arc.nasa.gov/#)
4) Transportation Safety Board of Canada accident reports

The incidents and accidents of interest constitute those where aircraft collided with an approach lighting system. A total of 110 accidents/incidents spanning 35 years of accident information were assembled and studied. The accidents/incidents were compiled in a FileMaker Pro database. The organization of the database is illustrated in Figure 14 and Table 4. Table 4 summarizes all fields included in the database. The table includes field types and Figure 15 shows graphically the organization of five database files comprising the approach lighting system accident database. The database relies on the FAA airport and runway facility directory data *(12)*, a world airports database compiled by ICAO, and the FAA Enhanced Traffic Management System (ETMS) aircraft designator to relate accident information entered by the research team with existing airport and aircraft information.

The database developed includes useful information of the accident, airport, and runway information (including the type of approach lighting system involved – see Figure 15 and Figure 16), links to satellite pictures of the airport, pictures of the event from various sources, narrative reports, and the accident/incident report of the appropriate agency.

A comparison of our database was performed with the accident and incident database collected in Airport Cooperative Research Program (ACRP) project 04-01 (Aircraft Overrun and Undershoot Analysis for Runway Safety Areas) *(13)*. This project collected a total of 459 accidents/incidents where aircrafts overran or undershot a runway. Note that such database is more extensive because in most cases overruns and undershoots do not collide with an approach lighting system. Moreover, the ACRP project 04-01 included some accidents beyond the dimensions of an approach lighting system.

A valid statistical analysis to determine the risk of collision with approach lighting systems at the individual airport level is not possible because collisions with approach lighting systems are very rare events. Some assumptions regarding the distribution of the probability of collision with approach lighting system would have to be made. A separate study conducted by ACRP Project 04-01 has established a methodology to estimate risk of aircraft undershoots and overruns. While such risks are related to the risk of colliding with an approach lighting system, the latter is much smaller because ACRP 04-01 looked at accidents in the context of Runway Safety Areas

(RSA). The footprint of RSA areas is much larger than that of approach lighting systems. Thus the probability of collision with an approach lighting system is rather small as will be determined below. A separate analysis of runway safety areas found that 38 (45%) of the 84 runway ends of airports visited by the research team are not in compliance with FAA RSA requirements. The remainder of the runways (46 or 55%) was found to be in compliance. This number is improving with time as many airports have taken the task to comply with FAA runway safety area requirements/

- A level of exposure of aircraft operations to collision risk with an approach lighting system can be obtained at the national level using FAA operational data for various airports. For example, for the 901 airports having an approach lighting system in place, there were 3,618, 618,291 operations in the national system (using historical data available in the FAA Terminal Area Forecast). During the period of analysis between 1975 and 2007, there were 110 accidents with known collisions with approach lighting systems. This translates into an accident rate with approach lighting systems of 1 per 37 million operations. This metric is remarkable in terms of safety. Recent statistics of aircraft fatal events for modern airlines suggest a fatality every 5.5-10.5 million operations.

**Table 4. Approach Lights Incident and Accident Database Structure**

| Category | Field | Field Type and Features |
|---|---|---|
| **Summary** | Aircraft Type | Text (FAA aircraft designator) |
| | Type of Occurrence | Text (Incident/accident) |
| | Airport Name | Text |
| | Airport Designation | Text (FAA 3-letter code or ICAO 4-letter code) |
| | Aircraft Damage | Text (substantial/minor) |
| | Carrier Name | Text (Carrier name/ Corporate / Private GA) |
| | ALS System | Text (ALSF-I, ALSF-II, MALS, etc.) |
| | Fatalities | Number |
| | Injuries | Number |
| | Date | Time (month:day:year) |
| | Time | Time (hr:mm:ss) |
| | Accident/Incident ID | Text (accident document docket number) |
| | Accident Runway | Text |
| | Accident Country | Text (US or non US) |
| | Source of Information | Text (NTSB, FAA ASIAS, etc.) |
| | Total Fatalities | Number (summary of query) |
| | Total injuries | Number (summary of query) |
| **Airport Information** | Airport Location Identifier | Text (FAA 3-letter code or ICAO 4-letter code) |
| | Associated State Name | Text |
| | Official Facility Name | Text |
| | ICAO Identifier | Text (ICAO 4-letter code) |

| | | |
|---|---|---|
| | FAA Airport Identifier | Text (FAA 3-letter code) |
| | Airport Latitude | Number (degrees, decimal) |
| | Airport Longitude | Number (degrees, decimal) |
| | Runway ID | Text (primary end/reciprocal end) |
| | Runway Heading | Number (degrees) |
| | Runway Length | Number (feet) |
| | Runway Width | Number (feet) |
| | Runway Edge Lights | Text (High / Med / Peri) |
| **Map** | Map_field | World Wide Web object |
| **Accident Photos** | Picture 1 | Graphic object |
| | Picture 2 | Graphic object |
| | Picture 3 | Graphic object |
| | Picture 4 | Graphic object |
| **Report** | Report | Container |
| **Narratives** | Accident Narrative | Text |
| | Additional Accident Narrative | Text |
| **Weather** | Descriptive Weather Condition | Text |
| | Basic weather | Text (VMC / IMC) |
| | Ceiling | Number (feet) |
| | Visibility | Number (miles) |
| | Wind Speed | Number (knots) |
| | Wind direction | Number (degrees) |
| | Precipitation | Text |
| **Aircraft Information** | Aircraft Designator | Text (FAA designator) |

| | | |
|---|---|---|
| | Weigh_Class | Text (FAA weight class) |
| | Model | Text |
| | Manufacturer | Text |
| | Aircraft Type | Text (Land-Based, Amphibian, etc.) |
| | Number of Engines | Number |
| | Type of Engines | Number |
| | Wake Vortex Class | Text (Small, Large, B757, Heavy) |

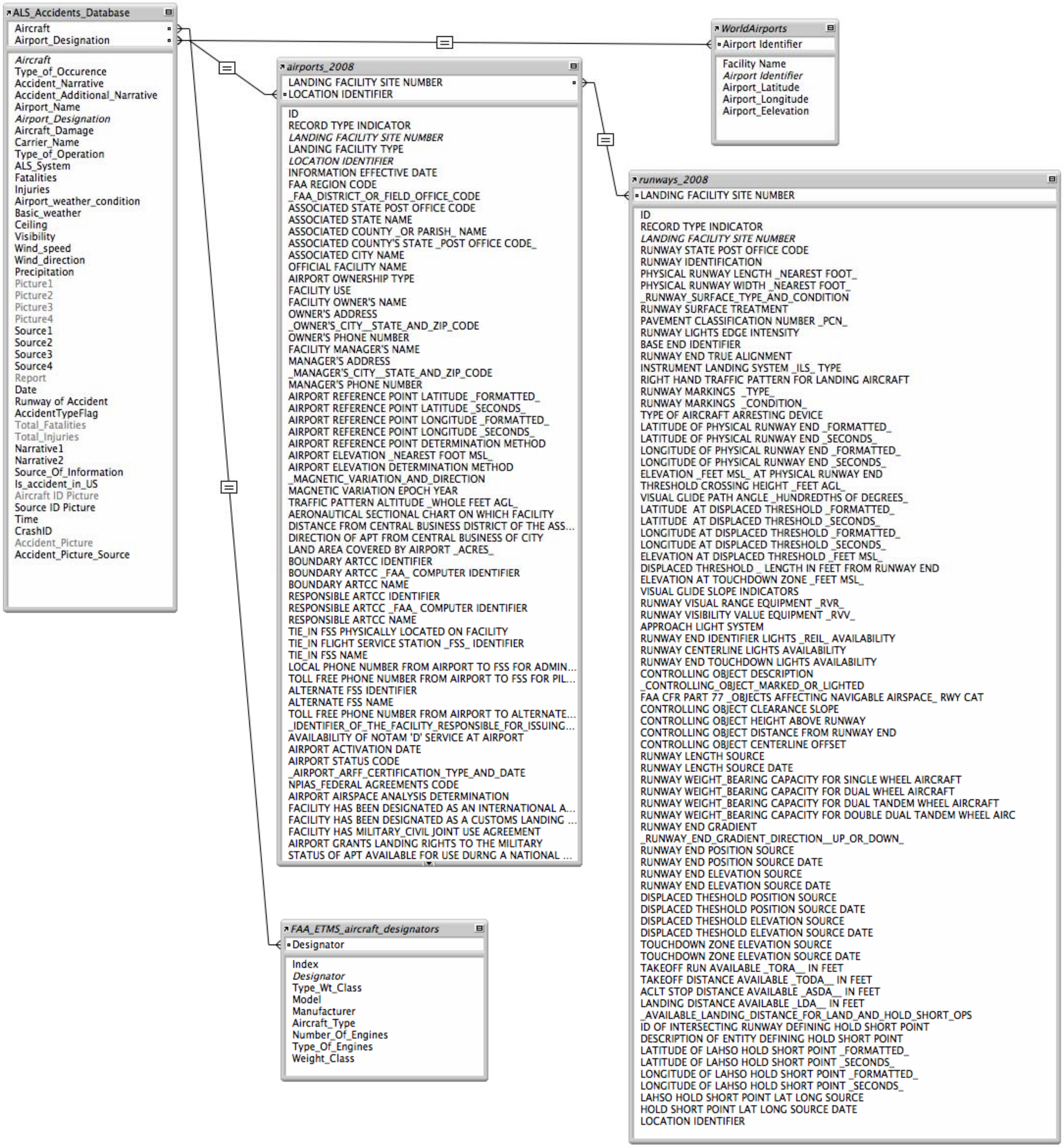



**Figure 14. Organization of a Relational Database of ALS Accidents and Incidents**

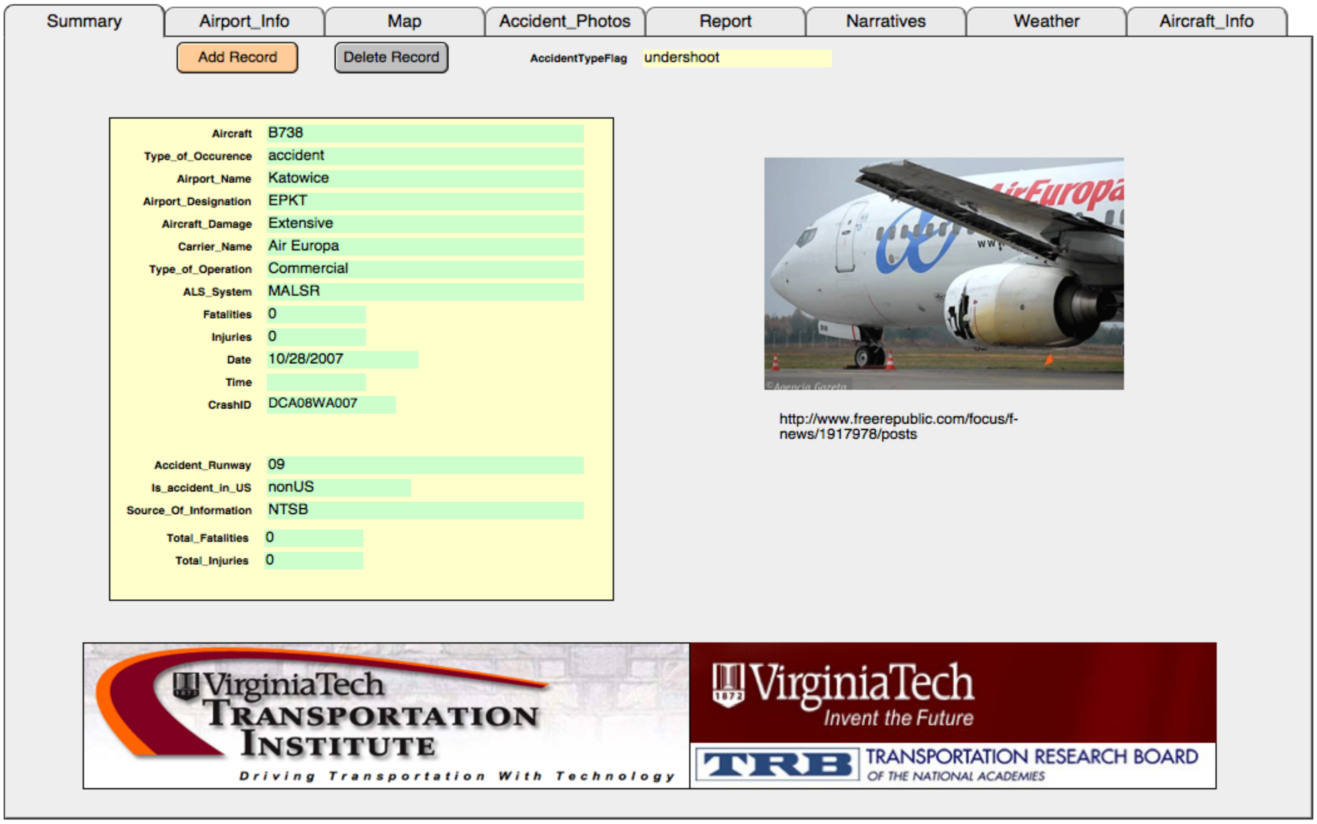
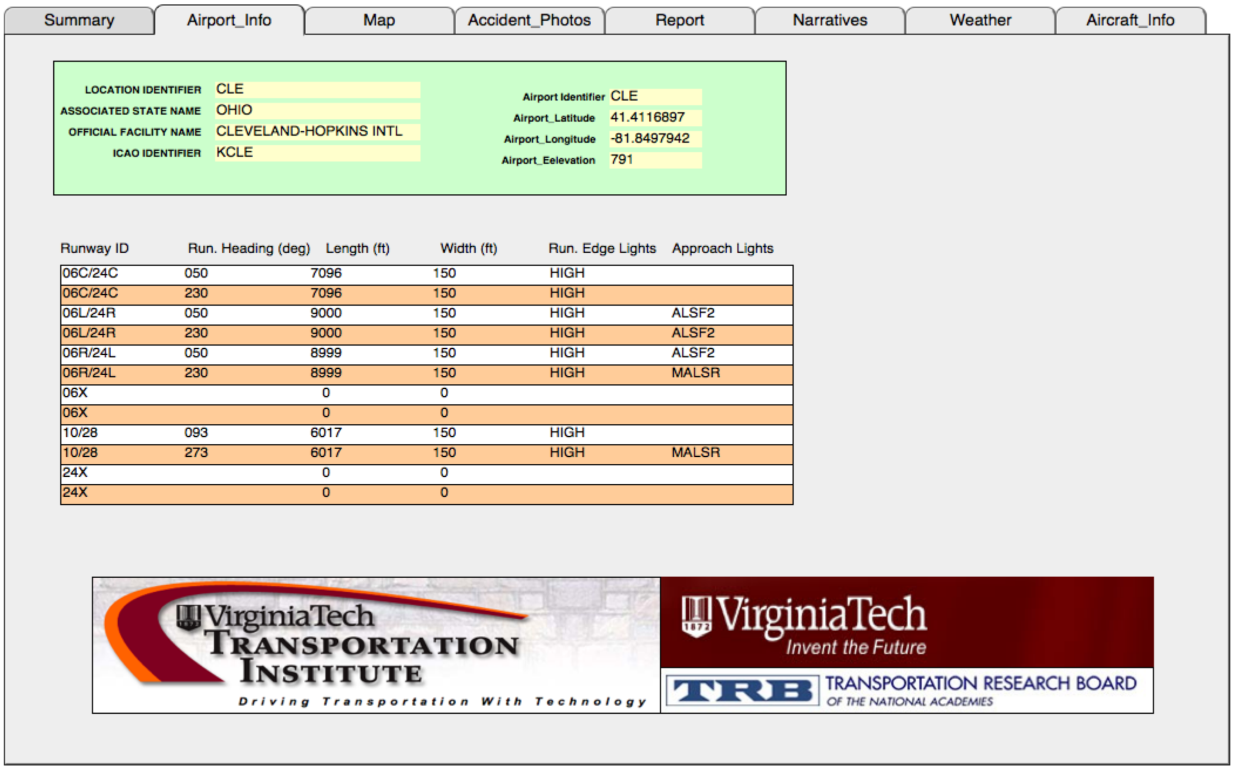



**Figure 15. Main Screen of the Accident/incident Database Constructed in this Project: Katowice Boeing 737-800 Accident**




| Runway ID | Run. Heading (deg) | Length (ft) | Width (ft) | Run. Edge Lights | Approach Lights |
|---|---|---|---|---|---|
| 06C/24C | 050 | 7096 | 150 | HIGH | |
| 06C/24C | 230 | 7096 | 150 | HIGH | |
| 06L/24R | 050 | 9000 | 150 | HIGH | ALSF2 |
| 06L/24R | 230 | 9000 | 150 | HIGH | ALSF2 |
| 06R/24L | 050 | 8999 | 150 | HIGH | ALSF2 |
| 06R/24L | 230 | 8999 | 150 | HIGH | MALSR |
| 06X | | 0 | 0 | | |
| 06X | | 0 | 0 | | |
| 10/28 | 093 | 6017 | 150 | HIGH | |
| 10/28 | 273 | 6017 | 150 | HIGH | MALSR |
| 24X | | 0 | 0 | | |
| 24X | | 0 | 0 | | |

**Figure 16. Airport and Runway Information Screen of the Accident/incident Database: Cleveland Hopkins Embraer 145 Accident**

Table 5 presents a summary of the 110 accidents collected in the database. These accidents span 35 years (starting in 1973) and include carrier, general aviation, and air taxi operations. The accidents include collisions with approach lighting systems and, in some instances, collisions with components of the ILS system (such as localizer antenna). (Military accidents were not included in this study.) The table includes the airport code and name, aircraft type, approach lighting system, and accident type (undershot or overrun).

A few findings can be drawn from Table 5:

a) 46% of the aircraft collisions with approach lighting systems involve MALSR (the most common type of approach lighting system)
b) 14% of the aircraft collisions with approach lighting systems involve higher voltage ALSF-1s and ALSF-2s
c) 4% of the aircraft collisions with approach lighting systems involve MALSFs
d) 8% of the aircraft collisions with approach lighting systems involve MALSs (no flashers)
e) 8% of the aircraft collisions involved localizer antennas
f) 2% of the accidents reviewed involved collisions with SSALRs
g) The remaining 18% of the accidents involved collisions with runway end lights, Visual Approach Slope Indicator (VASI) lights or unknown approach light sources listed as approach lights in the accident/incident reports

While no effort was made to collect data related only to fixed-wing aircraft, the database shows no significant presence of helicopters involved in approach lighting system accidents. Forty-two percent of the aircraft collisions with approach lighting systems involve jet-powered aircraft. Piston-powered aircraft account for 51% of the collisions with approach lighting systems. The remaining 7% of the accidents involve turboprop aircraft.

Instrument Flight Rule (IFR) flying conditions accounted for 43% of the accidents. The remaining 57% of the collisions with ALSs involved Visual Flight Rule (VFR) conditions.

**Table 5. Aircraft Accidents and their Interaction with Various Approach Lighting Systems**

| Airport Code | Date | Airport Name | Aircraft | Manufacturer | Model | Type Weight Class | ALS | Accident Type |
|---|---|---|---|---|---|---|---|---|
| ACK | 08/25/2000 | Nantucket | pa32 | PIPER | PA-32 Cherokee Six, Six, Saratoga, Turbo Saratoga | L1P/S | SSALR | undershoot |
| ACK | 07/30/1993 | Nantucket | b732 | BOEING | 737-200, Surveiller (CT-43, VC-96) | L2J/L | SSALR | undershoot |
| AGC | 01/06/1998 | West Mifflin | c500 | CESSNA | 500 Citation, Citation 1 | L2J/S | MALSR | overrun |
| AGS | 11/26/1981 | Augusta | b722 | BOEING | 727-200 | L3J/L | MALSR | undershoot |
| ATL | 12/25/1992 | Atlanta | pa23 | MILLER, US | Jet Profile | L2P/S | | undershoot |
| ATL | 11/20/1982 | Atlanta | ac80 | AERO COMMANDER | 680T, 680V Turbo Commander | L2T/S | Localizer | undershoot |
| AUS | 04/08/1994 | Austin | LJ35 | GATES LEARJET | 35, 36 (C-21, RC-35, RC-36, U-36) | L2J/S+ | Runway Edge Lights | undershoot |
| AVL | 05/20/1999 | Asheville regional | c172 | CESSNA | 172 | L1P/S | MALSR | undershoot |
| BEH | 08/06/1993 | Southwest Michigan Regional | c172 | CESSNA | 172 | L1P/S | MALSR | undershoot |
| BIS | 07/01/1996 | Bismarck Municipal | P28B | PIPER | PA-28-Cherokee | L1P/S | MALS | undershoot |
| BLI | 03/04/1989 | Bellingham | c185 | CESSNA | 185 | L1P/S | MALSR | undershoot |
| BNA | 01/07/1996 | Nashville | DC93 | DOUGLAS | DC-9-30 | L2J/M | ALSF-2 | undershoot |
| BNA | 07/08/1996 | Nashville | b732 | BOEING | 737-200 | L2J/L | Runway Edge Lights | overrun |
| BNA | 11/23/1987 | Nashville | b722 | BOEING | 727-200 | L3J/L | Runway End Lights | overrun |
| BOI | 10/09/2004 | Boise | sw4 | FAIRCHILD (1) | SA-227A | L2T/L/M | MALSR | overrun |
| BOS | 07/31/1973 | Boston | dc93 | DOUGLAS | DC-9-30 | L2J/M | ALSF-2 | undershoot |
| BOS | 12/17/1973 | Boston | dc10 | MCDONNELL DOUGLAS | DC-10 | L3J/H | MALSR | undershoot |
| BTR | 02/27/1988 | Baton | RYST | RYAN | ST-A, ST- | L1P/L | MALSR | undershoot |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Rouge | | | M,ST-R | | | |
| CCR | 10/13/1985 | Concord | p28b | PIPER | PA-28-201T/Dakota | L1P/S | MALS | undershoot |
| CID | 03/03/1989 | Cedar Rapids | c310 | CESSNA | 310 | L2P/S | MALSR | undershoot |
| CLE | 01/06/2003 | Cleveland | e145 | EMBRAER | EMB-145 | L2J/L | Localizer | overrun |
| CLE | 12/22/1998 | Cleveland Hopkins | dc3 | DOUGLAS | DC-3 | L2P/S+ | ALSF-2 | undershoot |
| CLT | 08/10/1991 | Charlotte | b762 | BOEING | 767-200 | L2J/H | Runway End Lights | overrun |
| CLT | 10/25/1986 | Charlotte | b732 | BOEING | 737-200, | L2J/L | Localizer | overrun |
| CLT | 11/23/1994 | Charlotte Douglas | dc3 | DOUGLAS | DC-3 | L2P/S+ | ALSF-2 | undershoot |
| CRG | 01/12/2005 | Craig Municipal (Jacksonville) | be30 | BEECH | 300 Super King Air | L2T/S+ | Localizer | overrun |
| DAL | 05/10/1996 | Love Field | b733 | BOEING | 737-300 | L2J/L | Unknown | runway excursion |
| DDH | 06/15/2005 | Bennington | C172 | CESSNA | 172 | L1P/S | Unknown | undershoot |
| DEN | 06/20/1990 | Denver International | b742 | BOEING | 747-200 (E-4, VC-25) | L4J/H | Unknown | overrun |
| DFW | 12/08/1993 | Dallas-Fort Worth | b733 | BOEING | 737-300 | L2J/L | MALSR | undershoot |
| DFW | 03/03/1981 | Dallas-Fort Worth | be36 | BEECH | 36 Bonanza (piston) | L1P/S | MALSR | undershoot |
| DIA | 11/21/2004 | Denver | md82 | MCDONNELL DOUGLAS | MD-82 | L2J/M | ALSF-2 | undershoot |
| DVN | 05/13/2003 | Davenport Municipal | be95 | BEECH | 95 Travel Air | L2P/S | | undershoot |
| EPKT | 10/28/2007 | Katowice | B738 | BOEING | 737-800, BBJ2 | L2J/L | MALSR | undershoot |
| ERI | 09/18/1982 | Erie | pa24 | PIPER | PA-24 Comanche | L1P/S | MALSR | undershoot |
| ESF | 11/16/1993 | Pineville | glf3 | GULFSTREAM AEROSPACE | G-1159A Gulfstream 3 | L2J/L | MALSR | undershoot |
| EWB | 11/01/2003 | New Bedford Regional | unknown | | | | MALSR | undershoot |
| FAR | 06/05/1997 | Hector International | m20T | MOONEY | M-20K/M | L1P/S | MALSR | undershoot |
| FLL | 10/02/1997 | Fort Lauderdale | c402 | CESSNA | 402 | L2P/S | MALSR | overrun |
| FLL | 10/23/1995 | Fort Lauderdale Hollywood | pa32 | PIPER | PA-32 Cherokee Turbo Saratoga | L1P/S | MALSR | undershoot |
| FLL | 11/28/1999 | Fort Lauderdale | pa24 | PIPER | PA-24 Comanche | L1P/S | MALSR | undershoot |
| FLL | 03/21/1988 | Fort Lauderdale | noordv | | | | MALSR | undershoot |
| FTG | 11/24/1997 | Front Range | c172 | CESSNA | 172 | L1P/S | MALSR | undershoot |
| FTW | 07/15/1984 | Fort Worth | lj24 | GATES LEARJET | 24 | L2J/S+ | MALSR | undershoot |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| FWA | 08/24/1996 | Fort Wayne International | SSAB | NORTH AMERICAN | F-100 Super Sabre | L1J/L | ALSF-2 | undershoot |
| GRI | 02/11/1999 | Central Nebraska Regional | ac50 | AERO COMMANDER | 500 Commander 500 | L2P/S | MALS | undershoot |
| GUC | 07/08/1992 | Gunnison-Crested Butte Regional | c177 | CESSNA | 177, Cardinal | L1P/S | MALSF | undershoot |
| HIO | 10/30/1995 | Portland-Hillsboro | c152 | CESSNA | 152 | L1P/S | MALSR | overrun |
| HRL | 02/08/1996 | Texas Central Valley | b722 | BOEING | 727-200 | L3J/L | MALSR | undershoot |
| HYA | 03/17/2000 | Barnstable | f900 | DASSAULT | Falcon 900, Mystere 900 | L3J/L | Localizer | overrun |
| IND | 09/19/2001 | Indianapolis | be20 | BEECH | 200, 1300 Super King Air | L2T/S+ | MALSR | undershoot |
| IND | 04/12/1989 | Indianapolis | be60 | BEECH | 60 Duke | L2P/S | MALSR | undershoot |
| JAX | 02/06/1989 | Jacksonville | b732 | BOEING | 737-200, | L2J/L | MALSR | overrun |
| JFK | 02/28/1984 | New York Kennedy | dc10 | MCDONNELL DOUGLAS | DC-10 | L3J/H | ALSF-2 | overrun |
| JFK | 01/23/1983 | New York | dc86 | DOUGLAS | DC-8-60 | L4J/H | Unknown | undershoot |
| JFK | 06/01/1988 | New York | b742 | BOEING | 747-200 | L4J/H | ALSF-2 | undershoot |
| LGA | 09/20/1989 | La Guardia | b734 | BOEING | 737-400 | L2J/L | MALSR | overrun |
| LGA | 10/19/1996 | La Guardia | md88 | BOEING | MD-88 | L2J/M | MALSR | undershoot |
| LHR | 1/17/2008 | London Heathrow | B772 | BOEING | B777-200 | L4J/H | ALSF-2 | undershoot |
| LIT | 06/01/1999 | Little Rock | md82 | MCDONNELL DOUGLAS | MD-82 | L2J/M | MALSF | overrun |
| LIT | 05/01/1981 | Adams Field | ac68 | AERO COMMANDER | 680F, 680FP Commander | L2P/S | MALSF | overrun |
| LNS | 09/28/1979 | Lancaster | AA5 | AMERICAN | AA-5 Traveler | L1P/S | MALSR | undershoot |
| LVN | 07/24/2002 | Minneapolis | be35 | BEECH | 35 Bonanza | L1P/S | MALSR | undershoot |
| MGY | 02/08/2001 | Dayton Wright Brothers | c172 | CESSNA | 172 | L1P/S | MALS | undershoot |
| MGY | 03/06/1993 | Springboro | p28b | PIPER | PA-28-201T | L1P/S | MALS | undershoot |
| MGY | 07/23/1993 | Dayton Wright Brothers | c337 | CESSNA | 337 | L2P/S | MALS | undershoot |
| MGY | 10/15/1988 | Dayton Wright Brothers | c172 | CESSNA | 172 | L1P/S | MALS | undershoot |
| MIA | 01/06/1990 | Miami | l29a | LOCKHEED | L-1329 Jetstar 6/8 | L4J/L | MALSR | overrun |
| MLB | 04/01/2000 | Melbourne | c152 | CESSNA | 152 | L1P/S | MALSR | undershoot |
| MOB | 08/12/2002 | Mobile Regional | c172 | CESSNA | 172 | L1P/S | MALSR | undershoot |
| MPTO | 06/03/1995 | Panama City | b742 | BOEING | 747-200 (E-4, VC-25) | L4J/H | Unknown | undershoot |
| MSP | 08/09/1999 | Minneapolis | dc10 | MCDONNELL | DC-10 | L3J/H | Runway | overrun |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | DOUGLAS | | | End Lights | |
| MYF | 12/31/1991 | San Diego | aest | AEROSTAR, US | 600, 601 | L2P/S | MALSF | undershoot |
| MYV | 03/19/2007 | Marysville | M20T | MOONEY | M-20K/M | L1P/S | | undershoot |
| NUQ | 08/07/1999 | Moffett Field | c152 | CESSNA | 152 | L1P/S | ALSF-1 | undershoot |
| OAJ | 12/26/2000 | Albert J Ellis | c152 | CESSNA | 152 | L1P/S | MALSR | undershoot |
| OLM | 08/12/1982 | Olympia | p28a | PIPER | PA-28-140/161/180/181 Archer, Cherokee, Cherokee Archer | L1P/S | MALSR | undershoot |
| ONT | 10/15/2002 | Ontario | b742 | BOEING | 747-200 (E-4, VC-25) | L4J/H | ALSF-2 | undershoot |
| ORD | 2/9/1998 | Chicago | B722 | BOEING | 727-223 | L4J/M | ALSF-2 | undershoot |
| PDK | 09/14/2007 | Atlanta | astr | IAI | 1125 Astra, Gulfstream 100 (C-38) | L2J/S+ | Localizer | overrun |
| PPT | 12/24/2000 | Pappeete (French Polynesia) | dc10 | MCDONNELL DOUGLAS | DC-10 MD-10 (KC-10 Extender, KDC-10) | L3J/H | Localizer | overrun |
| PSC | 12/26/1989 | Tri-Cities (Washington) | b462 | BRITISH AEROSPACE | BAe-146-200, Quiet Trader, Statesman | L4J/M | MALSR | undershoot |
| PWK | 11/11/2003 | Paulwakee | c560 | CESSNA | 560 Citation | L2J/S+ | NSTD | overrun |
| PWM | 07/20/2001 | Portland International | sf34 | SAAB | 340 (S100 Argus, Tp100) | L2T/L | Runway End Lights | overrun |
| RAP | 07/13/1977 | Rapid City | j5 | PIPER | J-5 Cub | L1P/S | MALSR | overrun |
| RUQ | 04/17/2005 | Rowan County | AT-6 | | | | MALSR | undershoot |
| RUQ | 12/09/2003 | Rowan County | unknown | | | | VASI | runway excursion |
| SEA | 01/05/1984 | Seattle | b722 | BOEING | 727-200 | L3J/L | Unknown | undershoot |
| SEA | 01/05/1984 | Seattle Tacoma | b722 | BOEING | 727-200 | L3J/L | ALSF-2 | undershoot |
| SFF | 08/31/1993 | Spokane | pa38 | PIPER | PA-38 Tomahawk | L1P/S | MALSR | undershoot |
| SHV | 03/20/2006 | Shreveport | ac50 | AERO COMMANDER | 500 Commander 500 | L2P/S | ALSF-2 | undershoot |
| SLC | 12/30/2000 | Salt Lake | md90 | BOEING | MD-90 | L2J/L | ALSF-2 | undershoot |
| SMF | 12/02/1979 | Sacramento | c172 | CESSNA | 172 | L1P/S | Unknown | undershoot |
| STP | 06/17/2007 | St. Paul Holman | bl17 | BELLANCA | 17 Viking, Super Viking, Turbo Viking | L1P/S | MALSR | undershoot |
| STP | 08/16/2001 | St. Paul | c404 | CESSNA | 404 Titan | L2P/S | MALSR | overrun |
| SVC | 07/15/1996 | Silver City | dragonfly | | | | MALS | undershoot |
| SYR | 11/09/1983 | Syracuse | p28a | PIPER | PA-28- | L1P/S | ALSF-2 | undershoot |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 140/161/180/ 181 Archer Warrior | | | |
| TKPN | 12/12/2007 | Vance W. Amory Airport | GLEX | BOMBARDIER | BD-700 Global Express | L2J/L | Unknown | undershoot |
| TRI | 03/30/1998 | Kingsport | c172 | CESSNA | 172 | L1P/S | ALSF-2 | undershoot |
| TXK | 06/07/1985 | Texarkana | jS1 | HANDLEY PAGE | HP-137 Jetstream 1 | L2T/S+ | MALSR | overrun |
| TYS | 11/16/2003 | Knoxville | be58 | BEECH | 58 Baron | L2P/S | MALSR | undershoot |
| UNV | 03/02/2003 | University Park | b722 | BOEING | 727-200 | L3J/L | MALSR | undershoot |
| UUU | 08/04/1995 | Newport | be58 | BEECH | 58 Baron | L2P/S | | overrun |
| VIS | 10/16/2003 | Visalia | be36 | BEECH | 36 Bonanza (piston) | L1P/S | MALSR | overrun |
| VIS | 09/07/1986 | Visalia | be36 | BEECH | 36 Bonanza (piston) | L1P/S | MALSR | undershoot |
| VNY | 12/02/1979 | Van Nuys | c182 | CESSNA | 182 | L1P/S | MALSR | undershoot |
| YHD | 11/22/1999 | Dryden Ontario, Canada | f27 | CONAIR | F-27 Firefighter | L2T/L | Unknown | overrun |
| YIP | 12/16/1994 | Willow Run | c212 | CASA | C-212 Aviocar | L2T/S+ | MALSR | undershoot |
| YYZ | 08/02/2005 | Toronto | a343 | AIRBUS | A-340-300 | L4J/H | MALSR | overrun |
| PSC | 12/02/1978 | Pasco | c150 | Cessna Aircraft | 150 | L1P/S | Unknown | undershoot |

The information contained in Table 5 above also outlines situations containing undershoots, overruns, runway excursions, and reports that did not contain a final conclusion to the nature of the event. The data suggest the following:

- 70% of approach lighting system strikes occurred when an aircraft undershoots
- 27% of approach lighting system strikes occurred in overruns
- 2% of approach lighting system strikes occurred from runway excursions
- 1% of approach lighting system strikes are unknown (not reported as undershoot, overrun, or excursions)

The degree of damage inflicted on both the aircraft and the approach lighting system is influenced by the type of aircraft and severity of the occurrence. The information provided in the table and the resulting reports also varies, but is worth additional attention.

### *ALS Strikes and Undershoots*

The data suggest that the most common approach lighting system collision occurrences are when an aircraft undershoots the approach. These situations are particularly problematic as the approach lighting systems are operational during inclement or nighttime approaches. The severity of the collision varies for each report due to system type as well as the introduction of frangible structures. A few examples of the collision types will be reviewed with respect to undershoot situations. As previously mentioned, the degree of hazards also varies given the type of system employed and the higher number of certain systems at airport locations, with more collisions involving MALSRs compared to ALSF-1s and 2s. However, grouping the collision information and reviewing the corresponding reports for both types will likely yield important hazard identification information.

A notable incident occurred in December 1973 at Boston-Logan International Airport. An Iberia DC-10 encountered fog conditions and was below the appropriate glide slope *(14)*. The impact point occurred at the approach light pier approximately 500 ft from the runway threshold. The first 300 ft of the approach lighting system was destroyed in addition to some of its pier structure. The aircraft continued a short way down 33L where it exited on the right-hand side and continued to its stopping point 3000 ft from the threshold. Though the approach lighting system and structures did play a role in the initial impact, the resulting rescue effort did not have to contend with ALS components. It appears in this instance that the support structures and resulting debris were the greatest concern.

Other, similar reports for General Aviation (GA) and larger airports suggest that the greatest hazard in an undershoot is the resulting debris and damage when an aircraft strikes the approach lighting system. However, in more recent years, the frangible nature of the approach lighting system decreases the damage inflicted but does not decrease the amount of potential debris that may be encountered. The remaining examples reviewed in Table 5 describe, in most cases, collisions with the last two to three sets of approach lighting systems. Debris from these impacts, dependent on aircraft size, appears to be approach lighting systems components such as bulbs and casings in addition to threshold lights that are hit. However, in most cases, despite damage to the aircraft and approach lighting systems at impact point, additional complications beyond impact either do not occur or are not mentioned in the reports.

***ALS Strikes and Overruns***

Unlike undershoots, incidents in which an aircraft overruns the runway and collides with the approach lighting system or related structures are less common. The hazards encountered when an aircraft impacts the approach lighting system in an overrun situation often include debris and related structures. Electrical concerns are less critical due to the fact that the approach lighting system at the opposite end of the approach is likely not activated. However, debris and approach lighting system structures can impair rescue and deplaning efforts. In addition, the final stopping point of the aircraft can vary both within and outside of the approach lighting system field, which can further complicate access points for rescue personnel.

A well-known example of an aircraft overrun is the American Airlines 1420 incident *(15)*. The immediate hazard encountered by the aircraft was the approach lighting system support structures that crushed the front of the aircraft and opened a hole on the left side. The report also mentioned that portions of the approach lighting system were intertwined with the aircraft fuselage and other components. However, despite the debris from both the aircraft and the approach lighting system, no further hazards were reported. The secondary hazard or limiter was the access point to the crash site. Subsequent to this accident, the runway safety zone has been extended and access roadways have been enlarged. Again, much like the undershoot incidents, the approach lighting system appears to provide debris issues, but in an overrun situation the approach lighting system is less likely to be activated.

Other overrun scenarios reviewed from the database offer further information with regard to structural hazards present and also different equipment being struck (e.g., Localizers), but little else in terms of issues has been directly reported. Beyond full reports, further complications with either the aircraft or rescue personnel are not well documented.

***Summary***

When reviewing the data and related reports with respect to undershoot and overrun situations, some interesting collision counts are accumulated. However, beyond those situations warranting an in-depth investigation, little is known about if and in what way an approach lighting system interacts in an evolving aircraft incident.

General hazards can be extracted from these reports which include debris, structure, and electrical concerns. In addition, a large portion of the reports review incidents that occurred during adverse weather conditions that affect either the approach or the resulting roll-out. Despite the obvious relationship between approach lighting system use and inclement weather, additional hazards and mitigation techniques can be influenced by weather-related information. For example, when visibility is reduced, the potential for an auditory indication in addition to a visual warning about the status of the approach lighting system is required. This provides redundant information for response personnel.

Overall, the database and related reports provide a starting point for further investigation of approach lighting system incidents and the results from previous occurrences. However, an in-depth interview with both FAA and airport personnel will provide both general and site-specific information beyond what was described in past reports.

## Task 3 – Airport Operations Review

In conjunction with Tasks 1 and 2, Task 3 gathered current mitigation practices and general techniques by directly interviewing airport operators, FAA officials, ARFF departments, and mutual aid response groups. The purpose of these interviews was to obtain in-depth site-specific responses regarding current operational procedures and to identify best practices that take system and institutional issues into consideration with respect to the mitigation of approach lighting system hazards.

***Methods***

**Airport Locations.** NPIAS defines 3,431 airports as relevant to the economic health and prosperity of the country. Of the 3,431 airports classified in the NPIAS, 3,364 are already in the system as of 2007. Sixty-four proposed airports are envisioned in the NPIAS plan for the next five years. Figure 17 illustrates the breakdown of the NPIAS airports into its basic components. In this project all types of airports were surveyed in order to understand the relevant issues between approach lighting systems and the specific need of each category of airports. For example, according to airport certification criteria contained in FAR Part 139 *(16),* commercial airports are required to have in-house fire-fighting equipment capabilities. These requirements can make a difference in the way airports address hazard analysis at their facilities.

A survey instrument was developed by the research team in order to solicit input on best practices adopted at each airport on how to respond to aircraft accidents where the approach lighting system was breached. Before conducting the survey, the research team conducted a "visual" inspection of satellite images for hundreds of airports within 600 miles of Blacksburg, VA to study specific approach lighting system configurations for every runway. These configurations and airports were then down-selected to 15 airports to be visited by the research team. Appendix B contains the list of all airports surveyed using Google Earth satellite images. Table 6 contains the list of the airports selected in this process and visited by the research team.

A variety of airport locations were chosen based on size, whether they possessed an ATC tower, approach lighting system hardware, and previous overrun or undershoot incidents. The airport locations were categorized based on the NPIAS outlined in Figure 17.

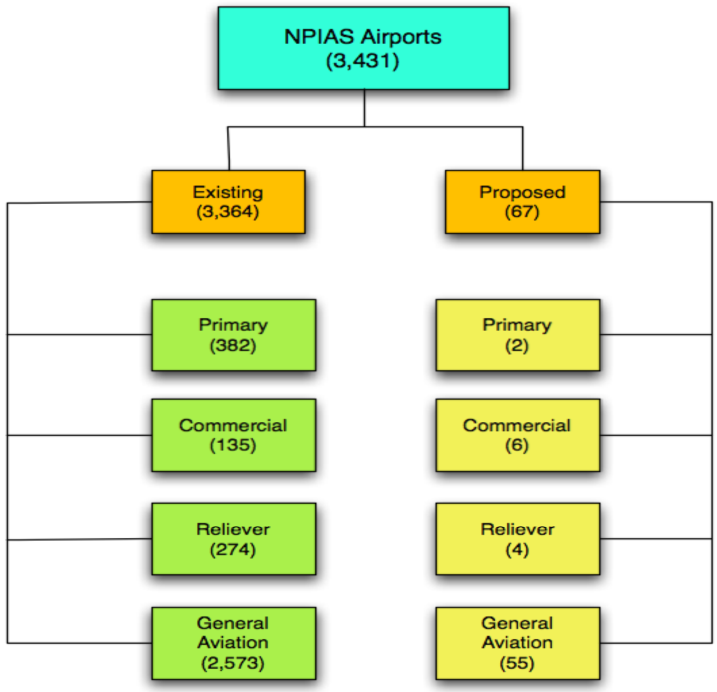



**Figure 17. Airports in the national plan for integrated airport systems.**

The airport locations visited by the research team have been further defined in Table 6 with additional information including runways, approach lighting system type, operations, and categorization based on the NPIAS class.

**Table 6. List of Airport Locations Visited by the Research Team (data source: FAA Airport Facilities Database, February 2008)**

| Airport ID | Airport Type (NPIAS Class) | Commercial Operations | Air Taxi Operations | General Aviation Local Operations | General Aviation Itinerant Operations | Required ARFF Index |
|---|---|---|---|---|---|---|
| Shenandoah Valley (SHD) | Primary | 2,003 | 0 | 10,575 | 13,288 | A |
| Roanoke (ROA) | Primary | 2,698 | 28,837 | 23,033 | 24,496 | C |
| Blacksburg (BCB) | General Aviation | 0 | 322 | 5,110 | 11,000 | None |
| Manassas (HEF) | Reliever | 0 | 1,398 | 41,899 | 94,930 | None |
| Dulles International (IAD) | Primary | 360,737 | 180,294 | 3,586 | 66,350 | E |
| Ronald Reagan National (DCA) | Primary | 274,092 | 0 | 0 | 3,413 | D |
| Tri-Cities Regional (TRI) | Primary | 4,097 | 16,751 | 17,969 | 27,502 | B |
| Greenville-Spartanburg (GSP) | Primary | 6,079 | 44,470 | 1,110 | 14,826 | D |
| Greenville Downtown (GMU) | General Aviation | 0 | 24,997 | 29,333 | 3,041 | None |
| Peachtree DeKalb (PDK) | Reliever | 0 | 0 | 47,650 | 154,601 | None |
| Teterboro (TEB) | Reliever | 8 | 75,324 | 16 | 123,681 | None |
| John F. Kennedy (JFK) | Primary | 352,341 | 24,514 | 0 | 7,180 | E |
| Boston Logan (BOS) | Primary | 248,297 | 126,37 | 0 | 31,444 | E |
| Little Rock (LIT) | Primary | 25,804 | 38,991 | 7,361 | 62,852 | C |
| Houston (HOU) | Primary | 110,035 | 43,484 | 1,287 | 80,170 | C |

When the airports of interest had been identified, the research team then proceeded to contact each location to identify the current airport operator and also the related FAA personnel. The initial contact served to introduce the project and confirm a convenient meeting time for the research team to conduct a site visit. In addition to the airport contact procedure, the research team was also required to apply for and obtain FAA security clearance to both talk with and obtain field access to the FAA facilities. It should be noted that access to the FAA personnel was not available at every location due to logistical constraints; however, interviews with airport personnel were achieved for every location. The research team only identified two locations where the FAA did not maintain the approach lighting system; namely an ODAL and MALSF configuration. Beyond these systems, all other MALSR and ALSF types were owned and maintained by the FAA.

**Personnel.** In an effort to gain information from all parties involved with the approach lighting system function, maintenance, and procedural implications, the research team interviewed a variety of personnel. Specifically, for airports the personnel included: airport directors, airport operators, on-site ARFF members, on-site electricians/managers, combined ARFF/security personnel, engineering services managers, facilities directors, and operations supervisors/managers. Not every facility included the previous list of personnel; however, at minimum, airport operations/maintenance personnel were involved in addition to ARFF or related staff (e.g., only two airports did not have on-site ARFF facilities). The FAA personnel interviewed at most airport locations included: Technical Operations (Tech Ops), Facility Managers, ATC Operations Managers, Planning/Engineering, and Airway System Specialists.

**Procedure.** When a convenient time had been established for each airport location, the research team then proceeded to visit every location to conduct the on-site interviews. The interviews took place in a board room or conference room at both FAA and airport facilities. The process of the interview followed the interview guide (Appendix B). After pilot-testing the interview guide on three airport locations, modifications were made. The research team adjusted some of the questions asked and also adopted a free-form approach. The free-form approach to the interviews allowed the flexibility of interviewees to direct the flow of conversation. Each critical topic was covered, but was not covered in the order conveyed in the interview guide. All of the answers and related information were captured through notes taken by each research team member. At the conclusion of the interview, any outstanding questions were clarified and the team members then proceeded to tour the facility's approach lighting system. While touring, the team had opportunities to photograph specific approach lighting system installations.

At the conclusion of the entire interview process the team gathered all related information for each airport location and identified commonalities, concerns, suggestions, and best practices for each location. After these elements had been identified, all responses and suggestions were then condensed into specific conclusions based on NPIAS categorizations presented previously (see Table 6.).

### *Results*

The results are presented based on current procedures, risks (hazard identification), and mitigation techniques (e.g., procedural and or automation). In addition, where applicable, the results also outline the best practices of facilities as well as alternate suggestions beyond the scope of the interview guide. The NPIAS categorization will be highlighted in the conclusions from airport responses.

**Current Procedures.** The majority of facilities, both large and small, had not considered the impact of approach lighting system hazards or potential hazards with respect to their current emergency response plan. Furthermore, few facilities had considered the implications of a compromised approach lighting system with respect to the walking wounded from an aircraft incident as well as the emergency response personnel. Facility size appears to play a role with regard to current procedures in addition to the required certification *(16)*.

Smaller facilities, which did not have the same resources as some larger facilities, often relied on common sense and any electrical "training" that the rescue response team (e.g., ARFF) might have. A common method used to deactivate the electrical field when ATC assistance was not available is manually shutting down the electric vault. These scenarios often involved obtaining access to those locations containing the vault (e.g., most often within FAA jurisdictional areas).

Specific procedures, often unwritten, included deactivating the electrical vault through "throwing" a switch. However, specific instructions on which switch to "throw" were often not known. In most cases the FAA-owned equipment was only accessible with FAA permission and keysets. When the facility had ARFF on-site but the facility was small ARFF members were required to navigate a potentially dangerous electrical field. Larger facilities often deployed an array of personnel that included electricians, ARFF members, and FAA personnel on call.

**Risks.** The risks identified by the facility staff and FAA personnel were common in nature. The risks presented by the researchers involved two defined "phases" of risks. The first phase of potential risks were thought of as "acute" or rapid onset risks and occurred when an aircraft was actively involved in an incident. In addition to these risks the researchers also asked about "post-incident" risks or those risks apparent when the incident aircraft had come to a complete stop and personnel were responding to the incident. As with the case of all incidents, the potential severity can vary dramatically; however, the focus of the questions was on the complications apparent with the approach lighting system when an aircraft had compromised the field. After these phases of risks had been discussed, any outstanding risks not captured in the previous two categories were discussed. The results to the risk assessment questions will be presented based on the level of operations and common conclusions across airport types will be highlighted.

*General Aviation.* General aviation facilities outlined a number of concerns with respect to the risks involved. The acute risks focused on potential fuel spillage and possible sparking when colliding with either the approach lighting system components (e.g., approach lighting system concrete bases or electric panels) or sparking from the approach lighting system electrical components themselves. These hazards were identified as the greatest concern which would lead to an additional risk of fire.

When asked about post-incident risks, the electrical field was of concern for both the responding agencies and the evacuating passengers. For the response personnel (ARFF or mutual aid), a major concern was the continued risk of ignition sources and the resulting risk of additional fires. Little concern was given to the debris hazards present at an incident site as the main focus is on saving lives.

Interestingly, a mutual aid fire department for one particular airport location had a high turnover rate, such that the response personnel often "switched" stations to a different area of town. This led to an additional risk based on familiarity with airport protocol and specific aircraft incident response techniques. The familiarity with airport equipment appeared to be of greatest concern, as the mutual aid groups responding to these facilities were not aware of specific electric vault locations.

Current Mitigation Procedures. Neither of the GA locations had specific procedures in place for de-energizing the approach lighting system or for verifying that the approach lighting system was de-energized. Of the two GA airports, one facility did have an ATC tower that was active during the day and late evening hours. In the event of an incident involving the approach lighting system the tower response would be to shut down the power using the switch in the cab. However, additional information on how to verify and disconnect the electrical field on-site was not known to the mutual aid responders.

*Reliever Airports.* The next category of airports, reliever airports, has a large variation due to size and location of the facilities. The risks given by the reliever airport facilities are outlined in Appendix 2. Again, to conceal specific locations, the airports have been alphabetically coded and randomized.

The acute risks identified by the reliever airport facilities and FAA personnel were consistent with those outlined by the GA facilities. The greatest risk concern was the potential ignition source when an aircraft was impacting the approach lighting system.

Similar to the GA airports, the most common hazard identified for post-incident risks included the live electrical field and the hazards posed to rescue personnel and walking wounded. The potential for increased injuries and additional hazard contributions through ignition sources were discussed as other potential post-incident risks.

In addition to these immediate concerns, further discussions with airport and FAA personnel revealed the lack of familiarity, in some cases, with the equipment residing on the airport facility. The FAA most often owns and maintains the approach lighting system, such that any incidents or issues with the system require FAA contact. With this methodology in place, airport personnel appeared not to concern themselves with FAA equipment with respect to how to de-energize the system from the vault. Most often, these practices were also hampered by the logistical constraints of having key access to federal facilities. This is perhaps an area of improvement that will help facilitate risk mitigation strategies for airport facilities.

<u>Current Mitigation Procedures.</u> The reliever airports have the benefit of ATC tower support to aid in the possible mitigation strategy for approach lighting system hazards. Most often, for those facilities that contained an ATC tower, the immediate response upon an incident would be to ask ATC to shut down the approach lighting system. Beyond these measures, additional incident procedures were not in place.

*Primary Airports.* The last airport category includes small non-hub, medium, and large hub facilities. The response to the identification of risks was varied based on size of the airport and the resources of the airport facility. The list of risks identified by the primary airports is presented in Appendix B.

Every facility identified the electrical danger posed during the acute phase of the incident and how that may be a source of ignition or danger to the response personnel. The differences in responses were mostly dependent on the size of the facility. Differences also occurred with the level of resources available. On-call electricians stationed at the airport may not know the intricacies of the FAA system, but were able to troubleshoot if an incident occurred. Thus, the electrical risks may have been less threatening for these facilities.

Almost all facilities identified the potential danger of the system's electrical field when ARFF or the mutual aid party was responding. Again, similar to the other facilities previously described, few airport operations or FAA personnel had considered the impact of the potential risk.

Interestingly, for some of the larger facilities, additional risks were identified that also played a dominant role in the potential threat to evacuating passengers and rescue personnel. Depending on location, the environmental terrain may impede rescue efforts or enhance the potential dangers. Those facilities located near water that also had approach lighting systems extend into the waterway outlined the structural issues and also the electrical/water interaction.

Finally, other risks identified included weather, wildlife, deactivating the approach lighting system and continuous power equipment risks, the interactions of de-energizing the lighting on one runway, and the effect that de-energizing the lighting on one runway has on other runways (e.g., approach lighting system power connections). These additional risks can negatively impact the incident situation and may increase the hazards encountered by rescue personnel. Though some may not be entirely predictable and mitigating may be difficult, at the very least being aware of potential situations can enhance the safety of personnel responding both from airport operations and the FAA.

Current Mitigation Procedures. Discussions with personnel at the primary airports revealed various levels of current mitigation procedures. These procedures ranged from few or none to ones that had some awareness of the range of risks when an incident occurs with the approach lighting system. Current mitigation techniques for the primary airports were also influenced by the size of the facility. Resources, much like those reviewed above, varied on facility size; thus, they influenced risk assessments and mitigation procedures in place.

The primary benefit of having a large facility was the staffing availability for airport operations. Electricians were available on-site for those facilities of substantial size; therefore, having this direct support mitigated to some extent the need for FAA technical operations to be available immediately. However, even for some large facilities, access to FAA equipment and understanding of FAA systems was perhaps limited. Crossover training between the two parties (e.g., airport and FAA) was not always evident.

Despite the lack of personnel, the smaller facilities did appear to have a close community relationship with the FAA personnel, which often transferred into information dissemination between the two facilities. Airport personnel at these facilities could discuss issues leisurely without a formal request. The transfer of information between individuals acted as a small but important mitigation technique. Personnel from the airport facility could document and describe different FAA buildings such that in an emergency they could identify where the electric vault was located and potential access to that vault.

Overall, both large and small facilities had strengths and weaknesses in their current mitigation techniques for incidents involving the approach lighting system. Overall, few of the airport or FAA personnel had considered the impact of an approach lighting system incident in depth and usually had not considered mitigation techniques in the event of a collision.

### *Summary*

Overall, the discussion points and categories reviewed offered interesting insight into both approach lighting system hazard identification and mitigation strategies. The previously identified points, including potential procedural and technological solutions, can be integrated into an SMS that will incorporate approach lighting system risks. The construction of an appropriate checklist that identifies some of the high-risk elements in addition to mitigation techniques supported by the interviewees will be a beneficial addition to the guidebook. The information gathered through the interview stage provides a valuable sounding board for both airport operations and FAA services.

## Task 4 – Hazard Identification

If an aircraft collides with an approach lighting system, be it due to an overrun when landing or colliding with a structure upon take-off, it can, depending on the extent of the excursion, provide further hazards to evacuating passengers or emergency personnel. The following list and review provides a summary of the potential hazards encountered which incorporates those hazard items identified from Task 3. The structure of the list provides an outline for a checklist in sequential format based on those concerns identified in Task 3. Additional items that did not arise during the interview process (i.e., Task 3) have been added in order to expand and incorporate additional hazards.

In an effort to categorize hazards appropriately, the following factors will be listed based on a sequence of potential incident events. For example, acute hazards and the associated risks are considered to be those factors encountered during an actual incident or when the aircraft is still in motion. Response hazards and accompanying risks are considered to be those elements encountered by rescue personnel or evacuating passengers. Identification of these categorized hazards will also aid in identifying appropriate mitigation techniques. It should be noted that some hazards may encompass both sequential categorizations which can be mitigated by a two-process approach that incorporates both acute and long-term solutions.

## Acute Hazards and Associated Risks

When an aircraft still in motion penetrates the approach lighting system in an undershoot or overrun situation, hazards become immediately apparent for the aircraft and the approach lighting system. The following summary includes hazards identified in Task 3 which were considered the most prominent by airport and FAA personnel.

### *Approach Lighting System Electrical Components*

During an incident, the aircraft is likely (depending on the severity of the incident) to make contact with the frangible structures and components of the approach lighting system. The initial and subsequent impact to either ODAL, MALS(R or F), or ALSF systems will create electrical hazards.

- Compromised and exposed wiring

The existing approach lighting systems have disconnects associated with the wiring system, such that the connections are released when an impact occurs in an effort to disengage portions of the system. However, despite extensive testing, failures in connections or other unforeseen circumstances can occur that may result in continuous power supplied to compromised wiring. From an acute risk standpoint, the exposed wiring is a potential ignition source for leaking or compromised aircraft fuel structures. In addition, systems that have a backup generator that supplies constant power provide an additional hazard source.

***Approach Lighting System and Aircraft Debris***

**Approach Light Components**

- Light support structures

Airports employ frangible approach lighting system support structures as part of their approach lighting setups. However, identifying how these are set up with regard to the surrounding terrain (e.g., land, water, wetlands, or a combination) and identifying these elements based on previous accident reports (i.e., Task 2) will result in a list of common hazards.

- Luminaires

The lighting itself can be a cause for concern; specifically, if exposed filaments are evident around the impact zone or if the resulting impact shatters the light bulbs. In addition, exposed filaments may also act as a potential ignition source if they come in contact with spilled or leaking fuel. The fragments from a broken light source and its casing may also be hazardous to passengers or first responders.

**Runway Location**

An additional acute hazard set is the location of the airport and its respective runways. Most airports have sufficient RSAs; however, the terrain beyond these areas influences the types of potential risks encountered during an incident. The outcome of the incident can be greatly influenced by environmental location.

- Land-based

Land-based approach lighting systems present different hazardous situations and related risks associated with a compromised system compared to a mixed environmental setting. Land-based systems may also have a different setup for the lighting, transformer, conduits, and related materials compared to mixed-environment (e.g., waterway, wetlands) systems. Even though these systems are located on land and not located in lake, river, or wetland areas, some systems have to be engineered differently due to the sloping terrain or other elements present within or beyond the RSA. For example, Runway 23 at Yeager airport has approach lighting structures housed predominantly on a tower and trestle system due to the grade of terrain and surrounding roadway networks.

- Mixed environments
    - Lake
    - River
    - Marsh or Wetlands
    - Harbor or Bay

The mixed environments create a unique hazard mitigation setting. For example, the approach lighting system used on 4R (ALSF) or 22L (MALSR) at Logan International Airport in Boston are mounted on wooden pier structures that extend out into the harbor. The wooden structures themselves are likely to cause increased damage in an undershoot situation compared to the frangible structures.

### *Response Hazards*

Acute hazards identified above outline potential immediate hazards on the severity of the aircraft-approach lighting system incident. However, additional hazards occur when the aircraft has come to a complete stop and response personnel are responding to the situation. The following identified hazards relate in a sequential form based on responding to an incident area from either an ARFF or mutual aid standpoint. The summary also includes potential hazards that may be encountered by evacuating passengers.

#### Accessibility to Incident

- Emergency response
- Accessibility to crash site
- Planned route
- Alternate route
- Land access/water access

Access to the incident location is paramount for quick response and preserving lives. Incident locations involving approach lighting systems are limited to those areas where the systems are housed; however, these are likely very different between each airports. Emergency response procedures lack access routes and mutual aid response routes. A last category that needs extensive consideration with respect to hazards encountered is the emergency response team's route, alternate route, and general accessibility. Some of these items will correlate with previous categorizations (e.g., route access – terrain types/environment types). It will be essential, especially for deplaning passengers and approaching rescue personnel, to be aware of the approach lighting system status and possible routes/access through or around the compromised system. In previous accident situations (e.g., AA Flight 1420), access to the site was compromised based on a combination of factors in addition to the compromised approach lighting system and support structures.

#### Approach Lighting System Debris Hazards

- Wire conduits
- Concrete base structures
- Luminaires
- Pier structures

In a post-incident situation there are many components of the approach lighting system that can be hazardous. In addition to the acute hazard of a live electrical field, debris from the approach lighting system can impeded rescue efforts and evacuating passengers. A brief summary of debris hazards is further described below.

In an undershoot situation, an aircraft's landing gear, depending on size, has the potential to dig up cabling and expose wires within conduits. In most cases the wiring is enclosed in Poly Vinyl Chloride (PVC) pipe with concrete surround; however, for some airports a direct bury method may have been used. Response personnel may encounter 'main' power feeds dug up by an aircraft's landing gear in addition to the live electrical field if the approach lighting system has not been de-energized.

Ground debris containing concrete base structures, luminaires, and wood elements from piers or ILS installations provide further walking and fire hazards in addition to aircraft debris. For example, at Groningen Airport in the Netherlands, an MD-88 crew rejected a takeoff and was subject to a runway overrun. During the overrun, the approach light structures were struck by the landing gear and, due to the soft turf just beyond the RSA, the concrete base structures supporting the approach lights were exposed and in some cases moved *(17)*.

In addition, components of the approach lighting system (such as the mounting structures for systems built over water and the luminaires themselves) provide a mixture of ground debris that the rescue personnel have to contend with. In addition to life preservation, which is the highest priority for ARFF crews, identifying combined approach lighting system/aircraft hazards requires some procedural input and continual training reminders.

**Weather Conditions and Operational Times**

- Rain
- Fog
- Snow
- Ice
- Daytime
- Nighttime

The environmental conditions can dramatically impact the cause and resulting hazard situation when an aircraft impacts the approach lighting system. These elements combined with day or nighttime conditions can increase the potential hazards encountered by rescue personnel and the passengers and/or crew.

Even though accident/incident causation cannot be limited to one specific type of weather condition, these elements adversely impact procedural factors followed after impact. For example, in the Little Rock incident, American Airlines Flight 1420 documented the restrictions in visibility due to weather-related conditions encountered by personnel and evacuating passengers and crew *(18)*. The visibility was substantially reduced and related weather conditions slowed the response time of vehicles accordingly. In other cases -- such as Air France at Toronto *(19)* - rain was another factor in the accident overrun but access was also limited due to the terrain. Passengers found themselves wandering towards the highway and some were picked up by passing motorists. These mixed environments proved hazardous to both the aircraft colliding with the structure and the resulting rescue teams.

**Tower Operation and Procedures**

- Tower Operational Times
- Non-towered facilities

The larger airport facilities have the resources and need to operate the control towers on a 24-hour basis. However, for smaller facilities, tower operational times vary, but most are discontinued after midnight. Reliance on tower operations during an incident is a first phase of response in an effort to shut down the approach lighting system. In cases where tower operations are not 24-hour, these efforts are not available.

FAA AC 150/5200-37 provides the concept of the SMS for airport operators. This system is a top-down approach to managing system risk at the airport and includes systematic procedures, practices, and policies for the management of risk, safety, and promotion of safety. The important aspect of the SMS in terms of the approach lighting system is the identification of hazards and risks and the design of appropriate mitigation strategies. The five phases of the process are 1) Describe the system, 2) Identify the hazards, 3) Determine the risk, 4) Assess and analyze the risk, and 5) Treat the risk.

The research team has identified the risks using the risk matrix; however, because this is an initial implementation of the SMS concept it is only considered an exercise and many parameters on how to grade the risk factors have yet to be explored in the SMS terminology. The information presented in this report is a preliminary attempt using the SMS concept. Additional recommendations for identifying risk are presented through a questionnaire format following the SMS concept recommendations.

The system description should be complete and encompass all of the critical components of the system under concern. For the hazard identification, all threats to the system must be stated and clearly categorized into the conditions which influence the hazard. The risk is then determined based on each hazard. As an example for the approach lighting system, the hazard would be debris in the runway safety area resulting from a frangible approach lighting system tower break, and the risk would be damage to the aircraft and other components of the approach lighting system. The fourth aspect of the task would be to assess and analyze the risks in terms of severity and likelihood. The risk is then determined using the matrix shown in Figure 13. The final aspect of the process is treating the risk through the development of mitigation factors that reduce either the likelihood or the severity of the event.

### *Risk Identification, Hazard Severity, and Overall Risk Level*

At the conclusion of identifying hazards from information obtained in Task 4, the research team proceeded with a risk assessment method. The team used the SMS template as a basis for categorizing each risk with respect to the severity, likelihood, and overall risk level for the identified hazards. At the conclusion of the review each hazard was assigned a severity and risk level; these are presented in more detail below.

## Acute Risk Factors

The following hazards and associated severity, likelihood, and risk ratings are based on those issues that are encountered when an incident is occurring. Table 7 below identifies the risks associated when the hazard is occurring during the acute phase. The severity rating of risk is dependent on the type of hazard and when seen from life-threatening standpoint. The table also outlines the likelihood of these risks occurring, taking into account previous accident reports and information gathered from Task 3. The hazard factors are then assigned a risk level which will help identify appropriate mitigation techniques and issues.

**Table 7. Acute Hazard Identification and Related Risk Factors**

| Type | Hazard | Risk | Severity | Likelihood | Risk Level |
|---|---|---|---|---|---|
| Acute | Approach Lighting System Electrical Components | Can be ignition source for fuel and vapor | Catastrophic | Probable | High |
| Acute | Runway Environment | Large non-frangible towers may damage aircraft during incident | Catastrophic | Extremely Improbable | High |
| Acute | Approach Lighting Components | Damage to Aircraft | Hazardous | Remote | High |
| Acute | Approach Lighting Components | Injury to Aircraft Occupants | Hazardous | Probable | High |

The acute risk levels were all given a high rating given the potential consequences of the risks occurring. For example, electrical components were identified as a potential source of ignition in the previous section and thus were assigned a catastrophic severity and a high risk level. In addition, due to the nature of the environment surrounding the runway, large non-frangible structures may cause catastrophic damage to an aircraft. Other components of the approach lighting system will likely impact the fuselage and have the potential to injure occupants which was also deemed a high risk. These initial ratings will be further analyzed and reviewed by airport and FAA personnel contacted during Task 3 in an effort to identify further risks and rate them appropriately. The intent is to create a hazard risk matrix that is reviewed and accepted by those in the industry.

**Response Risk Factors**

Similar to the risks identified in the acute phase of a potential incident, a risk analysis was also conducted for those items identified in the response phase. The results of the risk assessment are presented in Table 8 below:

**Table 8. Response Hazard Identification and Related Risk Factors**

| Type | Hazard | Risk | Severity | Likelihood | Risk Level |
|---|---|---|---|---|---|
| Response | Approach Lighting Components | Debris can limit access to critical response areas | Hazardous | Probable | High |
| Response | Approach Lighting Components | Debris in the response area can cause injury to response personnel | Hazardous | Remote | High |
| Response | Approach Lighting | Debris in the response area | Hazardous | Probable | High |

| Type | Hazard | Risk | Severity | Likelihood | Risk Level |
|---|---|---|---|---|---|
| | Components | can cause injury to walking wounded | | | |
| Response | Approach Lighting System Electrical Components | Compromised wiring can cause injury to aircraft occupants (e.g., electrocution) | Hazardous | Remote | High |
| Response | Approach Lighting System Electrical Components | Compromised wiring can cause injury to response teams | Hazardous | Remote | High |
| Response | Availability of Response Equipment and Personnel | Response team has no ability to disable ALS system if required | Hazardous | Remote | High |
| Response | Tower Operations Procedures | Incident occurs outside of tower operational time | Hazardous | Probable | High |
| Response | Tower Operations Procedures | No redundant methods for controlling the ALS system | Hazardous | Remote | High |
| Response | Weather Conditions | Difficulty identifying debris in low visibility | Major | Probable | High |
| Response | Weather Conditions | Lengthened response time in low visibility | Hazardous | Frequent | High |
| Response | Weather Conditions | Limited information about system status in low visibility conditions | Hazardous | Probable | High |
| Response | Weather Conditions | Possible injury and fire ignition exacerbation in wet conditions | Hazardous | Probable | High |
| Response | Availability of Response Equipment and Personnel | Response team does not carry equipment to test electrical components | Minor | Frequent | Medium |
| Response | Availability of Response Equipment and Personnel | Response team has no familiarity with the ALS system | Minor | Probable | Medium |
| Response | Tower Operations Procedures | No SOP to shut ALS system down in case of incident | Major | Remote | Medium |

The response hazards and the related severity, likelihood and corresponding risk levels is much larger during the response phase to an incident. For the majority of hazards identified in the response phase the risk rating was deemed to be high. These include potential injury to the rescue personnel in addition to further injury to aircraft occupants. Only three hazards were given a medium rating which was mostly determined by training factors, equipment needs, and procedural requirements.

The use of the SMS methodology is only being explored at FAA facilities and actual deployment and integration of the methodology is not known.

## Task 7 – Procedure Development

The second phase of the research project was to develop procedures that can be used to aid in identifying the hazards and risks when an incident involving an aircraft and the approach lighting system occurs. These procedures were developed using the information and research obtained in the hazards identified in Task 4 of the research project. The hazards were grouped into a sub-set of categories based on common elements such as: severity of hazards that directly affect aircraft and passenger/crew during and those hazards encountered for response personnel attending to the incident. After identifying the hazards and sub-categories a series of procedures were then explored to identify how to mitigate potential hazards that can be encountered during an incident and responding to an incident.

In an effort to identify the risks and hazards the research team constructed a questionnaire method that focuses on items such as "What if an aircraft collided with the approach lighting system –how would you de-energize the approach lighting system?" Constructing questions such as these is meant to promote additional thought and discussion between airport operations and other agencies in order to best identify mitigation efforts. The questionnaire will be expanded in greater detail in this report in an effort to explore the interaction between the questionnaire and Task 4 results. A shortened form of the questionnaire without the detailed explanations is presented in the guidebook for quick and easy reference.

## Hazard and Risk Identification Questionnaire Procedure

In an effort for airport operations, FAA, and response personnel to identify risk factors associated with approach lighting systems a questionnaire has been constructed. The purpose of the questionnaire is to provide a foundational reference to identify hazards and risks that may be applicable to airport locations and subsequent response operations. The question and answer section as described here and in the guidebook is broad such that questions presented may not be applicable to all airport locations. However, the intent is to encourage airport operators, FAA, and response personnel to expand and tailor solutions that can be applied to their location. The guidebook that is attached in the Appendix C contains identical questions but in a shorter format such that airport operations, FAA, and response personnel can quickly and easily reference information that pertains to their situation. In addition, the guidebook contains a checklist that provides mitigation techniques for the hazard/risk questionnaire.

### *System Awareness and Risk Discussion*

The first set of hazard and risk identification questions requires airport operations, FAA, and response personnel or the oversight group formed to identify risks and hazards for approach lighting systems. In an effort to achieve this and as a general starting point for hazard and risk discussions, the group or committee should clearly identify and discuss what systems exist on each of the runways at their respective locations. This general awareness question provides a foundation not only for the remaining questionnaire, but also discussions involving potential approach lighting system incidents. Following this initial question, other system awareness and discussion questions follow.

- What type of approach lighting system do you have on each runway?
- How would you shut down the approach lighting system if an incident occurs? (for each runway end?)
- Are there procedures or specific steps that must be followed to shut down the approach lighting system (what are they for each runway end)?
- Who has access to the approach lighting system control room/panel?

As identified in the interviews conducted in Task 3, a general awareness of approach lighting system hazards is a great starting point. In order to maximize the benefit of the hazard and risk identification questionnaire forming a small committee or group of diverse members from airport operations, response, planning, and the FAA is strongly recommended. Only a small number of airport locations and personnel interviewed had considered potential risk factors associated during an approach lighting system incident. In order to identify and promote open discussion about approach lighting system incidents the remaining questions revolve around current procedures. These generic procedure questions can quickly identify responsibility areas with regard to access and current operating procedures. These fundamental questions also provide a foundation for in-depth discussions about the risks of not planning for a potential approach lighting system incident. The committee or group of members gathered for this review may not be aware of FAA procedures (or vice versa) and the general goal is to promote awareness for all agencies.

***System Component Risk Discussion***

Once the foundational discussion has been initiated the next set of system component risk factors can be discussed. An immediate component risk that may occur during an approach lighting system incident is the potential for electrocution. This risk can significantly influence planning and procedures associated with electrocution mitigation. In addition to the immediate risk, questions regarding how response personnel know that the system has been de-energized are also asked. The following discussion points are intended to elicit potential risks and concerns for airport operations response, planning, and FAA personnel.

- Do response personnel know how to de-energize the approach lighting system?
- Do response personnel have any indication when the approach lighting system is turned off (for each approach lighting system on each runway end)?
- Does your approach lighting system have a back-up generator?
    - Which runway ends/approach lighting systems have generators?
    - If so:
    - How do you know if the back-up generator is running?
        - Which approach lighting system is it providing power to?
    - How would you turn off or shut down the generator in the event of an incident?
        - Are there multiple generators that may need to be de-energized in the event of an incident?
        - What are the procedures for shutting the generator(s) down in an emergency situation?

While interviewing personnel for Task 3, respondents became aware of the potential electrocution risk factors; however, these interviews also identified concerns about how approach lighting systems functioned when an emergency occurred. Specifically, concerns regarding how to de-energize a system were at the top of the list of comments. These risks are especially critical when identifying which agencies are responsible during an emergency situation. The goal of these questions is to identify the responsible parties and, where possible, cross-train individuals between agencies so that mitigation solutions can be recognized.

### *Debris and Associated Risks Discussion*

In addition to electrical risks, discussions should also include debris hazards that may pose potentially problematic situations when responding to an approach lighting system incident. The questionnaire outlines some potential risks that may endanger response personnel. These risks include support structure debris, secondary wiring, light bars, and glass hazards. Pieces of debris can impact access and egress of the aircraft by passengers and crew. While these items were not considered a high risk by interviewees, almost all participants interviewed acknowledged how structures and other debris may cause a delay during evacuation or response situations.

- What type of support structures are in place for the approach lighting system?
    - Are there solid structures that may further damage an aircraft or injure response personnel during an incident – how can injury be minimized?
    - How would debris from approach lighting system structures impact response efforts for both rescue vehicles and response personnel?

- Since, during an incident, an aircraft can dig up or expose approach lighting system wiring:
    - Do you have any equipment either on the vehicle or carried by response personnel that can detect energized electrical wiring or electrical fields?
    - Are there special procedures in place on how to use the equipment?
    - Who can use or is properly trained to use the energized wiring detection equipment?
    - How do you avoid or reduce the risk of electrical shock if there is wiring energized?

- Additional injury or debris can result from the components of the approach lighting system such as the support structures, casing, and the lighting itself. These questions ask about potential injury that may result:
    - Are there any procedures in place to minimize injury from the lights/light bulbs/glass of the approach lighting system for both evacuating passengers and response personnel?
    - How do you minimize potential injury to passengers, crew, and response personnel from other approach lighting debris, such as support structures, light bars, secondary wiring etc?

***Incident Access Planning***

Access issues beyond debris issues are also risk factors that need to be discussed. Examples of previous access issues encountered by response personnel include the American Airlines 1420 incident where rescue vehicles had difficulty getting to the incident scene. Discussions should occur to identify additional risk factors if an aircraft comes to rest beyond the fenced areas of the airfield? runway? or in situations that can potentially limit accessibility. The intent of these questions is to identify scenarios where response vehicles and personnel may encounter limitations either with procedural implications or with environmental limitations. Addressing these limitations with respect to the approach lighting system will allow for additional emergency response plan considerations and potential changes.

- Approach lighting systems can be placed in a variety of environments from solely land-based systems to systems that extend into a river, lake, harbor, or bay. The following questions review environmental features that may be unique to your airport location:
  - Do you have land-based runways and approach lighting system areas?
    - Do you have any specific environmental features that may limit response access (e.g., hills, slopes, ground condition, buildings, non-airport roadways etc)?
    - How is access limited by these environmental features?
    - How do these environmental features interact with potential debris from the approach lighting system (e.g., are there cable supports or large supporting structures because of the environment)?
    - Are there alternate access points and are these adequately covered in the emergency plan?
  - Do you have approach lighting systems that extend into waterways?
    - What procedures are in place if an incident occurs with an approach lighting system that extends into water (e.g., pier structures, rivers, harbor/bays)?
    - How is access limited by these features?
    - How do response personnel deal with additional hazards such as pier structures or wiring for approach lighting systems that extend into waterways?
    - Are emergency response procedures in place to shut down approach lighting systems in these areas?

- If an incident occurs with the approach lighting system access to these areas is critical for response personnel. The following questions review potential access issues that may occur when responding to an approach lighting system incident:
  - Are there accessibility issues if an incident occurs in the approach lighting system area?
  - Are there alternate and other planned accessibility routes for all types of response equipment within the approach lighting system area?
  - Can you think of any other accessibility issues that may occur if there was an incident involving the approach lighting system?

Risks associated with accessibility issues during inclement weather should also be discussed. The following set of questions asks about accessibility given different weather conditions. These items can impact response accessibility, speed of response times, and even navigating to the incident scene. During low visibility conditions that can occur during daytime and especially nighttime operations it is recommended that emergency planning take into account both accessibility issues and visibility issues during an approach lighting system incident:

- Is there accessibility issues if an incident occurs in the approach lighting system area and how are these influenced based on the following weather conditions for daytime and nighttime operations?
  - Rain
  - Fog
  - Snow
  - Icy conditions

Lastly, depending on the size of the facility and the resources available there may be additional SOPs in place with ATC tower operations. However, airport locations also work with limited or no tower operations. The next set of questions explores SOPs and operational limitation given the various tower configurations at airports. Given these various operating conditions, some of the next set of questions can be overlooked depending on your specific facility requirements.

- What procedures are in place for deactivating an approach lighting system if there is no ATC tower at your facility?
  - Have these procedures been reviewed by the mutual response groups?
- Are there any specific procedures in place when incidents occur during normal tower operation times?
  - If so, what are they?
  - Have they been recently reviewed or updated?
  - Can they be improved upon?
  - Are the response personnel notified if the tower shuts down the approach lighting system in the event of an incident?
- If you have limited ATC tower times:
  - What are the procedures if an incident occurs during "non-towered" times?
  - How is response personnel notified that the approach lighting system has been deactivated during an emergency and during non-towered times?
  - Who is on-call during non-towered times and do they have access to and knowledge regarding de-energizing the approach lighting system?
- The air traffic control tower may not be able to fully de-energize the approach lighting system. Are there redundant methods in place to shut down the system?

***Summary***

The risk assessment questionnaire format provides a starting point for group discussions that should include airport operations, response, planning, and FAA personnel. Identifying the hazards, as outlined in the questionnaire and then getting the group to think about the potential risks involved provides a foundation for reviewing the mitigation techniques described next.

While no method can provide an exact risk level at this point, the questionnaire allows a means of communicating within and between agencies to identify risks and possible solutions. The specific levels of risk may vary according airport size; however, the questionnaire format allows airport agencies to identify areas within their airport location that perhaps were overlooked or not deemed to be of high risk. The common goal of this exercise is to promote awareness of a potential approach light incident and the combination of elements that may impact risk for response personnel and for a broad range of agencies.

### Task 8 – Development of Mitigation Techniques

The goal of this task is to identify possible mitigation techniques for the hazards identified in Task 4. Hazards identified in Task 4 represent those items of concern that were mentioned by airport operations, planning, response, and FAA personnel when interviewed by the research team. The list of hazards is addressed in the same order as presented from Task 4; however, accompanying mitigation techniques along with merits and drawbacks are also discussed. The majority of suggestions to mitigate hazards identified in Task 4 are procedural; however, a few technological solutions are explored. It should be noted that some of the technological solutions are beyond the project scope and future research is required.

These strategies can be applied to a variety of airport locations with the intent to broadly disperse mitigation information. Some mitigation techniques may need further discussion by personnel in airport operations and other agencies based on facility size and resources.

### Incident Mitigation Techniques

Initial mitigation techniques focus on hazards identified by airport operations, FAA, planning, engineering, and response personnel during Task 3. These hazards were identified as what may occur during an incident or when the aircraft is still in motion. The following hazards and potential mitigation techniques are discussed further:

***Hazard/Risk:*** Approach Lighting System Electrical wiring may be a fuel ignition source

***Recommended Mitigation:*** Procedural shut down of approach lighting system(s).
Incorporating an SOP for approach lighting system incident responses and deactivation of the system allows airport operations, FAA, and response personnel to know the procedures required. In addition, specific personnel will have control over what system to deactivate and the correct procedures for deactivation. A disadvantage to this method is the response speed in which the system is deactivated. However, the cost for implementing an SOP regarding shutting down the approach lighting system is substantially less than redesigning a new system to incorporate technology to automatically de-energize the system. The initial costs of an approach lighting system SOP is the responsibility of airport operations, FAA, and response agencies in terms of personnel hours. However, once an SOP has been established it only requires small yearly updates as the needs of airport operations evolve. This method is feasible as a near-term solution to mitigating approach lighting system ignition risks.

***Future Mitigation:*** Automated shutdown of approach lighting system.
The advantage of an automated system is the immediate deactivation of the approach lighting system. Shutting down the system in this manner will minimize the potential ignition and

electrocution sources that may be apparent during an incident. However, to design and implement an automated system will require a substantial and costly redesign of current approach lighting systems and extensive testing to validate the system. These limitations preclude recommending an automated shutoff system as an immediate viable alternative for mitigating this risk. Additional research is recommended to explore how systems monitor and register when to shut down a system such that false alarms are minimized and reliability is maximized. Furthermore, future system designs by the FAA may consider incorporating an automated de-energizing process.

***Hazard/Risk:*** Large non-frangible towers/structures may damage aircraft during an incident

***Recommended Mitigation:*** Large support structures that provide a base below the frangible structures are necessary due to the terrain that the airport is situated on. Furthermore, other non-frangible components such as pier structures that house approach lighting systems are needed when the airport location is surrounded by rivers or other waterways. Removing such structures is often not possible given the terrain and financial cost. However, post-event mitigation efforts such as those enacted after American Airlines 1420 saw the runway safety area extended and access points reworked. Where feasible, it is suggested that these efforts take place at other airport locations that have similar issues; however, a large financial component is required and is often beyond the scope of the budget for some airports. Given these circumstances it is recommended the response agencies involved review and train using mock scenarios involving these support structures. Access points and support structure debris should be discussed when reviewing the airport emergency plan. These training scenarios will complement emergency response training and provide those responding to a potential situation with a general knowledge of hazards that may influence response methods. The cost for adding these training components and group discussions during an approach lighting system review is substantially lower than obtaining the capital financing to physically rework access points and runway safety areas.

***Hazard/Risk:*** Approach lighting system can damage aircraft and further injure aircraft occupants during an incident.

***Recommended Mitigation:*** Frangible structures have been extensively researched and undergone intensive reviews by the FAA in order to minimize the impact these structures have if an aircraft collides with them. Additional recommendations are beyond the scope of this project.

### Response Risks and Mitigation

The remaining risks identified during Task 3 and Task 4 have common mitigation recommendations that can be applied to all situations. These mitigation techniques will be listed and, where appropriate, specific mitigation techniques will be highlighted for those hazards that require further explanation. These common mitigation elements will provide a foundation for approach all hazard types and it is suggested that these be reviewed for each of the risks identified.

## Common Mitigation Strategies

The following mitigation techniques are applicable to the hazards identified for approach lighting safety. The majority of the hazards and associated risks identified will benefit from a common mitigation approach. Hazards such as approach lighting debris mitigation, tower operations, weather conditions, and response equipment and personnel availability can all benefit from the suggested mitigation techniques described in further detail following a review of the hazard items below:

***Hazards and Risks:***

- Debris from approach lighting system components can limit access to critical response areas.
- Approach lighting components' debris in the response area can cause injury to response personnel.
- Approach lighting components' debris in the response area can cause injury to walking wounded.
- Approach lighting system electrical components (such as compromised wiring) can cause injury to aircraft occupants (e.g., electrocution).
- Approach lighting system electrical components' compromised wiring can cause injury to response teams.
- Despite availability of response equipment and personnel response, it is not possible to disable approach lighting system (if required).
- Tower operation: incident occurs outside of tower operational time.
- Tower operations: procedures do not allow for redundant methods for controlling the approach lighting system.
- Weather conditions: difficulty identifying debris in low visibility.
- Weather conditions: lengthened response time in low visibility.
- Weather conditions: limited information about system status in low visibility conditions.
- Weather conditions: possible injury in wet conditions.
- Availability of response equipment: personnel response team does not carry equipment to test electrical components.
- Availability of response equipment: personnel response team has no familiarity with the approach lighting system.
- There is no SOP to shut approach lighting system down in case of an incident.

***Group Review of Mitigation Techniques:*** In an effort to establish a foundation to mitigate potential approach lighting system hazards it is suggested that a small group of airport operations, emergency response (on-site ARFF or off-site mutual aid emergency response personnel) and FAA personnel (as appropriate to the size/classification of the airport) be convened to examine the guidebook's hazard questionnaire and to agree on the hazards specific to the particular airport. Establishing a group with members from a variety of organizations will provide the depth and knowledge to handle the broad discussion points of the hazard questionnaire. In addition, it is suggested a yearly review of potential approach lighting system hazards using the questionnaire be conducted to update and discuss emergency response planning and procedures.

Having a cooperative group review and identify hazards can assist in cases where potential incidents may occur outside the fenced boundaries of an airport. In some cases approach lighting system light poles and structures are located outside of the airport boundary. In such cases, the emergency response personnel who deal with emergency situations outside the airport boundary should be included in this review. It is recommended that the formed committee or group establish a calendar reminder to re-examine preparations for aircraft incidents with the approach lighting system at an annual meeting in order to address the possibility of changes in the system, changes in security, and other issues. This action may be included in or accomplished concurrently with periodic reviews of emergency preparedness. Finally, as part of the research process, the research team has created an easy to use guidebook that identifies hazards and suggests mitigation techniques. It is suggested that a copy of the guidebook be provided to each member of the committee and also that a copy is easily accessible to those interested in reviewing approach lighting system hazards.

The group approach to mitigation planning provides input from a variety of sources that includes those agencies responsible for attending to a potential incident and also those agencies that own and maintain the equipment. The initial cost of establishing a committee will be high in terms of personnel hours; however, once established, the group can quickly identify those hazard areas applicable to their airport.

***Cross-training Mitigation Techniques:*** A potential mitigation strategy identified by the research team during the interview process was the establishment of cross-training between airport operations, FAA, and agency response personnel. An effort to familiarize or cross-train personnel on how the approach lighting system functions so that they are knowledgeable on system operations and shutting down the system during a potential incident was considered essential.

The cross-training effort should include conducting walk-through training as needed in order to confirm that personnel who might be involved in responding to an approach lighting incident know how to de-energize the system (including any emergency power sources to the system) as well as how to confirm that the approach lighting system equipment is de-energized at the scene. It is recommended that walk-through training on communications is conducted between emergency response personnel responsible for an incident outside the airport boundary with those responsible for de-energizing the system. Also, it is recommended that a walk-through of access points to the approach lights under various hypothetical situations is conducted in order to confirm access routes and that any desired alternate routes are acceptable.

Furthermore, specifically train and cross-train, as appropriate, all personnel who might respond to an aircraft accident involving the approach lighting system in order to (1) de-energize the system before entering an accident scene where the aircraft has collided with the system, or (2) operate the electrical test equipment to confirm that the approach lighting system is de-energized.

Incorporate the actions and strategies identified by the group into emergency response procedures, drills, and walk-through's as appropriate. Drills should include responders de-energizing the approach lighting system and checking that the system is de-energized. Include emergency response organizations that are responsible for handling accidents involving the approach lighting system outside airport property in these drills. During the hazard review it is suggested that individuals from the FAA and airport operations that have on-site electricians review with the remaining airport operations and response staff how the system operates and the current methods for shutting down the system.

***Response Planning and System Awareness Mitigation Strategies:*** A specific mitigation strategy identified during the interview process was the establishment of an in-house reference guide. The reference guide provided picture references for all buildings, including those designated specifically for approach lighting systems. The reference guide was used to orient personnel on the approach lighting system and other buildings/equipment within and around the airfield. It is suggested that this guide include the following elements to provide maximum benefit:

- Simple block diagrams of circuitry for the approach lighting system
- Photographs of approach lighting system buildings and components including light poles and supports, backup power supplies, and cutoff switches or circuit breakers for primary and backup power
- Photographs of breakaway electrical connections and approach lighting system fixtures
- Photographs of frangible approach lighting system fixtures
- Security features for the approach lighting system such as fence locks, building locks, and locking features on cutoff switches and or breakers

In addition to the reference guide, many interviewees suggested compiling a list of names, phone numbers (home, mobile, pager), and work schedules for all those who might be involved in responding to an aircraft/approach lighting system incident. This list can be included in the reference guide above and also placed in a convenient location for emergency purposes. It was essential to include:

- Those individuals who have access to approach lighting systems cutoff switches and/or breakers (e.g., control towers) or keys to facilities containing cutoff switches and/or breakers
- Those individuals most likely to be involved and their backups

***Approach Lighting System Access Planning:*** In addition to the cross-training mitigation suggestions, the research team also found that access to specific areas to de-energize the approach lighting system was required for response personnel. Establishing a means for personnel who might be involved in responding to an aircraft accident with an approach lighting system to have access to the areas required to de-energize the system may involve the following:

- Passing a set of keys for the approach lighting system's power facilities between people on various shifts, or locating the key in a key box which can be quickly accessed by all necessary personnel (e.g., ARFF or mutual aid response personnel).
- Memorandums of agreement between different organizations (e.g., airport operations and the FAA) authorizing access to the approach lighting system to de-energize it during an accident and specifying how the keys to the FAA facility will be maintained securely by those holding the keys.

- Memorandums of agreement from the FAA guaranteeing that the FAA will shutdown the approach lighting system in an emergency before the response personnel arrive at the incident site.

***Summary of Common Mitigation Techniques***

The preceding mitigation techniques provide a thorough foundation for discussing and reducing potential hazards and risks that occur before and during an aircraft-approach lighting system incident. These common mitigation strategies allow not only airport operations, but other agencies such as the FAA to identify where potential issues may occur and rectify some of those roadblocks by establishing procedures. In the majority of instances during the Task 3 interviews and hazard identification review the research team found varying levels of communication between airport operations other agencies. The initial cost of establishing a group of individuals from various agencies is a matter of scheduling and personnel hours. However, once established the research team does not anticipate increased costs to maintain updates and group reviews.

## Situation-specific Mitigation Efforts

Specific situations warrant addition mitigation efforts that go beyond the common techniques described in the previous section. These strategies have been tailored to further refine the previously described mitigation efforts. The following list identifies further mitigation techniques for specific hazards:

***Tower Operations Planning***

- Tower operation: incident occurs outside of tower operational time.
- Tower operations: procedures do not allow for redundant methods for controlling the approach lighting system.

It is recommended that the response planning group identify pre-existing procedures that may be in place for shutting down the approach lighting system from active ATC towers. In some instances the ATC tower may not have the ability to fully de-energize the approach lighting system. It is recommended that redundant shutoff procedures be put in place and that emergency response personnel confirm that the approach lighting system has been completely de-energized before proceeding onto the approach lighting system field.

In addition, it is recommended that specific procedures for non-towered operations be constructed for emergency and response personnel such that facilities with limited tower operations or non-towered facilities have a way of deactivating the approach lighting system. These planning measures include:

- Identifying tower operation times and procedures for approach lighting system emergencies.
- Identifying approach lighting system shut-down procedures and responsible personnel during non-towered operational times.
- Allowing emergency personnel access to approach lighting system power vaults so that response personnel can shut down the system.

These procedures may require integration with other currently active procedures available to ATC facilities. This may require agreements regarding FAA-owned approach lighting system areas and response personnel during non-towered operational times, which may include memorandums of agreement between airport operations and the FAA.

**On-site Emergency Approach Lighting System Procedures**

The following list provides specific procedures in order to mitigation those specific hazards identified in Task 4. The following hazards, previously listed in Task 4 are listed below for reference purposes. Mitigation procedures are presented after the list:

- Approach lighting system electrical components like compromised wiring can cause injury to aircraft occupants (Electrocution).
- Approach lighting system electrical components compromised wiring can cause injury to response teams.
- Availability of response equipment and personnel response has no ability to disable approach lighting system if required.
- Availability of response equipment and personnel response team does not carry equipment to test electrical components.

In an effort to minimize the risk of electrocution, by far one of the largest concerns gathered during the interview process, it is recommended that the approach lighting system be de-energized as soon as possible and before emergency response personnel enter the incident scene. Achieving this task will take a review group or committee as previously described; however, specific techniques for de-energization are also required. For example, the isolation of both backup and primary power supplies is required. This is recommended because frangible electrical connectors may malfunction and/or the system could be breeched on the energized side of the frangible connection. In this instance it may be desirable to physically lock the power supply switches/breakers with padlocks which are not to be removed until the emergency response is complete and electricians have confirmed the system safe.

During the planning stage of mitigating the approach lighting system hazards it is recommended that very large airports confirm that the approach lighting system can be de-energized for one runway while leaving it energized for other runways so that airport operations may continue while responding to an incident. Confirmation that the lighting system has been de-energized should be tasked to first responders such that they confirm that the approach lighting system is de-energized when they arrive at the scene.

Specific equipment and procedures to verify that the system has been de-energized requires, where possible, the purchase of cable detection units. These units can range in price from $1000-$4000 and consist of standard cable or "utilities" detection equipment. This equipment type will aid in detecting live cabling if an approach lighting system is still active and has failed to de-energize. A potential system can include the following procedures:

- It is suggested that a common "power cable" checkpoint be established for all runways that contain approach lighting systems. These pre-located checkpoints (as identified in the group mitigation meetings) will be areas where the approach lighting system cabling is known to enter the approach lighting system area. At these locations the ARFF and/or mutual aid response groups can verify if the approach lighting system has been de-energized by using a cable detection unit. These units are commercially available and can read if power cables are supplying electricity or not. Simple verification by one member of the response group can confirm that the approach lighting system has been de-energized and response teams can proceed accordingly. This technique can be used in situations where the status of the approach lighting system is not determined or if ARFF/mutual aid/or other response entities want to confirm the status of the approach lighting system.

**On-site Accessibility, Debris, and Weather Planning**

As a review the hazards from Task 4 are presented and then followed by the mitigation techniques.

- Approach light components' debris in the response area can cause injury to walking wounded.
- Weather conditions: difficulty identifying debris in low visibility.
- Weather conditions: lengthened response time in low visibility.
- Weather conditions: limited information about system status in low visibility conditions.
- Weather conditions: possible injury in wet conditions.

Debris hazards are unpredictable and the extent of debris will never be known beforehand; however, it is recommended that emergency personnel incorporate potential approach lighting system hazards into their training regimen.

Identification of debris and access concerns should be addressed when discussing potential hazards during an approach lighting system incident, specifically reviewing the effects of fog, rain, or snow conditions and how these may limit access to the incident if it occurs within the approach lighting system area. These access points and limitations should be identified prior to any incident by airport operations, ARFF and mutual aid response personnel, (and, where needed, FAA operations) to ensure that response plans take into account approach lighting systems.

Access for emergency vehicles and response personnel to reach areas where approach lights are located may already be included in existing emergency procedures. If the review group is unsure about this access, the group may wish to examine the means of access to areas surrounding the approach lighting system in the event that an aircraft may strike the approach lighting system. Additional issues of land-based structures on hillsides or in limited access areas should be discussed. Also, appropriate response techniques for approach lighting system areas that extend into waterways and use pier structures should also be included in emergency scenario planning. Prior to any potential incidents, the Emergency Response Plan should determine if adequate access exists or if alternate means of access should be provided.

Additional access concerns should be addressed for all weather conditions for all types of response vehicles. Specific fog, rain, or snow conditions may limit access to the incident if it occurs within the approach lighting system area. These access points and limitations should be identified prior to any incident by airport operations, ARFF and mutual aid response personnel, and where needed FAA operations to ensure that response plans take into account approach lighting systems.

**Task 9 – Guidelines Development**

All of the previous tasks led to the development of a guidebook. The guidebook incorporates those elements discussed in Tasks 7 and 8 and presents the information in an easy to read manner. In preparing the guidebook, particular attention was paid to: 1) the users of the guidebook, 2) the purposes of use, and 3) what benefits it will bring to the community of airport operators and responsible agencies. A short introductory section outlines the intent of the guidebook. Following these sections, the guidebook then presents a questionnaire that explores the hazards identified in the research project. After the hazard questionnaire, a set of mitigation techniques follows those outlined in Task 8 of this research report. The guidebook also contains a checklist of mitigation techniques that can be easily used.

## CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

This report has reviewed and documented on-site practices with regard to approach lighting system safety. A number of interesting results were obtained regarding current approach lighting system specifications, previous incident records, on-site practices and issues and, finally, a culmination of hazard types. With the information given, the report proposed hazard identification techniques and mitigation strategies.

Approach lighting systems are well-engineered and consist of various failure mode mechanisms that allow for continuous power during severe weather situations. However, despite these failure modes, the literature review revealed some oversights in the construction of the systems themselves. The literature review identified SMS procedures that can be utilized in the future for risk ratings when addressing approach lighting system safety. However, the implementation of SMS efforts into this report were considered premature such that further SMS reviews and discussions need to occur before implementing the rating system into the approach lighting safety area. Once the SMS has been adopted as an FAA standard the research team suggests that the approach lighting system guidebook be updated to reflect the established SMS methods. Currently, the SMS has not been adequately refined for use in this project.

The incident database showed that undershoot situations that involve collisions with the approach lighting system were more frequent than overrun collisions with the approach lighting system. However, the reports associated with these types of events lack specific details regarding the interaction of the approach lighting system with the aircraft incident. The reports often only state that the approach lighting system was struck, but there is no evidence if the system played a major role in the outcome of the situation or if it hindered or caused further safety concerns. The reporting process should allow for specific information to be entered regarding the approach lighting system with respect to details about damage, whether the system shut down or tripped breakers, whether the system functioned as operationally intended after the incident or if other complications were identified. These additional details can help determine how the system interacted with the incident aircraft and if the approach lighting system posed additional risks after the incident.

Initial efforts to implement the SMS were achieved in the present document; however, additional issues were encountered. The risk matrix appears to be adequately defined in FAA AC 150/5200-37; however, benchmarking is required to adequately rate both likelihood and severity of these risks. Further refinement of the document is required before airport operators can adequately apply these risk ratings to approach lighting system safety issues. The SMS review presented is deemed to be a start in this process; however, further efforts are required. The information given in this report regarding the SMS was purely for exploration purposes in an attempt to classify approach lighting system risks. The SMS matrix results are not considered to be usable by airport operations or other agencies.

The interview information gathered during the site visits proved to be a valuable addition to the information gathered from the literature and incident review when creating the hazard questionnaire and mitigation strategies. To begin, most of the airport facilities had not considered the impact an approach lighting system had on incidents and the additional risks to rescue personnel when a system was compromised. The research team also identified that the relationship between airport facilities and the FAA varied greatly between each facility. The procedural mitigation techniques suggested in this document require a high degree of collaboration between airport operations and other agencies including the FAA. During the interview process the research team found limited support for an automated system to de-energize the approach lighting system. The complications from adding something to the current system and extra monitoring were concerns identified during the interview process. Given this feedback the team focused on procedural and general awareness of approach lighting system incident risks rather than focusing specifically on technological solutions.

**Future Research**

Additional research is required in order to identify the technology needed to de-energize the approach lighting system when a valid incident occurs. During the interview process the research team asked about technological solutions and respondents voiced concern about how a system would identify a valid incident situation. Further research is required to investigate what a valid incident situation consists of and also what technology would need to be incorporated on current systems to allow for a system to de-energize. Multiple testing techniques will be required to ensure that systems do not deactivate unintentionally. The adoption of technological shutoff mechanisms may be considered in the future; however, extensive research regarding how the system detects an incident and what elements are shut down needs further exploration.

Finally, future research is required to identify appropriate warning mechanisms for response personnel during incidents involving approach lighting systems. A thorough human factors review of warning types (e.g., visual, auditory, etc.) should be considered in order to warn response personnel when an approach lighting system has been deactivated. Preliminary assessment of warning types suggests a two-point approach that incorporates both visual and auditory warning mechanisms. These warning efforts can be incorporated into future research regarding automated de-energization of systems that may be employed in the future.

## REFERENCES


1) Federal Aviation Administration, *Terminal Area Forecast (TAF)*, Software version 2006.

2) Trani, A.A., Baik, H. ,Swingle H.S., and S. Ashiabor, *Integrated Model for Studying the Small Aircraft Transportation System*, Transportation Research Record, Volume No. 1850, Transportation Research Board of the National Academy of Sciences, Washington, DC, pp. 1-10, 2004.

3) Transportation Research Board (a), Aircraft Overrun and Undershoot Analysis for Runway Safety Areas, Request for Proposal, Washington, DC, 2006.

4) National Transportation Safety Board, Aircraft Accident Database, Available online (http://www.ntsb.gov/ntsb/query.asp) 2008.

5) NASA Aviation Safety Reporting System (ASRS) database (http://asrs.arc.nasa.gov/#)

6) Federal Aviation Administration (FAA) Aviation Safety Information Analysis and Sharing (ASIAS) database (available at http://www.asias.faa.gov)

7) Aircraft owners and pilots association. Accessed online at http://www.aopa.org, February 2008.

8) Federal Aviation Administration, Airport Series 150 Advisory Circular Library, http://www.faa.gov/airports_airtraffic/airports/resources/advisory_circulars/index.cfm?template=homepage, accessed March 2008.

9) Headquarters Department of the Army. Army Aviation Lighting Technical Manual, http://www.army.mil/usapa/eng/DR_pubs/dr_a/pdf/tm5_811_5.pdf. December 1991.

10) International Civil Aviation Organization, *Aerodrome Design Manual Part 4: Visual Aids, 4th Edition, ICAO Doc 9157 – AN/901 Part 4*, Montreal, Canada, 2004.

11) Federal Aviation Administration, Airport Design, Advisory Circular 150/5300-13, Washington, DC, September 29, 1989 with changes 1-12 published in 2007.

12) Federal Aviation Administration Airport and Facility Directory. Available online at: http://naco.faa.gov/index.asp?xml=naco/online/d_afd. Accessed February, 2008.

13) Hall J., Ayres M., Wong D., Appleyard A., Eddowes M., Shirazi H., Speir R., Pitfield D., Caves R., Selezneva O., Puzin T. (2007). ACRP 4-01 Aircraft Overrun and Undershoot Analysis for Runway Safety Areas. Airport Cooperative Research Program, Transportation Research Board. Washington, DC, pp. 1-205.

14) National Transportation Safety Board, *Aircraft Accident Report: Iberia Lineas Aéreas de España, McDonnell Douglas DC-10-30 EC CBN, Boston Logan International Airport, December 17, 1973*, Washington, DC, November 1974.

15) National Transportation Safety Board (2001). Runway Overrun During Landing American Airlines Flight 1420 McDonnell Douglas MD-82, N215AA Little Rock Arkansas June 1,1999. Aircraft Accident Report, NTSB/AAR-01/02 (PB2001-910402). Washington, DC, 1-230.

16) Federal Aviation Regulations, Title 14, Code of Federal Regulations (CFR), Part 139. 2004. Available online: http://www.faa.gov/airports_airtraffic/airports/airport_safety/part139_cert/, Accessed April 2008.

17) Dutch Safety Board (2006). Runway Overrun Onur Air. Investigation Number 2003071. http://www.safetyboard.nl, accessed January 2008.

18) National Transportation Safety Board (2000). Airport and Emergency Group Chairman's Factual Report of Investigation. Accident DCA-99-MA-060.

19) Transportation Safety Board of Canada, *Aviation Investigation Report A05H0002, Runway Overrun and Fire, Air France Airbus A340-313 F-GLZQ, Toronto/Lester B. Pearson International Airport, Ontario, 02 August 2005*.

# APPENDIX A. DEPLOYMENT SUMMARY OF APPROACH LIGHTING SYSTEMS IN THE UNITED STATES.

This appendix contains information on all types of ALSs deployed in the National System of Airports in the United States (NAS). The data were collected from the FAA airport and runway facilities directory. The information is published by the FAA every 56 days. Figures 19 through 25 portray the data in graphical form.

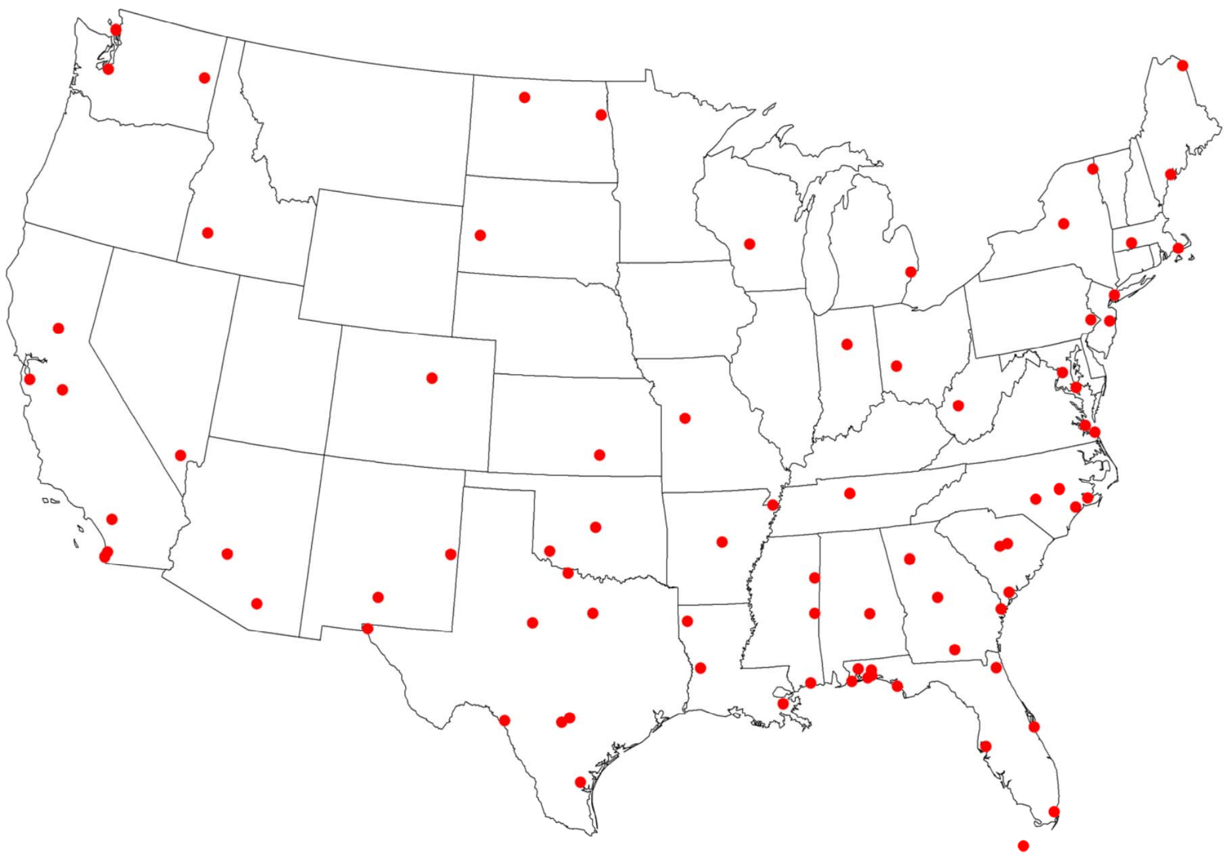


**Figure A-1. Location of Deployed ALSF-1 Systems in the United States**

**There are 129 installations of ALSF-1 systems at 84 airports in the United States. There are two Airports with ALSF-1 installations in Alaska and one in Guam (not shown on the map).**

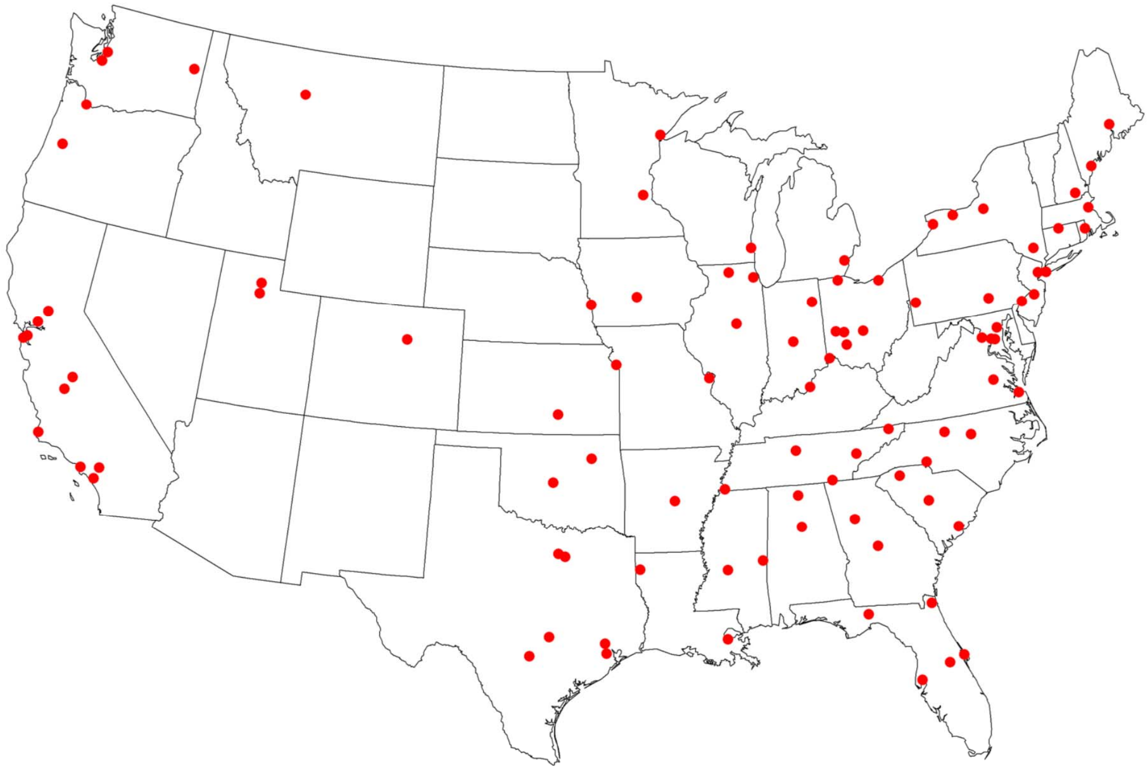


**Figure A-2. Location of Deployed ALSF-2 Systems at U.S. Airports**

**There are 154 installations of ALSF-2 systems at 99 airports in the United States. There are three airports with ALSF-2 installations in Alaska (not shown on the map).**

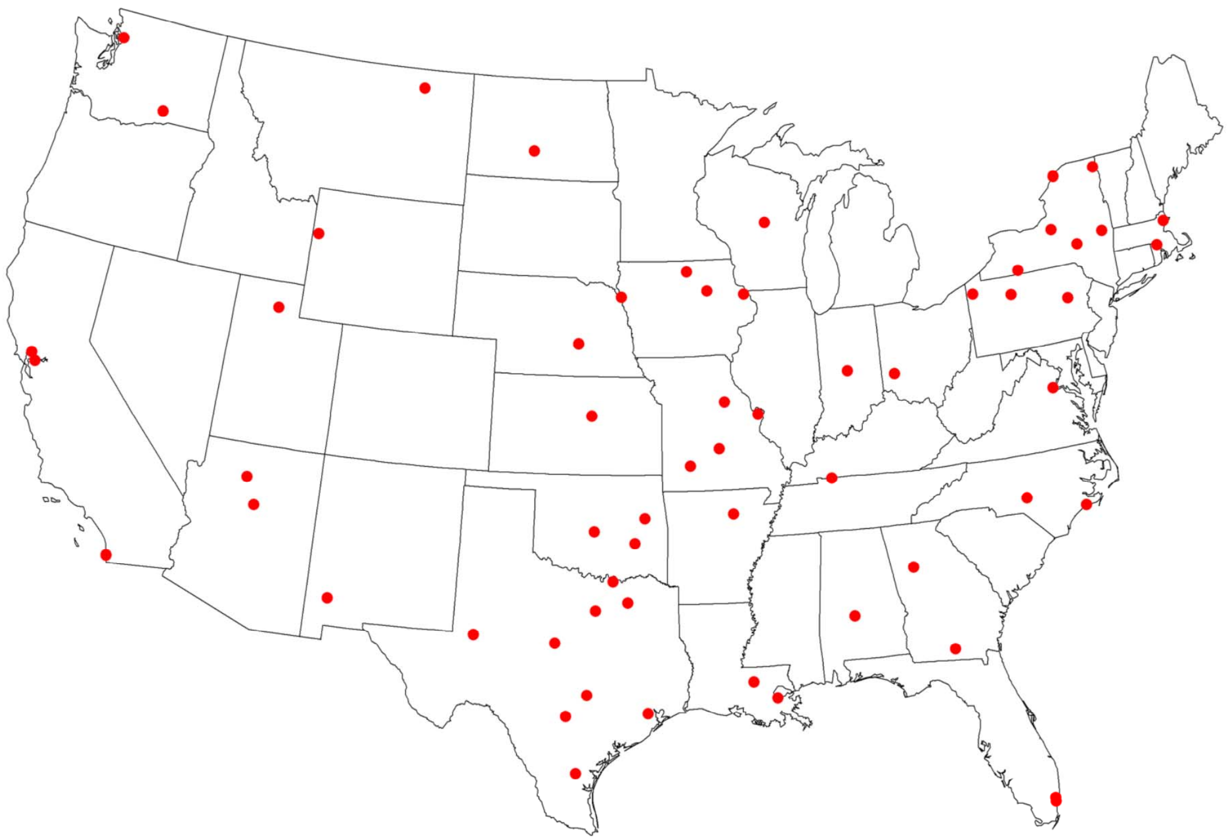


**Figure A-3. Location of Deployed MALS Systems in the United States**

**There are 61 airports with MALSs. There are 66 installations of MALSs at 61 airports in the United States. There is one airport with MALS installation in Puerto Rico (not shown on the map).**

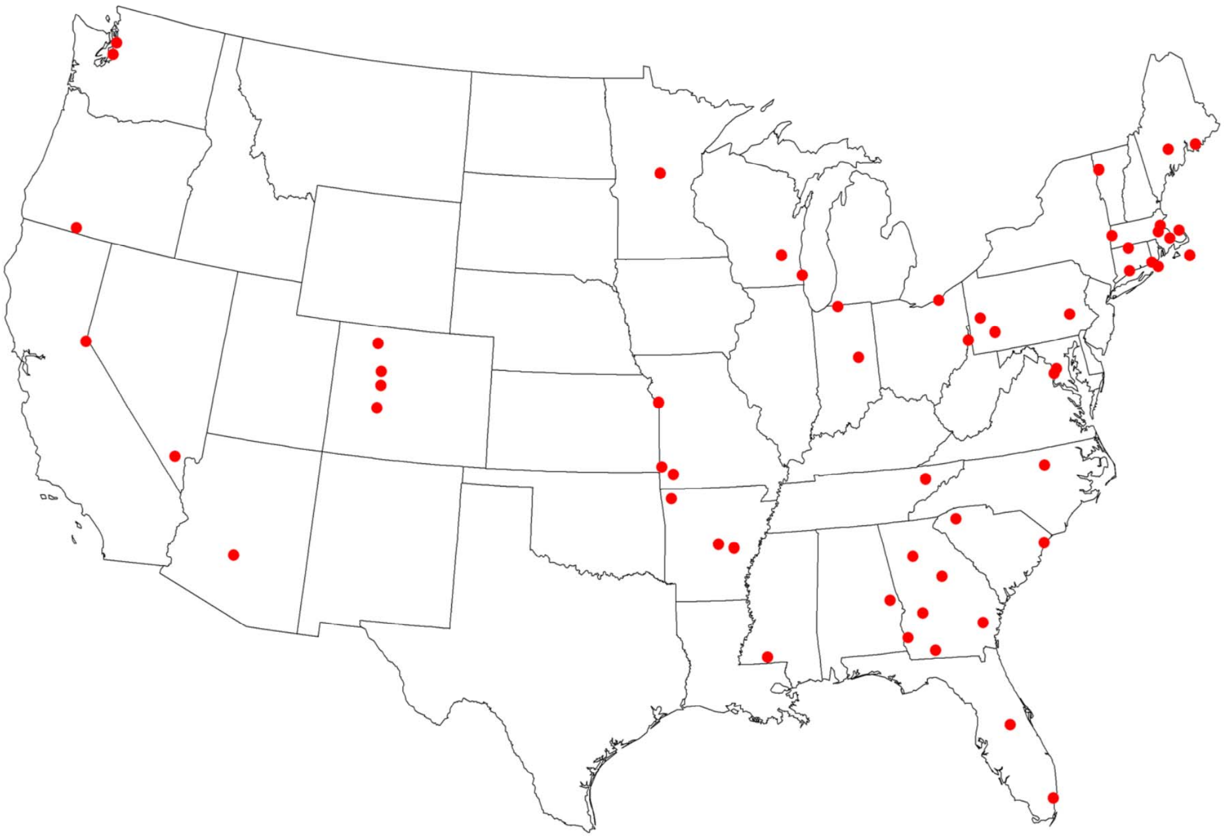


**Figure A-4. Location of Deployed MALSF Systems in the United States**

**There are 66 installations of MALSFs at 64 airports in the United States. There are seven airports with MALSF installations in Alaska and Two in Hawaii (not shown on the map).**

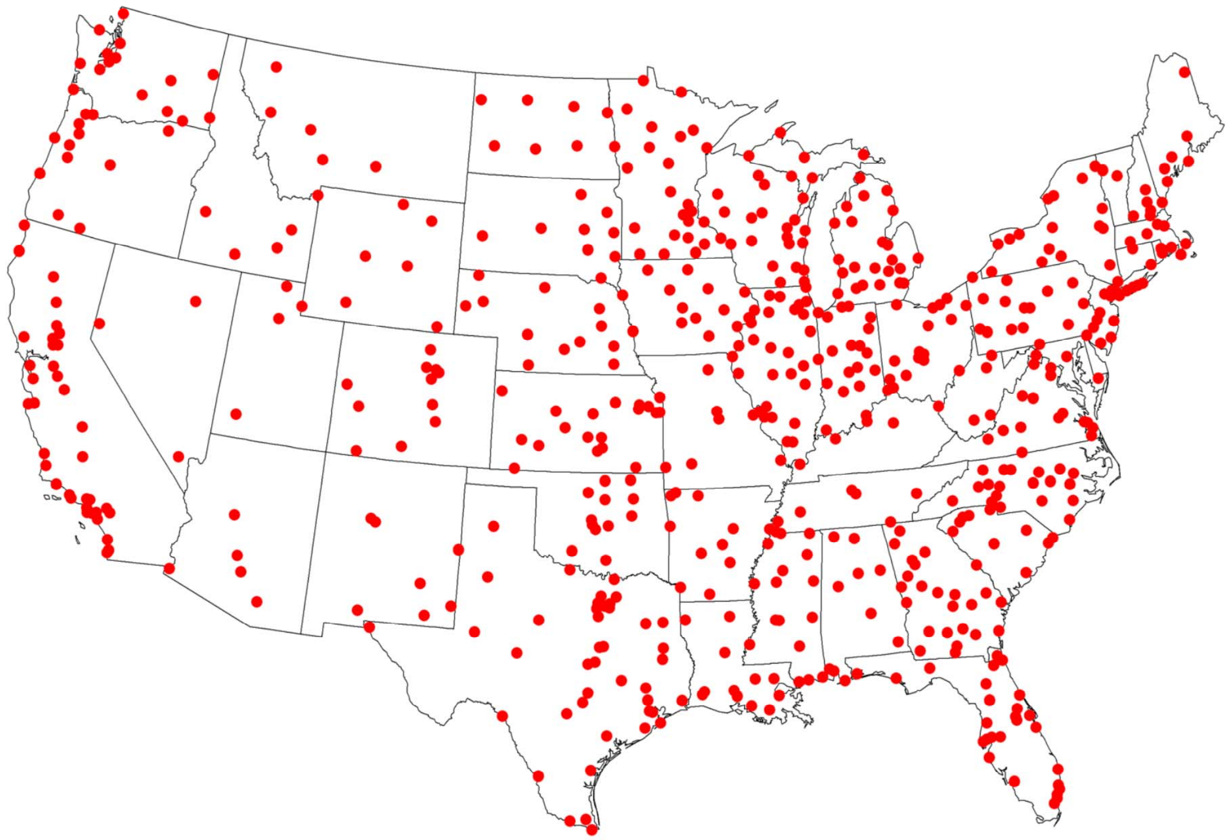


**Figure A-5. Location of Deployed MALSR Systems in the United States**

**There are 823 installations of MALSRs at 633 airports in the United States. There are 17 airports with MALSR installations in Alaska, 5 in Hawaii, 1 in Guam, and 1 in Puerto Rico (not shown on the map).**

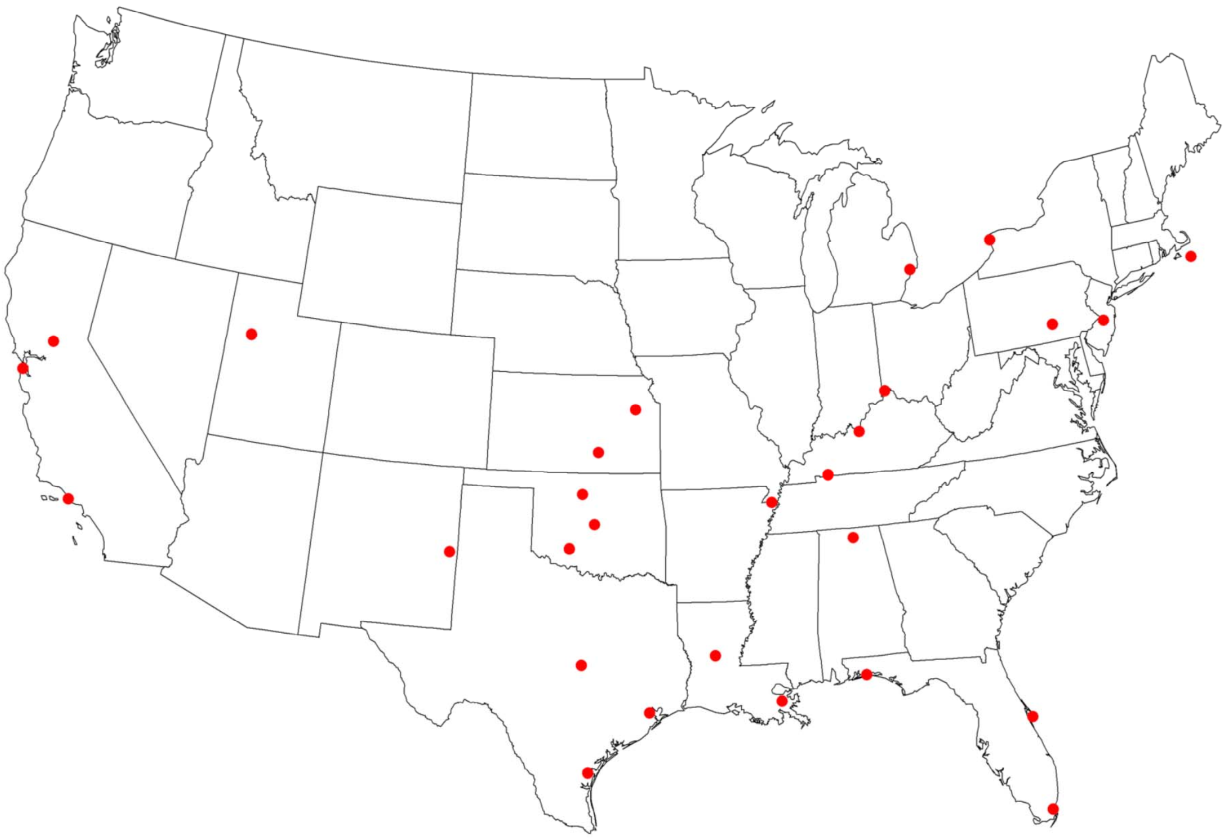


**Figure A-6. Location of Deployed SALS, SSALS, SSALR, and SSALF Systems in the United States**

**There are 32 airports with SALS, SSALS, SSALR, and SSALF installations. There are two airports with installations in Alaska and one in Guam (not shown in the map).**

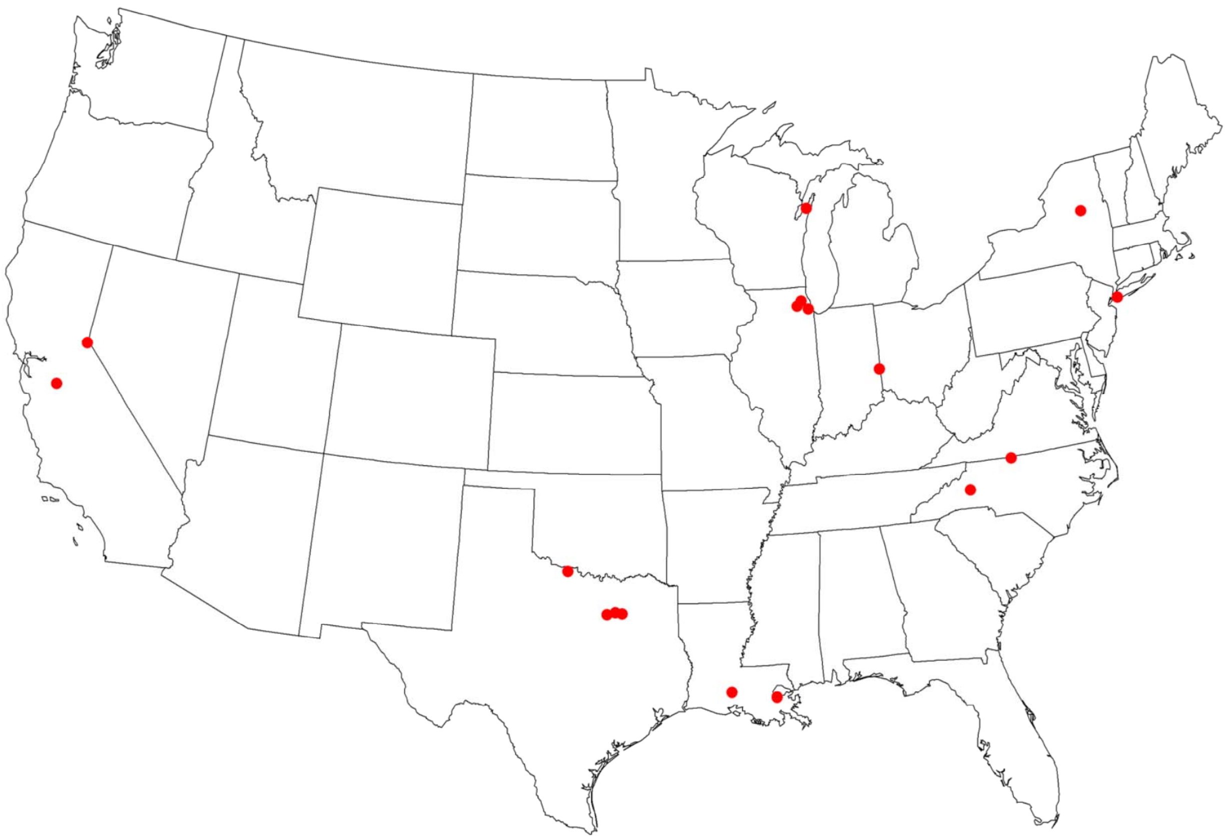


**Figure A-7. Location of Deployed LDIN Systems in the United States**

**There are 19 airports with 21 LDIN systems in the United States. Two of the 21 LDIN Systems are installed in Alaska (not shown).**

# APPENDIX B. APPROACH LIGHTING SYSTEM IDENTIFIED RISKS BASED ON AIRPORT TYPE

| Airport | Airport Type (NPIAS Class) | Tower Operation | Acute Risks Identified | Post-Incident Risks | Additional Risks |
|---|---|---|---|---|---|
| A | General Aviation | 7am – 10pm | Fuel, Sparking (Ignition source). | Electrical field for rescue personnel, electrical field for the walking wounded, fuel, debris. Terrain and corresponding roadways surrounding airport. | Fire department not familiar with specific airport electrical risks? Turnover of mutual aid facility. |
| B | General Aviation | Non-Towered | No response | Electrical risks for responders. | Access |
| C | Reliever | 6am – 11pm | Electrical is a source of ignition. | Electrical risks for responders. | No Response |
| D | Reliever | 24 hr | Electrical is a source of ignition. | Electrical field and debris. | ARFF isn't familiar with FAA facilities.<br>Wildlife issues, flooding and snow melt attribute to water issues. |
| E | Reliever | 6.30am – 10.30pm | Electrical is a source of ignition. | Electrical risks to responders. | Control tower can shutdown lights. |
| F | Primary | None | Sparking – ignition hazard. | Catching gear and flying debris. Electrical system of ALS is exposed. | Shutting down main electrical vault. |

| | | | | | |
|---|---|---|---|---|---|
| G | Primary | 24 hr | Electrical | Terrain | Not knowing FAA ALS specifications. |
| H | Primary | 24 hr | There are electrical issues, which is a safety concern for ARFF personnel or even energizing the aircraft or debris or other live wires. | Only concerned with electrical side of things, however, they don't have keys to any of the boxes owned by the FAA. | There isn't an electrical detection system on ARFF vehicles.<br>Access to electrical FAA facilities to de-energize at vault. |
| I | Primary | 24 hr | Piers, light posts are on piers.<br>Towers are frangible.<br>Pier is wood construction.<br>It is a live electrical field, however, in theory, it should blow the fuses on the primary side. | ARFF is not familiar with FAA electrical systems or turning the vaults off. | ALSF has generator backup which will kick in when "grid" power is lost.<br><br>Wildlife – birds. |
| J | Primary | 6am – 12:00am | Fire is a big hazard.<br>Concrete piers.<br>Metal (debris).<br>Hydraulic Lines<br>Electrical source of ignition. | Fire is the greatest risk to walking wounded. | |
| K | Primary | 6 am - 11:45pm | Electrical ignition. | Electricity | ARFF has not been briefed on FAA ALS facilities. They are cross-trained on all buildings, but not on electrical information. |

| | | | | | |
|---|---|---|---|---|---|
| L | Primary | 24hr | Electrical field (source of ignition) | | Landing long and the ALS is likely not activated. |
| M | Primary | 24hr | No written procedure.<br>Pier situations<br>Water hazards | Pier situations<br>Water hazards | Power down on system, then you also potentially disconnect another runway. Generator is constantly running in a CAT III situation.<br>ARFF has no means of checking for electrical fields. |
| N | Primary | 24hr | Frangible posts can be projectiles when an aircraft strikes them at excessive speed.<br>Ignition source given a live electrical field. | Accessibility with different terrain features.<br>Voltage concerns. | There are animal and terrain risks. Animals on the runway.<br><br>Weather risks – such as micro-bursts, wind shear or lightning.<br>Detecting electrical fields not available. |
| O | Primary | 24hr | Electrical | Live electrical field. | No electrical field detection on ARFF. |