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FAA Heliport/Vertiport Lighting Conference – Proceedings

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Federal Aviation Administration
Washington DC

November 1999

Final Report

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U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave., S.W.
Washington, D.C. 20591

NOV 16 1999

Dear Colleague:

Enclosed is a copy of a Federal Aviation Administration (FAA) technical report entitled **FAA Heliport/Vertiport Lighting Conference – Proceedings (FAA/ND-99/1)**. This report will be of particular interest to those who are planning for instrument flight rules (IFR) operations at heliports or vertiports.

As the vertical flight industry moves into IFR operations, it has become apparent to both FAA and the users that there is research and development to be done on heliport lighting. The lighting industry has developed a variety of technologies that appears promising for use in support of such operations. Still, there are many questions to be answered. The marketplace will answer some of these questions. Others must be addressed via research and development. In looking at FAA heliport lighting research done over the last decade and the resulting advisory circular guidance, it is clear that there are many more questions than answers at this time, especially as it pertains to emerging technology. To answer these questions would require much more in the way of resources than what is likely to be available in the near future. Thus, the FAA sought the advice of the aviation community on how best to proceed. This report documents the proceedings of a two-day conference called to discuss such recommendations.

We welcome your comments on this document and your advice on what future heliport lighting research efforts would be most likely to meet your operational requirements. Please send your comments to:

Federal Aviation Administration
Attn: Flight Systems Office, AND-520
800 Independence Ave., SW
Washington, DC 20591

We appreciate your assistance and we look forward to continued FAA/Industry cooperation on matters such as these.

Sincerely,

Steve Fisher
Product Lead, Flight Systems Technology Team

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1.0 BACKGROUND. As the Vertical Flight Industry moves into instrument flight rules (IFR) operations at heliports, it has become apparent to both FAA and the users that there is research and development to be done on heliport lighting. With the civil tiltrotor now in production at Bell Helicopter, there is also work to be done on vertiport lighting. In looking at the heliport lighting research done by the FAA over the last decade and the resulting advisory circular guidance, it is clear that there are many more questions than answers. To answer these questions would require much more in the way of resources than what is likely to be available in the near future. With this in mind, the FAA sought the advice of the aviation community on how best to proceed with the limited available resources.

1.1 Press Release/Call for Papers. With the advent of global positioning system (GPS) operations, the FAA has seen great interest in heliport procedures for flight during instrument meteorological conditions (IMC). Initial interest has come from operators of air ambulance helicopters. Corporate/executive and offshore operators are also very interested. Before the full benefits of such operations can be achieved, however, more definitive guidance is needed on the issue of landing site lighting.

In August 1998, the Federal Aviation Administration issued a press release announcing that they would hold a conference on heliport and vertiport lighting in the Washington DC metropolitan area in late January 1999. The aviation community was invited to present papers on a variety of lighting issues. Of particular interest were lighting systems to support non-precision approaches, non-precision point-in-space approaches, or precision approaches to heliports or vertiports. Heliport and vertiport lighting systems for use in visual meteorological conditions (VMC) were also of interest. Based on the response of the aviation community, the FAA planned and conducted a two-day conference.

1.2 Recent FAA Lighting Research. Recently, the FAA has published the following technical reports:

FAA/ND-97/20, Evaluation of a Heliport Lighting Design During Operation Heli-STAR

FAA/ND-98-1, Heliport Lighting - Technology Research

FAA/ND-98-2, Heliport Lighting - Configuration Research

FAA/ND-98-4, Heliport Lighting – U.S. Park Police Demonstration

These reports document the initial phase of an FAA/Industry effort to develop a cost-effective heliport lighting system for Global Positioning System (GPS) helicopter approaches. They speak of new technologies that could be of use as part of a heliport lighting system as well as military lighting systems that could be useful if optimized for civil heliport applications. The reports also document previous research that has attempted to determine what helicopter pilots need in the way of visual cues for heliport approaches at night or in poor weather.

While these technical reports address a wide range of heliport lighting issues, they raise more questions than they answer. The possibilities of dealing with these issues are exciting but the range of potential solutions is very broad. The FAA does not yet have answers to all the questions of interest to those who wish to implement improved heliport lighting systems. Additional work is needed. In particular, candidate lighting systems need to be developed, installed, and tested in a variety of operational scenarios in different environments throughout the country. If the FAA were to do all that seems appropriate, the cost would far exceed the available funding. Thus, we are looking for ways to achieve the maximum near term benefits within the limits of available funding. With this in mind, the FAA looked to the aviation community for their recommendations. The January 1999 Heliport/Vertiport Lighting Conference provided a venue for interested parties to offer their advice.

**QUESTIONS ADDRESSED AT
THE FAA HELIPORT/VERTIPOINT LIGHTING CONFERENCE**

January 26-27, 1999

1. What are the operational requirements of the vertical flight industry, particularly in light of emerging GPS-based technology?
2. What new technology lighting lends itself for use as components of civil heliport and vertiport lighting systems?
3. What military lighting systems lend themselves to approval by civil aviation authorities for use in civil operations?
 - 3a. What is the operational experience with such systems?
4. What lighting systems have been approved by civil aviation authorities around the world for use in IMC?
 - 4a. What is the operational experience with such systems?
5. What lighting systems have been approved by aviation authorities around the world for use in unusual applications (such as rooftop landing sites, offshore platforms, and remote locations without standard electrical power)?
 - 5a. What is the operational experience with such systems?
6. What are the top five heliport/vertiport lighting design issues on which Industry needs FAA guidance and what research is required to develop that guidance?

2.0 DISCUSSION. The various papers presented at the Conference are provided in Appendixes C, D, and E. This section provides a brief synopsis of some of the discussions that took place during the Conference.

2.1 Approach Lights. Some in Industry spoke of their strong desire to obtain "approach light credit" without the use of approach lights. Approach light credit typically means that the pilot is authorized to make an instrument approach when the visibility is ½ mile rather than ¾ mile. On a runway, it takes 2500 feet of approach lights to obtain this ¼ mile (1320 feet) credit. At a heliport, it only takes 1000 feet of approach lights to obtain this ¼ mile (1320 feet) credit. Still, at a heliport, this 1000 feet of real estate is often difficult or impossible to obtain. Several Industry spokesmen expressed a desire for "approach light credit" with a lighting system that does not extend significantly beyond the edges of the FATO.

The FAA gives approach light credits because approach lights provide certain visual cues to the pilot **before the pilot has acquired (can see) the touchdown point (heliport or runway end)**. The required cues are as follows:

1. Positive indication that there is a landing site ahead
2. Centerline guidance
3. Horizon cues (since the pilot is transitioning from instruments to visual cues, the use of the instruments is no longer appropriate)

Attendees made several suggestions as to how to satisfy these requirements without approach lights. Several aviation authority spokesmen addressed the possibility that laser lighting systems might be able to satisfy approach light requirements. However, their opinions conflicted. Testing has not yet been conducted to determine if laser lights will be visible through fog, rain, and snow during both daytime and nighttime operations. Cost could also be an issue.

Although this is a lighting conference, one speaker urged the attendees not to put on blinders by assuming that the need to make IFR heliport approaches presents a "lighting problem" and that lighting is the only possible solution. Instead, we should look at this as a "bad weather/IFR operations" problem. In the fixed-wing world, approach lighting has been a key part of the overall solution to this problem. It may be part of the overall solution to the problem of flying IFR heliport approaches in low-ceiling, low-visibility conditions. However, other possible solutions to this problem should not be ignored. Bear in mind that, in a Cat 3C approach, the pilot never sees the approach lights. Perhaps in working together, the FAA and Industry will be able to find an acceptable, cost-effective IFR solution involving decelerating GPS approaches without approach lights. Joint FAA/Industry efforts were very successful in the development of heliport nonprecision GPS terminal instrument procedures (TERPS). A similar FAA/Industry effort is being attempted for heliport precision GPS TERPS.

2.2 Acquisition Lighting. Research has shown that the first heliport lighting cue needed by the pilot deals with "acquisition". The pilot is flying in the vicinity of a heliport, perhaps at night, and wishes to "acquire" the heliport visually. In an IMC approach, the pilot breaks out of the clouds and seeks to visually acquire the heliport prior to the missed approach point. Under IMC conditions, it is important that visual cueing be adequate to allow the pilot to acquire the heliport quickly and thereby avoid the need for a missed approach. Even in VFC conditions, it is highly desirable for the lighting to enable the pilot to acquire the heliport quickly.

By allowing pilots to visually acquire the heliport more rapidly, acquisition lighting increases the safety margin of the facility. Acquisition lighting also has an environmental benefit since it enables pilots to find the heliport and land in an efficient manner. In the absence of acquisition lighting, pilots are sometimes forced to spend time flying around, generating noise, looking for the heliport. The heliport beacon is the light specifically designed to assist the pilot in visually acquiring the landing site.

2.3 Visual Glideslope Lighting Systems. Although there are many different models of visual glideslope systems available for installation at heliports and vertiports, none of these is considered as ideal. Among the characteristics that Industry looks for in a visual glideslope system are the following:

- Inexpensive
- Provides effective, intuitive visual cues to the pilot
- Can be flown without excessive pilot workload
- Require little real estate for ground system installation
- Does not blind the pilot in close to the landing spot
- Does not constitute an obstruction hazard when installed

At the conference, Industry spoke with decidedly mixed opinions on the value of a visual glidepath system. For example, at the Downtown Manhattan Heliport in New York City (better known as the Wall Street Heliport), the Port Authority of New York and New Jersey (PANYNJ) removed a precision approach path indicator (PAPI) system at the request of the users. At this heliport, users had commented that they did not use the system during approach operations. Once they had landed on the TLOF, users complained that the PAPI lights were so bright that it made taxi maneuvers difficult. It should be noted that the Wall Street Heliport is unusual due to the high level of ambient nighttime lighting from the skyscrapers of Manhattan. At other locations, users do see a benefit in a visual glidepath system. [This benefit has been recognized worldwide. In Volume II of Annex 14, Heliports, ICAO recommends that a visual approach slope indicator should be provided where the environment of the heliport provides few visual surface cues (5.3.5.1c).]

Attendees made several suggestions on better ways to provide visual glidepath cueing. One Industry spokesman suggested a notional glidepath lighting system that would be imbedded in the surface of the TLOF. The attendees were unaware of any existing lighting system of this kind.

These comments indicate that there is a market opportunity for an improved glideslope indicator and it is particularly apparent in two scenarios. The first scenario is at VFR heliports, particularly those where nighttime operations take place in an environment that provides few visual cues to the pilot or in an environment where the visual cues are deceptive. [An example of this would be where the topography, such as a shoreline or the edge of a heavily forested area provides a deceptive horizon cue.] The second scenario is at IFR heliports where a visual glideslope can be helpful during the visual segment of an IFR approach. It would be best if any new visual glideslope system would be able to function in both cases.

2.4 Light-Emitting Diode (LED) Lighting. Both Industry and aviation authorities are interested in the potential of light-emitting diode (LED) lighting. The idea of using lines of light, rather than point sources, is attractive. The fact that LED lighting can be flush-mounted is also of great interest. Before wide use of LED lighting can be expected at heliports and vertiports, the following questions need to be answered:

To what criteria should LED lights be designed and certificated?

Of the various visual cues needed by helicopter and tiltrotor pilots, which cues would best be provided by LED lighting?

In what configuration(s) should the LED lights be installed?

During this conference, the PANYNJ announced that they had installed LED lighting as a test demonstration at the Wall Street Heliport in New York City. This installation demonstrates the use of LED lights to mark the edge of the TLOF with a dashed yellow line. It also demonstrates the use of LED lights, to provide an indication that the TLOF is temporarily closed, with a red X in the middle of the TLOF. After some months of this demonstration, the PANYNJ reports that helicopter pilots in the area have responded in a very positive way to the use of LED lights. The PANYNJ report on this test is shown in Appendix F.

2.5 Floodlights. During the conference, several pilots complained that excessive heliport lighting is a problem at some heliports. The PANYNJ spoke of user complaints that the PAPI lights were so bright that it made taxi maneuvers difficult. Several pilots spoke of the problems associated with floodlights. While it is generally possible to locate and shield floodlights so that they will not shine directly in the pilots' eyes, these shields often lose their alignment over time. If the lights are radio activated, pilots may be able to turn them off. When pilots are unable to turn off the floodlights, they have been known to break the lights prior to departure. Often, however, even such direct action does not lead to a long-term solution to problems with floodlights. In some cases, floodlights are being used to provide a visual acquisition cue when a heliport beacon would be a more appropriate mechanism.

2.6 Choices. The FAA, the vertical flight industry, and the lighting industry jointly face a choice between a number of options:

Choice 1. Continue using the same FAA-approved lighting components and lighting systems. They are safe, relatively inexpensive (except for instrument approach lighting), components are readily available, and the lighting technology would remain based primarily on incandescent light sources. The benefit of this scenario is that relatively little needs to be done by either government or industry. The disadvantage is that this choice would delay or eliminate any chance that technology could provide cheaper, more effective, more reliable lighting. This choice would also limit operational benefits to helicopter operators because relatively few heliports have the space necessary to install current FAA-approved approach heliport lighting to support instrument approaches.

Choice 2. Encourage new lighting technology by modifying FAA standards and specifications to define light outputs rather than light sources. This choice requires that FAA and the lighting industry do a considerable amount of work in updating the FAA's lighting standards and specifications. The benefit of this choice is that heliport operators would have alternatives in their purchase and operation of lighting components. The disadvantage is the time and costs required to develop new standards and specifications. Operational benefits at IFR heliports may still be limited because relatively few heliports have the space necessary to install FAA-approved instrument lighting systems.

Choice 3. Develop new heliport lighting systems and standards for IFR heliports. These new systems would need to be affordable to heliport operators and have smaller footprints than the existing HILS and HALS. Benefits of this choice would accrue to the IFR helicopter operators who presumably could optimize their IFR operations. Disadvantages are the cost, to both government and industry, of developing new IFR heliport lighting standards. In addition, there are no assurances that an affordable, more compact lighting system will be able to achieve the performance necessary to reduce visibility or ceiling minimums.

Choice 4. This choice is a combination of Choices 2 and 3. Choice 4 delivers maximum potential benefits in terms of encouraging new lighting technology and achieving maximum operational benefits to IFR helicopter operators. Choice 4 provides new or updated specifications and standards for lighting components, and it offers the possibility of producing smaller, more compact heliport lighting systems to support instrument approaches. However, Choice 4 also carries the largest cost to government and industry and the same risks that the resulting lighting system may not be able to achieve the performance necessary to reduce visibility or ceiling minimums.

These choices need to be made primarily by helicopter operators and the lighting industry with input from government (FAA). It is industry's role to define their heliport lighting requirements. It is FAA's role to address industry's requirements by developing new or revised standards and specifications. This is best done as a cooperative effort involving both FAA and Industry.

3.0 SMALL GROUP DISCUSSIONS. On the second day of the conference, the attendees broke into small groups for discussion. A series of questions were proposed for three groups and the attendees each selected which of the groups they would like to join. The material below shows the questions posed to each group and the answers they agreed upon within the small group. At the end of the small group discussions, each group presented their answers to all of the attendees. Since not all items were discussed in detail, it should not be assumed that there is a consensus on all of the groups' answers.

3.1 Group 1.

3.1.1 Group 1 Discussions. Since the existing heliport system is primarily configured for VMC operations and privately owned, the highest immediate needs were centered about: (1) Improving the ability of helicopter pilots to visually identify a heliport under marginal visibility conditions or during night operations; and (2) Providing visual cues to the pilot to enable proper alignment on the approach path. The availability of new technology and different lighting configurations were discussed from the standpoints of improved safety and operations, and possible overall reduction of costs. Group members expressed a keen interest in the near term testing and possible approval of such technologies as cold cathode lights and light emitting diodes.

Differences in ambient lighting and terrain conditions create needs for different lighting configurations, colors, and intensities. Research is needed to define optimal lighting for heliports located in areas where ambient conditions may be significantly different.

With regard to IMC operations at heliports that are not collocated at an airport, it was recognized that although FAA advisory circulars provide guidance for non-precision and precision lighting systems, very few of these lighting systems have been installed. Most of the helicopter industry has no experience with either the HILS or HALS. This fact was not surprising. Prior to the availability of GPS, (with the exception of specialized nonprecision approach procedures to oil platform helidecks) system costs and land requirements made it difficult to establish nonprecision approaches at heliports. Precision approach procedures at heliports were even more difficult.

In 1996, the FAA approved GPS nonprecision approach criteria for heliports. This enabled the development of low-cost, nonprecision approaches to heliports. If approach lights are not available, higher minimums are established. Work under FAA's GPS WAAS Program should lead to near-precision approach capability at heliports. Joint FAA and NASA work is ongoing to obtain precision capability through use of differential GPS equipment. With the availability of low-cost nonprecision and precision approaches to heliports, it becomes important to explore the feasibility of developing low cost lighting or other non-light-based systems that would permit the lowest possible approach minimums to heliports. Research is also needed to determine how best to provide visual approach guidance to those who want to use different approach profiles to accommodate performance capabilities or to minimize noise impact on the local community.

In recognizing these development needs, the Group 1 believed it to be appropriate for the various elements of the Industry to coordinate and develop operational requirements and

to work in partnership with Government to develop technology for government certification.

3.1.2 Group 1 Questions and Answers. (*Answers are shown in Italics.*)

Question 1. Consider the full range of the operational requirements of the vertical flight industry, particularly in light of emerging GPS-based technology.

a. Which operational requirements are not currently being fully met by the lighting in place at heliports?

- At many heliports, the available real estate is insufficient to allow the installation of the IFR heliport lighting recommended by the FAA Heliport Design AC.*
- Current lighting does not lend itself to urban areas.*
- Current lighting does not provide lateral visual guidance.*
- There are no minimum FAA standards for TLOF lighting.*

b. Which operational requirements are not currently being well addressed by the FAA in their design guidance?

- Operational requirements are not adequately addressed by FAA heliport design guidance.*

c. What research, development, demonstration, or other actions could be taken to address these issues? Who should do this work?

- Research and development needs should be met through a Government/Industry/International partnership.*

Question 2. What new technology lighting lends itself for use as components of civil heliport and vertiport lighting systems?

a. What research, development, demonstration, or other actions could be taken to address these issues?

- Line lighting*
- Non-point-source lighting*
- Cold cathode*
- Fiber optic – side emitting*
- Heliport color and flash technology*

b. Who should do this work?

- Government/Industry Partnership leading to fast track development.*

Question 3. Currently, FAA guidance on heliport/vertiport lighting takes a "one size fits all" approach. With the wide variety in heliport designs and in their surrounding environments, some individuals have suggested that FAA guidance should address different lighting requirements for different environments.

a. What are the pros and cons of this approach?

-Current Guidance basically says that "One size fits all" but one set of heliport lighting recommendations does not provide the best guidance for heliport lighting in a wide variety of environments.

b. For what specific heliport/vertiport types/environments should such an approach be considered?

- | | | |
|------------|----------------------------|-------------|
| - Urban | Ground | Airport |
| - Suburban | Elevated | |
| - Remote | Roof Top | Non Airport |
| - Helideck | Water (Pier or Barge) | |
| | Various Ambient Conditions | |

c. In recommending different lighting for different situations, are there any pitfalls associated with a variety of standards rather than a single standard? If so, how should this be addressed?

-Group 1 did not specifically address this question.

d. Is there any research, development, demonstration, or other actions required before a decision could be made on this issue?

-Group 1 did not specifically address this question.

Question 4. What are the five most urgent heliport/vertiport lighting issues on which Industry needs FAA guidance and what actions are required to develop that guidance?

Question 5. What are the five most urgent heliport/vertiport lighting issues on which Industry needs some action to be taken by someone other than the FAA?

-Establish Government/Industry partnerships to develop lighting standards for items listed under the responses to questions 1 through 3. Item 2a should be put on a fast track for R&D.

3.2 Group 2.

3.2.1 Group 2 Discussions. Various military services have developed some innovative lighting systems for shipboard landings of helicopters and jet aircraft. They have also developed lighting systems for rapid deployment of temporary helicopter landing areas. Some of these concepts may be adaptable for civil sector use. Group members expressed concerns over potential equipment costs and possible special training requirements.

The "hockey stick" concept for lateral guidance, along with possible application of shipboard visual guidance technology shows promise for civil use. Military experience with the use of night vision goggles should be explored in depth.

Canada and Great Britain have considerable operational experience and have conducted significant research into helicopter operations under fog conditions at helidecks and heliports. Future work in this area should take advantage of this experience through their cooperative participation.

Consideration should be given to differentiating the lighting requirements of VFR and IFR heliports depending upon ambient conditions. Visual cueing requirements for heliports in urban, remote areas, on-airport, elevated, or above water differ in some respects. Future guidance should address these differences.

From an implementation perspective, Group 2 felt it appropriate for the various elements of the industry to coordinate and recommend priorities for analyzing military and oil industry visual cueing systems for use in civil applications. A Government/Industry team could best accomplish the required development and testing.

3.2.2 Group 2 Questions and Answers. *(Answers are shown in Italics.)*

Question 1. What military lighting systems lend themselves to approval by civil aviation authorities for use in civil operations?

- a. For what civil applications do these systems appear to be attractive?

-The "hockey stick" concept for line-up on elevated pads should be considered.

-Navy shipboard glide slope systems should be considered for civil application.

- b. Would these systems be usable "off the shelf" or would they need to be re-designed, re-engineered, or optimized in some way for civil use?

-These systems would need to be redesigned and optimized for civil use.

- c. What research, development, demonstration, or other actions could be taken to address these issues?

-Group 2 did not specifically address this question.

- d. Who should do this work?

-The feasibility of redesigned systems should be tested and demonstrated by an FAA/Industry team.

Question 2. Currently, FAA guidance on heliport/vertiport lighting takes a "one size fits all" approach. With the wide variety in heliport designs and in their surrounding

environments, some individuals have suggested that FAA guidance should address different lighting requirements for different environments.

a. What are the pros and cons of this approach?

-Group 2 did not specifically address this question.

b. For what specific heliport/vertiport types/environments should such an approach be considered?

-Group 2 did not specifically address this question.

c. In recommending different lighting for different situations, are there any pitfalls associated with a variety of standards rather than a single standard? If so, how should this be addressed?

-Group 2 did not specifically address this question.

d. Are there any research, development, demonstration, or other actions required before a decision could be made on this issue?

-The "one size fits all" concept does not work. Heliport lighting should consist of a modular system. The maximum light output should be chosen to satisfy the most demanding operational environment. Variable lighting intensity control should be provided to allow flexibility in setting the level that works best at a specific site.

Question 3. What are the most urgent heliport/vertiport lighting issues on which Industry needs FAA guidance and what actions are required to develop that guidance?

-Define operational requirements by:

- 1. Categories of operations*
- 2. Locations (on-airport, off airport, urban, rural, ground level, elevated, helideck, etc.).*

-Determine how to improve the IFR/VFR transition

-Review TERPS criteria related to visual cues, schemes, and patterns.

-Standardize color scheme and patterns.

Question 4. What are the most urgent heliport/vertiport lighting issues on which Industry needs some action to be taken by someone other than the FAA?

-Issues:

- 1. Glide slope and centerline identification at heliports.*
- 2. Methods of determining closure rates*

-Action needed by focused workshops with participation by:

1. *Pilots*
2. *Manufacturers*
3. *Owner/Operators*
4. *Military*
5. *NASAO*

3.3 Group 3.

3.3.1 Group 3 Discussions

The users are not currently able to answer many of the questions raised concerning heliport lighting. However, Industry would like to be involved in future lighting tests and demonstrations so that they can participate in the learning process and voice their opinions on the acceptability of various candidate lighting systems and components.

Heliport lighting should be unique; it should readily identify the location as a heliport. The pilot should be able to visually acquire the heliport at a distance of at least 2 to 3 miles. Lighting should help the pilot find the heliport more quickly, particularly if the heliport is located in an area with which the pilot is unfamiliar. Candidate lighting components need to be evaluated in a variety of environments. Are they bright enough? Are they conspicuous in bad weather? Are they candidates for FAA certification?

The Downtown Manhattan Heliport (Wall Street) has a very high level of ambient light throughout the night. This is an extreme example at one end of the spectrum. At the other end of the spectrum is the heliport located in a rural area with very few nearby building lights or streetlights. The vertical flight community faces the challenge of defining appropriate lighting for both of these extremes and for all the scenarios in between.

Since heliport lighting costs are not insignificant, it is important to seek heliport lighting that provides operational benefits in a cost-beneficial manner. Some of the newer lighting technologies appear to offer significant cost savings. While the acquisition cost may be similar to incandescent lighting, some of the new technologies appear to reduce annual maintenance costs by as much as \$95 to \$110 per light per year. If testing shows that they can provide better visual guidance at lower cost, the transition to these new technologies may be largely market driven. While FAA certification is not required at private, VFR heliports, certification would enable Industry to make this transition more quickly.

Helicopter pilots have been scud running for decades. The consequence has been accidents involving wire strikes and collisions with other obstacles. GPS offers a means of operating safely both en route and with heliport approaches and departures. Heliport lighting will be required if we are to make the most of GPS capabilities in IMC weather. Currently, some heliports are operating with sub-standard lighting. Such lighting provides the pilot with inadequate visual cues and increases the likelihood of heliport accidents.

The European community has a wealth of experience with IFR airports and severe low ceiling/low visibility weather that is more frequent than what is experienced in most of the USA. This has enabled the Europeans to make huge contributions toward the advancement of IFR airport equipment and procedures. With regard to IFR heliports, however, few in Europe are used for nighttime IFR operations. Many of the initial operational lessons are likely to be learned at hospital heliports in the USA.

There is much commonality between civil and military heliport lighting requirements. It is noteworthy that the North American Treaty Organization (NATO) tries to use civil and ICAO standards when possible. At the same time, military lighting has been optimized for military missions. In addition, military discipline and training allow operations that would not be acceptable in the civil environment. Before many military lighting components could safely be used to support civil operation, they would need to be redesigned and optimized for the civil mission. This redesign would also need to take into account the skills and the training of the civil helicopter pilot.

Limited testing to date has demonstrated that green cold cathode lighting works well for stand-alone VFR heliports. Since the majority of urban lights are white or yellow, green heliport lights help pilots visually acquire the heliport more readily. In contrast, an airport environment already has many green lights. Thus, the aviation community must consider whether green heliport lights will provide clear and unambiguous guidance at an airport helipad in the presence of many other green airport lights. If green lighting were to be adopted as the national standard for stand-alone heliports, there would need to be a transition period when green lights are an option, perhaps the preferred option, rather than a requirement. A lengthy transition, say 10 years, would probably be required. (International standardization is also an issue that should be addressed.) The FAA and Industry need to resolve the issue of heliport color standardization. What additional testing is required to allow a determination that the benefits of green heliport lights are sufficient to justify such a change?

Night vision goggles (NVG) compatibility with heliport lighting is likely to be a future requirement.

3.3.2 Group 3 Questions and Answers. (*Answers are shown in Italics.*)

Question 1. What lighting systems have been approved by civil aviation authorities around the world for use in IMC applications? What is the operational experience with such systems? What research, development, demonstration, or other actions are required before these systems could be used in the USA?

-Approved (JAA/ICAO) Lighting Systems

Question 2. What lighting systems have been approved by aviation authorities around the world for use in unusual VFR applications (such as rooftop landing sites, offshore platforms, and remote locations without standard electrical power)? What is the operational experience with such systems? Is there any research, development, demonstration, or other actions required before these systems could be used in the USA?

-VFR Heliport

1. Acquisition (not less than 1000 feet/3 nm) VFR/VMC

- a. ICAO standard: flashing beacon – white (Annex 14, Section 2)
- b. FAA standard: rotating beacon – white/green/yellow (AC150-5345-12)

2. Final Course Alignment

- a. VFR – N/A (No requirement currently defined)
Option – ICAO SPEC – Alignment/Glide Path
- b. Line up lighting on the final approach heading
-Industry considers FATO/TLOF edge identification to be sufficient
-Identifiable from _____ * nm at 500 feet AGL.
(* Group 3 was unable to come to a consensus on this distance.)

Question 3. Currently, FAA guidance on heliport/vertiport lighting takes a "one size fits all" approach. With the wide variety in heliport designs and in their surrounding environments, some voices have suggested that FAA guidance ought to address different lighting requirements for different environments.

- a. What are the pros and cons of this approach?
- b. For what specific heliport/vertiport types/environments should such an approach be considered?
- c. In recommending different lighting for different situations, are there any pitfalls associated with a variety of standards rather than a single standard? If so, how should this be addressed?
- d. Is there any research, development, demonstration, or other actions required before a decision could be made on this issue?

Group 3 did not specifically address questions 3a-3d.

Question 4. What are the most urgent heliport/vertiport lighting issues on which guidance is required and what actions are required to develop that guidance?

- For use at heliports that are not located at airports, develop a certification specification for green edge lighting. (Case by case consideration is appropriate for heliports located at airports where green airport lighting might cause confusion)

-Modify the heliport design AC to recommend green edge lighting (for non-airport facilities).

[Timing is an issue on when these first two actions should be taken.]

-In next revision of the FAA Heliport design Advisory Circular, review the ICAO Annex 14 lighting requirements/recommendations

-Develop a certification specification for LEDs

-Work with aviation authorities in other countries so that the FAA can accept their heliport lighting research results and vice versa.

-Allocate the required research among the interested aviation authorities.

Question 5. What are the five most urgent heliport/vertiport lighting issues on which Industry needs some action to be taken by someone other than the FAA?

Group 3 did not specifically address this question.

4.0 CONCLUSIONS.

4.1 Vertical Flight Industry Conclusions.

4.1.1 Industry has concluded that the current Heliport Approach Light System (HALS) requires more real estate than what is likely to be available at the vast majority of heliports. They seek a system that will allow them to make instrument approaches at low weather minimums with lights that do not extend much beyond the edges of the FATO.

4.1.2 Industry is not particularly familiar with the results of recent lighting research and they are not prepared to define their requirements for various lighting cues in great detail. They look for this to be done by lighting researchers in Government and academia. However, Industry does wish to be consulted at various stages as heliport/vertiport lighting research and development progresses.

4.1.3 Industry has concluded that the four basic needs that heliport/vertiport lighting and marking should provide are the recognition (visual acquisition) of the facility from a reasonable distance, identification of the landing area and approach, orientation and closure clues during the approach and ground maneuvering and parking.

4.1.4 Industry has expressed significant interest in new lighting technology, such as cold cathode lighting and light emitting diodes (LED's). However, before wide use of these technologies can be expected at heliports and vertiports, a number of questions need to be answered.

4.1.5 Due to obstacles or issues on the closing of VFR airspace, some in Industry have concluded that precision IFR operations at a downtown facility are not practical for essentially all current heliports. On both of these issues, the Wall Street Heliport is a

vivid example. The many tall obstacles (skyscrapers and bridges) in the area have precluded the development of a precision approach with low minimums. The heavy use of the adjacent East River as a VFR flyway conflicts with IFR procedures at Wall Street. Others in Industry are more optimistic about the prospects of precision or near-precision IFR operations at urban heliports and vertiports. While recognizing the constraints of the situation at Wall Street, they see this as a unique facility/environment. Other urban locations may have less intractable constraints.

4.1.6 Industry has concluded that lighting systems are equally important for VFR night and poor weather heliport operations as well as for the IFR-VFR transition

4.1.7 Industry has concluded that research needs to be done to design and qualify the many new lighting technologies coming on the market for heliports and vertiports. The advantages and drawbacks of each system need to be determined.

4.1.8 Industry has concluded that the "Buy Your Minimums" approach to lighting tailored to each location is one way of having the basic system with additional lowering of minima for added enhancements.

4.1.8 Industry voices suggest that the following represent some of the more immediate heliport lighting needs:

- a. Improve the ability of helicopter pilots to visually identify a heliport under marginal VFR visibility conditions or during VFR night operations; and
- b. Determine how to improve the IFR/VFR transition (during approach operations).
- c. Provide visual cues to the pilot to enable proper alignment on the approach path.
- d. Define operational requirements by categories of operations and by locations (on-airport, off airport, urban, rural, ground level, elevated, helideck, etc.).
- e. Review TERPS criteria related to visual cues, schemes, and patterns.
- f. Standardize heliport lighting color scheme and patterns.

Industry voices suggest that the following represent some of the most urgent heliport/vertiport lighting issues on which Industry needs some action to be taken by someone other than the FAA. (Action is needed by focused workshops with participation by pilots, helicopter owners/operators, manufacturers, NASAO, Military.)

- a. Glide slope and centerline identification on heliports.
- b. Methods of determining closure rates

4.2 Aviation Authority Conclusions.

4.2.1 The FAA, Canada, and the United Kingdom aviation authorities have concluded that a new lighting requirements document must be developed for the certification of light emitting diode (LED) lighting components. The research required to develop such a document is currently underway. The three aviation authorities are working on different research tasks and have agreed to share results. They have also agreed to consult with one another informally before making final decisions on this matter.

4.2.2 Although the manufacturer has argued that cold cathode lights have some unique qualities that justify the development of a "non-generic" certification requirement, the FAA has not yet been convinced on this point. Thus, the FAA has concluded that it is not appropriate to develop a new certification requirement AC for cold cathode lights at this time. Rather, the FAA believes that these lights can be certificated under the existing requirement (AC150/5345-46, Specifications for Runway and Taxiway Light Fixtures). The FAA might reconsider this position if the characteristics of cold cathodes were proven to be unique. Such a demonstration could be done by one of the testing organizations identified in AC 150/5345-53, Airport Lighting Equipment Certification Program. The manufacturer should be responsible for the associated demonstration costs.

4.2.3 The papers presented by various military authorities were very instructive on what can be done under difficult circumstances. Some of the military equipment is probably too expensive for most civil applications, although it might be of interest in special IFR applications. However, other military equipment may be of interest if it were modified and optimized for civil use.

4.2.4 In remote locations where electrical power may not be available, Canada has extensive experience with the use of reflectors as an alternative to heliport lighting. Both experience and testing has shown, however, that reflectors often don't work very well when coated with even a very thin later of dew, frost, or other materials. The performance of such reflectors is marginal, even under the ideal conditions, and performance tends to deteriorate rapidly with exposure to environmental conditions. As an example, reflector performance deteriorates rapidly as the reflecting surface is abraded when rotorwash "sand blasts" the reflector with small particles of sand and grit.

4.2.5 As the FAA develops and refines the requirements for heliport instrument lighting, care must be taken to develop all resulting specifications as functional performance specifications that detail the required characteristics of the light output and not merely the characteristics of a light source. New ways to produce a light evolve as lighting technology advances. Developing specifications for the light source, rather than the light output, tends to inhibit innovation and technology improvements. (It should be noted that there are practical limits to the extent that specifications can be made "generic". When these limits are exceeded, the cost of the testing required for the certification of a new light becomes excessive.)

4.2.6 It is in the interest of Industry to expand the FAA list of approved lighting in order to remove any barriers, however artificial and unintentional, to the introduction of new lighting technologies that may improve VFR and IFR heliport operations.

4.2.7 The cues required for a safe instrument approach are: acquisition, line-up, glideslope, horizon, closure rate, and touchdown. These cues are also required during VFR night and marginal VFR operations at landing sites.

5.0 RECOMMENDATIONS.

5.1 The FAA and Vertical Flight Industry should continue to work cooperatively on heliport/vertiport lighting issues and look for opportunities to jointly conduct research and development projects.

5.2 In view of Vertical Flight Industry interest in new lighting technology, such as cold cathode lighting and light emitting diodes (LED's), the FAA should work cooperatively with the lighting manufacturing industry to enable the certification of new lighting products.

5.3 The FAA should conduct research to define and qualify the advantages and drawbacks of the new lighting technologies coming on the market for heliports and vertiports. In particular, the FAA should determine which cues would best be provided by the various lighting technologies and in what configuration(s) they should be installed.

5.4 The FAA and the Vertical Flight Industry should look for alternatives to the current heliport approach light system (HALS). While approach lights may be part of the overall solution to the problem of flying IFR heliport approaches in low-ceiling, low-visibility conditions, other possible solutions to this problem should not be ignored.

5.5 To some extent, heliport lighting designs are site and operations specific. One design will not work best for all situations. The FAA and Industry should consider whether some manageable grouping of possible heliport types would be appropriate. Three types are proposed here: rooftop, ground-level/off-airport, and ground-level/on-airport. The FAA should develop guidelines to assist heliport/vertiport designers in developing one or more cost-effective systems tailored for each of these groups. There may also be a need to develop systems for other scenarios.

5.6 The current Heliport Design AC states that "An even number of lights, at least eight, uniformly spaced with a maximum interval of 25 feet (7.5 m) between lights is required to define a circular FATO or TLOF." Plainly speaking, it recognizes that a circular FATO or TLOF may be outlined with a circular pattern of lights. Other aviation authorities make similar recommendations. A serious disadvantage of such lighting is that it provides no lateral course line guidance. (To the helicopter pilot, a circle of lights will look like an ellipse from all azimuths.) By contrast, a square or rectangular pattern of lights provides the pilot with better visual cues, particularly at a distance during nighttime operations. To maximize the positional cues, FATO or TLOF lights should produce patterns consisting of straight lines even at those locations where the TLOF is a circle. As a minimum, this should be recommended as an option in the next revision of the Heliport Design AC.

APPENDIX A. AGENDA

HELIPORT/VERTIPOINT LIGHTING CONFERENCE

January 26-27, 1999

DAY ONE

7:00 – 8:00 AM Pick up Registration Materials

OPENING

8:00 Introduction and Administrative Issues, Robert Smith, FAA, AND-710

8:15 Welcome and Opening Remarks, Shelly Myers, FAA, AND-1

USER REQUIREMENT - PRESENTATIONS

8:30 Hibernia oil field lighting experience
D'Arcy Hart, Center for Offshore Aviation Research, Newfoundland CANADA

9:15 LED testing at the Wall Street Heliport, Jay McGowan, PANYNJ

9:35 BREAK

9:55 Ray Syms, Heliport Consultant

10:25 Group Discussion

AVIATION AUTHORITIES - PRESENTATIONS

10:40 Defining the Lighting Requirements, Tony Smith, UK Ministry of Defense

11:20 New Visual Aids for Ship Operations of Helicopters, Lt Cdr Peter Symonds,
RN Directorate Naval Aviation Support (presented by Tony Smith)

11:50 LUNCH

1:00 Offshore Helideck Lighting, Hassina Maycroft, UK Ministry of Defense
(presented by Tony Smith)

1:30 The Impact of COMM/NAV/Surveillance Technology, Dan Salvano, FAA,
Deputy Director – Office of Communications, Navigation, and Surveillance
Systems, AND-2

1:50 FAA Heliport and Vertiport Lighting Recommendations
Robert Bonanni, FAA, Airport Design Division, AAS-100

- 2:10 FAA Lighting Standards and Certification
Tod Lewis, FAA, Airports, Engineering and Specifications Division, AAS-200
- 2:40 U.S. Navy shipboard lighting systems for helicopter operations
- 3:10 BREAK
- 3:30 George Bray, NAWC, Lakehurst NJ
- 3:20 USMC Heliport Lighting, Rob Rinderer, NAWC, Lakehurst NJ
- 3:40 Retro-reflective Markers, Guy Heneault and Eduard Alf, Transport Canada
- 4:10 Lighting Research in the USA, Edwin McConkey, FAA contractor
- 4:40 Group Discussion
- 5:30 PM **INFORMAL INFORMATION EXCHANGE**
- 7:30 PM **AVIATION AUTHORITIES MEETING**

HELIPORT/VERTIPORT LIGHTING CONFERENCE

January 26-27, 1999

DAY TWO

LIGHTING MANUFACTURERS - PRESENTATIONS

7:30 – 8:00 AM Informal discussions prior to meeting

8:00 Reynold Schmidt, Lightbeams

8:45 Nick Hutchins, Hil-Tech International

9:30 Emergency Lighting, Dr. John Leverton

9:50 BREAK (Sign up for small discussion groups)

10:10 **SMALL GROUP DISCUSSIONS**

12:00 LUNCH

1:00 **SMALL GROUP PRESENTATIONS**

2:00 **OPEN DISCUSSION/PANEL DISCUSSION**

Discussion of the Conference Questions

Identification of areas where guidance is needed

Identification of work to be done

Identification of the top 4-8 priorities

6:00 **CLOSING REMARKS**

Appendix B. Presenters and Attendees

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APPENDIX C. USERS PAPERS

Hibernia Oil Field Lighting Experience

D'Arcy Hart, Center for Offshore Aviation Research, Newfoundland CANADA

LED Testing at the Wall Street Heliport

Jay McGowan/Ralph Gatto, PANYNJ

Heliport Design and Real Life Prospectives, IFR and VFR Lighting and Marking Issues,

Raymond Syms, Heliport Consultant

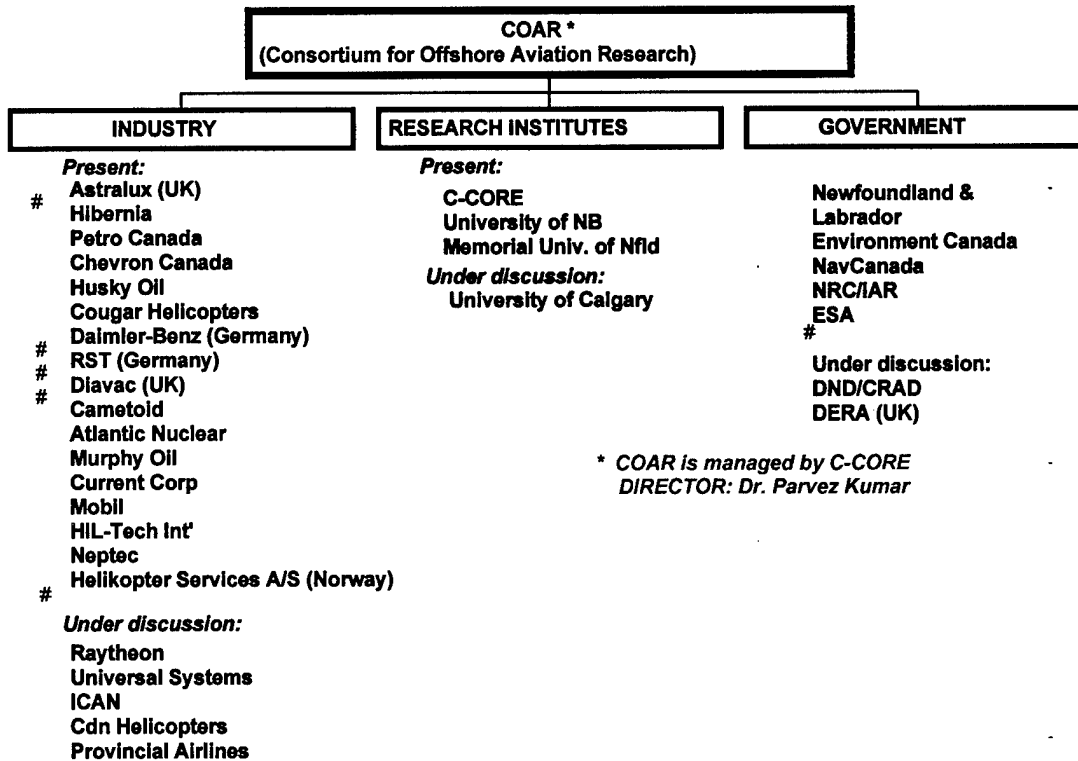
DISCLAIMER: The papers in this Appendix represent the opinions of the authors and of the organizations that they represent. These opinions are not necessarily consistent with FAA policy or plans.

Lighting Solutions for Offshore Oil Platforms Helidecks in Low Visibility

**C-CORE: D. Hart, G. Piercey
P. Kumar, A. Smith**

Cougar Helicopters: R. Burt, K. Jamieson

RESEARCH PARTNERSHIPS



* COAR is managed by C-CORE
DIRECTOR: Dr. Parvez Kumar

Indicates European participation

CURRENT DEMONSTRATION PROJECTS

- ▶ **THE CURRENT PROJECTS WITHIN COAR ARE:**
 - ▶ To provide approach path guidance through optical means
 - # ▶ To measure the physical characteristics of fog and precipitation under real conditions
 - ▶ To provide approach path guidance through Differential GPS
 - # # # ▶ To provide enhanced vision systems (e.g. Head-Up-Display with Virtual Reality)
 - ▶ To test Ice-Phobic materials on the airframe to eliminate inflight ice formation
- ▶ The deliverables will be Operational Charts and/or Onboard Systems which enable pilots to make decisions enhancing safety and increasing operational reliability in conditions which are close to or below legislated approach minimums (i.e. visibility of 1/2 nautical mile or less)

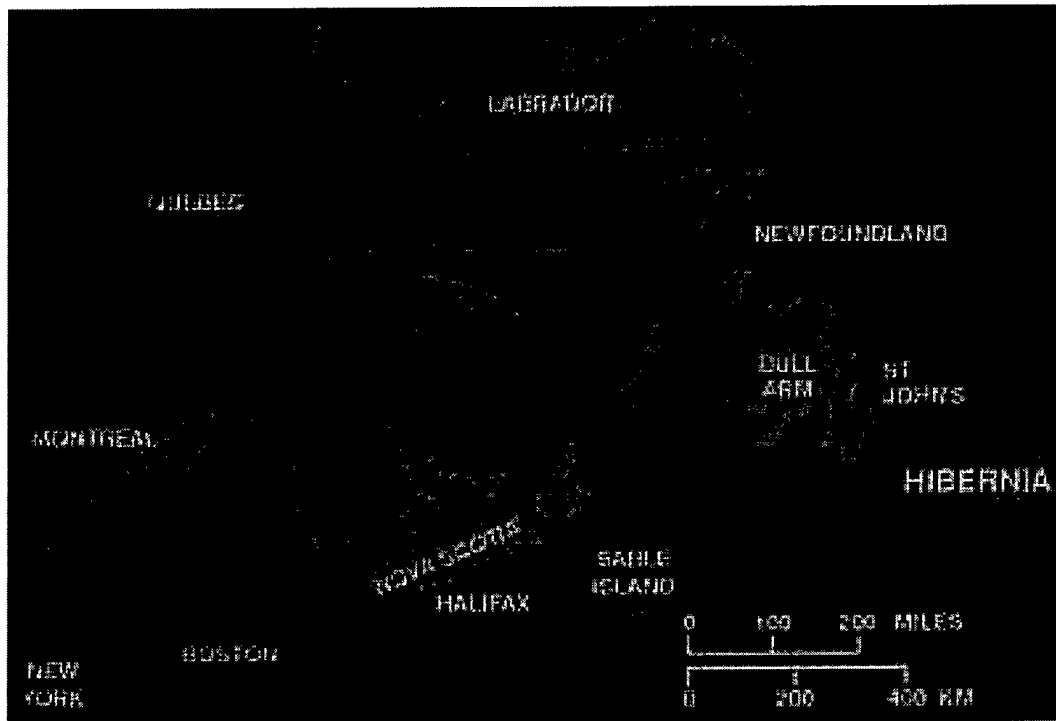
Indicates European participation

PRIORITIES FOR THE FUTURE

OIL & GAS OPERATIONS: COAR

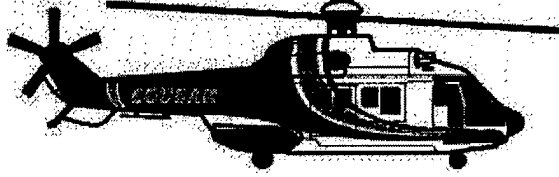
- ◆ **Modification of GPS Approach Procedures. Establish a small working group in order to get non-precision GPS approved. [Cougar Helicopters, NavCanada, DoT]**
- ◆ **DGPS: the determination of multi-path errors on the Hibernia platform. [Cougar Helicopters, NavCanada, UNB, HMDC]**
- ◆ **Determination of the helideck environment: measurement of turbulence, wind shear, etc. [C-CORE, DERA, Univ. of Trondheim, HMDC]**
- ◆ **Low-level air traffic control on the Grand Banks. [C-CORE, Northern Radar, NavCanada, Cougar Helicopters, International Ice Patrol, CCG, DND/SAR]**
- ◆ **Head-up displays: [C-CORE, MUN, Cougar Helicopters, ICAN, DND/SAR, CCG, DoT, HMDC]**
- ◆ **Accurate fog and weather forecasting. [Oceans Ltd., AES, C-CORE, HMDC]**
- ◆ **Development of visibility sensor for use on offshore platform [Cougar Helicopters, C-CORE, AES, HMDC, Canpolar East]**

HIBERNIA



- 315 km south of St. John's, NF in 80 meters of water
- 3 billion barrels of oil in place, 20% estimated recoverable

COUGAR HELICOPTERS



Eurocopter AS332L
Super Puma (De-Iced)

Aircraft Specifications

Cruise Speed:	130 kts
Max. Passengers:	18
Max. Take Off Weight:	8,600 kg
Range (internal tanks):	3.30 hrs

COUGAR HELICOPTERS

Hibernia Flight Statistics

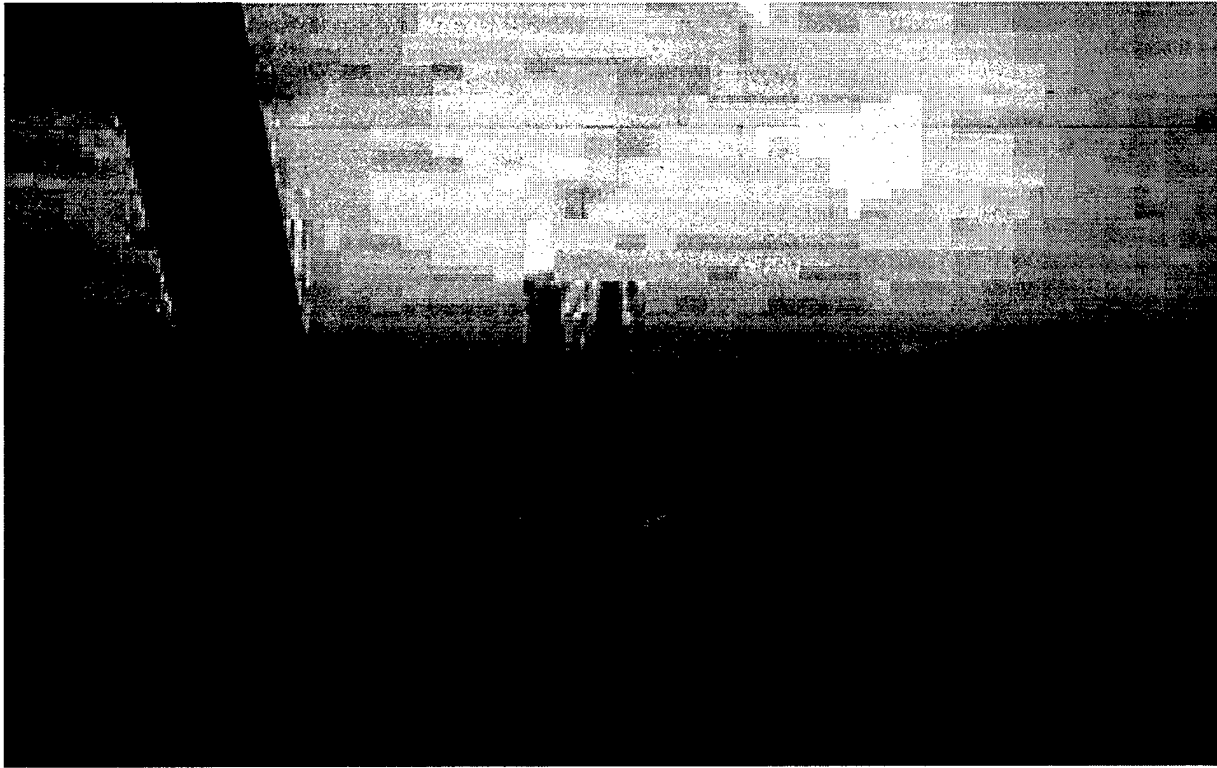
May/97-Aug/98

Total Offshore Flights	1,006
Missed Approaches	64 (6.4%)
Delayed flights due to weather	204 (20.3%)

Total Passenger Transfers	15,103
Same day	11,949 (79.1%)
One day delay	2,450 (16.1%)
Two day delay	429 (3.0%)
Three day delay	200 (1.3%)
More than three day delay	75 (0.5%)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Total Flights	65	78	75	51	76	65	64	56	48	61	49	50
Missed Appr.	6	11	8	2	3	1	1	2	2	7	1	3
(%)												
As scheduled	71	68	72	77	83	80	86	94	94	74	73	81
1 day delay	12	21	23	21	13	20	14	6	0	18	25	10
2 day delay	7	9	5	2	4	0	0	0	0	3	2	3
3 day delay	10	2	0	0	0	0	0	0	0	5	0	4
>3 day delay	0	0	0	0	0	0	0	0	6	1	0	1

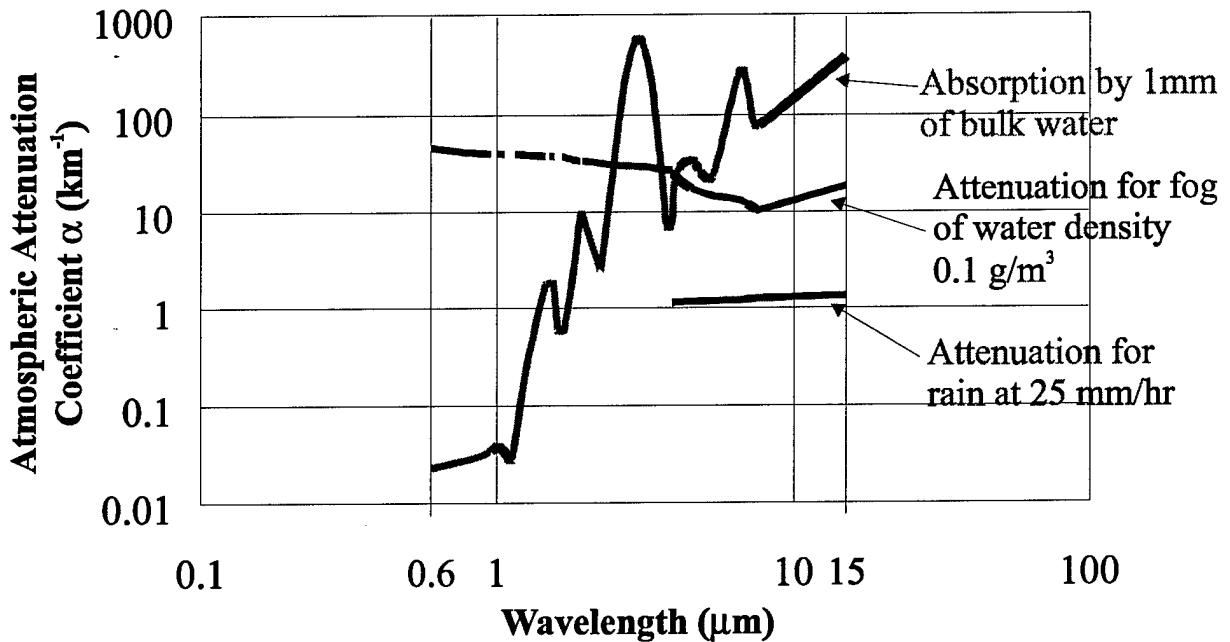
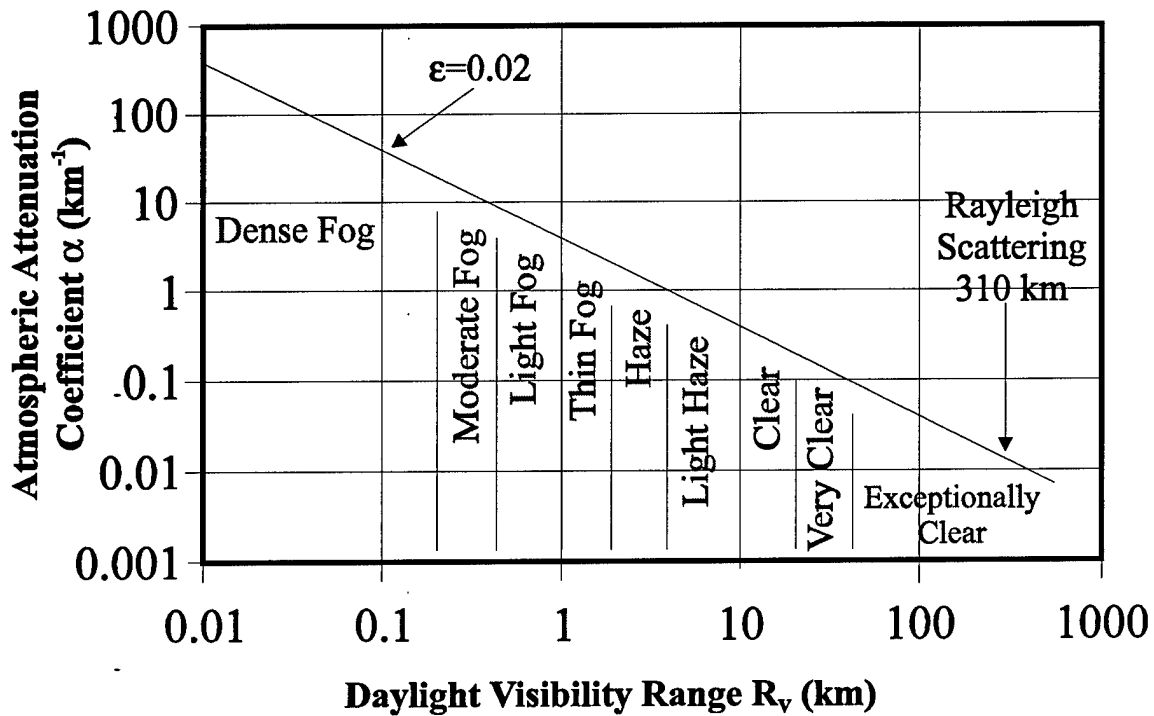
HELIDECK APPROACH



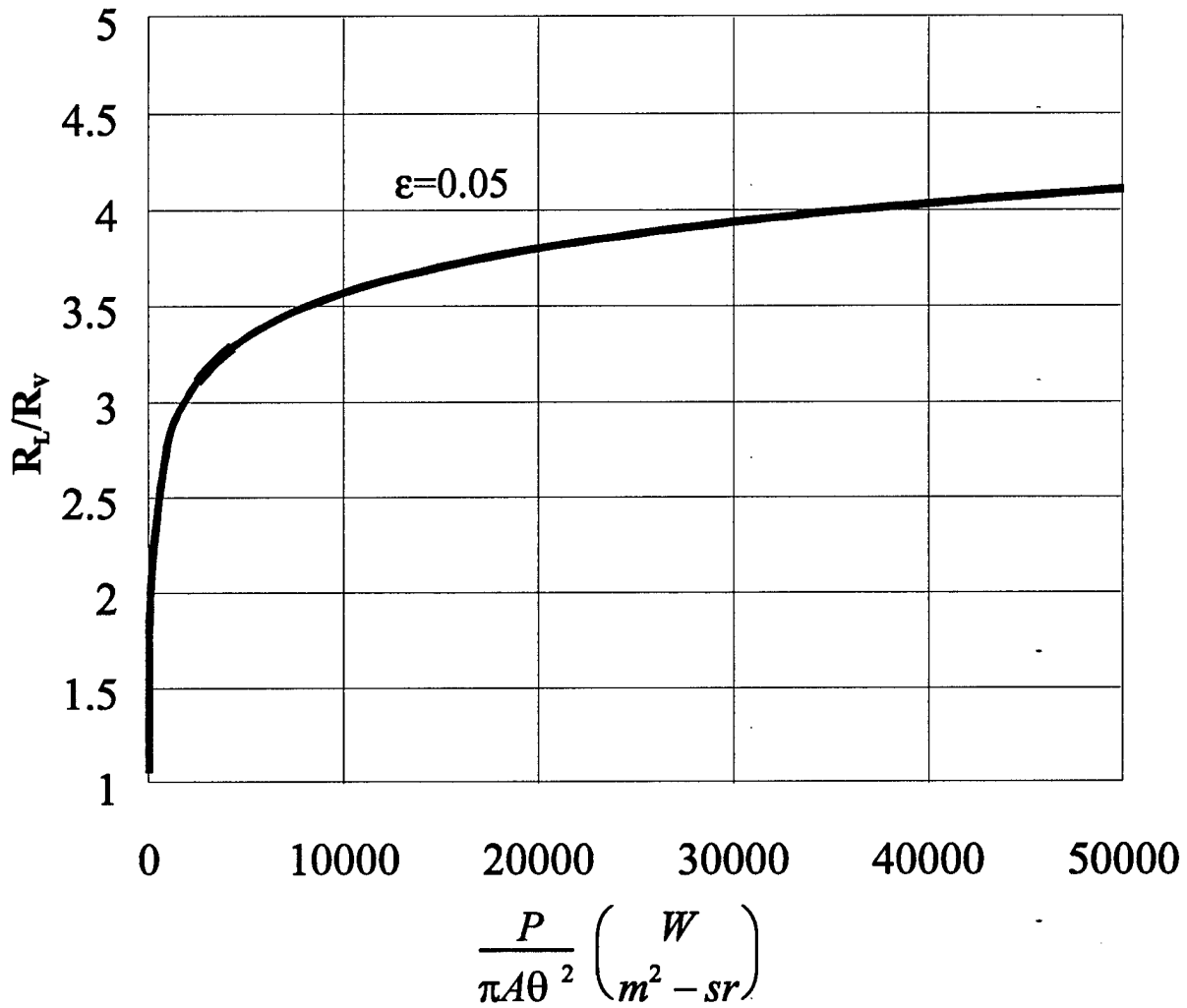
Visual reference of platform required at distance of 0.5 nm (1 km) or must execute missed approach.

In summer months, visibility is less than 1 km 50% of the time on the Grand Banks due to advection fog.

ATMOSPHERIC ATTENUATION



VISUAL RANGE OF LIGHT



$$\frac{R_L}{R_v} = 1 + \frac{\ln \left[0.22 \left(\frac{P}{\pi A \theta^2} \right) - 1 \right]}{\ln \left[\frac{1}{\epsilon} \right]}$$

Optical Depth $OD = \int_0^{R_L} \sigma \, dR$

Contrast at distance R_L , $C = \left[\frac{L_0 - L_g}{L_g} \right] e^{-OD} > \epsilon$

LIGHTING EXAMPLES

1) Commercial Helideck Light Fixture

- two 40 Watt fluorescent bulbs
- enclosure with yellow polycarbonate diffuser
- 25 Candela light output
- 0.17 m² diffuser area

$$\frac{P}{\pi A \theta^2} = 0.22 \frac{W}{m^2 - sr}$$

2) Experimental lights

- 75 Watt spot light
- 11 cm diameter, 20° full angle divergence
- 3% of output into photopic band

Calculated output,
$$\frac{P}{\pi A \theta^2} = 2500 \frac{W}{m^2 - sr}$$

LIGHTING EXAMPLES

$$\text{Measured output, } \frac{P}{\pi A \theta^2} = 710 \pm 165 \frac{W}{m^2 - sr}$$

$$\frac{R_L}{R_V} = 2.7$$

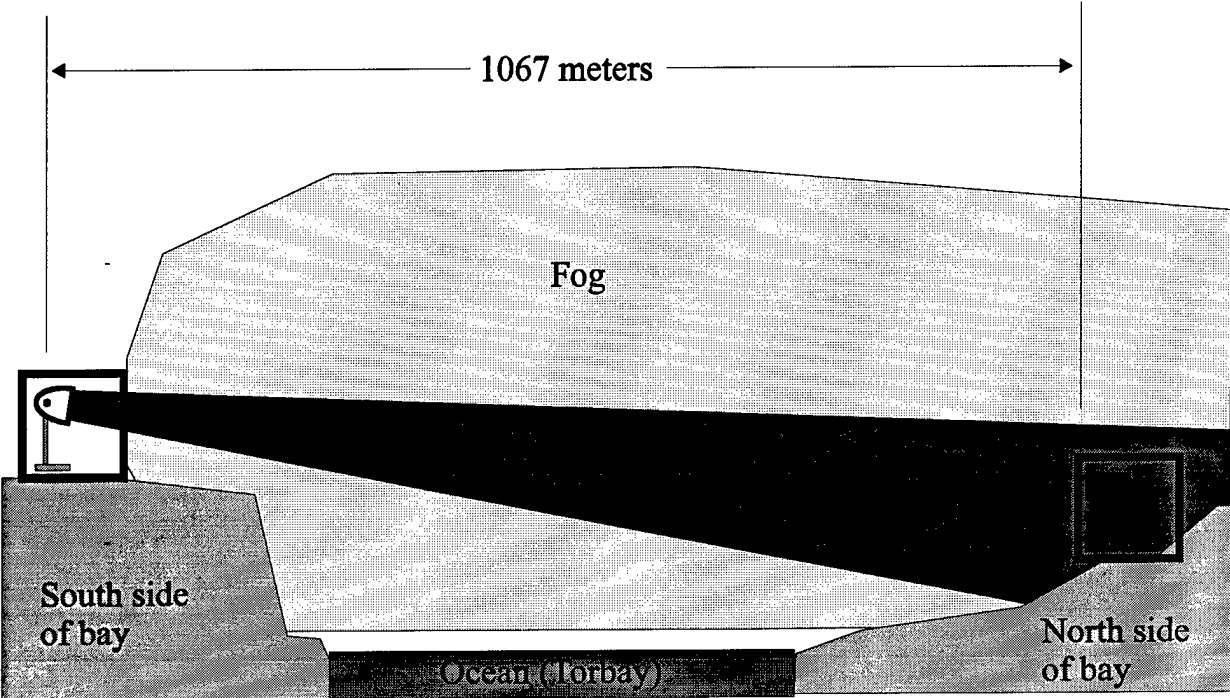
3) Commercial Searchlight

- 1000 Watt searchlight
- 25.4 cm diameter, 10° full angle divergence
- 600,000 Candela light output

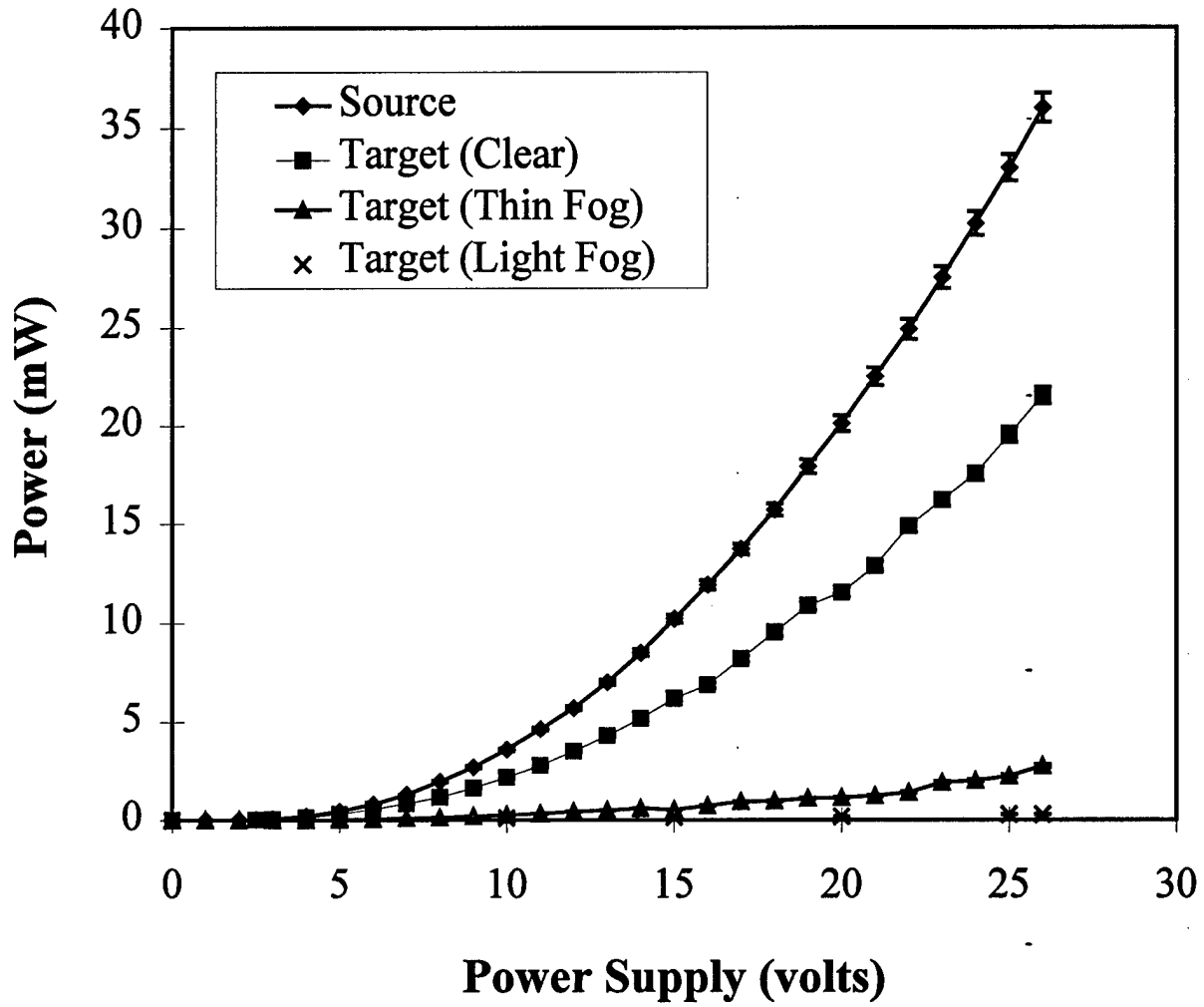
$$\text{Calculated output, } \frac{P}{\pi A \theta^2} = 17,300 \frac{W}{m^2 - sr}$$

$$\frac{R_L}{R_V} \cong 3.7$$

FOG FACILITY SCHEMATIC



Searchlight Power Output Source at 0.6m, Target at 1067m

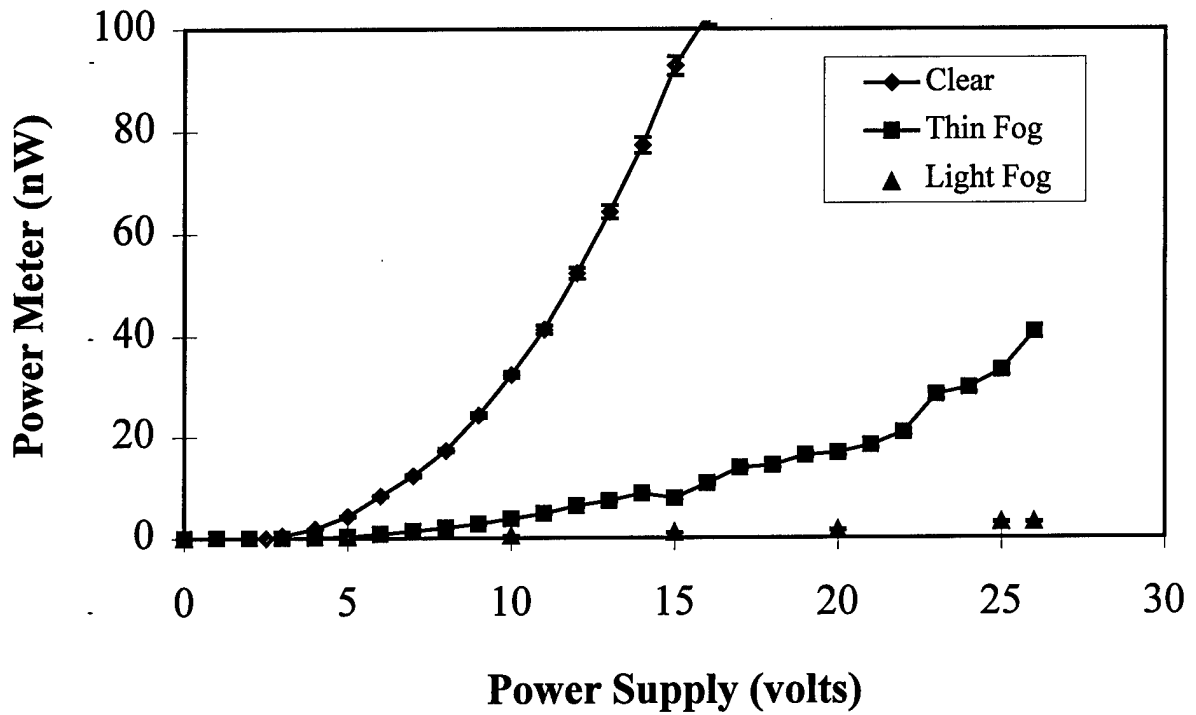


Target Site - Transmitted Power at 1067m

Clear - $\nu=0.2 \text{ km}^{-1}$

Thin Fog - $\nu=2.3 \text{ km}^{-1}$

Light Fog - $\nu=4.8 \text{ km}^{-1}$



TESTING OF LED LIGHTING AT THE WALL STREET HELIPORT

John J. McGowan, Heliport Manager

Jay McGowan – Personal History

I started flying in 1961 in army ROTC at the University of Vermont. Commissioned in Medical Service Corps and onto active duty in 1962. Graduated from flight training April 1964 and helicopter qualification September 1964. Flew Air Ambulance, dust off, in Vietnam October 1964-October 1965. Then spent 2 ½ years in Japan flying virtually all Vietnam evacuees to and from U.S. hospitals in the Tokyo/Yokohama area. Next was a year of air ambulance flying in Korea. I resigned my commission and returned to the U.S. in 1969. Started flying with Port Authority of New York and New Jersey (PANYNJ) in 1970.

Downtown Manhattan Heliport – History and Present Configuration

The Wall Street Heliport, as we call it, was opened by the Port Authority in 1960 on a New York City owned pier. The heliport was one of four serving Manhattan and is located on the East River in lower Manhattan. The wooden pier eventually rotted away and the heliport was closed in 1984 when portions fell into the river. It was rebuilt as one of the FAA demonstration heliports and reopened in 1987. A barge was added to the pier to expand its capabilities and modern terminal was built. Wall Street is FAR 139 Certificate for scheduled air carrier use. The lighting system meets the requirements of AC 150/5390-2A. It currently serves courier, corporate, sightseeing, private and charter customers.

LED Awareness

Six months ago I stopped to see a friend in the Aviation Department of the PANYNJ. He was busy and I went up in the cubicle next to his talking to Ralph Gatto, our lighting expert. Ralph asked if I had seen the LED installation at JFK, wondering if there might be an application for them at heliports. When he lit the sample LED lighting, I was hooked. When he told me the cost savings they could offer, I became an advocate. When others showed the same enthusiasm, Ralph and I discussed how to declare a standard. Upon hearing of this conference and the FAA interest in a demonstration, Ralph and I wrote up a proposal for our director. It was accepted and LED light lines were installed. The installation was turned on Friday last in dreary weather.

Why Installed at Wall Street

It has always been my contention that urban heliports were hard to find and something needed to be done. At Wall Street, the rotating beacon that was devised for this purpose didn't do the job and angered the neighbors. The PANYNJ requested and the FAA granted an exemption to remove it. For one-time locations, we always asked the police to turn on their flashers. Ralph explained various things that could be done with LED's and put me in touch with HIL-Tech as they installed the taxiway hold line at JFK Airport. I heard of more capabilities from HIL-Tech. Heliports like Wall Street have problems with IFR lighting because there is no real estate, only water. Installation of HILS and HALS is not possible. We had installed two PLASI's but they were never used and they blinded the pilots after landing. We removed them based on user requests. We needed full presentation for VFR and IFR from just a helipad. Our first intent was to find out how the LED's would be received by pilots and how visible they would be.

Configuration and Presentation

As seen in the video, we put double lines on three sides of the pier without disturbing the current lighting. We also installed a temporary red X to get pilot response. Ten minutes after turning on the X, a pilot called to ask why we were closed. We are presenting steady and flashing combinations for pilot responses in our demonstration.

Hoping to Accomplish

Our goals are to determine if LED lines are bright enough for aviation use, to find out what pilot responses are, what is their conspicuity during inclement weather, and prove them a worthy candidate for FAA certification for heliport, vertiport and airport use.

How Did It Turn Out

When we turned the lights on last Friday, the weather was terrible: rain and fog. The lights showed up better than my widest dreams. The flashing sequence sets the helipad apart from all other neighboring lights. I was at first fearful they would be distracting on landing. So was one of the passing helicopters and he requested an approach to a hover to "determine if they were disconcerting." He reported no visual problems and liked the whole set up. The X in the center of pad was also blinking for this test. Five helicopters made reports; four liked it and one didn't. A further observation elicited, "Wow, the DMH disco. Looks great." The fog then closed in and helicopter flying in New York City ceased. One pilot saw a single steady line Thursday in rather heavy fog and rain. He saw the LED's from about two miles and 500 altitude. If this is an indication, I think the test will be a huge success.

Pilot Survey

I spent the past weekend reading FAA/ND-98/1, 98/2 and 98/4 on Heliport Lighting. I came away with a distinct feeling that IFR and VFR presentations were being confused and overlapped in some instances. Frequent mention was made of a Glide Slope

Indicator for both VFR and IFR. Our experience at Wall Street says why for VFR? Pilots don't use it and in fact the Eastern Region Helicopter Council (ERHC) asked us to remove them. My experience says that one wouldn't be used on a precision 100' and ¼ mile visibility approach. There wouldn't be time for it or the pilot fly the GSI and not the helicopter. A non-precision 400' and ¾ mile visibility approach would be the same. A great deal of research has obviously gone into getting the pilot from cloud breakout to sitting on the helipad. There is no real estate available in urban settings for extensive lighting. In fact there are movements afoot to eliminate what little real estate we now have. They are also very active to ensure no vertiports with their Design Guide required real estate demands get installed. We will never see one in New York City. I would like to suggest that all lighting be designed for on heliport presentation, that extensive use of cockpit Heads Up Displays be made and that all heliport 100' and ¼ mile heliport approaches be made only using autopilot, auto deceleration, and auto hover.

Lighting System Ideas

While in discussions with Ralph Gatto, the attached suggestion suddenly came up utilizing LED lines. After reading the reports I would add a line of red LED line at the fore edge of the helipad with a 5 degree presentation. It is our intention to get people thinking "out of the box" rather than saying this is the way it should be. The three LED line presentations – what the pilot would see – could be taught to pilots. If they saw a certain presentation on breaking out they would automatically go around or continue to land. Don't tell them, but pilots can be trained to respond like Pavlov's dog. They are very goal oriented and trainable. The "all lines lead to the middle idea" came up at dinner and it passed along. I was rather impressed in reading about lite pipes and MOLS, Mirror Optical Landing System. Perhaps all three could be combined or LED lines arranged to show what a MOLS does. As a pilot in New York for many years and now a Heliport Manager I very much feel that lighting aids and guidance should be contained on the heliport.

Need for New Standards

Technology is advancing by leaps and bounds and anti-heliport forces are gaining strength and militancy. I call on the FAA to open up and approve the new light sources as acceptable standards for heliport, vertiport and airport use. If that is done, industry will use these sources and design light sources and fixtures that will be acceptable, will be an improvement in presentations to pilots and offer huge savings to the landing facility operators. LED's have a MTBF, I'm told, of 32 years. We have estimated that an LED runway centerline fixture would offer a savings of \$45 in electric and \$50-\$65 in maintenance per light. There are approximately 290 lights per runway at JFK. A saving of \$27,550 to \$31,900 per runway times 4 runways is not insignificant to the Port Authority.

Engineering Comments

The technology of LED's is moving rapidly. The LED line tested at Wall Street is much brighter than what was installed at JFK. We have just been shown a new LED that is

very bright and will match many other lights in lumen output. Put a lens with it and who knows what the boundaries are?

Demonstration

The Wall Street Heliport is open for visitation and evaluation. With prior notification, personnel would be available at the heliport lighting console to demonstrate the system's capability. Needless to say, the Port Authority is very excited about the performance potential, MTBF, ease of installation of the LED, system and the long term cost savings to their dwindling budget.

Caution

Similarly styled, but vastly inferior brightness LED lights were installed at JFK as taxiway lights a few years back. Their performance was marginal due to inferior technology in the LED's themselves and the fact that the installation contractor mounted some of the strips below grade making them impossible to see at any other angle than directly above. Pilots complained about not being able to see the taxiway lights but the problem was with the below grade mounting, hence giving the LED technology a bad reputation. This poor performance left a bad taste in the mouth of many JFK employees involved in the test and hence they are skeptical about this new technology being employed at the airport again.

[Editor's note: Results of the PANYNJ lighting demonstration are shown in Appendix F.]

CHIEF PILOTS
DIRECTORS OF OPERATIONS
HELICOPTER CREWS
PILOTS

The Port Authority, in conjunction with the FAA, has installed an LED test light system at the Wall Street Heliport, DMH. This system is being tested to see if it is worth pursuing getting LEDs qualified by the FAA to become a lighting standard for heliports/vertiports and possibly airports.

The ERHC has been asked to help in this process. Pilot comments and input are needed to determine if further testing should be done. This is our chance to influence the future of our industry. PLEASE complete survey forms as often as you can and whenever you see different configurations or have a new thought to pass on. Leave the completed forms at your Manhattan destination heliport. (I will visit the heliports to pick them up). You may also fax them to me, if you don't land in Manhattan, at 201-288-0308.

If you are just passing by N.Y. please detour over DMH to observe and give us your opinion.

Our thanks in advance to everyone for taking the time to do this.

Jay

PLEASE PRODUCE THE QUESTIONNAIRES LOCALLY

HELIPORT LIGHTING TEST

In conjunction with the FAA, the Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them, future testing will commence. If you say no, the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey _____

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:	Better	Same	Worse	
Heliport stands out:	Better	Same	Worse	
Visibility from a distance is:	Better	Same	Worse	
Visibility in rain is:	Better	Same	Worse	
Visibility in snow is:	Better	Same	Worse	
Visibility in fog is:	Better	Same	Worse	
Guidance to Touch Down Area is:	Better	Same	Worse	
Peripheral cues for actual landing are:	Better	Same	Worse	
Which presentation is most helpful:	Single line	or	Double line	
Blinking the lines makes them:	More	Same	Less	Conspicuous
Blinking the lines does, does not create a problem for actual landing from a hover.				
If you saw the red lights what do they tell you? _____				
Do you ever feel you are landing into a "black hole?"	Yes		No	
If yes, do these eliminate that?	Yes		No	
If not, do these create that?		Yes		No
Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'				

COMMENTS:

Please leave at any heliport or fax. Thank you. Jay

**Heliport Design & Real life Prospectives
IFR & VFR Lighting and Marking Issues**

Presented by

Raymond A. Syms, President
Raymond A. Syms & Associates
Long Branch, New Jersey 07740

Background & Experience

37 years in professional aviation as a mechanic, pilot, chief pilot, researcher and 15 years as a professional aeronautical consultant. Over 10,000 hours as helicopter and airplane pilot. Have developed over 100 heliports, inventoried and inspected over 1,000 for FAA, state and regional study efforts.

Presentation

I am here as a professional consultant. While I have been a member of the HAI heliport committees and the FAA/Industry Heliport/Vertiport Design Guide Working Group for over 14 years, the opinions I express here are not the official positions of either of those groups. The information I present today is based on my own professional experience and understanding of real-life heliport and IFR issues.

It is good to see the FAA asking for input from the helicopter industry. The acknowledgement that the users are the final authority in the appropriateness of various systems and research is very refreshing.

Speaking Points

- The questions poised to the rotorcraft industry reference to Heliport/Vertiport lighting issues and priorities can not be answered with only the information currently at hand.
- The need for the segment of the helicopter industry that uses GPS IFR approaches to be fully briefed on the state of the art referencing the lighting and marking work already accomplished by the military forces and foreign governments. This may best be accomplished by a detailed report that includes diagrams and analysis of the results of these studies. This report should be tailored to the real-life conditions that exist in the current and contemplated Heliport/Vertiport system in the U.S. and it's area of authority.
- The need for the entire transition from IFR to VFR in rotorcraft to be understood and differentiated from the needs of fixed-wing aircraft. Given the demand centers of rotorcraft being in urban and metropolitan areas it is not likely that many current or future Heliports/Vertiports will have the space required for precision approaches. The speeds and inherent maneuverability of rotorcraft indicate that the larger spaces and lighting patterns needed for fixed-wing are simply not needed or economical for rotorcraft operations.
- While lighting is indeed a very important portion of the Heliport/Vertiport IFR equipment requirements, the total package of lighting and marking as it relates to pilot cues during approaches and landing has to be examined and put into prospective.

- It is essential that the rotorcraft industry be involved in the process that is meant to understand and assist the rotorcraft physical, operational and regulatory structure. The past practice of the FAA where the industry was not involved with the design, directions and real-life applicability of numerous research studies resulted in study work that has had very little value to advancing the state of the art.
- The four basic needs that lighting and marking serve at Heliports/Vertiports are the recognition of the facility from a reasonable distance, identification of the landing area and approach, orientation and closure clues during the approach and ground maneuvering and parking.
- Lighting systems are equally important for VFR night and poor weather as well as the IFR-VFR transition
- The lighting and marking systems need to be practical and affordable. The availability of thousands of feet of real estate for lighting systems is just not available at the typical heliport.
- The use of already existing light sources close to the facilities can assist in identification. These sources are shopping centers, freeways, lighted interchanges, VFW signs, and other easily identified lighting sources.
- Research needs to be done to design and qualify the many new lighting technologies coming on the market for heliports and vertiports. The advantages and drawbacks for each system need to be performed.
- The “Buy your minimums” approach to lighting tailored to each location is one way of having the basic system with additional lowering of minima for added enhancements.
- Precision IFR into a downtown facility is not practical for essentially all current heliports due to obstacles or closing of VFR airspace issues.

This conference is the first step of hopefully many being taken by the FAA seeking advice from the helicopter industry. The incorporation of real-life needs and knowledge of the current and future Heliports/Vertiports and teaming with the industry is essential for the advancement of the helicopter and tiltrotor transportation system.

Thank you for your attention.

APPENDIX D. AVIATION AUTHORITIES PAPERS

Defining the Lighting Requirements
Tony Smith, UK Ministry of Defense

New Visual Aids for Ship Operations of Helicopters
Lt Cdr Peter Symonds RN Directorate Naval Aviation Support
(presented by Tony Smith)

Offshore Helideck Lighting
Hassina Maycroft, UK Ministry of Defense (presented by Tony Smith)

The Impact of COMM/NAV/Surveillance Technology
Dan Salvano, FAA, Deputy Director – Office of Communication, Navigation, and
Surveillance Systems, AND-2

FAA Lighting Standards and Certification
Tod Lewis, FAA, Airports, Engineering and Specifications Divisions, AAS-200

U.S. Navy shipboard lighting systems for helicopter operations

US Navy Lighting Systems to Helicopter Landing Facilities
George Bray and Dave Eisen, NAWC, Lakehurst NJ

Portable Lighting for US Marine Corps Expeditionary Airfields
Rob Rinderer, NAWC, Lakehurst NJ

Retro-reflective Markers
Guy Heneault and Eduard Alf, Transport Canada

Lighting Research in the USA
Edwin McConkey, FAA contractor

DISCLAIMER: The papers in this Appendix represent the opinions of the authors and of the organizations that they represent. Unless the presenter is an FAA employee, these opinions are not necessarily consistent with FAA policy or plans.

DEFINING THE LIGHTING REQUIREMENT

Anthony J. Smith
Airport Operations Group
Flight Management and Control Department
Defence Evaluation Research Agency (DERA)
BEDFORD, UK

- 1 To be successful any form of aviation lighting should be developed to meet a clearly defined operational need.

The necessary guidelines for helicopter operations are to be found in the International Civil Aviation Organisation (ICAO) International Standards and Recommended Practices, Aerodromes, Volume 2 – Helicopter (Annex 14). Within this document which is in the form of an international agreement, the application, location and characteristics of those visual aids that have been found to be necessary for the safe and efficient operation of helicopter under visual flight rules are described. No such guidance exists for instrument flight rules operations. It should be noted that the aids specified by ICAO “shall apply to all helicopters intended to be used by helicopters in international civil aviation”. Interpretation of this international agreement does allow you to do much as you like in your own backyard. However, helicopters increasingly cross international boundaries and some heliports travel round the world in support of oil and gas exploration. Adherence to international standards should be seen as a help rather than a hindrance to the application of good practice in visual aids design.

- 2 In the ICAO documentation there are some key concepts that in effect lead to the definition of helicopter lighting needs. The five main definitions are:-
 - (a) Aiming point – The point at which the helicopter will arrive in the hover on completion of the approach.
 - (b) Final approach and take-off area (FATO) – A defined area over which the final phase of the approach manoeuvre to the hover or landing is completed and from which the take-off manoeuvre is commenced. When the FATO is to be used by performance Class 1 helicopters, the defined area includes the rejected take-off area available.
 - (c) Heliport – An aerodrome or a defined area on a structure intended to be used wholly or in part for the arrival, departure and surface movement of helicopters.
 - (d) Helideck – A heliport located on a floating or fixed offshore structure.
 - (e) Touchdown and lift-off area (TLOF). A load-bearing area on which a helicopter may touch down or lift off.

In practice it is possible for the FATO to contain both the aiming point and the TLOF. In other cases the TLOF is displaced from the FATO and is reached by (air) taxiing the helicopter from the aiming point.

Offshore, the FATO may be a 'virtual' area over the sea.

- 3 In the ICAO Annex 14 (Heliports), there are currently 26 specifications developed by a panel of experts some 10 years ago. For the purposes of this paper, 7 of the main lighting specifications are described. At the present time, the North Atlantic Treaty Organization (NATO) has no agreed standards for heliport lighting, but is moving towards adoption of the ICAO standards, a process that should be completed in a 2-3 year time frame.
- 4 The heliport beacon normally uses discharge source lighting technology to produce the required signal, which is in the form of the Morse letter H.

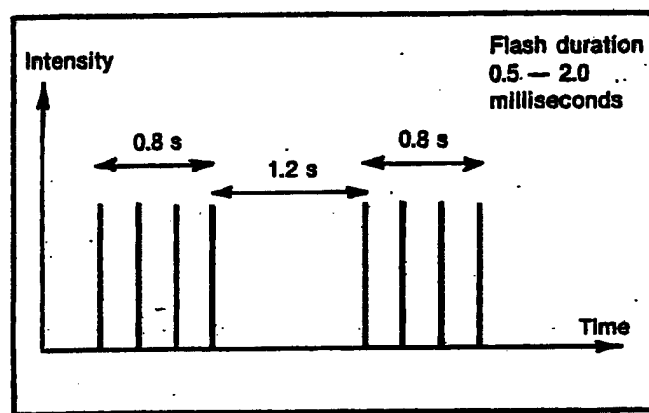


FIG 1 - HELIPORT BEACON FLASH CHARACTERISTICS

The effective intensity of the beacon is 2500 candelas (cd).

- 5 The approach lighting consists of a minimum of three centreline lights and a crossbar. Additional centreline lights may be added. Lights beyond the crossbar may be flashing in sequence.

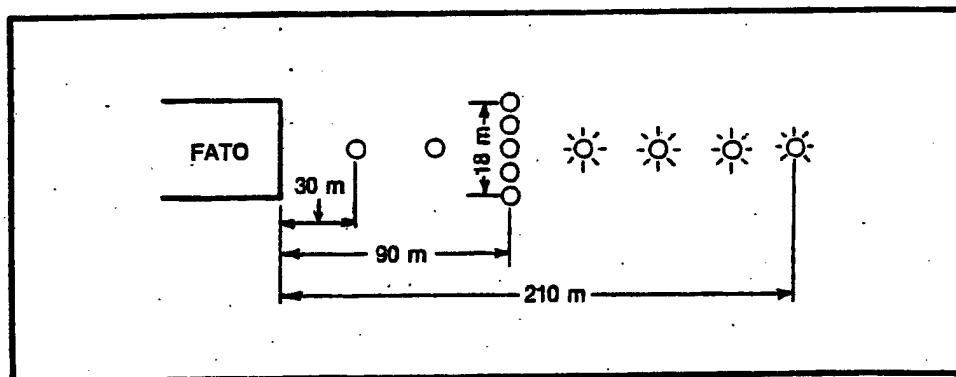


FIG 2 - APPROACH LIGHTING

The intensity of the lighting is at least 350 cd.

- 6 Alignment guidance should be provided when a particular approach direction must be flown or when there are few visual surface cues or where it is impracticable to install approach lighting. The signal format should at least indicate 'right of track', 'on track', 'left of track' and should be such as to avoid confusion with other aids. An intensity of 9000 candelas (cd) is required.

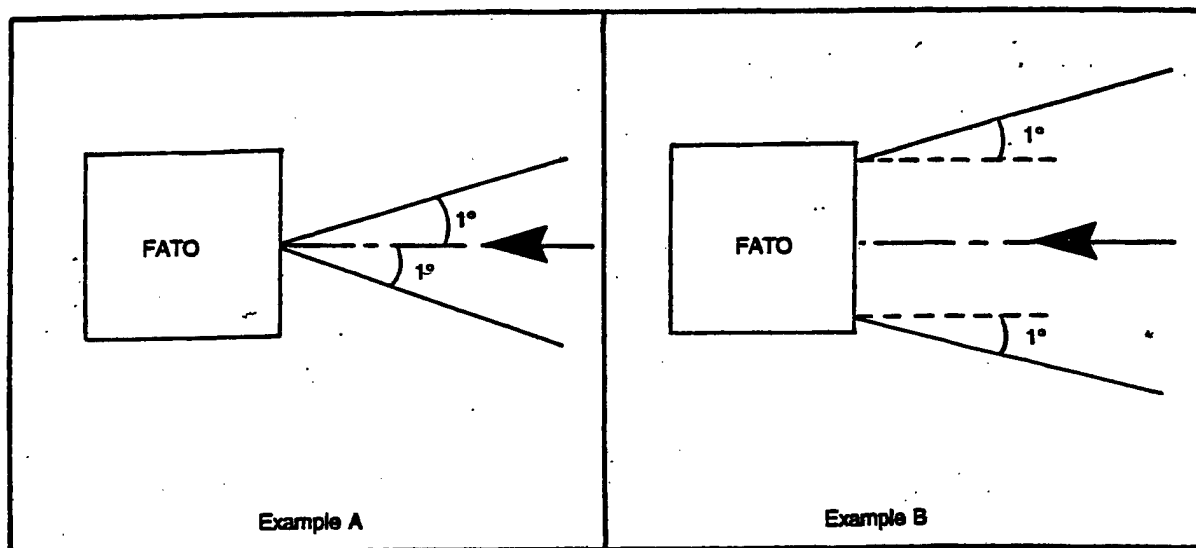


FIG 3 – DIVERGENCE OF THE 'ON TRACK' SECTOR OF AN ALIGNMENT GUIDANCE SYSTEM

- 7 Where there is a lack of surface cues or where there is a specific requirement to fly a stable approach then a visual glideslope indicator should be provided. The PAPI or A-PAPI system may be used, but there are circumstances where a single light projector is the only practical solution. In these circumstances, a Helicopter Approach Path Indicator (HAPI) can be used. An intensity of 9000 cd is specified. (see Figure 4)
- 8 Final approach and take-off area (FATO) lighting is used at surface level heliports intended to be used at night. It may not be required if the FATO and TLOF are coincident. (see Figure 6)

The lights are spaced uniformly along the edges of the FATO as follows: -

- (a) for an area in the form of a rectangle, at intervals of not more than 50 m with a minimum of four lights on each side, including a light at each corner.

- (b) For any other shape of area, at intervals of not more than 5m with a minimum of 10 lights. An intensity of 100 cd is specified.

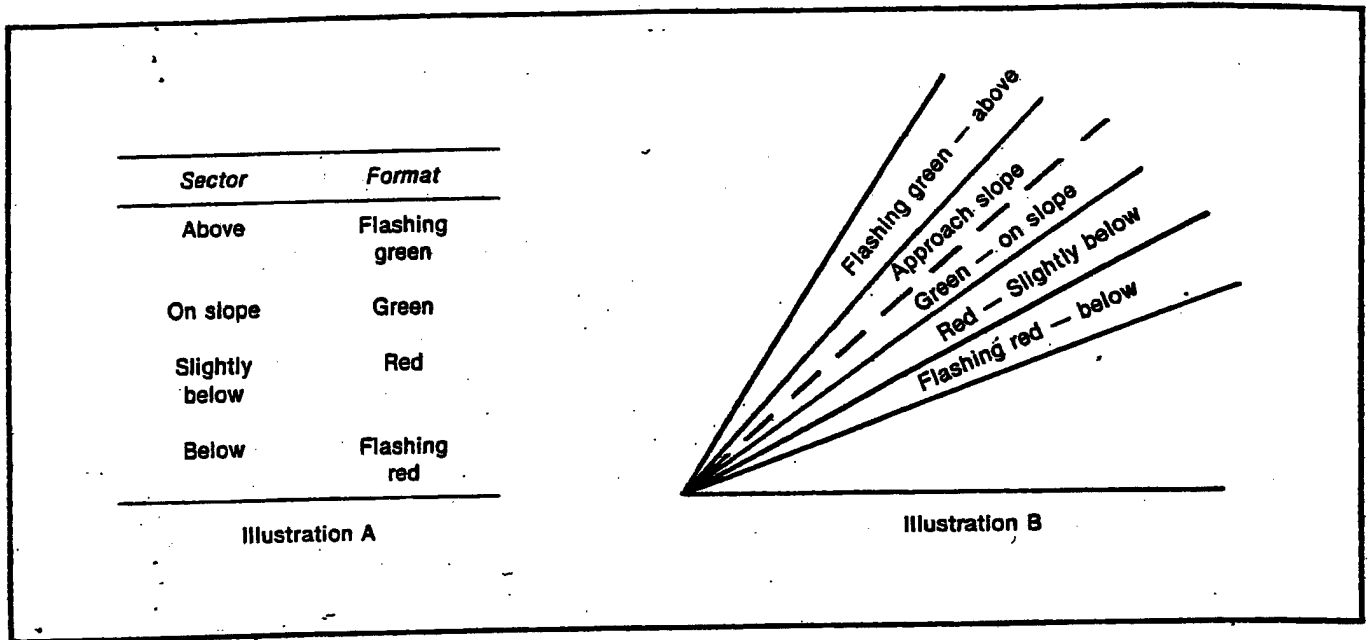


FIG 4 – HAPI SIGNAL FORMAT

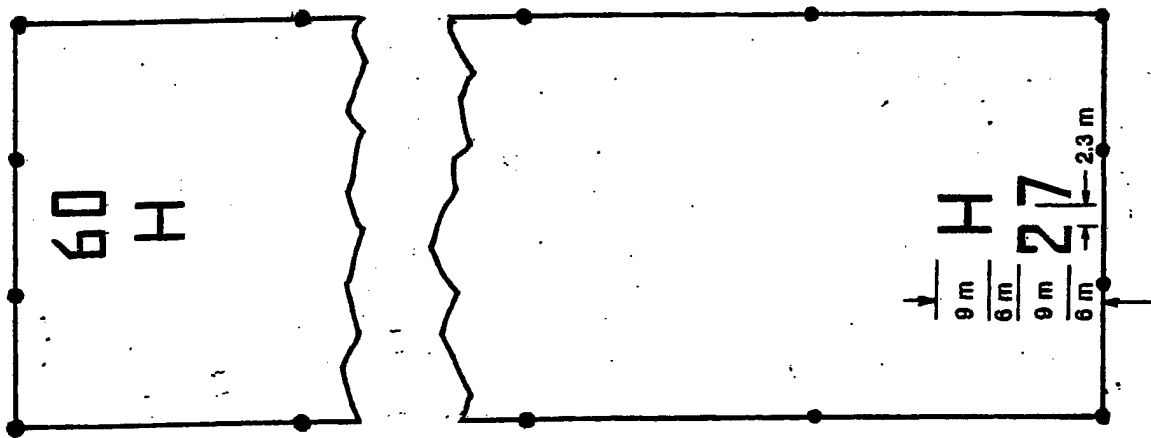


FIG 5 – FATO AREA LIGHTING

- 9 The aiming point lighting consists of a minimum of six lights defining a triangle (see Figure 6). In many locations, it is necessary to inset the lighting in the surface of the FATO. An intensity of 100 cd is specified.
- 10 The touchdown and lift-off (TLOF) lighting is provided for night operations and has a number of options depending on the configuration of the TLOF.

At surface level heliports the lighting should consist of one or more of the following: -

- (a) perimeter lights
- (b) floodlighting
- (c) luminescent panels, where FATO lighting is in use

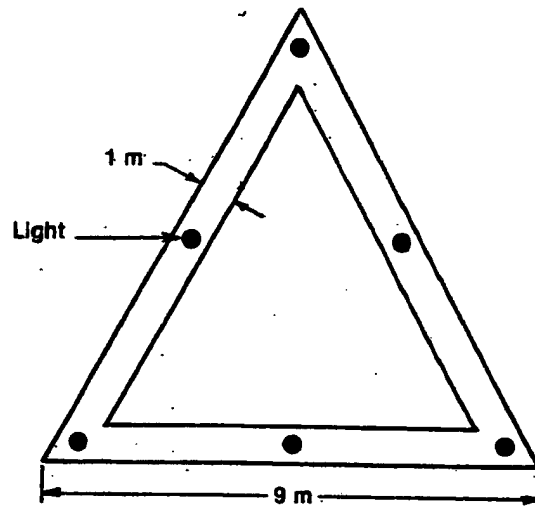


FIG 6 – AIMING POINT LIGHTING

At elevated heliports or helidecks the lighting consists of perimeter lights and/or floodlighting and luminescent panels. Good textural cues are particularly essential at elevated heliports or helidecks. There may be very few other sources of visual cueing available to the pilot in these circumstances. To maximise the positional cues the lights or panels should produce patterns consisting of straight lines even at those locations where the TLOF is a circle. An intensity of 25 cd is specified.

11 Bearing in mind that a set of agreed specifications already exist and are in use for visual flight rules and night operations, the current conference may wish to consider 3 particular areas for future development.

- (a) Recent developments such as helideck status lights that improve flight safety.
- (b) the application of new technologies, both to the existing specifications and to new requirements.
- (c) The development of visual aids for instrument flight rules (low visibility precision approaches)

12 In the 10 years since the ICAO specifications were developed there have been technological developments that should be applied to helipad lighting to improve efficiency and safety. For example the development in the UK of a deck status

light and the increasing availability of techniques such as fibre optic lighting and light emitting diode (LED) lighting which provide the potential for greater reliability and longer operational life if applied to lighting systems.

Another improvement, particularly in the case of LED is that the light emitted can be a more saturated signal colour than that produced by the tungsten lamps coupled with absorption filters. In addition there are no energy losses that are due to the filtering process.

Modern design and manufacture methods for optical components could lead to improvements in beam control. This could enhance the performance of lighting systems by using the available flux within beams that are properly directed to the area where they are intended to be used whilst reducing the amount of stray light.

13 The most challenging area for future developments concerns low visibility operations. With the advent of GPS offering as it does the potential for a precision approach on instruments followed by a visual phase including the hover and landing it is timely to review the issues that lie ahead.

14 To meet the requirements of low visibility operations it can be expected that some elements of the present system will continue to be required, but with higher intensities specified. In particular the following lights will need to be redesigned:

- FATO
- Approach
- Alignment
- TLOF

In all cases the redesign should include consideration of both intensity values and beamspread taking into account likely flight paths, siting constraints and the need to avoid glare. DERA has recently developed a mathematical modelling tool, Visual Sequence (VISEQ), which can be used to do the necessary design work.

15 The need for long patterns of lights to support low visibility approaches must be addressed. For conventional fixed wing operations a lighting pattern consisting of 900 m of approach lighting and 3000 m of runway lighting is normally required. The opinion is often expressed that none of this lighting is required for helicopter operations. Research has shown that such a statement can be true if the deceleration to the hover can be entirely flown on instruments. In this case only TLOF lighting/FATO lighting may be required.

16 However, if the deceleration phase of the approach is to be conducted in visual flight, then visual cues must be available.

17 There are two distinct low visibility requirements that can be described. The needs for visual aids are very different for the two cases.

- 18 Type 1 approaches may be described as instrument approaches in cloud to a cloud break before the decision range and start of the deceleration process. The visibility below the cloud is sufficient for the pilot to see the aiming point prior to commencing the deceleration.
- 19 Type 2 approaches occur when fog exists from ground level to a height well above that at which the decision to land has to be made. In this case, the pilot only sees a (small) segment of the ground just ahead of the helicopter. Both Type 1 and Type 2 operations are currently described by the ICAO Precision Approach Category 1 operation.
- 20 Research carried out for the UK CAA by DERA illustrated the problems associated with the Type 2 approach. In flight trials it was seen that, in order to retain the limited visual references, pilots were reluctant to make significant attitude changes (<5 degrees) during the deceleration. As a result stopping distances were typically 900 m (3000 ft). Since this operation requires visual references it is an inescapable conclusion that at least 900 m of lighting pattern must be available.
- 21 The lighting can be in the form of approach lighting or FATO lighting or some combination of both that provides the essential 900 m pattern.
- 22 The conclusion can however be drawn that in the future low visibility operations may require additional lighting.

For Type 1 operations, developments may be limited to some modest changes to the lighting intensities.

For Type 2 operations extensive high intensity lighting systems will be required.

If instrument decelerations are used then existing lighting will require little change.

- 23 Lighting specifications exist for night VFR operations. The performance of these aids in terms of efficiency and safety can be improved and the results of recent research can be used to augment the range of lighting specified.

Technological developments offer the potential of improvements to existing systems and can be used to realise new requirements.

Low visibility operations will require research to define the type of operations that are to be supported. When this matter has been resolved then new lighting can be designed using techniques such as VISEQ.

NEW VISUAL AIDS FOR SHIP OPERATIONS OF HELICOPTERS

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This paper, presented at the FAA Heliport/Vertiport Lighting Conference on 26 and 27 January 1999, uses material previously prepared by a member of the Visual Aids Team led by A J Smith. The work reported provides the basis for the implementation of the new aids by the Ministry of Defence (MoD) under the responsibility of Lt Cdr Symonds.

The Development and Application of Novel Visual Aids to Increase Operational Limits at the Helicopter/Ship Dynamic Interface

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ABSTRACT

Pilot visual cueing aids have a significant impact on the operational limits of helicopters involved in ship operations. Lighting aids fitted to frigates and destroyers of the Royal Navy have undergone little development over the years. With the introduction of larger and more capable aircraft to vessel of this size the problems of the recovery task in particular have shown the need for more effective pilot visual cueing devices. This paper reports on the development of a package of improved visual aids for use on small ships. These include; an electro-luminescent panel (ELP) based lighting system with additional aircraft positioning cues, the use of roll-stabilized horizon bars and the development of a sensor-driven active hover position indication (HPI) system to assist the pilot in positioning the aircraft accurately over the flight deck. The impact of the use of Night Vision Goggles (NVGs) was also investigated. The trials programme included extensive use of the Defence Research Agency's (DRA) Advanced Flight Simulator (AFS) to provide a high fidelity in developing ideas and also provided support to subsequent land and sea-based flight trials.

INTRODUCTION

The operation of helicopters from small ships is always a demanding task and becomes increasingly so in unfavourable environmental conditions. The advent of large helicopter operations from Royal Navy frigates, as a prelude to the introduction of EH101 Merlin, has heightened awareness of the difficulties, particularly of the recovery task. The Defence Research Agency (DRA) at Bedford is currently engaged in an integrated research programme to examine aspects of these operations. The principle long-term objectives of the work are to improve understanding of the problems of deck operations and to increase the operational effectiveness of current and future helicopters. To realize these potential improvements in effectiveness, work is being carried out in three UK Ministry of Defence funded applied research programmes dealing with; developing approach guidance techniques and aids, identifying handling qualities criteria for helicopter/ship operations and improving the simulation of helicopter/ship interface for both research and training purposes. The initial results of the handling qualities work were presented at the American Helicopter Society (AHS) Forum in 1994 (reference 1). This paper details the work carried out to improve the visual cueing environment for the pilot during the recovery task, including concepts, the conduct of trials, results and conclusions and a review of the future programme.

Another element of the programme deals with the development of new profiles and procedures for recovery and an automatic approach guidance system that can deliver the aircraft to the ship by driving the autopilot. This work is the subject of a further paper to be presented at AHS Forum 51 (reference 2).

There are many factors that limit the operational envelope of ship-based helicopters: aircraft performance and handling qualities, sea state, relative wind and visibility being among the most prominent. The largest possible operating envelopes are of primary concern to ensure the maximum effectiveness and availability of the aircraft/ship team, particularly as the helicopter often constitutes the ships' primary weapons system. Heavy use of towed-array sonar, which can seriously hamper the ships' ability to manoeuvre and to be effectively stabilised, means that to maintain current flexibility, aircraft must be more tolerant of adverse relative wind conditions and ship motion.

Current visual cueing provisions in small ships of the Royal Navy were generally developed in the early days of operations and small helicopters. Operations at night and/or in bad weather can be adversely affected by a paucity of visual cues available to the pilot to safely conduct a recovery. The few cues offered by the ship may be in a rapidly altering visual frame as the vessel moves in rough seas. Whatever cues are available, they must provide adequate rate, attitude and positional information in an easily assimilable form such that the pilot can conduct a precise and timely approach and landing.

Although use of night vision goggles (NVGs) is a routine part of helicopter operations, the Royal Navy has not conducted operations at the ship interface as part of normal procedures. Other naval air arms have used enhanced visual aids as a means of improving operating limits. Part of the research programme was to investigate the use of NVGs as an aid to ship recovery both with and without the improved visual aids package.

The research described in this paper forms part of a broader collaboration between the US, UK, Canada and Australia under the auspices of The Technical Collaboration Process [TTCP (HTP-6)]. This collaboration deals chiefly with piloted simulation of the helicopter/ship dynamic interface for pilot training, test and evaluation of vehicles and systems, defining operational limits and for aiding in research work. However, the collaboration also provides opportunities to discuss broader dynamic interface issues and to exchange pilots and engineers during trials.

AIMS AND OBJECTIVES

This research programme is not aimed at a particular aircraft type, although it is recognised that the EH101 Merlin represents the most demanding challenge for small ship operations. This work has used the aircraft as a case study. In poor conditions the pilot loses many of the traditional cues used to close with the ship and position for landing. This deficient cueing environment, plus the other problems of ship operations such as ship motion and ship air wake and turbulence effects, frequently means a higher

than desired workload and pilot anxiety level. This in turn affects the conditions in which the aircraft can safely operate. These conditions, called the ship/helicopter operating limits (SHOLs), are measured in terms of relative wind and deck motion. Aircraft control margins are also considered when establishing the SHOLs.

The specified limits for deck operations for Merlin are severe, with demanding relative wind capability at high sea states. This, coupled with the fact that it is a single-pilot aircraft which has a very long potential mission endurance, means that the pilot will need every assistance to conduct a safe recovery in severe conditions. The visibility and cloud base limits are also demanding and there is a desire to reduce them further. Current research is aimed at a limiting visibility of 100 metres.

For a landing to be successful the aircraft must touch down within structural load limits and such that the deck lock probe on the belly of the aircraft can engage in the deck lock grid. For the Type 23 frigate the grid is rectangular in shape and 2.3 metres long by 1.8 metres wide, representing a relatively small target.

The ultimate aim of the research is to improve the cueing environment such that the pilot workload is reduced for a particular set of conditions. This can bring improvements in aircraft availability (the 'operational day') and an increase in the operational flexibility of the ship.

To accomplish this increase in the availability and flexibility improved ship-mounted cueing aids, both passive and active, and the use of NVGs have been investigated. The research programme aims to develop concepts to the point where the customer (MoD) can effectively specify equipment for procurement.

CURRENT VISUAL CUEING PROBLEMS

Current visual cueing provisions for helicopters in Royal Navy small ships consist of:

- painted markings on the flight deck and hangar face
- a string of fixed white lights positioned along the top of the hangar roof to provide a night horizon reference
- discrete floodlighting of the flight deck for night illumination
- a glidepath indicator (GPI) to provide approach path cues

While these have provided adequate service, the introduction of larger aircraft to small ship operations dictates that, if these operations are to be fully effective, improvements are required. These aids are incompatible with the use of NVGs.

The sort of cueing problems that may be faced by the pilot of a Merlin recovering to the deck of a frigate could include:

- Hover height over the flight deck – at typical centre of gravity conditions, the size and attitude of the aircraft will mean that the pilots eye point will be over

12 feet above the deck when the main wheels make contact. In higher sea states, where reasonable wheel clearance from the deck will be necessary in the hover, the aircraft will be at a height where the pilot will be able to see little or none of the flight deck and hangar face. This will make rate, attitude and position cueing difficult, particularly in the fore/aft axis and significantly more so if there is no visible horizon.

- Recirculation – Merlin will be a large aircraft operating to a relatively low deck – the Type 23 frigate flight deck is 16 feet from the water. This, together with a high disc loading, is likely to make recirculating spray to be an increased problem.
- The Flight Deck Officer (FDO) – provides visual cues to the pilot by the use of marshalling signals and is positioned on the starboard forward end of the flight deck. He is a key element in deciding when it is safe to land. Not only is the pilot unlikely to be able to see the FDO much of the time but, due to the downwash, it may be difficult or impossible for the man to keep his footing on the deck in severe conditions. Indeed, there may be a case for reappraising the role of the FDO before Merlin is deployed on small ships.

Current visual cues are deficient in several respects:

- The Glide Path Indicator (GPI) is unstabilised. With significant ship motion this is a severe limitation. A new, stabilised, device is in development. This was not part of this work.
- Traditional painted markings are limited to the hangar face and flight deck – the pilot may not be able to see these markings much of the time.
- The standard horizon reference is fixed and provides little indication of ship motion. The use of individual white lights can also cause confusion.
- Current floodlighting provides patches of light on the flight deck. This gives poor rate and attitude cues and produces areas of light and dark that can be confusing for the pilot.
- Rain, spray and wet surfaces are illuminated by the floodlighting and this can cause dazzle, glint and optical distortion.
- Use of white lighting is not tactically advantageous.

At night, with current aids, the pilot sees a pattern of cues that differ markedly from those used in daylight and offer a considerably less dense cueing environment (see **figure 1**). Application of solutions, which provide a richer cueing environment offer the possibility of, improved cueing and lower pilot workload.

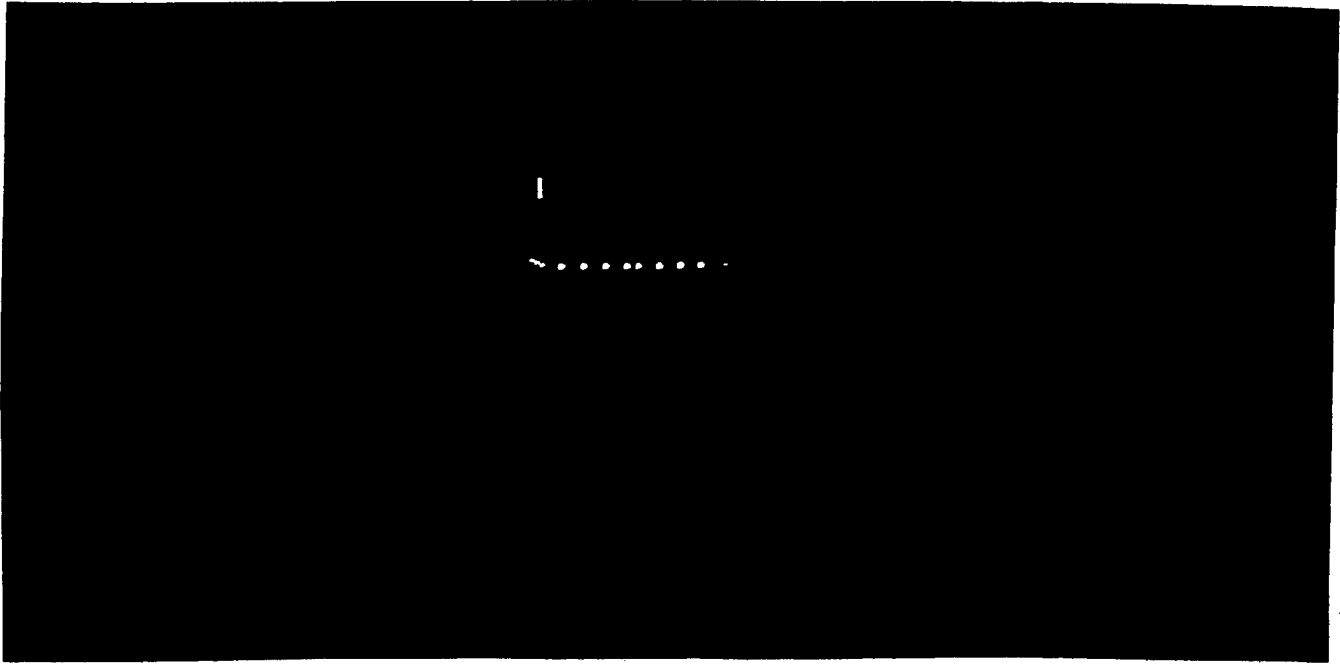


Figure 1 – Current Royal navy small ship flight deck lighting seen from port quarter.

IMPROVED VISUAL AIDS

Full details of the visual aids described below can be found in references 3, 4, and 5.

Electro-luminescent panels (ELPs)

Electro-luminescent panels have been used to develop a replacement or supplement to traditional floodlighting. The technology is identical to that used in NVG-compatible cockpit lighting. In this application the panels were approximately 1.5 metres long and 6 centimetres wide. Each panel is divided into four sub-sections (see figure 2). The panels are only a few millimetres thick and consequently are easy to position and mount. These panels are commercially available and modifications for trial work were limited to the waterproofing of electrical connections. A light green panel colour was chosen for this application, primarily because its compatibility for NVG operations.

The use of these panels for lighting on vessels is not wholly new, as they have been used to illuminate stabilised horizon bars. The French Navy has used a limited number of panels to provide additional cueing for pilots operating to ships. The difference with this application is the extent of the installation. The ELPs were positioned to provide the pilot with outlines of structures with which he is familiar. Many of the panels were placed along the usual painted markings around the flight deck. However, to attempt to overcome some of the field of view limitations a number of panels were also positioned on the hanger face and roof. Figure 3 shows the pattern used in the latest AFS trials. The pattern recommended as a result of flight trials and subsequently proposed to the Royal Navy for installation in the Type 23 frigate is shown in figure 4.

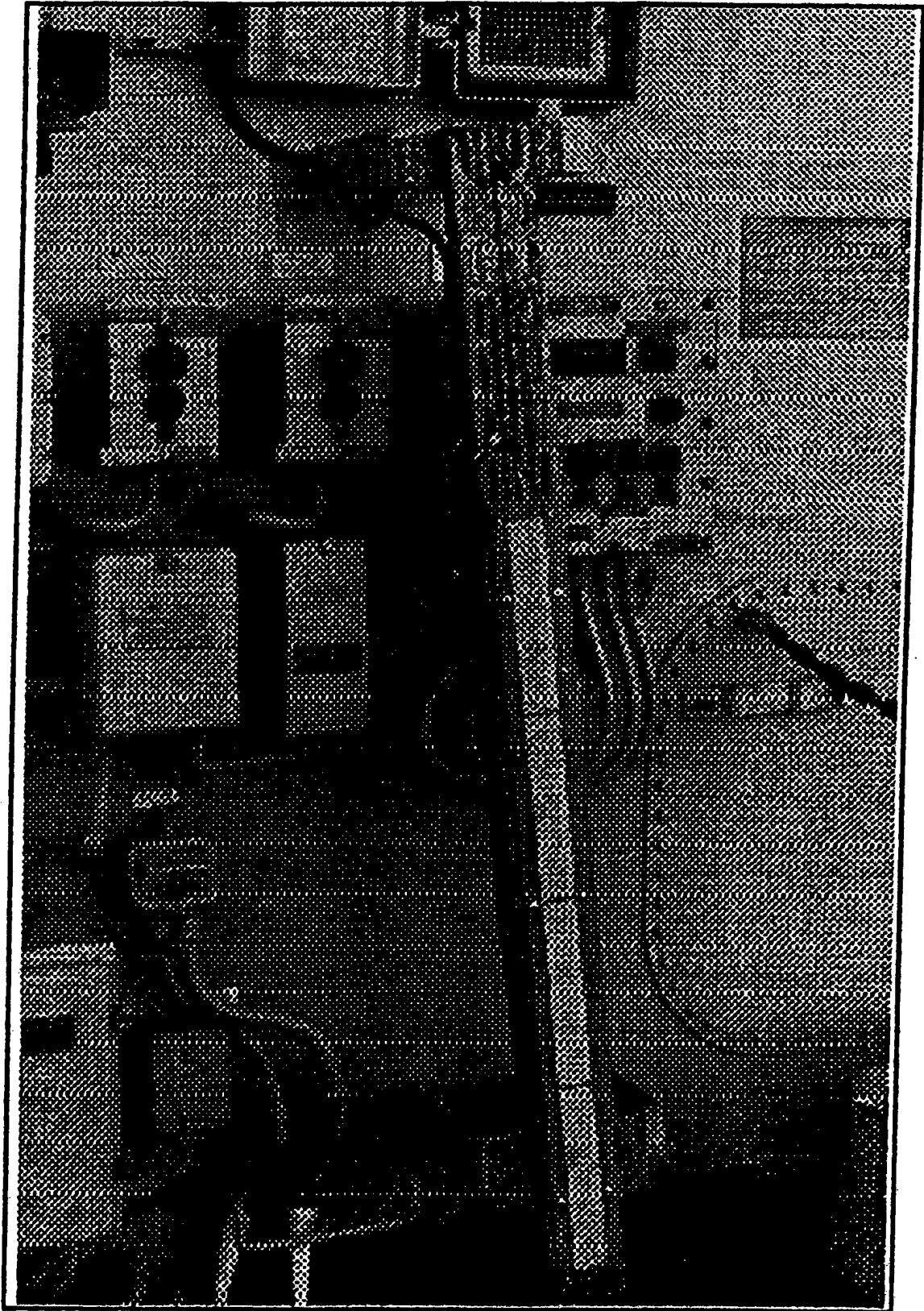


Figure 2 – ELP panel used in ship trails. Note four individual blocks making up panel

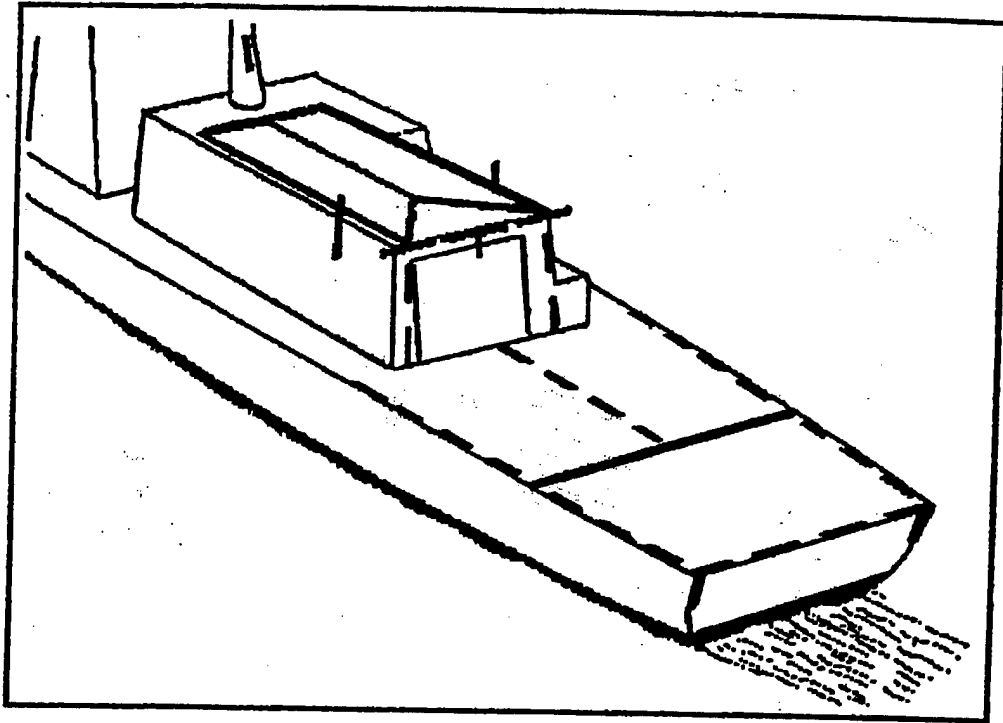


Figure 3 – ELP pattern used in later AFS trials

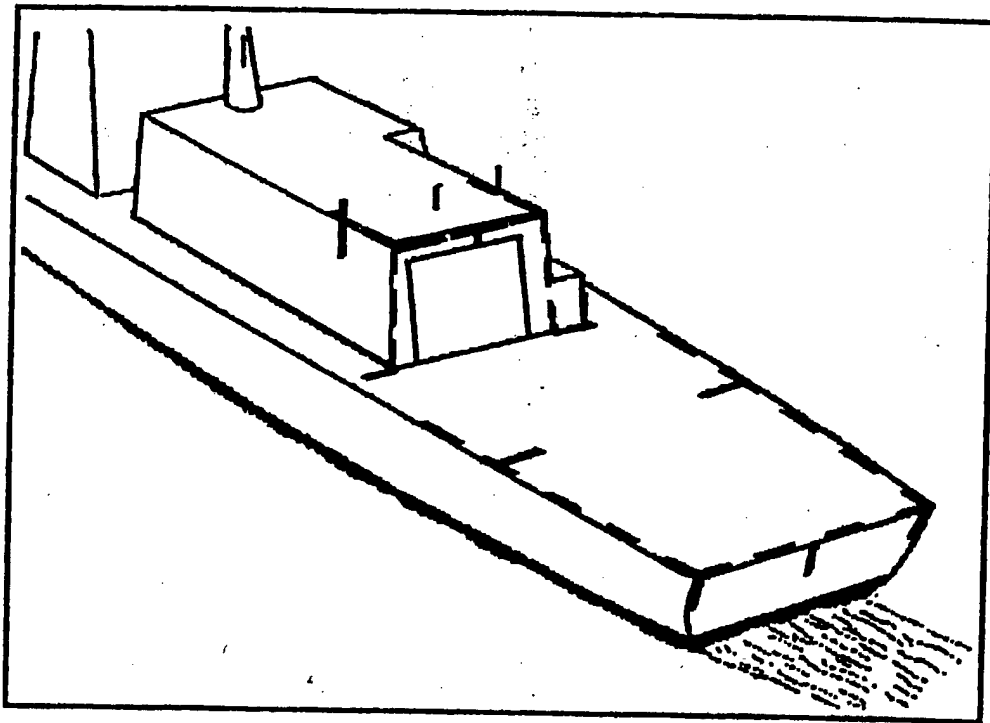


Figure 4 – Final ELP pattern recommended on completion of ship trials

The key elements of the pattern are:

- flight deck edges
- Stern – to provide strong closure rate cues during final approach
- Fore/aft positioning line – which is positioned such that the pilot ‘sits’ on the line when the aircraft is in the correct fore/aft position
- Hangar face – to provide positioning and attitude cues for final approach and over the flight deck
- Horizon bar – to provide a static horizon reference
- Hangar roof – to provide cueing over the flight deck where no other substantial cues are available

Additions to the basic pattern to assist in positioning and height keeping tasks alongside and over the flight deck:

- A centre-line cue was provided on the top of the hangar face (see figure 4)
- A similar centre-line cue was provided on the main mast to give a parallax reference to other centre-line cues (see figure 4)

The issues that had to be addressed during the trials included the number of panels, their location and size, as well as assessing the applicability of ELPs to the task.

Another issue centred on whether the pattern should be arranged such that the centre-line was along the centre-line of the flight deck or aligned fore/aft through the pilot. If through the centre-line of the flight deck, the pattern is generic and equally suited to the pilot or co-pilot. Selecting the second option could provide stronger lateral cueing for the pilot but makes the system less generic as the layout is biased to one aircraft type. Both options were evaluated during trials.

An extension of the horizon bar ‘eyebrows’ to provide a more comprehensive reference (see figure 3) both over the deck and when on the approach in conjunction with the vertical line-up poles (see below) was investigated. There was also an intention to investigate the combined use of the line-up poles on either side of the hangar and the extensions to assist in glidepath cueing on the final approach. However, it was not possible to fit these extensions for the major ship trial and consequently only a brief assessment of this system has been made at sea.

While there was a full array of panels on the hangar roof for the AFS trials, this was not possible for the ship trials because of structural and equipment fit constraints. A partial installation was made. In place of the full centre-line in the middle of the hangar roof

two panels were mounted in vertically, one on the after end of the hangar roof and the other on the main mast (see **figure 4**).

Line-up cues

It was identified that additional line-up cues for positioning alongside and over the flight deck would be highly desirable. These cues were intended to be simple, fixed additions to the basic ELP pattern, designed to aid in the correct alignment of the aircraft on the flight deck. They were lit with ELPs for nighttime operations. As with the basic ELP pattern only one version of these aids was evaluated during each trial.

Chevrons lit with ELPs were placed at the aft end of the hangar roof and at the forward end of the flight deck against the hangar door. These were arranged such that the pilot would look directly down the line when alongside the flight deck to assist in positioning. The chevron on the hangar roof would also assist in lateral and height cueing (see **figure 3**).

Vertical poles were added on either side of the hangar to provide the pilot with a triangulation of the aircraft's position over the flight deck. A diagram showing the principle behind the positioning poles is in **figure 5**. They can also be clearly seen in **figure 4**. As the aircraft attains the correct fore/aft and lateral position these poles would begin to occult with the edges of the hangar. Moreover, if both poles disappear behind the hangar then the pilot has a clear indication that he is getting too close to the hangar face. The poles were arranged such that the distance between the corner of the hangar and the pilot's eye was three times that between the poles and the corners of the hangar. This is a well-recognised gearing for this type of aid. Half the length of the pole protruded above hangar roof level so that in the hover the poles would always be visible whatever the position of the aircraft.

Horizon bar

Roll stabilised horizon bars have seen service with many Navies around the world and are highly valued. However, the Royal Navy has always used a fixed horizon reference. This trial work sought to determine the usefulness of roll-stabilised horizon bars. At night and/or in severe weather, particularly when the visible horizon is poor or obscured, the stabilised horizon bar can provide an indication to the pilot of ship roll attitude. This assists in determination of ship motion and in divorcing movement of the ship from movement of the aircraft. Both of these tasks can be very demanding in poor conditions.

The bar had the same green colouring as the ELP pattern. This in common with other aids, was aligned to the lateral centre of the flight deck, or to the pilots fore/aft line, as dictated by the rest of the pattern (see **figure 3**). Ship trials used a currently available device.

The ends of the horizon bar and adjoining eyebrows were pointed in later simulator trials to attempt to improve the degree of ship roll attitude cueing from the stabilised horizon bar (see figure 3).

Hover position indication system

The limited field of view afforded to the pilot of a large helicopter operating to a small ship, together with the lack of accurate positioning information over the flight deck, led to research into providing the pilot with sensor-derived position information. This would use an electro-optic tracking system to drive a display mounted either on the hangar in front of the pilot or on a pilot helmet-mounted display (HMD) and showing the plan position of the aircraft in relation to the designated landing area (DLA). The DLA is defined as the area in which the aircraft must land for the deck lock probe to engage the deck lock grid. A wholly new research programme was not required for tracking the aircraft as a system was being developed to provide location information close to the ship was under active investigation for approach guidance purposes (reference 2). It is not intended to cover the full technical details of the system here, but a breakdown of the basics is given below.

Electro-optic tracking system

The electro-optic tracking device was required to be able to track a single rotor helicopter along the approach path and over the flight deck, by day or night and in poor visibility. There were several options for providing tracking, but one of the key considerations for this programme was minimum cost with maximum flexibility. The Canadian RAST III (Recovery Assist, Secure and Traverse) system uses laser beacons mounted on the aircraft and cameras mounted on the flight deck to provide the position information (reference 6). In trials this provided good accuracy, but required a comprehensive aircraft fit and two cameras. An alternative solution has been sought to provide a system that does not require an aircraft fit, therefore saving on weight and complexity.

The system adopted for development uses an 8-10 micron band infrared camera to carry out monostatic ranging on the helicopter's main rotor. As the rotor is warmer than the surrounding air, due to friction heating of the blades, these show up well on infrared picture. No aircraft fit is therefore required. The camera is fixed-frame with the ship motion being processed out. The system knows the rotor diameter of the aircraft through operator selection. As the size of the rotor in the frame is dependent on aircraft range from the camera, and the system knows the position of the rotor in the frame, it can provide range and position information. The system in development should be able to track the aircraft out to 900 metres, subject to visibility, provide range information inside 200 metres and achieve a position accuracy over the flight deck or better than 0.1 metres in range and 0.2 metres in azimuth.

The system has only recently been delivered from the contractor. Land-based flight trials should commence in June 1995 with a full sea-based flight trial taking place in early 1996.

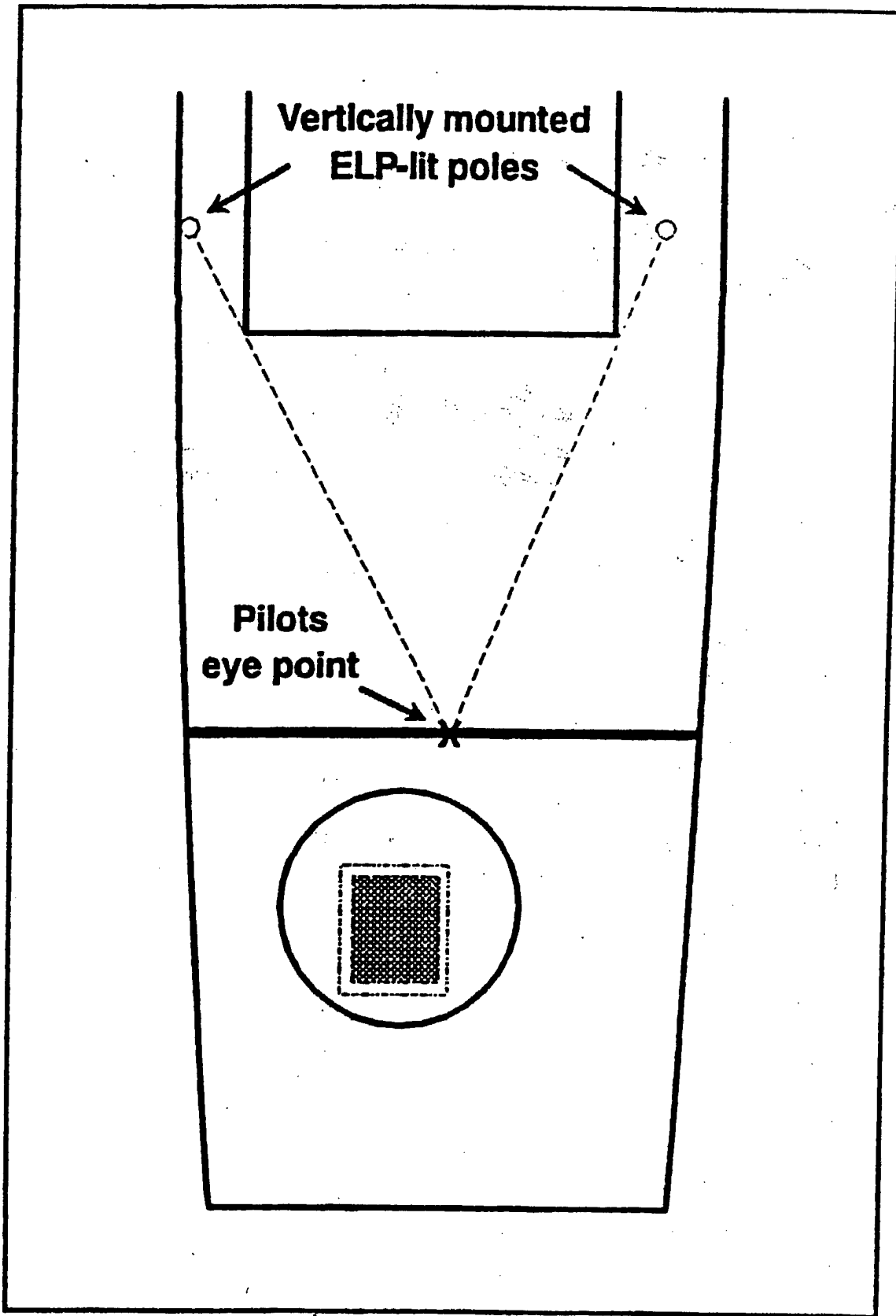


Figure 5 – Line-up pole geometry. When the aircraft is in the correct position, the poles just occult behind the hangar

Although the system has its advantages, these are problems to be addressed. The raw information provided is referenced to the deck lock probe position on the belly of the aircraft. However, without further data the system will not take account of the fuselage attitude or yaw. The deck lock probe could therefore be a considerable distance from where the system thinks it is. For example, in a strong crosswind the pilot will make a lateral control input to counter drift. This will cause the rotor disk to incline into the direction of the wind. It will also cause a change in fuselage attitude. The system, in basic form, would then provide a position for the aircraft based on the deck lock probe being perpendicular to the disk, thus causing a discrepancy in the position provided. There is a similar problem associated with yaw offsets from the ships heading. There are ways of overcoming these problems by the use of further image processing or by providing look-up tables for aircraft attitude in particular relative wind conditions. For yaw it would be possible to datalink the ships heading to the aircraft flight control system as a datum for heading hold. These issues are being addressed by current research. Flight trials will be required before they can be resolved.

The information provided by the system could be passed to the aircraft by datalink where it could be fed into the flight control system. The autopilot could then position the aircraft alongside and/or over the flight deck for landing. This could include an automatic landing capability (see reference 2). The same information could be used on an in-cockpit, probably helmet-mounted, display. Alternatively, the information could be used on the ship to drive a display system giving the pilot additional cueing.

Position Display Systems

Trials thus far have concentrated on a ship-mounted display system. There were many issues that required addressing in formulating the type of displays to be evaluated. In brief, these were as follows:

- a. The information that the display should provide for the pilot. Many options were available, including pure position, with additions including mixtures of rate information and velocity vector.
- b. The display format; there were many ways in which the information could be displayed and where it should be provided.
- c. Where the information should be presented.
- d. The area of the flight deck over which the aircraft position would be displayed.
- e. Display sensitivity.
- f. Whether the DLA position indicated should be corrected for ship pitch and roll such that as the ship moves in the axes the effective 'centre of DLA' indicated also moves.

- g. The visibility arc of displays.
- h. The physical size of displays.
- i. The colours to be used in display elements.
- j. Whether displays should be roll-stabilised.

Initial designs considered the questions above and the first display formats were evaluated after brief initial work using the AFS. A primary design aim was that pilots would not require specific training to understand the information being presented, and several pilots were initially consulted for comments and ideas. Early in the programme it was decided to adopt a plan position display format, which is already familiar to pilots. The result was the format shown in **figure 6**.

The central box of the display represents the DLA and the red cross the deck lock probe position. When the pilot has positioned the aircraft such that the cross is in the central box the correct landing position has been attained.

Cranfield Institute of Technology (now Cranfield University) human factors experts were contracted to look at the issue of display formats. Work included detailed discussions with Fleet and test pilots and consideration of all of the issues noted above. A preferred format was proposed (reference 7 and **figure 7**). All further formats have been developed with careful consideration of this work.

Two display formats were evaluated in an early AFS trial. The formats were as follows:

- a. A generic display, a description and schematic of which is at **figure 6**. A key feature of the display was to provide rate information through the use of 'pixels'. Throughout the trial this was referred to as the 'Bedford Display'. It should be noted that this format was derived in-house as a generic test article and was included in this trial as a comparison to the other display format.
- b. The second display format was that proposed by Cranfield Institute of Technology (CIT). The recommended display format was reproduced exactly on the AFS (**figure 7**). It was referred to as the CIT display through the trial.

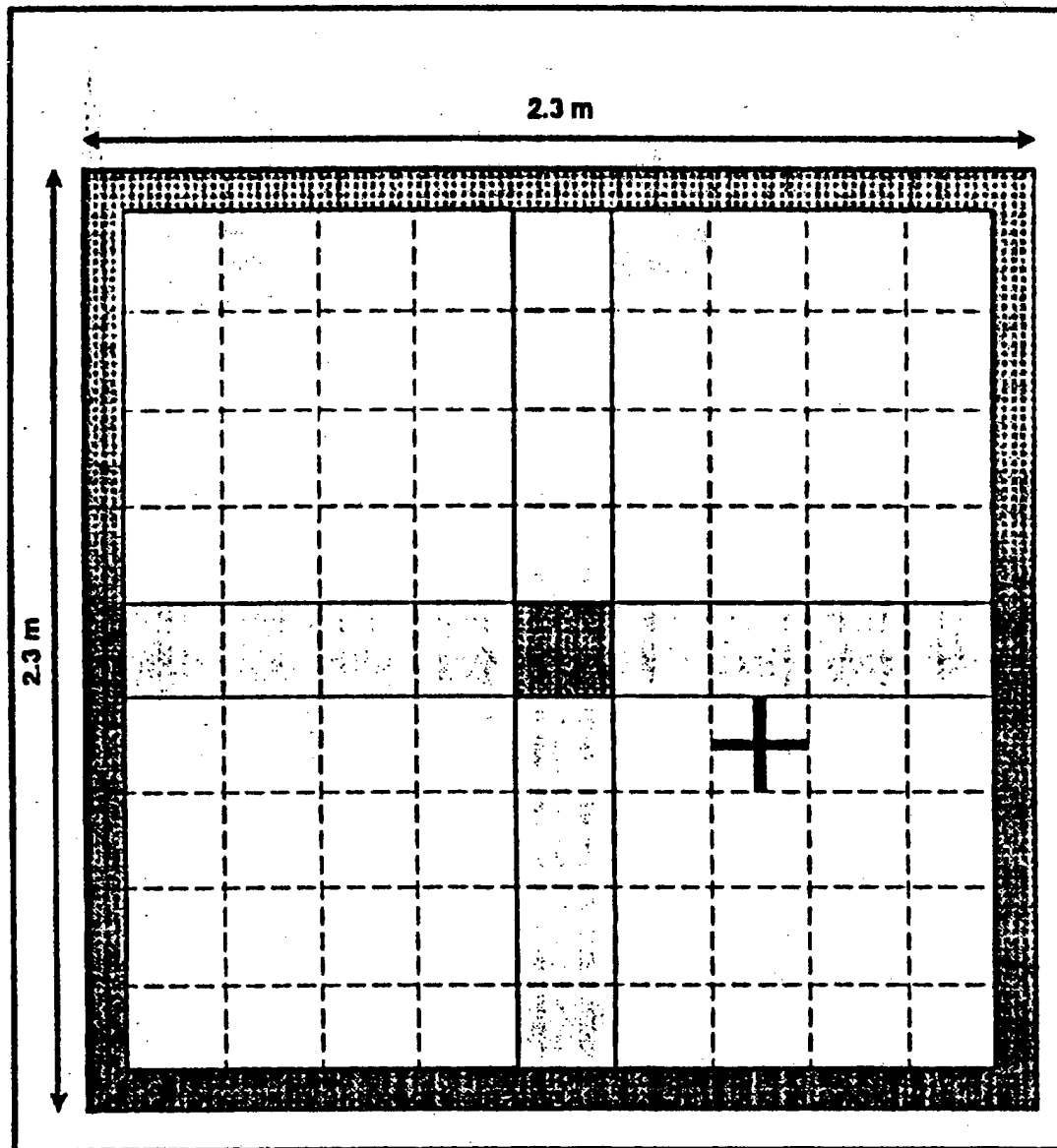


Figure 6 - Bedford HPI - each element of the display represents approximately a 0.7m square of deck area.

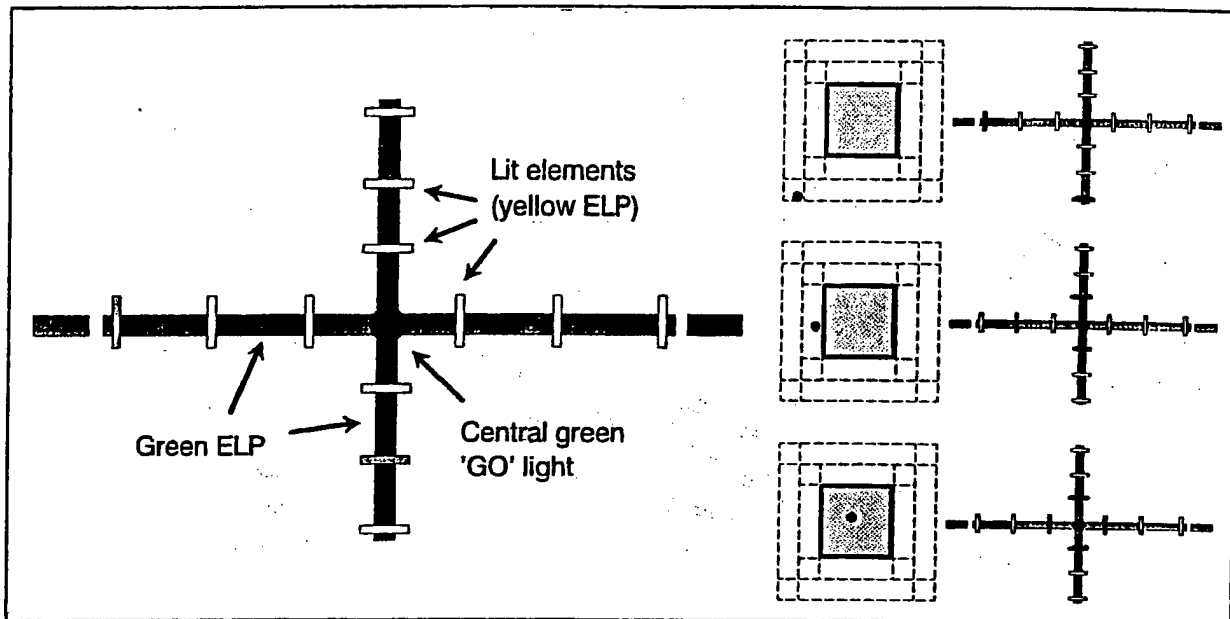


Figure 7 - Original Cranfield-derived display format (CIT display) showing some display conventions

Pilot comment and the results from this trial led to developed displays to attempt to overcome shortfalls. This will be discussed in detail in the results section. These developed displays were evaluated during further AFS trials. Two new formats were developed and a general description of these displays was as follows:

- a. The first new format, known as CIT1 (**figure 8**), simply added a further layer of position information in the DLA. Display logic and the areas of the deck covered are identical to the original display.
- b. The second format, named CIT2 (**figure 9**) utilised a combination of the original CIT display and the Bedford display. Display logic and the deck area covered are shown in the figure.

All displays were set up such that the displayed position related to the deck lock probe in the fore/aft axis. However, a limitation of the simulation meant that laterally the display was tied to the centre-line of the aircraft at the pilot's station. This meant that if the aircraft made a landing that was cocked-off the ships centre-line an inaccurate position would show. However, this was not considered to be a major disadvantage in evaluating the concept. The deck area over which the display indicated was the same for all the CIT display derivatives. This area was recommended by the CIT work and is shown in **figure 10**. The area covered by the Bedford display was considerably larger (shown in **figure 6**). In all cases the displayed position of the centre of the DLA was maintained

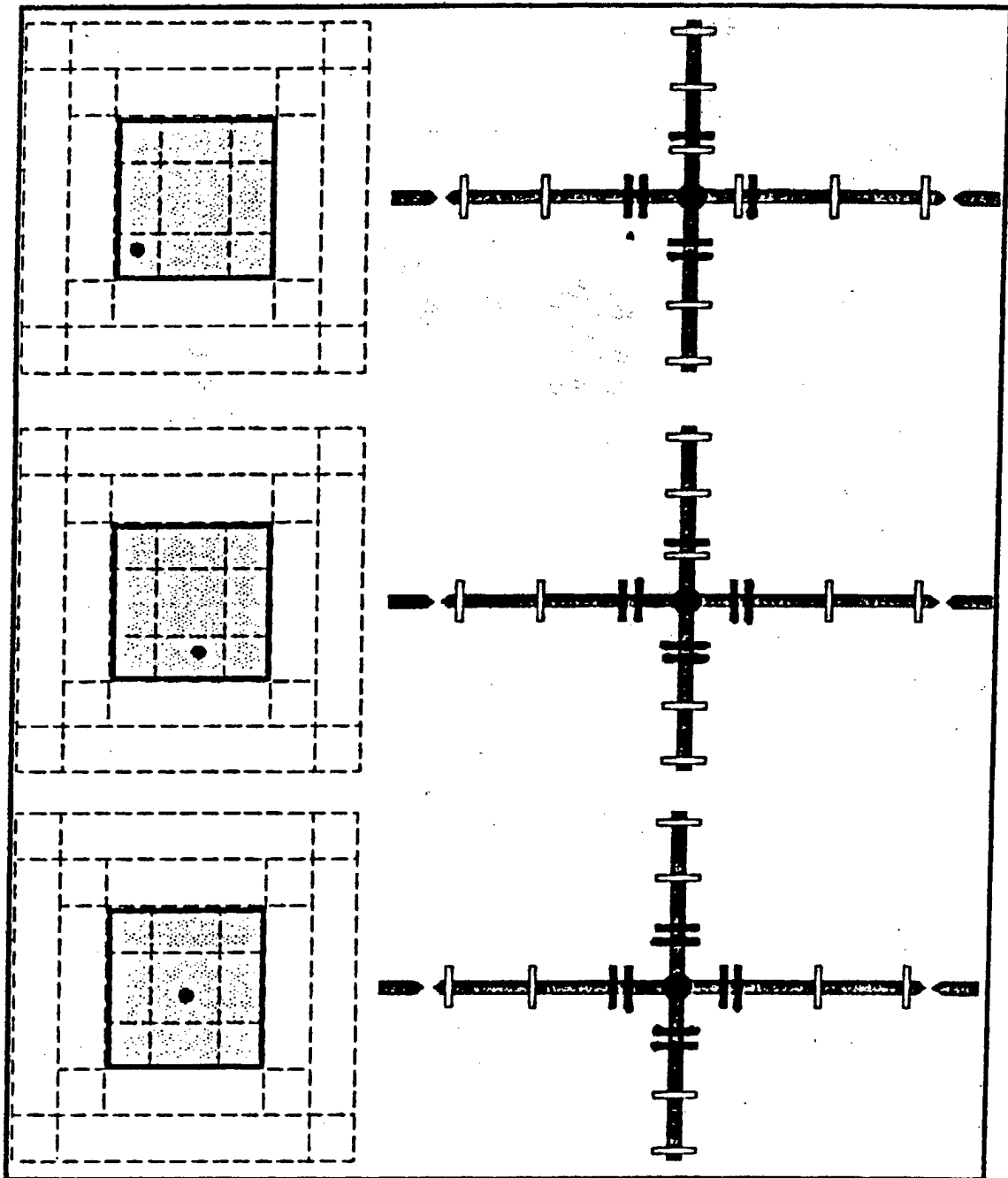


Figure 8 - CIT1 display with improved DLA cueing, showing some examples of display conventions. The additional elements in the centre of the display provide the pilot with additional rate and position information.

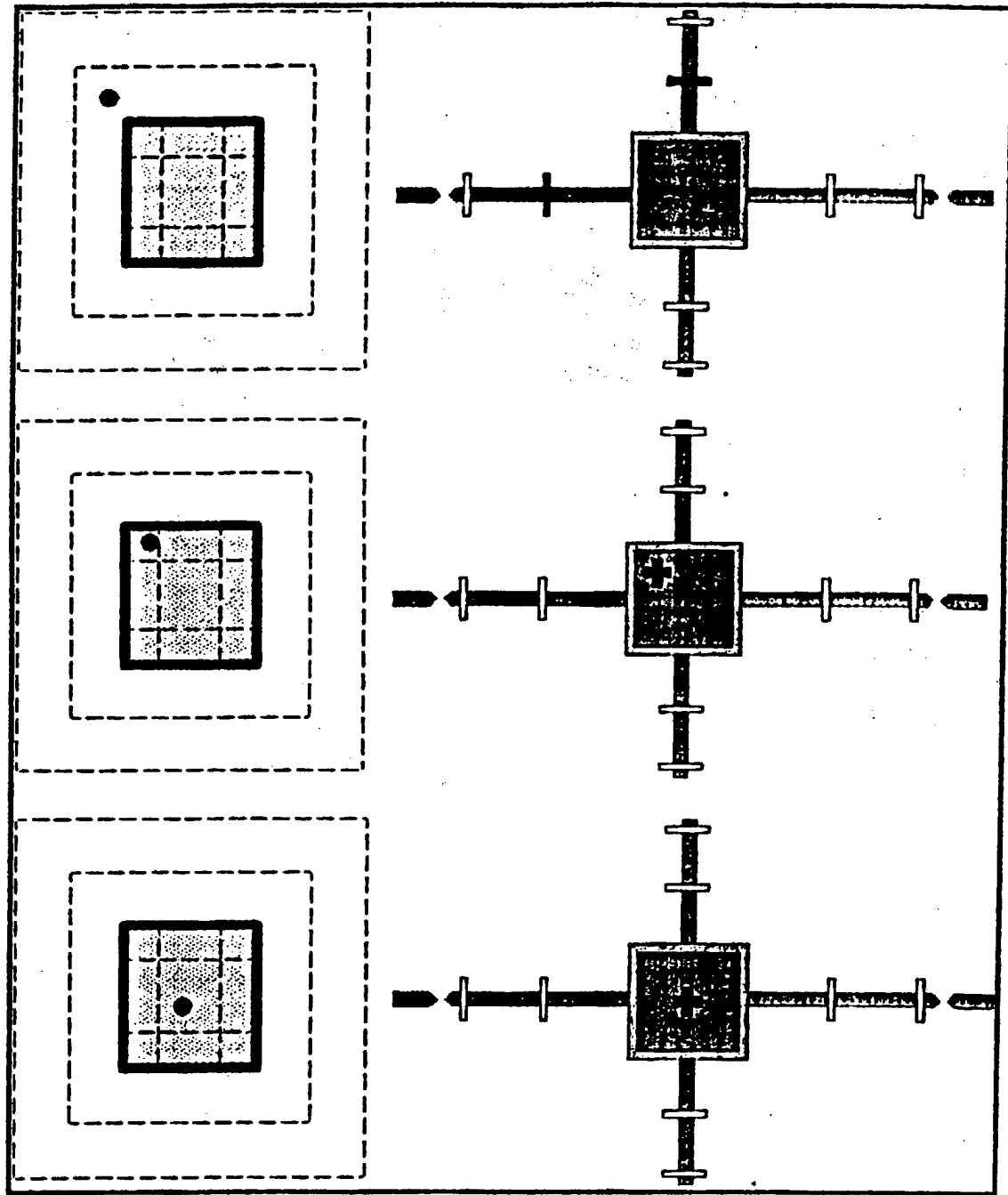


Figure 9 - CIT2 display showing some examples of display conventions. Operation of the DLA cueing element is similar to the 'Bedford' display (figure 6).

independent of ship motion. Consequently, as the ship pitched and rolled the indicated position of the centre of the DLA remained the same

Two of the CIT-derived displays contained a green indicator light at the centre of the display (see **figure 7**). This was used as a 'safe to land' indication, either in regard to ship motion or when in the DLA, or as a wave-off light. For the first set of trials the light was used as an additional indication that the aircraft was over the DLA, flashing green at the appropriate time.

The Bedford display was placed directly above the horizon bar and the CIT displays replaced the stabilised horizon bar. In initial trials both display formats were trialled in both fixed and roll-stabilised modes. Later trials only evaluated roll-stabilised displays, as these were preferred. No flight trials with the device have taken place to date. However, initial flight trials are scheduled for 1995 and the preferred display format from these trials will be utilised for these.

NVG operations

Evaluations of the benefits of NVG for small ship recoveries were carried out in hand with other flight trials. The goggles used in the trial were standard-issue Nite-Op Gen II. In all the trials the non-flying pilot used NVG. During NVG specific runs the subject pilot and the remainder of the crew were also on NVG. Runs were conducted with the ship blacked-out and with various visual aid combinations.

CONDUCT OF TRIAL

Methodology

The visual aids developed in this trial work have undergone a structured development process. Initial ideas were discussed and then evaluated using the AFS. The simulator provides an ideal vehicle for development work and, indeed, has been the primary development tool. The device can accommodate rapid alterations to items being investigated. Concepts can be quickly and cheaply assessed and their applicability for further development work determined. The AFS has provided invaluable support with many benefits in cost, time, repeatability, availability, and flight safety.

Land-based flight trials were then used to develop promising ideas further, particularly in the case of the ELPs, using a dummy flight deck. Finally, developed ideas were tested in sea-based flight trials. The AFS was used throughout to support flight trials.

Advanced Flight Simulator

The AFS constitutes the DRA's flight simulation facility at the Bedford site. It is a general-purpose research tool that retains a high degree of flexibility to enable tailoring for a wide range of fixed and rotary with applications. The simulator can be configured to meet the needs of a particular task by selecting hardware and software options.

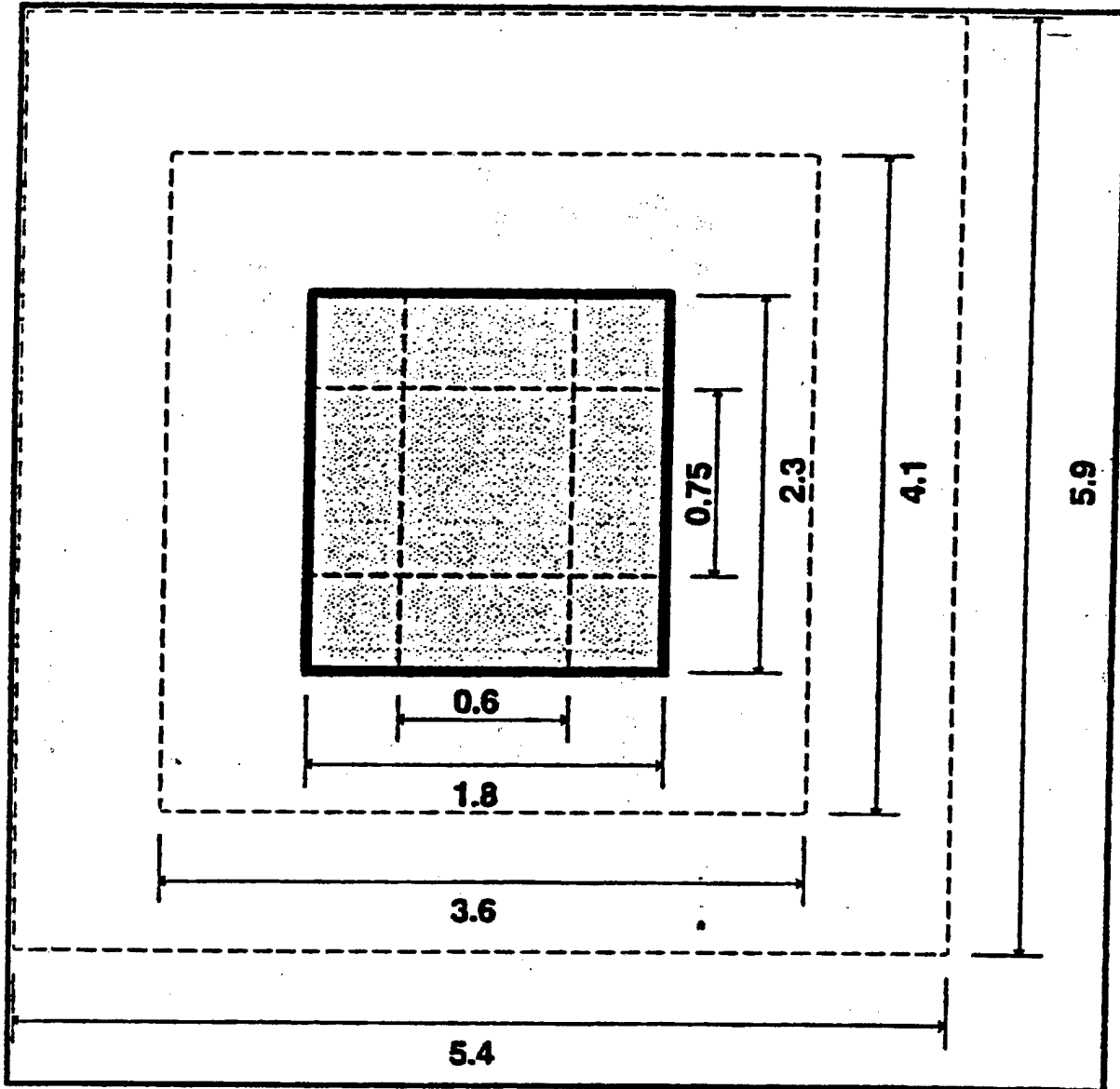


Figure 10 - Area of flight deck over which CIT displays provide information. Measurements given symmetrically about deck lock grid centre in metres. DLA is shaded area.

Briefly, the various elements of the facility are summarised below; a more detailed description can be found in reference 8.

Motion System

Platform motion cues are generated by the 5 degree-of-freedom Large Motion System (LMS). The system provides motion in the roll, pitch, yaw and heave axes and, depending on cockpit orientation when mounted on the motion platform, in either sway or surge axes. For the studies reported in this paper the sway axis was utilised. **Figure 11** shows the general arrangement of the motion system together with its performance characteristics. This is one of the highest performance systems in the world and provides excellent stimulation on the pilots motion sensory mechanisms (reference 9).

Visual System

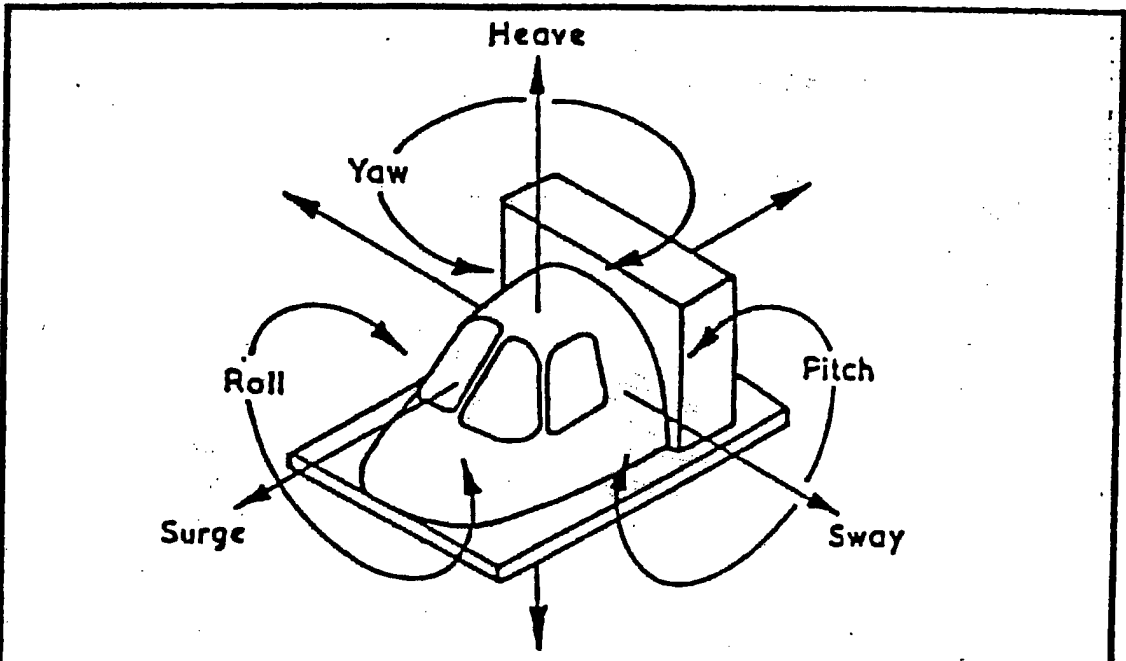
A photo-textured computer generated image system is employed to provide visual cueing through three monitors mounted in the cockpit. The monitors were mounted with a centre window and one side window mounted either side of the centre. This gave a horizontal field of view of ± 63 degrees and a vertical field of view of ± 18 degrees and ± 24 degrees for the centre and side windows respectively.

For this series of trials a photo-textured model of a Type 23 frigate was used. The visual aids under development were mounted on this visual model (see **figure 12**).

Cockpit and Controls

The cockpit used for the trials had a generic layout based on the pilot's station of a Lynx helicopter. This gave conventional controls and instrument arrangements. Stick travel and centering forces were modeled on the Lynx. Control feel was provided by an electrically activated digital system.

Vibration cues in the vertical axis were applied through an 'active' seat at a simulated 5R frequency and modulated by airspeed and normal acceleration effects.



PERFORMANCE ENVELOPE

Axis	Displacement	Velocity	Acceleration
Pitch	± 0.5 Rad	± 0.5 Rad/s	± 2 Rad/s ²
Roll	0.5 Rad	1.0 Rad/s	3 Rad/s ²
Yaw	0.5 Rad	0.5 Rad/s	1.5 Rad/s ²
Sway (Surge)	4m	2.5 m/s	5m/s ² (0.5g)
Heave	5m	3 m/s	10m/s ² (1.0g)

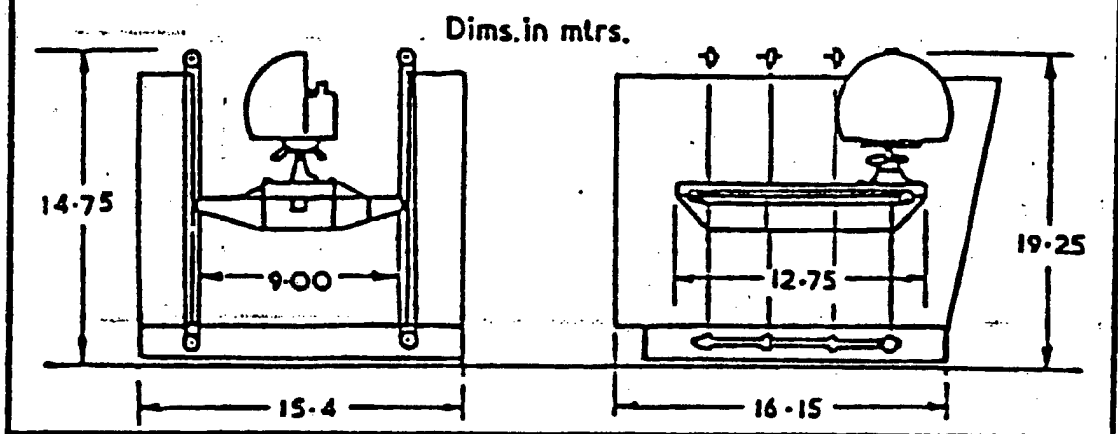


Figure 11 - AFS Large Motion System performance

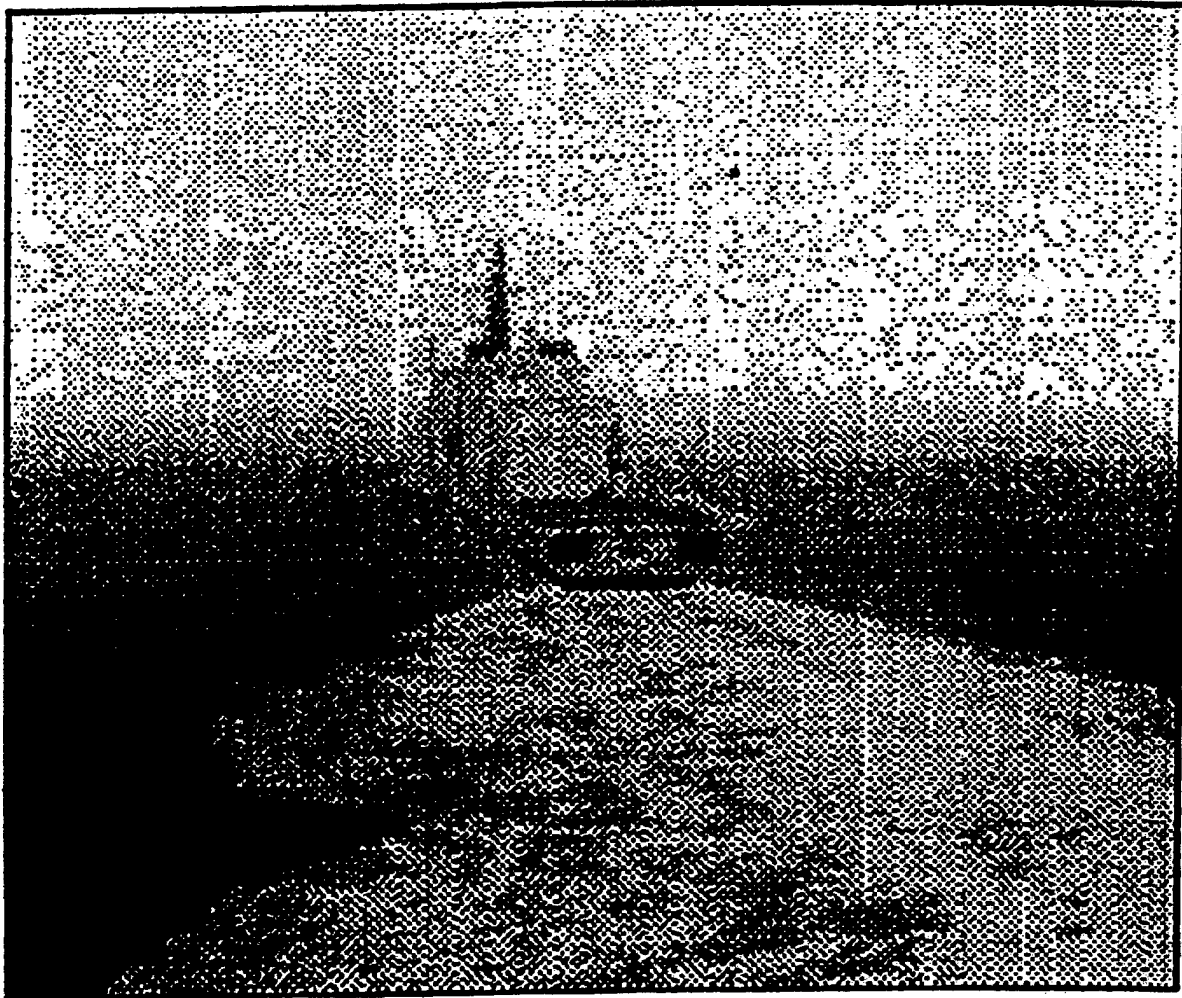


Figure 12 - Visual simulation of Type 23 frigate

Models

The aircraft model was provided by the DRA Conceptual Simulation Model (CSM), described in references 8 and 10. It uses low order equivalent system representation and was configured with data for the EH101 for these trials to provide an approximation of an aircraft of this class. A baseline configuration in terms of aircraft weight, engine characteristics and fuselage aerodynamics was modeled. A 'traditional' rate command control system was employed and estimations were made for control bandwidths. Details of the configurations used during the trials can be found at reference 4.

Ship motion was provided by time history data from a Type 23 frigate ship motion computer model, although limited in these trials to roll, pitch and heave axes. The trial work based used a case with a ship speed of 12 knots and an encounter heading with the waves of 135 degrees (measured from the stern). Sea states between 3 and 7 were simulated by scaling the data. This was considered valid by the compilers of the model, as the modal period is constant with sea state over this range.

Flight Trials

Flight trials were carried out using a dummy deck facility at DRA Bedford and ships at sea. The main ship trial was carried out as part of the integrated test programme using a Type 23 frigate. Opportunities were taken before this to put elements of the ELP lighting in various ships, including a Leander class frigate, the Aviation Training Ship and in a CVS class aircraft carrier during operations in support of the United Nations in the Adriatic.

The major ship trial took place in a Type 23 frigate off the west coast of Scotland. This location was selected because it afforded the possibility of sheltering from the worst of the weather to allow trial flying to continue (the last major trial was in January 1994, a time of typically severe weather in the region). Consequently, even with poor conditions it was usually possible to find an area where useful work could be undertaken.

The vessel was fitted out with a set of commercially available ELPs that were expected to produce similar results to production equipment. The GPI was not used during the trials.

All flight trials were carried out using a Westland Sea King Mk 4X aircraft. This was a standard, fixed-undercarriage, transport version of the aircraft. All NVG-compatible cockpit was fitted and additional avionics forming the major elements of the GPS automatic approach guidance system were also included. The aircraft also carried data recording equipment and standard and NVG video cameras.

Task Development

During all the various elements of the trial work it was a specific aim of the team to ensure that all tasks, whether in the simulator or in flight trials, were assessed using, as much as possible, the same performance parameters and pilot questionnaires. This assisted in being able to compare results, as well as providing pilots with continuity and reducing the overheads in running trials.

Task design was based on a mission task element (MTE) concept promoted in combat helicopter flying qualities research. A MET represents a discrete task, representative of a realistic mission phase with defined initial and terminal conditions. The mission phase under investigation in these trials was the Royal Navy deck approach profile. This meant placing the aircraft on a 3-degree glide slope and a 165 degree radial from the port bow (see **figure 13**). Pilots were instructed to fly a standard approach to the 'port wait' position. At this point the aircraft is brought to a hover alongside the flight deck where the main rotor should be clear of the ships side and the aircraft in the correct fore/aft position. The intention was then for the aircraft to hold in this position until a suitable quiescent period in ship motion was identified. The aircraft was then manoeuvred over the landing point and a landing made when the pilot was satisfied with positioning the deck motion.

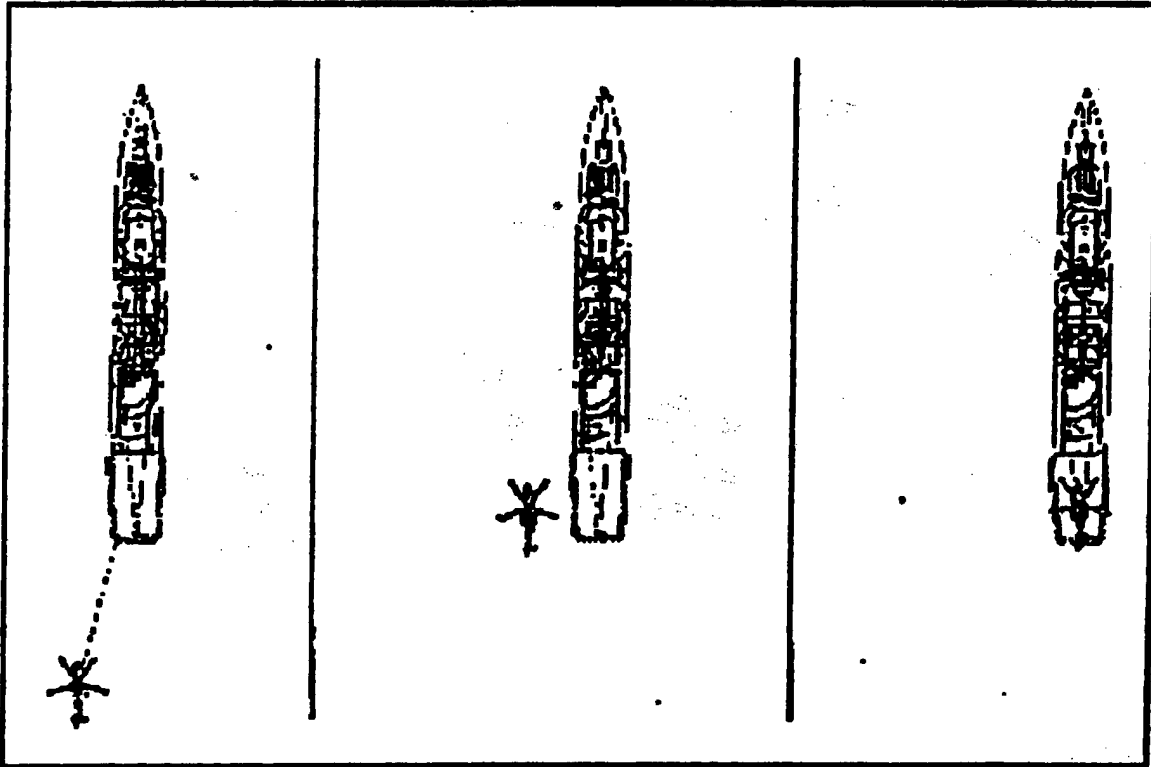


Figure 13 - Royal Navy approach and landing profile

For assessment purposes this profile was divided into two MTEs, as follows:

- a. Approach to and maintenance of a steady hover alongside the flight deck.
- b. Sidestep manoeuvre, positioning over the flight deck and landing.

In the simulator presenting the pilot with various combinations of night and day visual conditions and using different sea states altered the task. Various visual aid combinations were assessed, although all included the baseline ELP pattern and the line-up cues, with the fixed or roll stabilised horizon bar or HPI added.

Obviously, during flight trials prevailing weather conditions were accepted if within realistic limits and all runs were conducted at night. There were occasions where ship motion was out of limits which precluded landing. However, assessment runs were still made in these conditions. Typical weather conditions ranged from sea state 2 with 20-knot winds in moderate visibility to sea state 4 with 30-knot winds in snow showers. As in the simulator various combinations of visual aid were flown. These varied from a totally darkened ship for NVG assessment, through the standard lighting arrangements, to various combinations of ELP, floodlighting and fixed and stabilised horizon bars. The ELP pattern again always included all the additional line-up cues.

Assessment

Success in completing the task was measured not only against the pilot perception of his performance, but also by setting task performance parameters. These parameters were monitored and recorded and, in the simulator, were available to the pilot during debriefing. The parameters were structured to reflect the Cooper-Harper handling qualities rating (HQR) scale (figure 14 and reference 11) for pilot subjective assessment. Consequently, task performance was divided into bands of 'desired' (Level 1), 'adequate' (Level 2) and 'unacceptable' (Level 3). These ratings were included in a post-run debrief questionnaire. This was backed by a post-sortie questionnaire.

Task performance parameters for the simulator trials included accuracy of landing and vertical velocity at touchdown. However, in the flight trials it was only possible to measure accuracy of landing. Even then, there were occasions during the sea trials when landings were not possible due to the conditions. Consequently, there were some runs where data related to pilot subjective opinion only.

Pilots

A large mix of pilots has been involved in trial work. As well as a Defence Research Agency (DRA) project pilot several pilots from A&AEE were involved, some with little deck landing experience. Pilots from the Merlin Project Office and also flew the simulation. The Technical Collaboration Process (TTCP) also brought in pilots from the US Naval Air Warfare Center and the Air Engineering and Test Establishment of Canada. Several of these pilots participated in both the simulation and ship trials. The diverse nature of the pilot pool provided valuable additional insight to the programme.

RESULTS

General

The results presented below are derived from the sorties flown during three major simulation trials and flight trials at sea. Early simulator trials concentrated on evaluating a large number of visual aid options across a range of conditions. Consequently, the number of data points from each combination was sometimes low. However, this allowed rapid focusing on the better display options.

During formal flight trials, a total of 109 night runs were made as well as 34 runs in daylight to provide supporting data. Informal ship trials added to this total.

Comparison of various versions of visual aids that were evaluated in different trials must be conducted with caution. Direct comparisons may not be valid for several reasons:

- a. The basic ELP pattern was altered between the first three simulator trials, and the cueing environment was substantially different between flight and simulator trials.

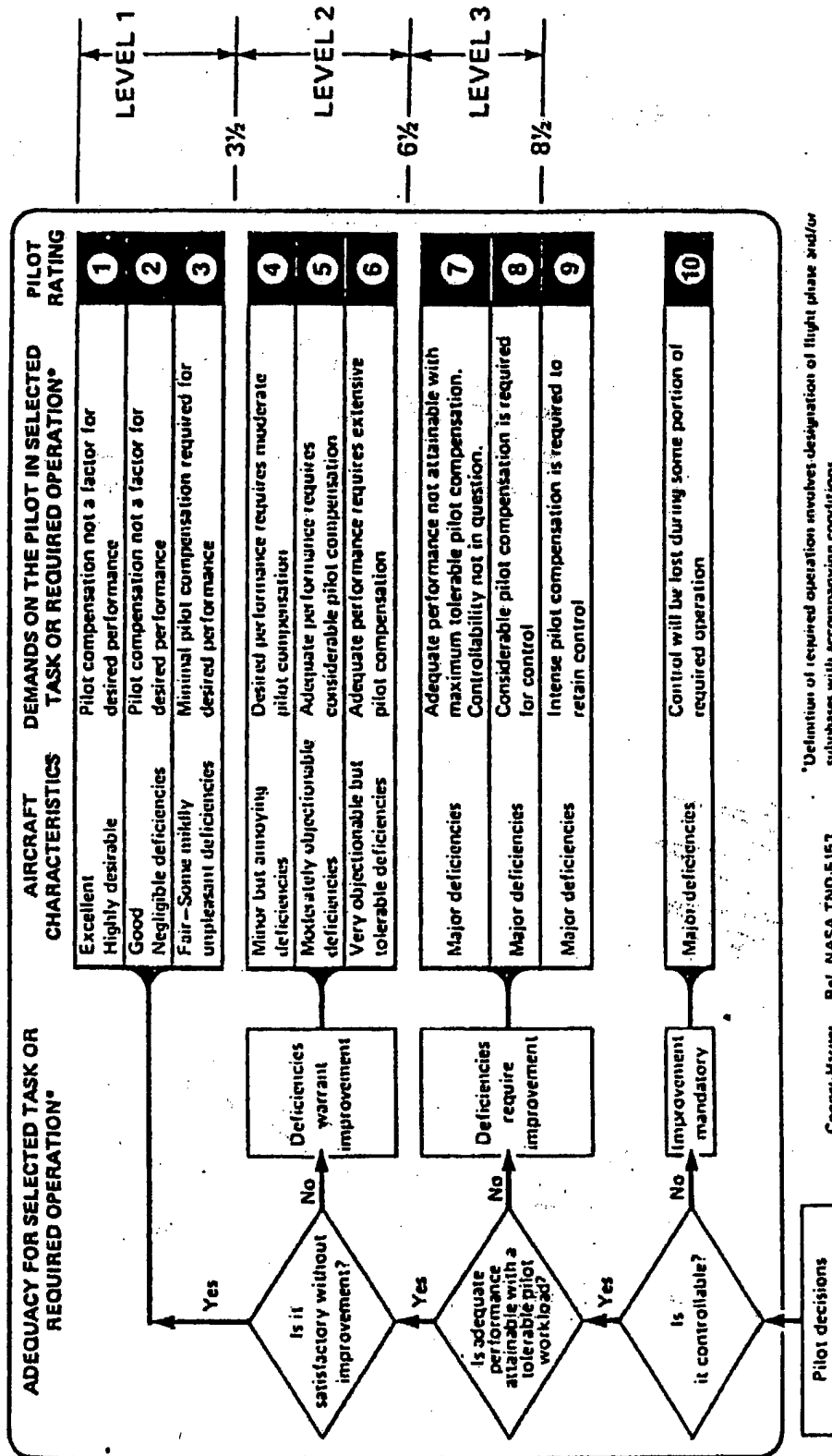


Figure 14 - Cooper-Harper handling qualities rating scale, showing associated levels

- b. The task is substantially different for landings conducted with a hover position indication system.
- c. The simulated aircraft model was based on the EH101. The aircraft used for flight trials was a Sea King with different handling characteristics.
- d. The simulated environment was simpler than that in the real world.
- e. The conditions encountered during flight trials did not closely match those used in the simulation.

However, it is still possible to compare the results and trends indicated by the ratings and performance indicators if these constraints are recognised.

Electro-luminescent Panels

A typical ship trial view of the ELP pattern seen during the final stages of the approach is at **figure 15**. It was agreed by all pilots that the panels provided a much-increased level of cueing over traditional lighting methods. There were several general reasons given for this:

- a. The panels provided pilots with structure with which they were familiar and hence greatly improving the pilot's perception of position in relation to the ship on the approach and improved position cueing over the flight deck.
- b. The distribution of panels of known size gave pilots much-improved rate and attitude cueing during the approach and over the flight deck. The blocks of light indicated clearly to the pilot when the aircraft or ship attitude changed and gave early indication of rate build-up in any axis.
- c. The panels provided a much clearer guide as to the attitude of the ship and hence assisted in detection and assimilation of ship motion.

It was noted in particular that panel groups that formed right angles were particularly effective.

Figure 16 shows the mean HGRs for the approach phase for the ship trial. The spread of pilots returned for each condition is shown on this plot, as with all the other rating pilots. The Cooper-Harper Level 1/2/3 boundaries are also shown. The standard white lighting produced poor Level 2 ratings. The plot clearly shows a marked improvement when the ELP pattern was used. The HQR moved from poor Level 2 to mid-Level 2. This plot also clearly shows the impact of the use of NVGs. Use of the goggles alone improved the approach of HQR to 4.5.

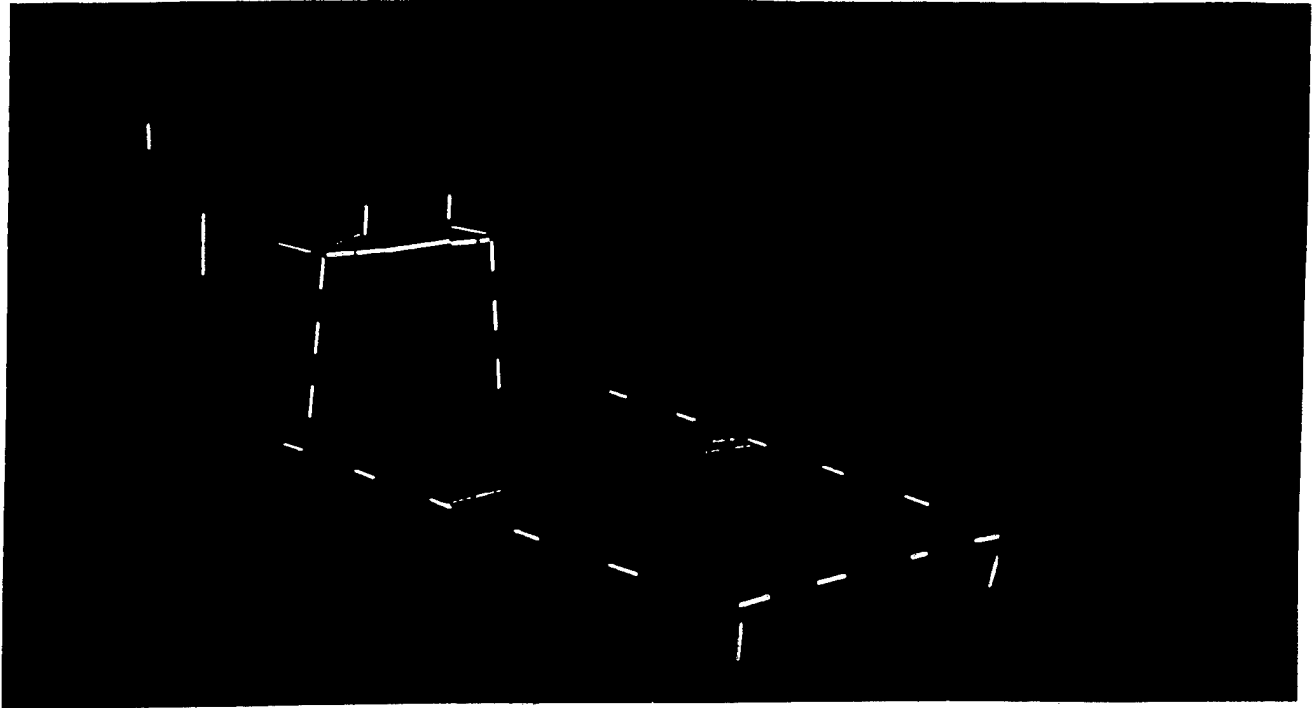


Figure 15 - ELP arrangement fitted for Type 23 ship trials, seen from the port quarter

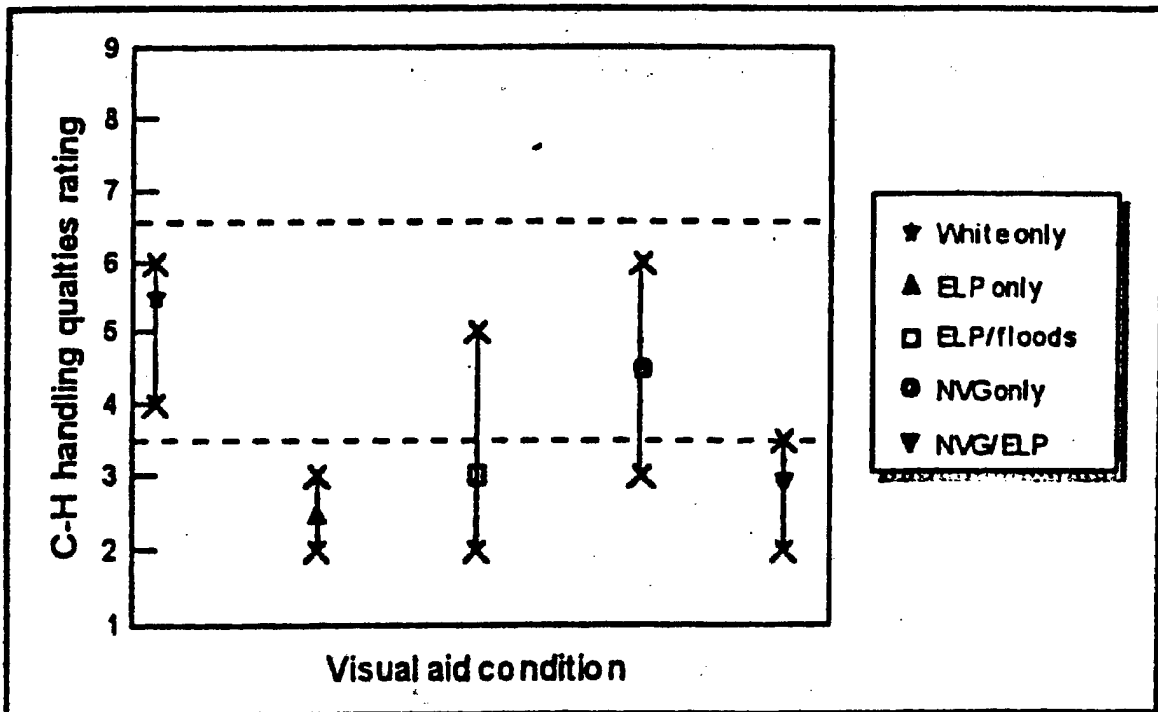


Figure 16 - Ship trial approach MTE - mean HQRs for each visual aid condition.

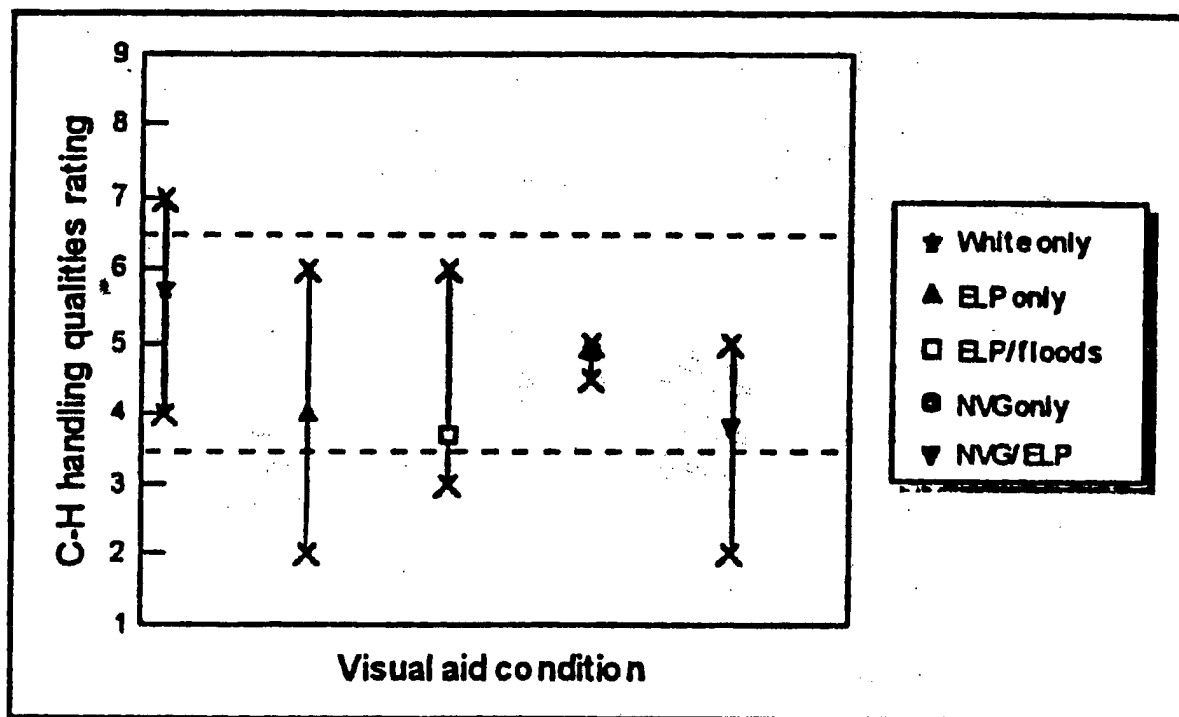


Figure 17 - Ship trial landing MTE - mean HQRs for each visual aid condition

During approaches using ELP pilots were able to rapidly assimilate their relative position to the ship, detect ship motion and gauge closure rate. Pilots were capable of conducting an approach at night with very little visible horizon and in moderate sea states, even without a GPI. It was noted that the RADAR altimeter was used less with the ELPs. It was noted that height cueing on NVG alone was poor. With or without NVGs pilots found approaches with the ELP deck lighting much less demanding.

The main focus of attention during the approach was the panels on the stern. The fore/aft positioning line and those on the superstructure. Panels on vertical surfaces provided the primary cues. The panels on the flight deck gave height cueing and a degree of ship motion cueing. The principal comments of pilots concerning the approach included:

- a. More ELPs on the stern would be useful to improve closure rate cues.
- b. Vertically placed panels and those forming right angles gave the best cues.
- c. The panels make the approach task very different from traditional methods. Situational awareness was much improved.

When alongside the ship pilots generally focused on the panels on the superstructure, although those on the flight deck were useful in assessing ship motion. Generally, it was felt that much superior assessment of ship motion was possible with the ELPs. Roll was easy to detect and assess.

Pitch, although easy to detect, was difficult to assess. **Figure 17** shows the mean HQRs achieved during the landing MTE of the ship trial. The pattern is very similar to the approach phase. Standard white lighting shows the poorest performance again, at nearly 6. Use of NVGs conferred a one-point improvement. Very similar performance was achieved with use of ELP with or without NVG at just outside Level 1. Use of the floodlights with ELP showed a slight improvement over the other combinations. The results certainly support the common pilot comment that the at-sea-landing task is not Level 1 except in the most benign conditions.

Landing scatter plots for the ship trial show that these were not larger at night than during the day. Comparison of landings with and without NVG using ELP lighting (**figure 18**) shows that there is little increase in scatter with NVG. However, the average distance from the ideal landing point is greater for NVG-assisted landings.

With the ELPs in use, the main cues over the flight deck were again provided by those on the superstructure. A general criticism was the lack of a lit vertical line down the face of the hangar in front of the pilot. A vertical bar had been included in simulator trials (**figure 3**), but was not initially available on the ship. Added later, it was successful in greatly improving lateral cueing.

Initial trials had arranged the ELP pattern such that the centre-line of the pattern coincided with the centre-line of the flight deck (in this case the centre-line of the deck lock grid). However, pilots found this arrangement wanting. There was a strong desire to have the pattern arranged such that the cues were aligned with the pilot's centre-line. Changes were made for later simulator trials and such a pattern was used on the ship trial. Most agreed, however, that this was desirable rather than a necessity.

It was noted that, once over the flight deck, the only ELPs available to the pilot were those on the hangar face and roof. The additional panel added to the mainmast in the second trial and ship trial was not found to be particularly useful. Pilots did, however, comment that a panel mounted vertically along the lateral centre-line of the hangar roof may be useful. This was evaluated during ship trials in January 1994 and was found successful.

A useful feature of the panels on the ship trials, rather than those modeled in the AFS, were that each real panel is split into four identical size blocks (see **figure 3**). These blocks provided assistance in determining aspect to the panels and assisted in rate cueing.

Extensions applied to the horizon bar 'eyebrows' in later simulator trials, following success in an initial ship trial, did not produce the expected bonus of approach path cues

in conjunction with the vertical poles. In view of the success of this arrangement in the ship trial, it is likely that this was a simulation-related discrepancy.

Pilots noted that the flight deck appeared to have a 'black hole' effect when using ELPs only. Consequently, during ship trials, recoveries were made with ELPs and floodlighting at a dim setting. Pilots found this a little distracting during the approach task and consequently the HQR returned suffered (see figure 17). However, during the landing task the addition of the flight deck textural cues afforded by the floodlighting improved overall cueing and there was a small improvement in the HQR returned for this task. Pilots commented that the ideal combination would be for no floodlighting during the approach and for it to be activated when the aircraft was in the hover alongside the flight deck.

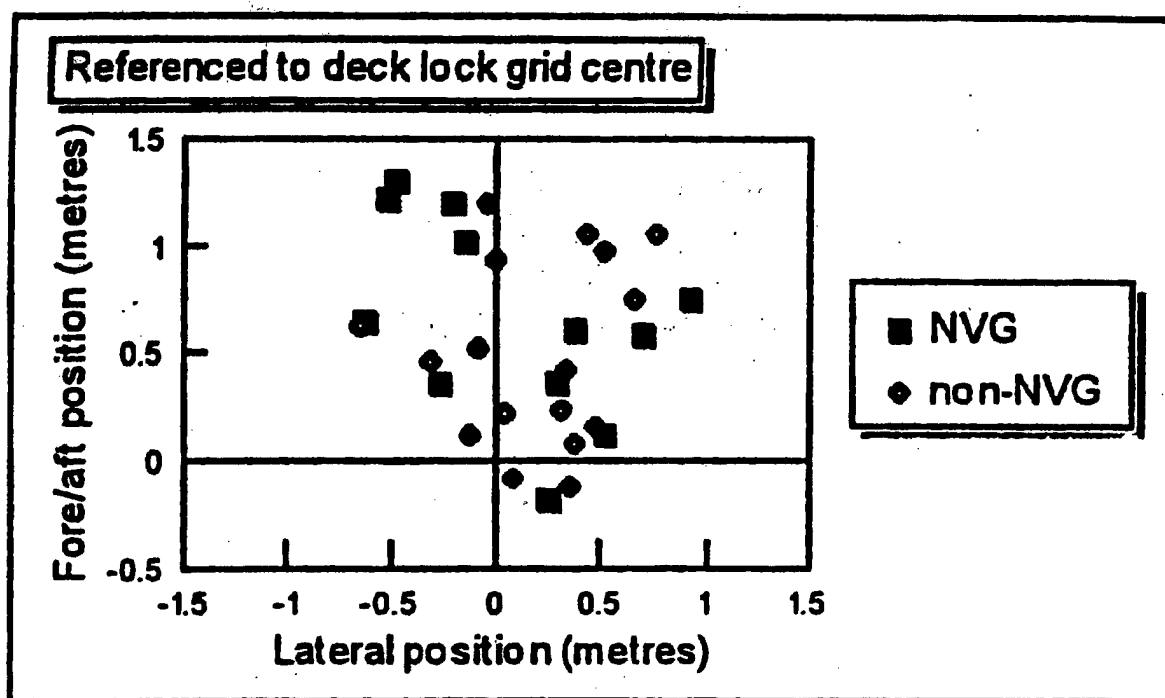


Figure 18 - Ship trial comparison of landing scatters for NVG/non-NVG landing using ELP lighting.

Stabilised Horizon Bar

Pilots agreed generally that the provision of a roll-stabilised horizon bar was an enhancing feature. When in the hover alongside the flight deck pilots found the device useful for attitude references. Generally it was considered that ship roll angles of greater than 2 degrees were detectable, as was rate of roll. The primary advantage of the equipment was the easing of the task of determining a quiescent period in ship motion in which to conduct a landing, especially in heavy sea states and at night. This was

considered to reduce recovery times. There were indications that use of a stabilised horizon bar increased workload at night. This may be a consequence of the pilot having to work harder to take in the additional information.

It was noted that pilots who were familiar with the use of this device (US and Canadian) made more comments about it and noticed it much more when it was not available. Royal Navy and Royal Air Force pilots were not generally conscious of using the bar, but were aware that the roll information was there if needed. This raises the issue of procedures and training that may require consideration if the device were to enter service.

More than one UK pilot found the device illogical, with the inner part of the display showing the horizon and the outer part the attitude of the vessel. It was suggested that it would be more logical to have the centre of the bar fixed to represent the ship, and the outer part moving as a horizon reference.

Line-up Cues

The additional line-up cues can be considered in three parts:

- a. **Chevron on hangar roof:** This received a mixed reaction from pilots. None found it a useful line-up cue alongside, although some found it useful as part of the general pattern of available aids. Over the deck a number pilots used the chevron for lateral positioning and one pilot in particular found it a useful height cue. The general consensus was that the chevron provided a useful additional in the simulator, but that the richer cueing environment the real world would make it superfluous. Certainly during the ship trial some pilots found the panels in this area distracting.
- b. **Chevron on flight deck:** This cue was rarely commended on and little used by pilots. It acted as rough cue as to position alongside in the hover. It was added to the pattern during ship trials at the request of pilots but none found it useful.
- c. **Vertical poles:** The line-up poles were generally found to be an excellent cue over the flight deck. In simulator trials a small minority of pilots did not use them. However, during flight trials all found them of some use. The majority of pilots regarded them as the primary aid for fore/aft positioning over the flight deck. There was no clear evidence in the task performance of the pilots to suggest that the poles generated greater landing accuracy for those who used them or less for those who did not. The poles were used in the following ways:
 - i. During the final approach they provided a height reference, particularly in later trials where the horizon bar was extended such that the poles were cut by the extension. A rough glideslope reference

resulted with pilots flying the aircraft such that the amount of pole above the extension remained constant.

- ii. Over the flight deck most pilots considered the poles the primary means of fore/aft cueing when no hover position display was available. Pilots used the overall pattern of ELPs for rough positioning and then switched to the poles for fine-tuning. The gearing of the system was considered good. The lateral distance between the poles was identified as a difficulty by some pilots. They could not be viewed at the same time and rapid head movements were needed occasionally. However, as pilots became familiar with the system this did not cause concern. Pilots noted that the poles also provided some assistance in ship roll identification.

During ship trials it was noted that in sea states over approximately 4 the poles were becoming limited, as they were moving excessively. This made it difficult to pick up useful information. Although use of this cueing device when on NVG was made more difficult by the restricted field of view offered by the goggles, pilots had little trouble with the additional head movements required.

Hover Position Display System

General

All the results relating to the hover position display system were generated during simulator trials. From the initial format ideas were accepted for development or rejected as indicated by pilot ratings or subjective comment. In total four different display formats were evaluated. It is not possible to directly compare the ratings for some displays as the ELP pattern was changed between trials. However, it is considered that this did not adversely affect trends.

To include all the plots of the relative HQR, task performance and workload ratings in this paper would make for a lengthy and potentially confusing presentation of results. Consequently, the results from the initial AFS trial have been omitted, although explanations as to why particular formats were not developed further are included.

Approach MTE

Generally, pilots were not aware of using the displays for any form of cueing until the aircraft was in a hover alongside the flight deck. Consequently the displays did not have a measurable affect on the approach MTE. Once established in the hover alongside the flight deck most pilots found that the structure of the display was being used for additional cueing, although none of the displays were providing an indication of aircraft position.

Landing MTE

When over the flight deck, pilots used the line-up poles to position the aircraft until the display began to provide position information.

All pilots liked the additional information that displays provided over the flight deck. Comments indicate that pilots were being forced to be more accurate and that the displays were allowing better accuracies to be attained. While it was clear from early trials that landing accuracy was being improved by use of the displays, adequate data points for each display in each set of conditions were not collected using the best increase in performance. In the final trial, where a significant number of data points were collected using the preferred CIT1 display format, it was clear that there was a tightening of the scatter pattern (figure 19). This does show an improvement in fore/aft scatter with use of the position display. This increase in accuracy was balanced by a probable increase in the amount of time the aircraft spent in the hover over the flight deck. Although the data was not conclusive, there were clear signs that the pilot will spend longer achieving this higher accuracy. One pilot commented that the display effectively acted like a co-pilot.

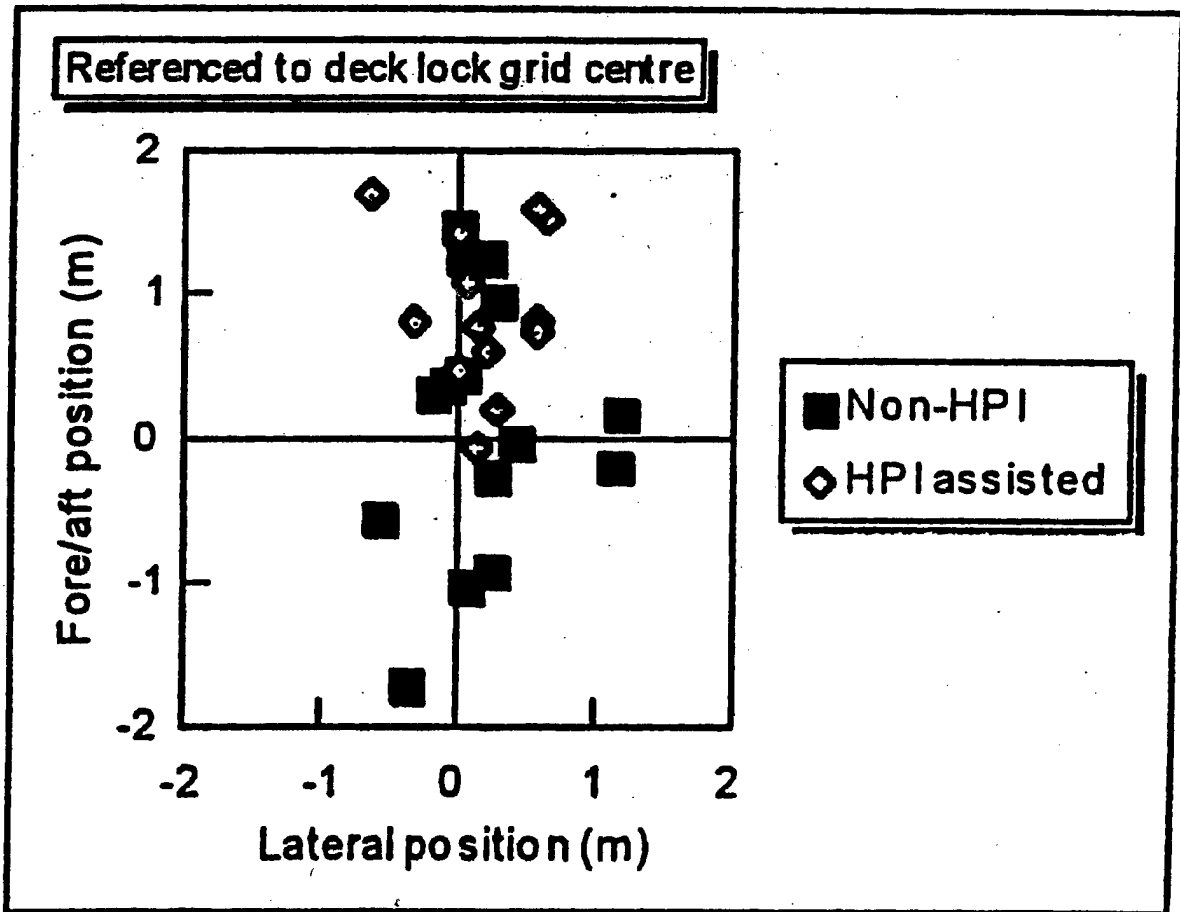


Figure 19 - Scatter for landings with and without CIT1 HPI system

At no point were pilots confused about what information was being displayed. There was some initial concern among pilots that the fore/aft indication, being vertically mounted, could be confused for a height cue when workload was high. This problem did not occur.

Initial trials did not show a clear trend in the HQRs in favour of a particular display over landings without assistance. However, the final trial landing HQR data (figure 20) does not show an improvement in ratings with use of the display. Consideration of pilot workload (figure 21) and task performance ratings (figure 22) shows that there appears to be a perceived increase in performance with little impact on workload. While there is an indication that the use of a display improves task performance, it is less clear to what degree and the effect it has on workload.

Many of the pilots considered that an increase in the area of the deck over which the display indicated would be useful and would increase confidence. Generally speaking, most pilots became more comfortable with the area displayed as experience was gained.

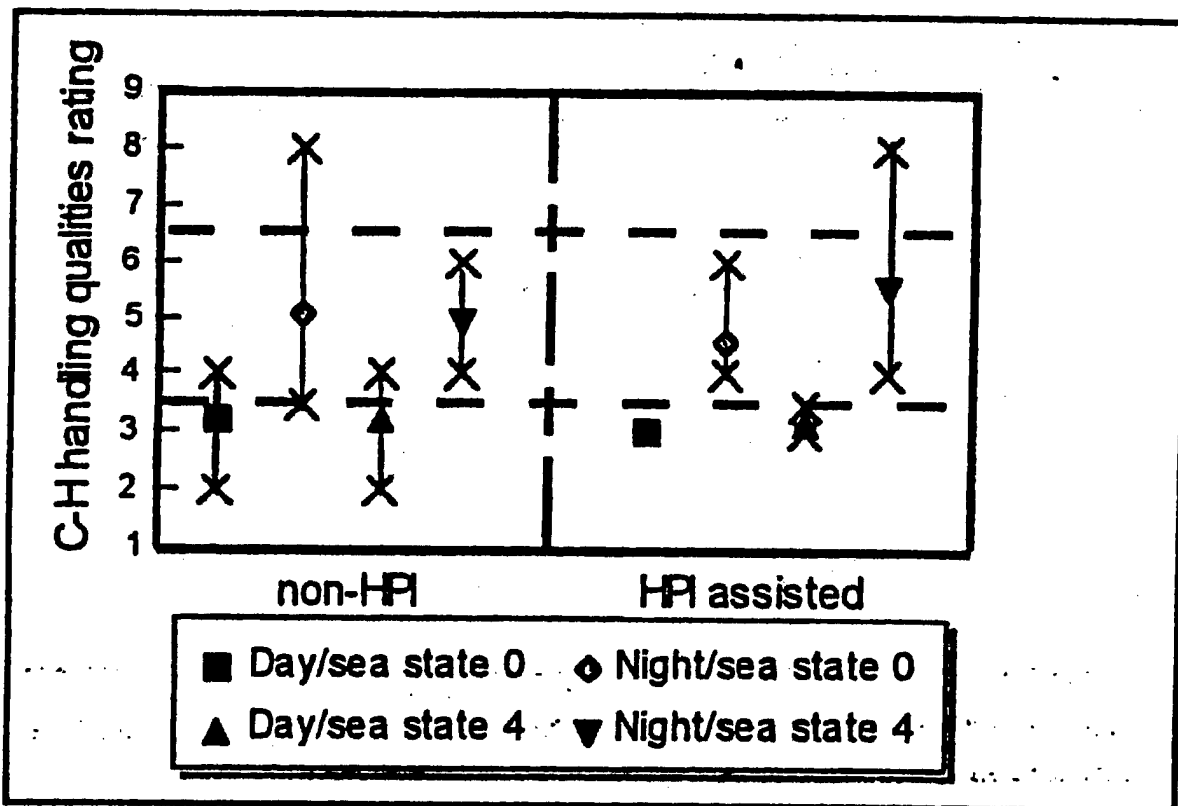


Figure 20 - Mean HQRs for landing MTE with and without CITI HPI in all conditions

Throughout the trials, pilots commented that the displays were positioned too low on the hangar face, particularly in higher sea states. This was supported by the work carried out by CIT (reference 7) which suggested that the centre of a display would ideally be 1 m above hangar roof level if considering an EH101 operating to a Type 23 frigate. Conversely, pilots also found it difficult to maintain view of the display during the descent for landing. In the later case it was generally agreed that it was necessary to transfer from the display to other cues to carry out the landing.

It was also clear throughout the trial that pilots preferred roll-stabilised displays. The CIT-based displays were roll-stabilised as a complete unit and this was well received.

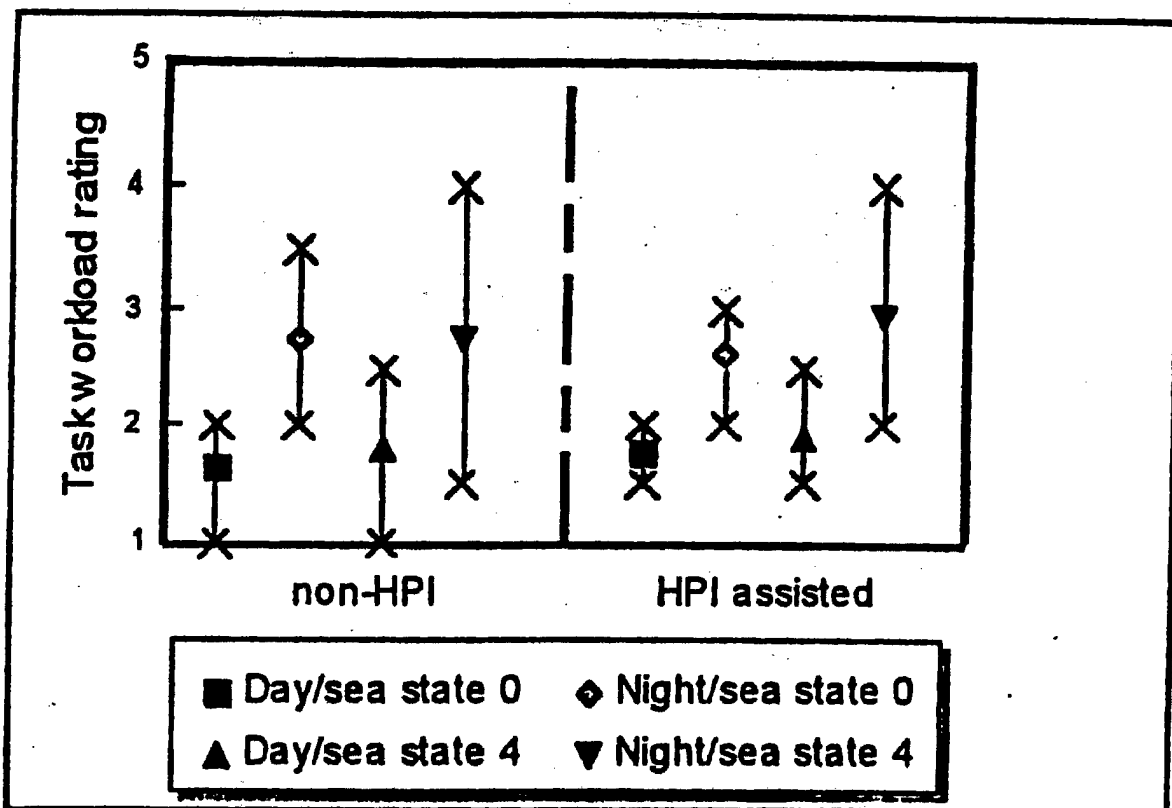


Figure 21 - Mean task workload ratings for landing MTE, with and without CIT1 HPI in all conditions.

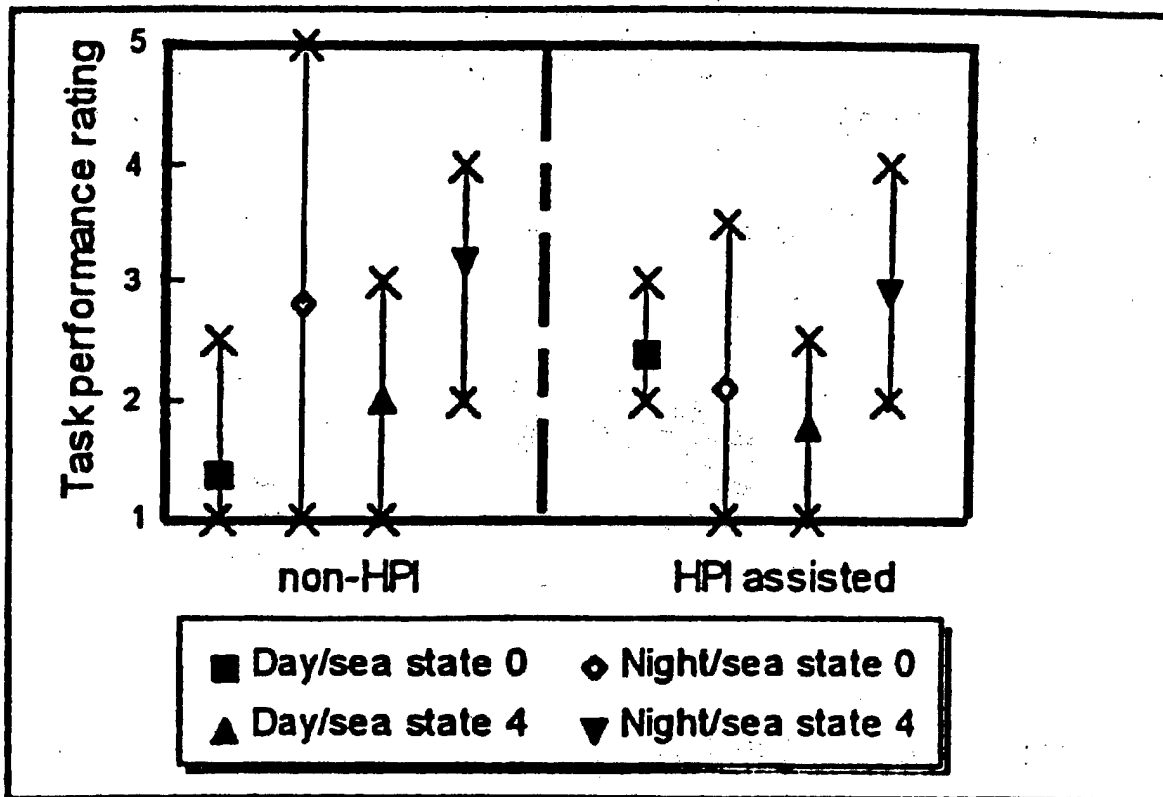


Figure 22 - Mean task performance ratings for landing MTE, with and without CITI HPI in all conditions.

Comments on Particular Displays

Below is a resume of the key points of interest of each display format trialled.

Bedford Display (see figure 6): The main points raised were as follows:

- a. The level of position and rate information provided by this display was generally considered adequate. All pilots commented that it would be beneficial to have more position and rate information available in the area covered by the DLA. This would assist in overcoming the reduction in comfort pilots felt due to not having any indication of where they were inside the DLA. This gave a 'sharp-edged' effect where the indication went from being indicated as 'safe to 'unsafe to land' with no warning.
- b. Generally pilots considered the area of the deck over which the display indicated aircraft position was adequate.

- c. All pilots noted that the display appeared to be very large in the field of view when the aircraft was in the correct landing position. The display obscured many of the traditional cues pilots utilise on the hangar roof and superstructure.
- d. The colours used in the display were not commented on adversely.

CIT Display (figure 7): Principal areas of interest were:

- a. Pilots considered that the display provided good position information at an adequate sensitivity. There was no difficulty with interpreting the two elements on the position information into a solution of aircraft position. The same comments about additional rate and position information in the DLA were made of this display as for the Bedford Display.
- b. Display size was good and it did not interfere with other cues. The vertical element of the display assisted in lateral positioning as it aligned with the central strip along the hangar roof and the vertical drop line on the hangar face. Yaw pedal activity was considerable less when compared with Bedford Display runs. This display was considered less intrusive.
- c. Colours used on the display were liked by pilots.

CT1 display (figure 8): This display format included additional rate and position information for the DLA. Comments were as follows:

- a. Generally pilots much preferred the increased level of cueing available with this display, although one pilot commented that the display sensitivity in the DLA may be too great in higher sea states.
- b. The combination of colours used on this display was liked.

CIT2 display (figure 9): This display combined the Bedford and CIT display formats to provide greater cueing in the DLA. The key points raised were as follows:

- a. The level of cueing provided by this display was preferred over the original CIT format. Pilots generally found that this format was easier to interpret once in the DLA because the position information was presented in a more logical form. However, this was balanced by having to cope with two distinct display formats combined in one display, which some pilots found distracting.
- b. The use of red colouring for crosses in the centre of the display was not liked.

The initial display physical dimensions indicated by the CIT work were liked. There were no adverse comments about the size of the CIT-based displays, or any of the individual elements.

The final trial concentrated on the CIT1 display that had been identified as the preferred format. Performance improvements were possible with this type of aid, as demonstrated by the landing scatter plot shown in **figure 19**. However, pilots questioned the level, or density, of cueing being provided. More than one pilot noted that even with the improvements introduced over the CIT display, aircraft movements were not being picked up rapidly enough. This deficiency in rate cueing meant that it was easy to overshoot the optimum landing position.

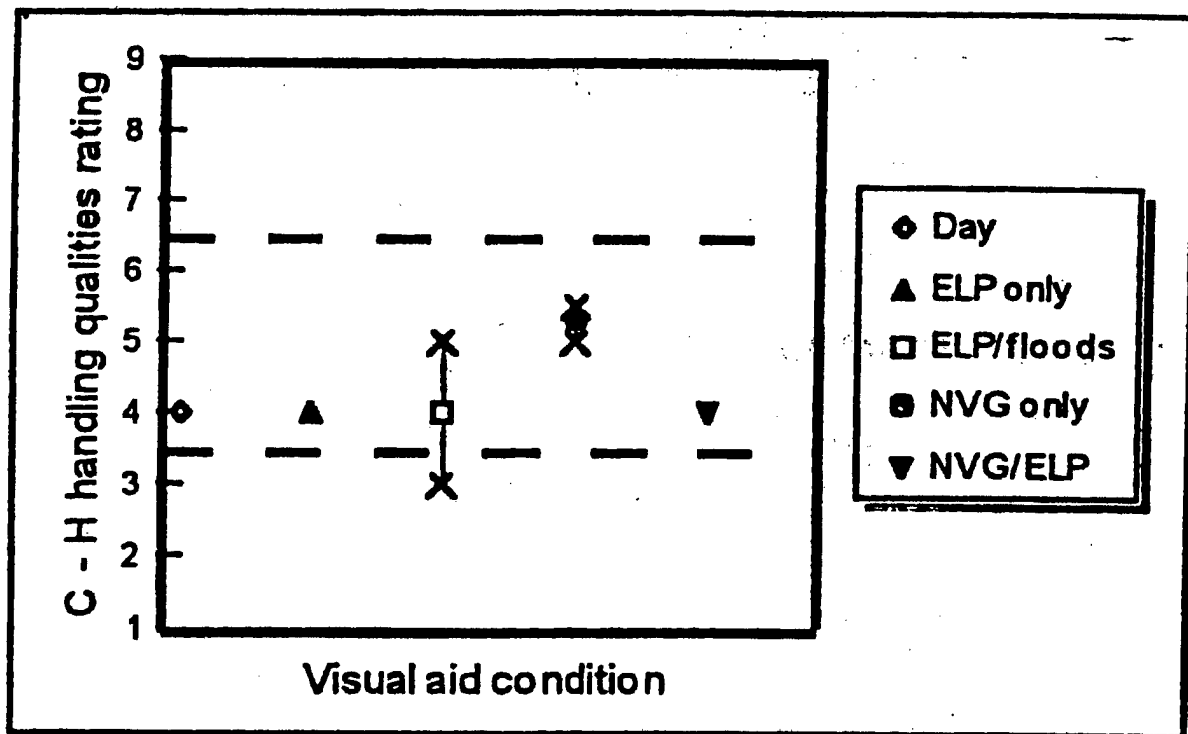


Figure 23 - Dummy deck trials landing MTE - mean HQRs for each visual aid condition.

DISCUSSION

General

The ship trial took place off the West Coast of Scotland during January 1994. Consequently weather conditions were variable and outside the control of the trials team. These variations did not have a significant affect on the approach task results, where the spreads around the mean ratings were small. The spreads for the landing task were larger, as may be expected. However, the mean ratings for the ship trial compare very well with the results from the dummy deck trials (**figures 17 and 23**), which were all conducted in similar conditions. They match very well in both in the trends achieved and values of the HQRs. The spreads of points for the dummy deck trial are significantly smaller. This was to be expected as the conditions were less variable for these trials. A high degree of confidence has been placed in the results.

The discrepancy between the HQRs for the simulator and similar conditions in the real world may be explained in several ways. The aircraft model used in the simulation was generic and conceptual. There was no control cross-coupling. The simulation contained no ship air wake or turbulence modeling, which is recognised as a significant task driver. This has no real bearing on the validity of the results in these trials as they were a comparative exercise. Finally, the cueing environment provided in the simulator is not as rich as in the real world. The field of view is significantly less than that available in a real aircraft, particularly downwards and to the right, a key area in ship recovery. The discrepancy in the ratings of one point is easily within the bounds of the limitations described above. However, it should be noted that the trends shown in the results for the simulator and the real world were very similar.

ELPs

There is no question that the ELPs greatly improve visual cueing in both the approach and hover MTEs. The approach task clearly showed that current lighting provisions in small ships are inadequate. Task performance and workload were both appreciably greater for the runs where standard white lighting was in use. Use of the ELP lighting pattern produced a marked improvement in workload and a significant improvement in the HQRs returned. All pilots agreed that the level of cueing provided by the ELPs was much superior to anything previously experienced. Approaches were completed from ranges of greater than 1 nm without the assistance of a GPI. Internal scan of cockpit instruments was required less often.

For the landing MTE it was again clearly shown that current white lighting provisions are not ideal. None of the visual aid combinations trialled showed Level 1 performance for the conditions encountered during ship trials. All the ELP-based runs, with or without NVGs, showed similar HQRs (**figure 17**). NVG-only approaches were approximately 1 HQR point worse. The HQR date is supported by the typical landing scatter plots for the ship trial (**figure 18**). This shows that the size of the scatter is the same for all ELP-

based runs, with or without NVGs. The additional textural cues provided by the NVGs are probably countered by the reduced field of view available and the lack of depth perception. It was noted during the ship trials that the number of ELPs mounted on the hanger roof for the simulator trials was excessive. This was probably due to the deficient cueing environment in the simulator. The number used during the ship trial was adequate.

Pilots in the first trial did comment that they would prefer all the aids aligned with the pilot's centre-line rather than a centre-line geared to the centre of the deck lock grid. In the second trial, where this was implemented, no pilots commented on alignment, indicating that they were satisfied with the modified arrangement. There are, however, implications of following this approach; the pattern will be aligned for the right hand seat pilot and for a particular aircraft type.

Pilots considered that the best results were achieved from the use of ELP lighting alone for the approach and a mix of ELPs and dim floodlights for the landing. The floodlighting provides additional textural cues over the flight deck. A procedure such as this would be difficult to accomplish operationally, and it was considered that the use of ELPs alone for landing did not cause a noticeable reduction in performance.

These results indicate that operational availability and flexibility could be increased by use of ELP lighting. It has also been shown that there are no operational or flight safety penalties in allowing NVG recoveries to be made at the end of sorties that have been conducted using NVGs, either using no lighting or with ELP-based lighting. The use of these ELP-based aids would be likely to reduce the amount of time the aircraft would spend in the hover both alongside and over the flight deck. ELP lighting has a significant tactical advantage over traditional white lighting.

Pilots found it very easy to adapt to the ELPs and were all immediately aware of the ease in which they could assess position, attitude and rate cues, even from extreme angular approach offsets. Pilots unanimously considered that adoption of ELP lighting could have a significant impact on operational limits for night deck operations.

It was also noted during ship trials that the ELPs provided good lighting for flight deck crews, even when conducting NVG operations. In particular the flight deck edge was well defined, and this was considered to improve safety.

Line-up Cues

The additional chevrons added to the flight deck and hanger roof during simulator trials were found to be superfluous during flight trials. Indeed, the panels mounted on the hanger roof were found by some pilots to be distracting.

The line-up pole system was considered to be very successful by most pilots, although one did not use them except when deliberately assessing them. Pilots considered that they provided a good coarse guide to lateral and fore/aft position over the flight deck.

They were particularly useful in light and moderate seas. In heavy seas, the poles were becoming limited, as the relative movement between aircraft and ship increased. During the trial the poles were mounted vertically, while in the simulator they had been mounted in line with the sloped side of the hangar. Either method was found suitable, but there may be detail differences in the use of these that require further evaluation.

These poles are much less a consideration if a HPI is fitted. However, they still provide useful cueing up to the point where the display begins to track and would form a useful back-up if the HPI were to become unserviceable.

Stabilised Horizon Bar

The bar provided an indication of ship roll angle and rate, even in moderate seas. This allowed for better detection and prediction of ship motion and assisted the pilot in maintaining aircraft attitude and position over the flight deck. It was clear that the pilots who had routinely used this device prior to the trial made more use of it and missed it more when it was not available. There may be some training implications in the use of this device.

Hover Position Display Systems

The concept of using the HPI was generally liked by pilots. Results from ratings did indicate to some extent which was the preferred display format. However, it was pilot subjective opinion that was the most influential factor. The CIT1 display, with the additional DLA cueing, was clearly the preferred choice. The final AFS trial cycle, which focused exclusively on this display, confirmed the findings of earlier work. The addition of an HPI had the following effects:

- A reduction in landing scatter, although this was not significant in simulator trials
- There was evidence of an increase in pilot workload – although this was not borne out in later trials through either ratings of cyclic control activity
- Pilots focus almost exclusively on the display to the detriment of other cues

Although the reductions in landing scatter were not significant in these simulator trials, it was clear from pilot comment that the display did increase confidence.

Evaluating the HPI concept has been taken as far as possible in the simulator. The various deficiencies in the simulation mean that the rest of the work must be completed using flight trials. Accurate assessment of the impact of the display on landing scatter will be a key factor in flight trials. The landing scatter plot (**figure 19**) showed an improvement in performance with the HPI being used. This improvement in performance was better defined in the final simulator trial than in previous work, although this may be simply explained by the larger number of landings carried out at

each condition. The day and night scatters appeared similar when the HPI was in use. This was an indication that the pilots used this cue almost exclusively to position for landing such that the degradation in other cues caused by night conditions did not have a significant effect. There did not seem to be an underlying trend for the degree of scatter to significantly increase with sea state. This is probably an indication that pilots were waiting quiescent periods before landing-on.

The perceived increase in workload when using the HPI, although not shown in the ratings (**figure 21**), may be significant. The discrepancies in workload are likely to be a reflection of the differences in the task brought about by the introduction of an HPI system.

The display should only be used in the final stages of positioning the aircraft for landing. This was to overcome the concern that if the entire landing MTE were conducted with sole reference to the display, pilots could become fixated on the display and be less aware of what was happening to the aircraft or ship. This concern was highlighted by some pilots who recognised that, when using the display, they took little or no notice of other available cues and became very 'blinker'. Use as a confidence check and as a device for cross-checking with other cues supports the determination that the area of the flight deck indicated by the display should remain confined to the region immediately adjacent to the DLA. There may be some fine-tuning to be completed in the light of future flight trials. It is clear that training will be a major factor in the use and success of any HPI-device that may be accepted for service.

Roll stabilisation of the display was considered by pilots to be desirable to provide improved indication of ship motion and assist in aircraft attitude stabilisation.

The problems relating to the origin on the aircraft from which the HPI system takes its datum position cannot be investigated in the simulator. This question will require resolution during flight trials.

The mounting position of the HPI caused pilots some problems. A consistent desire for the device to be mounted about 1 m higher than at present has been noted. However, the field of view in a real aircraft is considered likely to improve this situation. During ship trials it has been noted that hover heights are lower than in the simulator, although this was with a Sea King rather than the larger EH101 Merlin. In any case it is likely that engineering considerations would prevent the HPI from being mounted any higher than at hangar roof level. Mounting above this point would require significant structure that would interfere with the radar cross-section of the vessel as well as weapon and sensor arcs.

The desire by some pilots for increased sensitivity and density of displayed information to improve rate cueing raises some questions. It is known there is some trade-off between the degree of cueing and the amount of information that the pilot can usefully absorb. Incorporating additional elements in the display is under consideration and is a candidate for a small trial effort on the simulator.

NVG Operations

The results from the last ship trial clearly showed that NVGs could provide a significant performance increase during the approach and landing task when compared to standard deck lighting. Pilots considered that the best results were achieved from the use of ELP lighting along for the approach and a mix of ELPs and dim floodlights for the landing. The floodlighting provides additional textural cues over the flight deck. A procedure such as this would be difficult to accomplish operationally, and it was considered that the use of ELPs alone for landing did not cause a noticeable reduction in performance.

These results indicate that operational availability and flexibility could be increased by use of NVGs or ELP lighting, or a combination of both. It has also been shown that there are no operational or flight safety penalties in allowing NVG recoveries to be made at the end of sorties that have been conducted using NVGs.

The ship could be picked up and identified at approximately comparable ranges using NVGs or ELPs. NVGs with ELPs considerably enhanced this range. Tactically, the use of NVGs with no ship lighting proves the best solution, although use of ELP lighting has a significant advantage over traditional white lighting.

All of the pilots who flew in this trial were familiar with NVG's. However, two had not previously flown NVG recoveries to ships. None of the pilots had noteworthy problems completing the tasks, and this may be an indication that NVG-familiar crews will not require significant additional training.

Simulation Issues

Simulation deficiencies will have influenced the results of the simulator trials. The key areas where it was noted that this may be the case included:

- Aircraft mathematical model - which was conceptual in nature
- Visual system field of view - much reduced over the real world scene available to the pilot
- Scene content – even photo-textured image systems cannot produce the richness of visual scene available in the real world
- Lack of an effective ship air wake and turbulence model, which forms one of the key task drivers in operations in severe conditions

Having noted these deficiencies it should be remembered that real aircraft also have deficiencies. While we need to strive for improvements in the simulation, the trends for the results were considered to be realistic and offer a convincing baseline for future corroboration in flight. This has been shown to be the case in subsequent flight trials

where discrepancies between simulator and real world have always been relatively minor. Any differences have shown that the results in the simulator are more conservative than the real world, which ensures that use of the AFS will not lead to over-confidence in the real world.

Continual improvement in the fidelity of the dynamic interface simulation available on the AFS is sought. Planned improvements over the next few months include:

- a. Integration of a simple and cheap pilot helmet-mounted display system for HPI information.
- b. A considerable improvement in the field of view available in the simulator from a doubling of the number of image generation channels from 3 to 6. This will see lateral field of view increase from 120 degrees to 220 degrees and the elevation increase from 48 degrees at best to 66 degrees. This is in the region of the pilot's chin window, an important area for ship operations, and will have a significant impact on the quality of the simulation.
- c. Further integration and testing work on an effective ship air wake and turbulence model, already being tested on the AFS.
- d. Incorporation of 5-axis ship motion.
- e. Start of work to provide a high fidelity EH101 Merlin aircraft model.

FURTHER WORK

Some of the problems identified with the HPI display system may be eased or eliminated by presenting the positional information on the pilot's helmet visor rather than on a fixed display on the ship. However, as there is little or no need for an anti-submarine warfare (ASW) helicopter pilot to be equipped with an HMD to fulfill the primary mission, cost is a concern in the use of this equipment as an approach and landing aid. Supplying an HMD for the recovery task only would probably not be supportable. Recognising this, the Bedford team has looked for a cheap HMD solution. This certainly means avoiding the need to provide head-tracking. A commercially available visor-mounted mini-television screen is being used to introduce the concept to pilots. A modified AH-64A low speed symbology set was used for initial evaluations. The first simulator trial has been completed to evaluate this concept. Results have yet to be analyzed.

Future work on HMDs will be undertaken in the light of the results of simulator trials, and will include investigation of the impact of visually coupled control and display systems. Development of appropriate symbology will be a key issue.

The simulator will be used next year to begin the process of developing ELP patterns for other Royal Navy aviation capable ships. The simulator will also be used if necessary in support of the flight trials for the HPI.

Land-based flight trials will take place this year using the electro-optic tracking system to drive the HPI format favoured after simulator trials. Answers to concerns not addressed by the simulator trials will be sought.

The final sea-based flight trial will take place in early 1996. This will bring together all the elements of the precision approach guidance and autopilot work as well as the HPI and final ELP layouts.

CONCLUSIONS

This paper has presented the results from a series of simulators and flight trials to develop an improved cueing environment at the helicopter/ship dynamic interface. The research has included: evaluation of the use of ELPs as a replacement for traditional white lighting, incorporation of additional fixed position cueing aids, use of roll-stabilised horizon bars and the development of an active display system to present the pilot with accurate position information over the flight deck. The trials were a success and have led to the recommendation of the procurement of an ELP-based lighting suite for small aviation-capable ships of the Royal Navy. From the analysis of the results the following conclusions can be drawn:

- a. ELPs provide a highly successful alternative to traditional floodlighting, giving much improved levels of rate, position and attitude cues. This allows approaches without use of the GPI from ranges in excess of 0.5 nm. All pilots found it easy to adapt to the system and consistently returned HQRs two or more points better than for standing lighting. The adoption of ELP lighting could have a significant positive impact on operational limits and availability.
- b. The line-up poles alongside the hangar make a valuable contribution to positioning the aircraft accurately over the flight deck. Usability in high sea states has yet to be confirmed.
- c. The stabilised horizon bar makes ship motion detection and prediction easier for pilots, both alongside and over the flight deck. This assists the pilot in maintaining aircraft attitude and position over the flight deck.
- d. An HPI system offers improvements in landing scatter and an increase in pilot confidence. The CIT1 format was preferred by pilots, although with concerns about the level of rate cueing. Flight trials are required to carry the work forward.
- e. Use of NVGs for ship recovery can offer significant operational benefits. NVGs alone provide a significant improvement in performance with consequent reduction in workload. Use of NVGs with the ELP-based lighting system offers no advantages over use of the ELPs on their own.

The close match between results of ship and simulation trials supports the validity of the AFS for use in this type of work. In areas where there are differences the simulation work has always indicated poorer results than were achieved in flight trials. Thus, use of simulation will not lead to overly optimistic results with the risks this may incur in subsequent flight trials. Further planned enhancements will continue to improve the standard of the simulation. The recognised deficiencies in the simulation were not considered to have seriously impinged on the evaluation work carried out.

This work demonstrates that there is considerable potential to improve the standard of visual aids in small ships. The ELP-based visual aids package has been recognised as providing a significant improvement in capability for helicopter/ship operations. Simulator trials indicate there is merit in continuing research into the provision of a sensor-driven hover position display system to assist pilots in positioning the aircraft over the correct landing point.

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Offshore Helideck Lighting

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This paper was presented by AJ Smith at the FAA Heliport/Vertiport Lighting Conference, held in Washington DC on the 26-27 January 1999. Any views expressed are those of the authors and do not necessarily represent those of DERA/HM Government or the UK CAA.

Abstract

The paper presents a review of recent UK offshore helideck lighting research, conducted by the Defence Evaluation and Research Agency, on behalf of the UK Civil Aviation Authority. Trials have been conducted and are on-going on UK and Dutch offshore gas installations. This paper describes the lighting systems evaluated, indicating the cueing requirement(s) that they intend to address and outlines the results of the evaluations.

Areas that need to be addressed by future research are also outlined.

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1. Introduction

The North Sea is the area bounded by Norway, Denmark, Holland, England and Scotland. The region is rich in oil and gas, which is extracted and brought to the land by pipe and tankers. Personnel and supplies have to be ferried from the numerous (300+) offshore platforms and helicopters are the normal mode of the transport except for heavy and bulky cargo. The weather in the region is frequently dominated throughout the year by combinations of poor visibility, strong winds and, in winter, icing conditions.

Visual aids for civil helicopter operations are already specified in ICAO Annex 14 Volume 2. These requirements are for Visual Flight Rules (VFR) operations and there are no agreed specifications for Instrument Flight Rules (IFR) operations. The final approach and the landing phase of all offshore helicopter flights are carried out by reference to visual cues derived from the destination platform superstructure and lighting. An extensive survey conducted by the CAA in 1995 highlighted the problems pilots experienced when operating to offshore platforms.

The research being conducted by the Defence Evaluation and Research Agency (DERA) at Bedford for the UK CAA therefore consists of an evaluation of various candidate technologies that might be beneficially adapted to enhance the visual cues environment at night.

2. Visual Cues and Aids Required

The final approach and landing can be sub-divided in to a series of discrete visual tasks, which are rig location, rig identification, helideck location, final approach and hover/landing. Table 1 summarises visual task, cues and aids associated with each phase as well as problem areas pilots have commented on.

3. Trials Conducted to Date

A number of offshore trials have been conducted by DERA in the last five years on both Shell platforms in the UK Sector of the North Sea and on NAM platforms in the Dutch Sector of the North Sea. This section summarises the candidate visual aids that have been evaluated to overcome the problems highlighted above.

3.1 Unsafe Helidecks

A recent programme of work has been completed on an 'Helideck Status light signalling system'. The objective of this work was to 'develop and validate a specification for a lighting signalling system for offshore platforms capable of warning pilots of approaching helicopters if the helideck is in an unsafe condition'.

Commercial, off the shelf (COTS) lighting equipment was installed on the helidecks of several complex platforms and dedicated and 'in-service' flight trials were conducted. A key factor in the recognition of the signal as a warning was the use of a red, flashing light. The specification has now been published in CAA paper 98003 and incorporated into Civil Air Publication (CAP) 437 by reference.

3.2 Helideck location and Final approach

a) Electro-Luminescent Panels (ELPs)

Green Electro-luminescent panels (typical luminance 60-100 cd/m²) for use as nighttime only aids have been applied in two ways:

i) Perimeter lighting

Equally spaced panels of approximate lengths of 1.2m are mounted on the helideck in such a way that they can be easily seen by approaching helicopters and helicopters on the deck (inverted 'V's along the edge of the deck - each made up of two standard ELPs).

The panels were initially trailed on a 'complex' platform where the cultural lighting levels were high. The evaluations showed that the ELPs did not provide a significant improvement to the existing visual aids in this environment as they were not bright enough. However, the potential benefits of using ELPs together with green perimeter lights on small, unmanned platforms have produced some favourable results.

Phase	Visual Task	Visual Cues/ Aids	Problems
Rig location	Sensor search	Contrast of platform against sea/ dark background	In poor visibility.
Rig Identification	Observe defining features	Position of platform in relation to others Outline / shape of platform Sign board	Wrong rig landings due to many similar looking platforms within a small area. Lack of superstructure particularly with small, unmanned platforms cause disorientation Current sign board location and illumination insufficient to make board conspicuous.
Helideck location	Search within platform structure	Shape of helideck Colour of helideck Deck edge lighting	Complex platforms have unnecessarily high level of cultural lighting (pollution). Currently all platform lights (helideck and cultural lighting) is yellow/ white therefore helideck shape, size and location difficult to identify. Helideck obscured by superstructure in certain approach tracks. If floodlights are too bright or misaligned can cause pilots discomfort glare.
Final approach	Detect helicopter position in 3 axes Detect rate-of-change of position	Apparent size and change of size Orientation and change of orientation of known features/ markings/ lights Nil	Lack of superstructure particularly with small, unmanned platforms cause disorientation. Not enough cues to judge rate of closure and height
Hover and landing	Establish deck status Detect helicopter position / attitude and rate-of-change of position in 3 axes	Known features/ markings Lights Deck texture	Danger of landings taking place on 'unsafe' platforms. Not enough 'textural' cues on the helideck to allow aircraft orientation, rate of closure, lateral, longitudinal and height information to be obtained.

ii) Lighting the painted 'H' on the helideck

The full extent of the 'H' marking on the helideck has been covered with an ELP 'H' on a small, unmanned platform. Early trial results indicate that the 'H' provided useful, glare-free, perspective cues in the final approach allowing improved rate of closure and depth perception judgements to be made. The 'H' was particularly valuable from a range of around 0.5 mile. Pilots suggested that the size of the lit 'H' should be increased.

It should be noted that the deck-edge floodlights, when switched on, 'washed out' the effect of the ELPs.

b) Green Perimeter Lights

In order to allow the perimeter lights to stand out from all the yellow/white platform cultural lighting, the colour of the lamp/lens units have been changed on a NAM offshore helideck for trial purposes. Two adjacent helidecks on a Dutch platform were used for comparing green perimeter lights with yellow perimeter lights. Early results indicate that this simple and cheap change allowed the helideck to be located at around 2.0- 1.5 miles and the helideck shape to be clearly identified from around 0.75- 1 mile. (The yellow lights allowed the shape to be identified from around 0.5 mile). The pilots commented that the green lights were also less likely to cause glare in the final approach and landing phases.

Trial data to date suggests pilots preferred the green perimeter light (point sources) to the ELP perimeter lighting (strip lighting), although this may be because of the perimeter lights being of higher brightness.

c) Floodlights

A number of Dutch platforms and a few British platforms in the North Sea have deck level floodlights installed. It is believed that the original requirement for these lights was to produce sufficiently high luminance levels on the helideck surface at nighttime to emulate daylight. Poorly aligned floodlights can be a source of glare to pilots of approaching and landed helicopters.

The research being conducted at the moment is revisiting the operational need for these floodlights. Recent trials have suggested that the floodlights are not required in the platform acquisition phase and in fact, make it more difficult to locate the pattern of helideck perimeter lighting. The floodlights may, however, be useful in providing the textural cues required in the final approach and hover/ landing phases. These re-defined requirements could mean that the beamsread of existing floodlights need to be addressed.

3.3 Hover and Landing - Rate of Closure Cues and Depth Perception

a) Helideck Net

The cost of maintenance, difficulties of helideck cleaning, obscurity of helideck markings and the general inconvenience of landing nets, has motivated the offshore industry to promote their removal. Reports received from pilots, however, indicated that the visual cues, in particular the textural cues which they use to judge height and horizontal movement over the helideck, have been reduced with the removal of the landing nets.

The research presently being conducted is aimed at designing a mesh system that can replace the net without removing the textural cues.

The benefits and disbenefits of helideck floodlights or the helicopter searchlight used with the mesh system are also being evaluated in both laboratory and field trials.

4. Further Research to be Conducted

a) Light Emitting Diodes (LEDs)

Recent progress in LED technology has meant the latest lamps are of an intensity and viewing angles that may be suitable for the offshore environment at night.

The suitability of strips or blocks of encapsulated LEDs are currently being considered as an alternative method of providing lit areas on the surface of the helideck. In particular, the benefits of lighting the circle around the 'H' for improving textural cues are being looked at.

b) Reducing Light Pollution

The problems of providing good visual signalling at offshore facilities are significantly increased by the high levels of light pollution produced by inappropriate cultural floodlighting units that are badly sited and inadequately maintained. Until this problem is addressed the task of providing good visual cueing for aviation purposes will always be very difficult.

Consideration is being given to conducting a 'light audit' of a typical complex offshore platform to establish what types of cultural lighting are being used and whether the unwanted light emissions can be controlled.

c) Rig Identification

CAA paper 92006 states that the externally lit signs currently displayed on the sides of platforms do not have sufficient luminance contrast. CAP 437 recommends that new lighting technologies (such as LEDs and fibre optics) be used to improve the contrast and conspicuity of these signs. A specification for the signs needs to be developed.

d) Helideck Obscuration

The position of the helideck is not standardised and since the final approach direction is strongly influenced by the prevailing wind direction there will be occasions when obstructions on the platform or the superstructure itself will totally obscure the deck from sight. A visual aid system such as large lit chevrons installed on the sides of the superstructure may help to make the location of the helideck obvious.

e) Helideck 'Floating' at Night

At night some small, simple platforms that have little superstructure can appear to be floating and appear 'two-dimensional' to an approaching aircraft. Pilots have suggested that reflected or direct lighting below the helideck, on the 'legs' of the structure, may help in creating a 'three-dimensional' picture.

The Impact of Communications, Navigation and Surveillance Technology on Vertical Flight Operations

Mr. Daniel Salvano, Deputy Director
FAA Office of Communications, Navigation and Surveillance Systems (AND-2)

The Potential of CNS Technology --- Surveillance

Satellite based CNS will permit wider and more comprehensive coverage, especially at lower altitudes.

- GPS based surveillance systems will have the ability to cover areas not currently available from traditional radar systems.
- The ability to relay signals from ground to space permit airspace management in many areas outside of urban and high altitude operations.
- GPS based surveillance will permit new initiatives such as Free Flight Phase I to be implemented.

Emerging surveillance technology may have the greatest potential for enhanced services for the General Aviation community, including helicopters and advanced vertical flight aircraft.

The Potential of CNS Technology --- Navigation

One of the perils for low flying aircraft and helicopters is Controlled Flight into Terrain (CFIT).

- Improving pilot situational awareness can drastically reduce CFIT accidents.
- GPS based technology is ideally suited for providing real time navigation information for the pilot.
- The preciseness of satellite navigation is even more effective for flight operations below 2000 feet above ground level and in obstacle-rich environments, such as cities and urban complexes.

During Operation Heli-STAR in 1996, the use of GPS and satellite data linked to the cockpits of over 80 different types of aircraft proved the value of this type of navigation service.

In Chattanooga in 1995-1996, air ambulance helicopters using GPS instrument approaches combined with ADS-B type surveillance information were able to use flexible routes and expanded surveillance coverage to support missions into adjoining mountain valleys.

The Potential of CNS Technology --- Communication

Cumbersome and awkward communications by voice can be another adverse impact on pilots operating at low altitude.

- When the demands for communicating exceed the pilots ability to fly, a serious chain of events begins that could lead to disaster.
- Preplanned digital information provided on demand can help improve the pilot's situational awareness without increasing pilot workloads.

Aeronautical data link (ADL) systems will significantly reduce workload and enhance awareness.

Flight Information Services (FIS) information can be quickly and routinely updated.

- Amendments to flight plans
- Weather graphic displays
- Heliport and destination services and needs

The Role of the CNS Office in CNS Systems Technology Development

The CNS Systems Office (AND) has three major integrated product teams working on expedited implementation of CNS technology:

- Communications Systems Integrated Product Team (AND-300)
- Navigation Systems Integrated Product Team (AND-700)
- Surveillance Systems Integrated Product Team (AND-400)

A fourth integrated product team (AND-500) is being organized:

- to support the applied technology and flight demonstrations of CNS systems
- to provide coordinated and efficient response to user group issues
- establish joint partnerships with industry

This new team will include the following teams and projects:

- Safe Flight 21
- General Aviation and Vertical Flight
- TCAS
- Gulf of Mexico

HELIPORT/VERTIPOINT LIGHT FIXTURES

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Introduction

Based on the questions raised during the preparation for this meeting and on the questions that are generally raised about lighting certification, I intend to address the following issues:

1. How does FAA specify heliport/vertiport light fixtures?
2. What is the certification process for light fixtures?
3. What is the process for amending the specification to allow new technology?

Specifications for heliport/vertiport light fixtures

The specification of interest is AC 150/5345-46, Specifications for Runway and Taxiway Light Fixtures. This is a performance-oriented specification. In recent years, the FAA has tried to write all of their lighting specification to be both "generic" and performance-oriented. By "generic", I mean that the specification it does unnecessarily dictate the technology to be used in meeting the requirements of the specification. In practice, however, one should recognize there is a limit on how generic one can be without being excessive proscriptive and without making the certification process excessively expensive. New technology often offers a means to do things that could not previously be done. New technology may also offer far greater flexibility in choosing how certain requirements are to be met. As a result, new technologies may require modification of the current specification.

Lighting specification generally covers the following topics:

1. Environmentals
2. Light chromaticity (color)
3. Light intensity
4. Size/shape

However, lighting specifications do not specify light source or wattage.

Certification process for light fixtures

The certification process consists of the following steps:

1. Design the product to meet the requirements of AC 150/5345-46, Specification for Runway and Taxiway Light Fixtures.
2. Contact a certified third-party certifier listed in AC 150/5345-53, Airport Lighting Equipment Certification Program.

3. After all requirements are satisfied, the third-party certifier will issue certificate of conformance.

4. FAA will list product on the Internet (FAA home page: www.faa.gov)
[Select Airports, Select Advisory Circulars, Select AC 150/5345-53, Appendix 3]

Process for amending the specification to allow new technology

The amendment process depends on what in the specification needs to be revised:

Are changes required to the environmental requirements?

Are the specification requirements geared to a particular technology?

Are research and development required to provide a basis for amendment of the specification?

Process for amending the specification to allow new technology

The FAA will determine whether new technologies warrant review of the specification.

The FAA will determine whether research and development are necessary. (Note: R&D funding has been very limited in recent years and this can delay the amendment of a specification.)

Conclusions

With the cold cathode lights, it appears that no revision of the lighting specification is needed. The manufacturer can apply for certification under the existing specification. Whether cold cathode lights will meet all the requirements of the current specification is not yet clear. However, the FAA does not see that any of the requirements of the current specification are in need of revision.

The manufacturer has claimed that the cold cathode technology has a unique advantage over incandescent lighting in that it does not cause an after-image on the retina of the eyes of the pilot. On this basis, the manufacturer has requested that the FAA develop a lighting specification that could only be met with cold cathode technology. The FAA has identified what testing would be required to substantiate the claim of a unique cold cathode benefit. However, this claim has not yet been substantiated to the FAA's satisfaction.

With the light emitting diodes (LED's), research is required to determine how these lights should be tested and what criteria should be used for their certification. Research efforts are currently underway in the United Kingdom, in Canada, and in the USA. In an era of tight resources, this work is being done cooperatively rather than duplicating efforts. We expect that the aviation authorities in these countries will informally share results and consult with each other prior to making decisions based on the research.

US Navy Lighting Systems for Helicopter Landing Facilities

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Abstract

This paper provides a description and use of lighting systems utilized on US Navy helicopter landing facilities. The emphasis is primarily on shipboard facilities with a brief description of Navy land based facilities. Expeditionary Air Fields (EAF) are not discussed. These lighting systems were developed through an evolutionary process and are used on many different types of ships with varying mission requirements thus not all systems are on every ship. A detailed description of each light and its photometric characteristics and its intended use is described including a brief description of night vision device (NVD) requirements and emerging illumination systems.

Introduction

Flight control on Air Capable Ships has evolved over a quarter of a century from a painted landing area with landing signal enlisted (LSE) personnel on deck, to a fully capable multi-vehicle landing pad. Pilots approaching small ships at night in heavy weather are critically reliant on visual cues through approach, hover and landing. In addition ship personnel such as landing signal enlisted/officer (LSE/LSO), aircraft handlers, maintainers and controllers must have enough illumination to perform their functions safely on a moving deck in poor weather conditions without interfering with the pilots' visual cues. Coupled with this is the requirement to operate all weather in all types of lighting conditions from full daylight to operations with night vision devices. Thus the lighting systems have evolved through an evolutionary process to meet the needs of the operators. Different landing pad configurations have led to different constraints and have resulted in restrictions in locating visual cues. Thus compromises must be made in locating various system components. These are usually resolved through flight testing. A standard suite of lighting fixtures and visual cues have been developed and are applied across all ships to maintain common equipment to reduce support costs. While meeting the needs of air operations, this evolutionary development has led to a number of different lighting and guidance systems and support equipment with different vintage technologies. The current visual landing aids for air capable ships include Stabilized Glide Slope Indicator (SGSI), center line lights, Horizon Reference System (HRS), Vertical Drop-line Lights, Port and Starboard Edge Lights, Forward Port Edge Lights, Spot Pad Lights, Deck Edge Lights, NVD Blue, Yellow and White Overhead Floodlights, Deck Surface Floodlights, Homing Beacon, Rotating Beacons and various paint schemes. The characteristics of these systems are detailed in this paper.

Visual cueing requirements

Visual cues are a critical part of the landing and takeoff and have a significant impact on operational limits and safety. Primary cues are provided for the pilot but secondary cues must also be provided for controllers and maintainers. Pilot visual cueing is generally broken down into three phases: approach, hover and landing. In the approach phase, the pilot needs direction to the ship and glide slope information to maintain proper approach height and to assist in judging and controlling approach speed and decent rate. This is currently provided by the centerline line-up lights and the glide slope indicator at distances over $\frac{3}{4}$ NM. As the aircraft gets closer the pilot can discern the landing box and the drop line lights and then some of the deck illumination. All of these systems assist the pilot in judging closure rate, glide slope, and lineup. Closure rate is usually discerned by monitoring airspeed, altimeter and glide slope information at longer distances, and the landing pad size rate of growth inside of $\frac{1}{4}$ NM. All of these cues are degraded in poor weather conditions, which is why some of the visual cues are redundant. When the pilot approaches the hover position, his scan shifts to lighted horizontal and vertical surfaces to gain fine closure rate control. At the same time, the pilot must maintain attitude control of his aircraft. This information usually comes from the natural horizon and his view of the ship. To enhance these cues, in poor visibility and high sea states, a horizontal reference bar and flood lights illuminating lines on top of the hanger were added. The HRS is primarily used with a recovery assist system that provides a high normal force through an attached cable to assist the pilot in centering the aircraft over the rapid securing device (RSD) by creating an artificial horizon. When landing the pilot refers to intersections of illuminated surfaces and texturing or features in his field of view to set up a stable hover and to control decent rate to the deck. The pilot's scan also includes horizon information to maintain a stable attitude. Thus lights that illuminate the deck must be positioned such that they do not interfere with his visual cueing. In particular, overhead floodlights have to be located and aimed so the pilot does not look directly into the sources. In addition to the pilot, deck personnel need sufficient light to perform their functions safely. Blue deck edge lights are used to outline the deck and overhead and deck surface floods provide illumination for chock and chaining as well as personnel movement, loading, unloading and maintenance.

Lights used for visual cueing

The various flight deck lights, their filters and lamps are listed in Table 1. For a description of the location of each lighting fixture and the required markings, the appropriate ship class guidance plan should be consulted. Following the table is a brief description of each of the lighting fixtures and their intended use. **Figures 1 through 8** include line diagrams of the various fixtures and **figure 9** shows where the lights are mounted on a representative ship.

**TABLE 1
TYPICAL LIGHTING FIXTURES INSTALLED ON US NAVY SHIPS**

QTY	Description	Part Number	National Stock Number
21	Deck Surface, Hanger Wash, RAST Ext. hover line up line Floodlights	NAWC 619403-1 or NAWC 619403-10 (NVD)	5R0-6230-01-031-3260 N/A
2/fixt	Lamp, 28V, 100W, Par 36 *	NAWC 411113-6 P/O 619403-1	9G-6240-00-917-0772
2/fixt	Lamp, 28V, 100W, Par 36 *	NAWC 523654-1 P/O 619403-10	9G-6240-01-418-5021
1/fixt	Red Filter Bracket Assy *	NAWC 517575-1 P/O 619403-1or -10	9G-6210-01-030-9466
1/fixt	Blue Filter Bracket Assy *	NAWC 517575-2 P/O 619403-10	9G-6210-01-382-5298
5	Deck Edge Light	NAWC 609024-1	5R0-6220-00-862-3221
5	Lens, Red	NAWC 318837-2	5RM-6210-00-550-8876
1/fixt	Lamp, 12.5V, 38W *	NAWC MS15564-6 P/O 609024-1	9G-6240-00-295-2729
14	Overhead & FWD Structure Fldlts	NAWC 506829-1	5RM-6210-00-878-1131
14	Lamp, 120V, 300W	MS15535-6 (300PAR56/4WFL)	9G-6240-00-056-0737
14	Filter, Red *	NAWC MS24489-1 P/O 506829-1	9G-6210-00-633-6886
8	Filter, Blue, NVD	NAWC 522936-1	9G-6210-01-389-2498
8	Filter, Amber	MS24489-4	9G-6210-00-990-6010
1	Homing Beacon	NAWC 523290-1	5R0-5220-00-727-0869
1/fixt	Lamp, 150PAR46/1, 32V *	MS15607-2 P/O 523290-1	9G-6240-00-984-3354
7	Line-up Lights, unidirectional	NAWC 508447-1	5R0-6210-00-878-1127
1/fixt	Lamp, 45W quartz, 6.6A *	NAWC 410488-1 P/O 508447	9G-6240-00-083-9092
3	Forward Extended Lineup Lts	NAWC 515364-1	5RM-6210-00-086-6153
1/fixt	Lamp, 45W quartz, 6.6A *	NAWC 410488-1 P/O 515364	9G-6240-00-083-9092
1	Vertical Drop Line Light Bar	NAWC 617682-4	5R0-6250-00-107-8813
4	Lamp, 13V, 18W, PAR 36 Red	NAWC 411113-8, (Com 4414R)	9G-6240-00-946-4809
5	Obstruction & HIFR Lt Fixture	M16377/27-004	9G-6210-00-299-7703
3	Globe, Red (HIFR) **	M16377/27-002	9G-6210-00-914-4152
3	Globe, Amber (HIFR) **	M16377/27-007	9G-6210-01-220-3315
2	Globe, Blue (Obstruction)	NAWC 518340-1	5RM-6210-01-042-8652
5	Lamp, 120V, 50W (HIFR & OBST)	MS15586-2 (Rough Service)	9G-6240-00-143-3070
3	Lamp, 120V, 15W (HIFR) **	15A15FR115V	9G-6240-00-143-3071

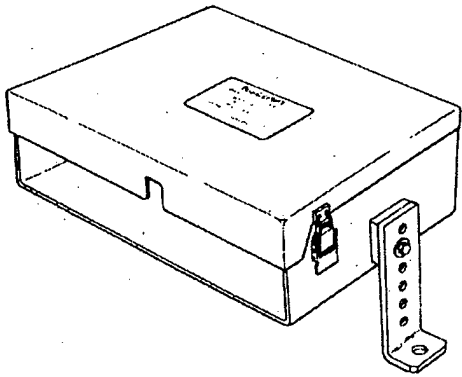
* Provided with applicable fixture

** Hand changed depending upon operational conditions

Hangar Wash Floodlights (9 - NAWC 619403-1 or -10) (Figure 1) These provide floodlighting of the aft face of the hangar/forward structure to give additional surface and structure detail to an approaching pilot. The floodlights illuminate the structure just forward of the operating area providing depth perception and closure rate to the aircraft pilot. Additionally, these illuminate applicable markings on the hangar structure for night visual cues to both the pilots and the flight deck community servicing the aircraft. These floodlights provide either red, white, or NVD blue floodlighting. The floodlight color is accomplished by hand changing the appropriate filter. Red filters are installed for wartime conditions only; white flood lighting (no filter installed on fixture) is used for normal air operations, and NVD blue filters are installed for night vision operations, normal operations, and for wartime conditions. These floodlights are physically NVD compatible by filtering. The Hangar Face floodlights are connected to a dimmer (in the main lighting control panel) and a motor driven variable transformer (separate from the control panel). The intensity of the floodlights is variable from blackout to full.

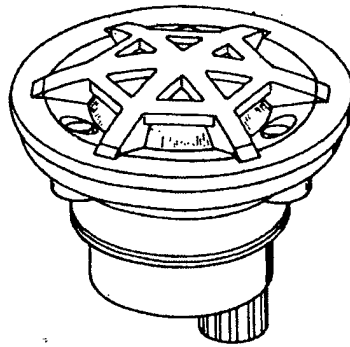
Deck Surface Floodlights (12 - NAWC 619403-1 or -10) (Figure 1) These provide floodlighting of the flight deck peripheral to give additional deck surface detail to an approaching pilot. The floodlights illuminate the flight deck outer edges which the overhead floodlights cannot cover and eliminate irregular shadows on the flight deck. They also provide illumination to the wheel spots and other markings when hovering aircraft block normal lighting sources. This allows Landing Signal Enlisted (LSE) personnel to ascertain a pilot's landing position and then provide him appropriate hand signals for landing adjustments. The floodlights also provide additional lighting for ordinance loading outboard of the aircraft where no other floodlighting is available. These floodlights provide either red, white, or NVD blue floodlighting. The floodlight color is accomplished by hand changing the appropriate filter. Red filters are installed for war time conditions only; white floodlighting (no filter installed on fixture) is used for normal air operations; and NVD blue filters are installed for night vision, normal operations (pilot flying aircraft unaided, no goggles), and for wartime conditions. These floodlights are physically NVD compatible by filtering. The Deck Surface floodlights are connected to a dimmer (in the main lighting control panel) and a motor driven variable transformer (separate from the control panel). The intensity of the floodlights is variable from blackout to full.

Deck Edge Lights (5 - NAWC 609024-1) (Figure 2) These red filtered lights provide an outline of the obstruction-free helicopter deck area and are installed coincident with the aft peripheral marking. These lights are installed in such a manner that the helicopter pilot's view of them is not obstructed during his approach. These lights also provide deck edge definition to the flight deck community while performing their required tasks. Since these lights are not inherently NVD compatible, they must be controlled by light intensity when NVD operations are being performed. The Deck Edge Lights are connected to a dimmer (in the main lighting control panel) and a motor driven variable transformer (separate from the control panel). The intensity of the lights is variable from blackout to full.



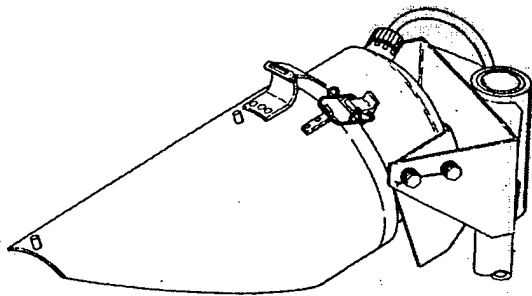
Deck Surface Floodlight
Rast Extended hover line-up line
Hanger Wash Floodlight
NAWCAD 619403-1

Figure 1



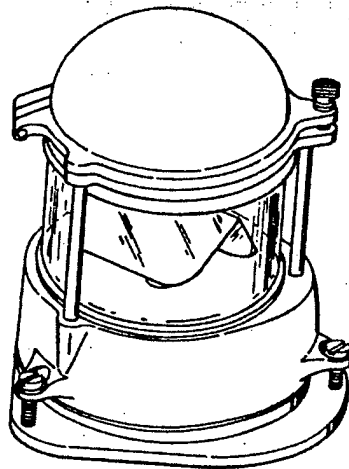
Deck Edge Light
NAWCAD 609024-1

Figure 2



Overhead Flood Light
Forward Structure Floodlight
NAWCAD 506829-1

Figure 3



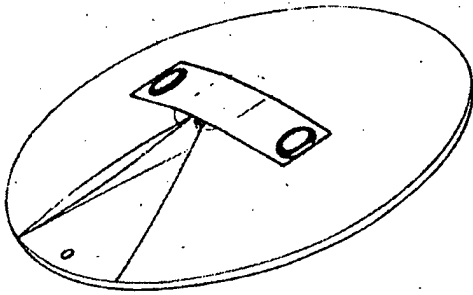
Homing Beacon
NAWCAD 523290-1

Figure 4

Overhead Floodlights (14 - NAWC 506829-1) (Figure 3) These floodlights are used to provide illumination of the helicopter flight deck for support of night operations. The number of overhead floodlights required is dependent on the size of the flight deck area and the mounting location of the lights. The floodlights are mounted above and forward of the flight deck and are oriented to provide uniform illumination of the operating area. These floodlights provide either red, white, yellow, or NVD blue floodlighting. The floodlight color is accomplished by hand changing the appropriate filter. Red filters are installed for wartime conditions only; white floodlighting (no filter installed on fixture) is used for normal air operations; yellow filters are installed also for normal air operations; and NVD blue filters are installed for night vision operations (pilot flying aircraft aided with night vision goggles), normal operations (pilot flying aircraft unaided, no goggles), and for wartime conditions. These floodlights are physically NVD compatible by filtering. Due to the general inaccessibility of these floodlights, hand-changing filters is not always desirable, so there are generally two banks of floodlights installed on the ship. One bank is equipped with yellow filters (normal air operations) and one bank is equipped with NVD blue filters (for NVD and wartime operations). The banks of overhead floodlights are switched and controlled from the main lighting control panel. The overhead floodlights, depending on the number installed, are connected to a dimmer (in the main lighting control panel) and a motor driven variable transformer (separate from the control panel). The intensity of the floodlights is variable from blackout to full.

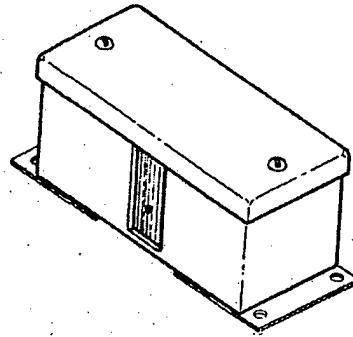
Homing Beacon (1 - NAWC 523290-1) (Figure 4) This is used to give the helicopter pilot a visual guide, flashing white light beam, for homing when he approaches within the optical horizon. The beacon is mounted high on the main mast so that the beam is parallel to the horizon and is visible for at least 330 degrees in azimuth. The fixture has 360-degree coverage but may have 30 degrees blocked by the mast. The beacon provides a minimum effective intensity of 1500 candles over a span of seven degrees in elevation and produces approximately 90 white flashes per minute. The intensity of the Beacon is variable from blackout to full. The homing beacon is not NVD compatible and is turned off during NVD operations.

Line-up Lights (7 - NAWC 508447-1) (Figure 5) These are installed coincident with the line-up line to indicate the line of approach to the helicopter area. These lights are located so that the pilot's view of them is not obstructed during the helicopter's approach. Line-up lights installed for Lamps MK III landing approaches form a line-up path from the aft edge of the flight deck forward as far as feasible, which may pass through the touchdown circle. Spacing between the lights is basically uniform, but may vary slightly to avoid installation problems. To energize the low voltage lamp, a 120v/6.6v step-down transformer is provided for each line-up light assembly. Each of the line-up light circuits is independently wired through switching arrangements connected to a dimmer control in the main lighting control panel and a flash sequencer capable of sequentially strobing the line-up lights. Since these lights are not inherently NVD compatible, they must be controlled by light intensity via a dimmer on the main lighting control panel when NVD operations are being performed. These lights are dimmable from full intensity to a black out condition from the main lighting control panel.



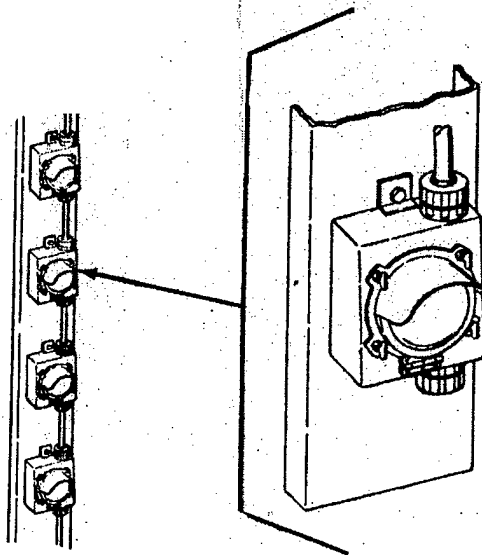
Line-up Light, Uni-Directional
NAWCAD 508447-1

Figure 5



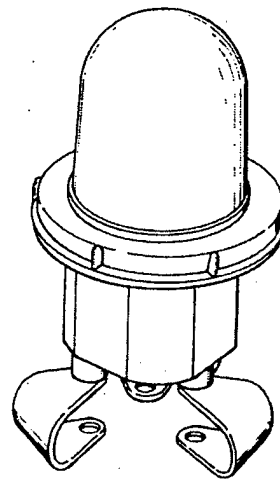
Extended Line-up Light
NAWCAD 515364-1

Figure 6



Vertical Drop Line Bar
NAWCAD 617682-1

Figure 7



Obstruction Light
HIFR Light
Fixture - M16377/27-004
Globe, Red - M16377/27-002
Globe, Amber - M16377/27-007

Figure 8

Extended Line-up Lights - Extended line-up lights are a forward and aft extension of the deck installed line-up or spot pad lights to provide the helicopter pilot with additional line-up and depth perception cues during the approach and touchdown maneuver. Extended line-up lights, installed at the forward end of the landing line-up line, extend up the hanger face. The aft extension of the line-up lights extends vertically downward.

Forward Extended Line-up Lights (3 - NAWC 515364-1) (Figure 6) - The extended line-up is provided by installing three light fixtures vertically up the face of the hangar uniformly from the flight deck.

Vertical Drop Line Light Bar (1- NAWC 617682-4) (Figure 7) - The aft extension of the line-up lights is accomplished by the installation of the vertical drop-line light bar. This bar extends vertically downward at the aft intersection of the line-up line and the ship's hull. The light bar contains four (4) red light fixtures that contrast with the white line-up lights in the deck.

Since these lights are not inherently NVD compatible they must be controlled by light intensity via the dimmer. These lights are dimmable from full intensity to a blackout condition from the main light control panel.

HIFR Lights (Figure 8) - The Hot In-Flight Refueling (HIFR) heading lights give the helicopter pilot a visual indication of the ship's heading and provide a height reference during night in-flight refueling operations. Three HIFR heading lights are installed on the port side of the ship in a line parallel to the ship's centerline. Spacing between lights is 20 feet, beginning outside the rotor clearance distance but not exceeding 240 feet from the HIFR marking on the flight deck and extending forward. All HIFR heading lights are the same distance above the ship's baseline and are simultaneously visible to the helicopter pilot when the aircraft is hovering opposite the HIFR spot (letter "H") at approximately 30 feet to the port side of the ship. HIFR heading lights are installed 20 to 25 feet above the HIFR deck and/or 30 to 40 feet above the ship's waterline, except where visibility of the lights is obscured, in which case their height may be up to 50 feet. A single on/off switch located in the lighting control panel controls all lights. The HIFR heading light is a watertight assembly consisting of a light fixture, red globe and a 120-volt, 50-watt rough service lamp. When yellow lighting is required in lieu of red lighting, the red globe and lamp are replaced with a yellow globe and 15 watt lamp. The HIFR lights are not NVD compatible and are not used during NVD operations.

Obstruction Lights - The obstruction lights outline the structure forward of the helicopter landing area at the highest points on the extreme port and starboard sides. They greatly increase the pilot's ability to judge his position relative to the forward obstruction during approach, takeoff, and transition to forward flight. There are generally two (2) obstruction lights installed on ships with hangars; one outboard of the aft starboard corner and one outboard of the aft port corner. On ships without hangars, the lights are installed at the top and outboard limits of the shipboard structure closest to the operating area. A single on/off switch controls the obstruction lights. The obstruction light is a watertight assembly consisting of a light fixture, blue globe, and a 120-volt, 50-watt rough service lamp. The obstruction lights are not NVD compatible nor are they dimmable and are turned off during NVD operations.

RAST Extended Lineup Line Floodlights (NAWC 619403-1 or -10) (Figure 1) -

These are deck surface floodlight fixtures that are used on top of the hangar to illuminate four (4) RAST extended lineup lines (one set port and one set starboard) for helicopter hover alignment over the RSD (Rapid Securing Device) for RAST haul down. One deck surface floodlight is located between the port set of extended lines and the other is between the starboard extended lines. Each floodlight is located as aft as possible on the hangar top and aimed forward. These floodlights provide either red, white, or NVD blue floodlighting. The floodlight color is accomplished by hand changing the appropriate filter. Red filters are installed for war time conditions only; white floodlighting (no filter installed on fixture) is used for normal air operations; and NVD blue filters are installed for night vision, normal operations (pilot flying aircraft unaided, no goggles), and for wartime conditions. These floodlights are physically NVD compatible by filtering. The RAST Extended Lineup Line floodlights are connected to the hangar wash floodlight dimmer (in the main lighting control panel) and it's associated motor driven variable transformer (separate from the control panel). The intensity of the floodlights is variable from blackout to full.

Deck Status Light - The Deck Status Light System consists of a three-color light fixture and associated panel controls for operating the lights. The deck status light is mounted forward of the helicopter landing area, usually at the aft face of the hangar so that it can be readily seen by the flight deck crew and the helicopter pilot. The system provides visual color signals denoting, to the helicopter pilot and deck crew, the status of the flight deck. When flashing, the lights indicate the following deck conditions:

1. Green filtered lamp - A clear deck situation exists (landing and take-off allowed)
2. Amber filtered lamp - Engage or disengage rotors.
3. Red filtered lamp - A fouled deck situation exists (landing and take-off is prohibited)

The deck status light consists of three lens assemblies (red, amber, and green) and three 28-volt, 150-watt, par 36 lamps mounted within a watertight, bulkhead mounted enclosure. Within the deck status light enclosure is mounted a solid state flasher, control relays, and step-down transformers required for the operation of the lights. Controls for energizing the lights, adjusting the brightness, and selecting the light to be displayed (the circuit precludes energizing more than one light at a time) are located in the helicopter control station (operations request panel), RAST control station (RAST control panel), Combat information Center (CIC response panel) and the Bridge (bridge response panel). The lights are flashed at 90 flashes per minute and are dimmable from blackout to full intensity. The deck status lights are not NVD compatible and are not used during NVD operations.

Stabilized Glide Slope Indicator (SGSI) - The SGSI is an electro-hydraulic optical landing aid designed for use on air capable and amphibious assault ships. The glide slope indicator, which is mounted on a stabilized platform, provides a single bar of light of either green amber or red light. The indicator color indicates to the pilot of the approaching aircraft whether he is above (green), below (red), or on (amber) the correct

glideslope. By varying the aircraft altitude in order to keep the amber light bar visible, the pilot maintains the correct glide path to the ship's landing pad. The bar of light is a virtual image formed by magnifying an illuminated slot and then spreading the image horizontally with a lenticular lens. This bar of light appears to move up and down within the cell face as the observer moves up and down. The color changes as the bar moves behind the color filters located behind the lenticular lens. Thus, a color-mixing zone is created at each color interface that provides trending information to the approaching pilot. In use, the pilot flies the red amber interface that is fixed at three degrees. In order to maintain the correct glide slope with a pitching and rolling deck, the light cell is mounted on an electro-hydraulic stabilized platform. This equipment uses a local gyro for reference and develops electronic error signals that in turn controls hydraulic cylinders that move the platform to maintain a level position to the horizon. For fault detection, the internal gyro is compared against input from the ship's gyro. The SGSI is not NVD compatible and is not utilized during NVD operations.

Vertical Coverage - Green (high) ----- 1.5 degrees
 Yellow ----- 1.0 degrees
 Red (low) ----- 6.5 degrees

Horizontal Coverage - 40 degrees, (+/- 20 degrees)

Display type - Extended source, display must look the same as the US Navy SGSI (PN 618291-3) to an approaching pilot.

Virtual image distance = 57.3 inches

Virtual image source height = 0.183 inches

Angular scale factor 1 inch = 1 degree on the cell face

Optical Aperture - The existing SGSI has an optical aperture of 9-7/16 inches high by 14 inches wide.

Intensity -

Green - On axis 4000 candelas (cd) minimum, 1300 cd min. at 20 degrees off axis

Yellow - On axis 8500 candelas minimum, 2750 cd min. at 20 degrees off axis

Red - On axis 3000 candelas minimum, 1000 cd min. at 20 degrees off axis

Remotely adjustable from 0 to 100 percent of full intensity

Color -

Green - Aviation Green, Category 1, Grade A of Federal STD-3

Yellow - Aviation Yellow, Category 1, Grade A of Federal STD-3

Red - Aviation Red, Category 1, Grade A of Federal STD-3

Glide Slope - Center command path adjustable from 2.0 to 6.0 degrees, 1/4 degree increment minimum. Capable of being aimed +/- 45 degrees from dead aft

Stabilization -

1. Roll - +/- 20 degree, 8-second period

2. Pitch - +/- 6 degree, 5-second period

3. Stabilization accuracy < +/- 6 arc minutes

TABLE 2
Summary of photometric characteristics of Flight Deck Lighting Fixtures

FIXTURE	PART NUMBER	PEAK INTENSITY (Candela's)	AZMUTH COVERAGE (Degrees)	ELEVATION COVERAGE (Degrees)
Deck Surface, Hanger Wash, RAST Ext. hover line up line Floodlights	NAWC 619403-1 or NAWC 619403-10 (NVD)	2800 (white) 800 (red) 1600(cb white) 260 (blue w/cb) ² (cb=cool beam)	+/- 40	+/- 10
Deck Edge Light	NAWC 609024-1	15 (red)	360	+/- 90
Overhead & FWD Structure Fldlts	NAWC 506829-1	9000 (white) 4900 (yellow) 3400 (red) 1350 (NVD blue) 1600 (blue) ¹	+/- 30	+/- 15
Homing Beacon	NAWC 523290-1	14000 (white)	+/- 5	+/- 5
Line-up Lights, unidirectional	NAWC 508447-1	40 (white)	+/- 20	-5/+25
Forward Extended Lineup Lts	NAWC 515364-1	100 (white)	+/- 20	+/- 20
Vertical Drop Line Light Bar	NAWC 617682-4	275 (red)	+/- 25	+/- 12.5
Obstruction & HIFR Lt Fixture	M16377/27-004	45 (white,50W) 2.5 (blue,50W) 6 (yellow,15W) 5 (red,50W)	360	+/- 135
Stabilized Glide Slope Indicator Cell	NAWC 618291-1	4000 (green) 8500 (yellow) 3000 (red)	+/-20	1.5 (green) 1.0 (yellow) 6.5 (red)

Note 1) This combination is shown for reference only and is not used on DDG-51.

Note 2) The blue filter can only be used with a cool beam lamp or the filter will crack.

Modeling and Simulation

To assist in the lighting design, a program was developed to model the ship lighting through simulation. The concept is to measure the existing lights and input their illumination parameters into a program and provide an output of the deck illumination from any viewpoint. The photometric characteristic of each of the fixtures with the appropriate lamps and filters were measured in the NAWCAD Lakehurst Photometric Lab. These computer files were then imported into a graphical package and two and three-dimensional plots of the data were generated. The results are presented in graphical form of light intensity verses angle. A typical example is the intensity distribution for a new fiber optic light fixture. (See **figures 11 and 12**) The results of these photometric measurements were then converted into the Illumination Engineering Society (IES) format and imported into an off the shelf simulation program that calculates the illumination levels on the flight deck. The physical model of the flight deck and the lamp locations were prepared in Auto CAD and imported into the lighting simulation program. Any combinations of lamp intensities, surface reflectance and filter characteristics can be included in the program. The program has been used to determine deck illumination

levels for several ship classes to determine deck illumination levels. See **figure 10** for a typical deck illumination output. However, it was quickly pointed out that the lights are not optimal for the intended use. Tailoring lighting profiles from lamps usually would be cost prohibitive since off the shelf bulbs are inexpensive. However, high efficiency lamps, such as metal halides, and inexpensive plastic fiber optic light pipes are becoming available that would allow cost effective custom illumination designs which would greatly reduce maintenance and provide more even deck illumination

NVD Compatibility: The original light fixtures were not designed to be NVD compatible. In recent years, the use of NVD's has increased and the ship lighting has been modified to make it more compatible with NVD operations. This has meant the inclusion of filters on various deck lights to provide enough lighting for deck personnel to perform their required functions, yet limit the light getting to the goggles. This lighting is a compromise between goggled and non-goggled personnel. Filters were added to limit the amount of light emitted in the more sensitive range of the goggles. The light from the fixtures causes the NVD devices to reduce their available gain but is sufficient to prevent blooming of the NVDs. The light fixtures are also aimed to provide best deck illumination but not allow direct viewing of the lamp by the pilot with NVDs. Only the Deck Surface Floods and the Overhead flood lights with spectrally controlled blue filters are utilized during NVD operations.

US Navy Helipads

A helipad is defined as a prepared area designated for takeoff and landing of helicopters. The Helipad facility consists of the following Visual Marking and Lighting Systems:

1. Helipad Markings (see **figures 14 & 15**)
2. Perimeter Lights (see **figure 13**)
3. Approach Direction Lights (**optional**) (see **figure 13**)
4. Landing Direction Lights (**conditional**) (see **figure 13**)
5. Helipad Beacon (**special**)
6. Helipad Floodlights (**special**)

Perimeter Lights: These lights define the boundaries of the helipad for helicopter operations at night. The perimeter lights provide visual cues to pilots for identifying the helipad area during take-off and landing operations. The helipad perimeter lights provide the required visual guidance at night for Visual Flight Rules (VFR) operations without the use of other related facilities (landing and approach direction lights).

The helipad perimeter lights consist of a row of lights along or near the four sides of a Helipad as shown in **figure 14**. These lights are usually the elevated type except semiflush lights may be used in areas where helicopters with wheels may be taxiing between the helipad and the parking or service areas. Both types of fixtures emit omnidirectional yellow light.

The fixtures are located in a straight line ± 6 inches along each edge of the helipad and each line of lights are equidistant from the edge of the pad parallel to the extended centerline of the helipad. The lights may be located as far off the edge as 10 feet if necessary.

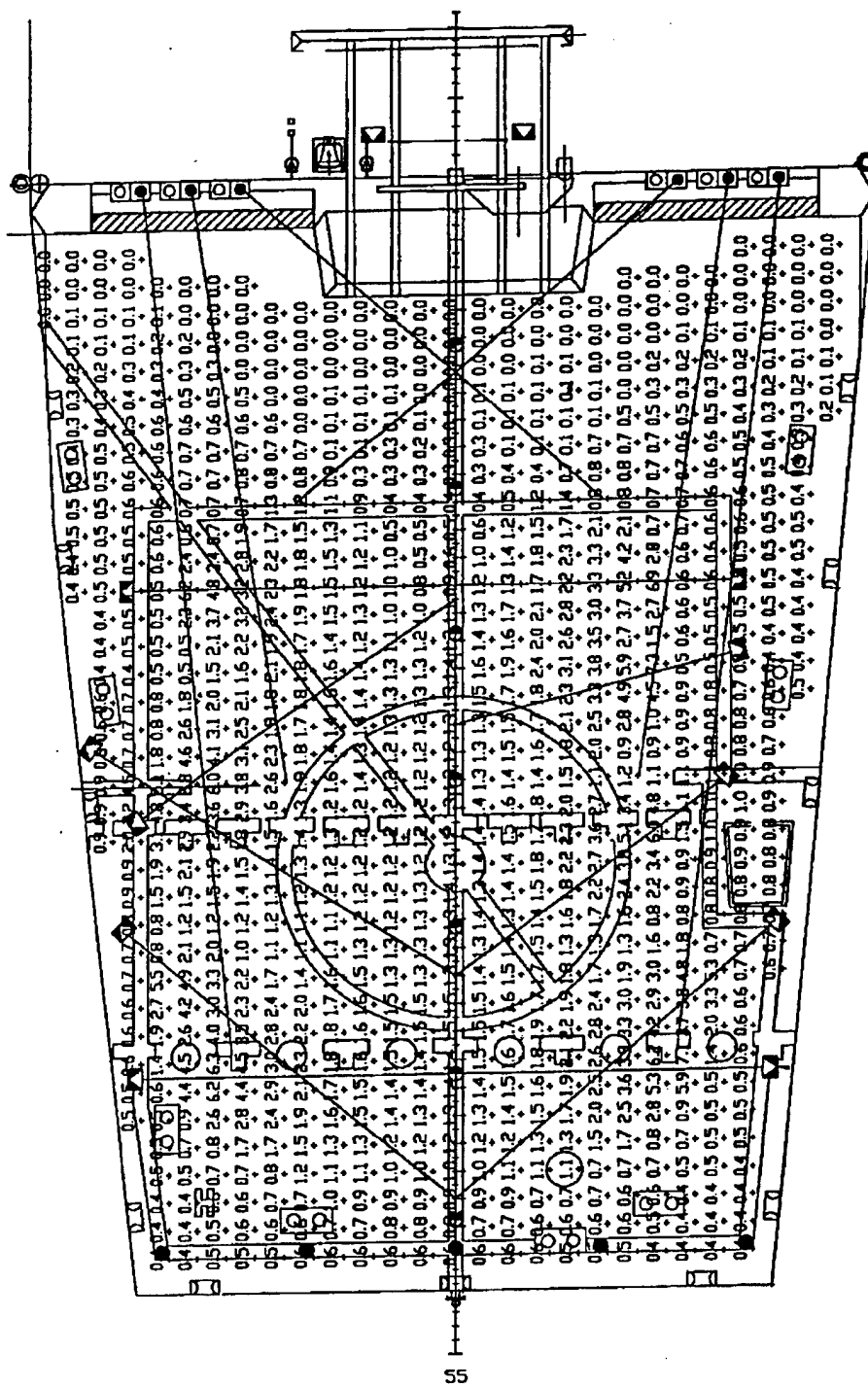


Figure 10 - Calculated Horizontal Intensity Distribution at Deck Level (footcandles)

Fiber Optic Centerline Light

□ Candela vs Horizontal vs Vertical Coverage

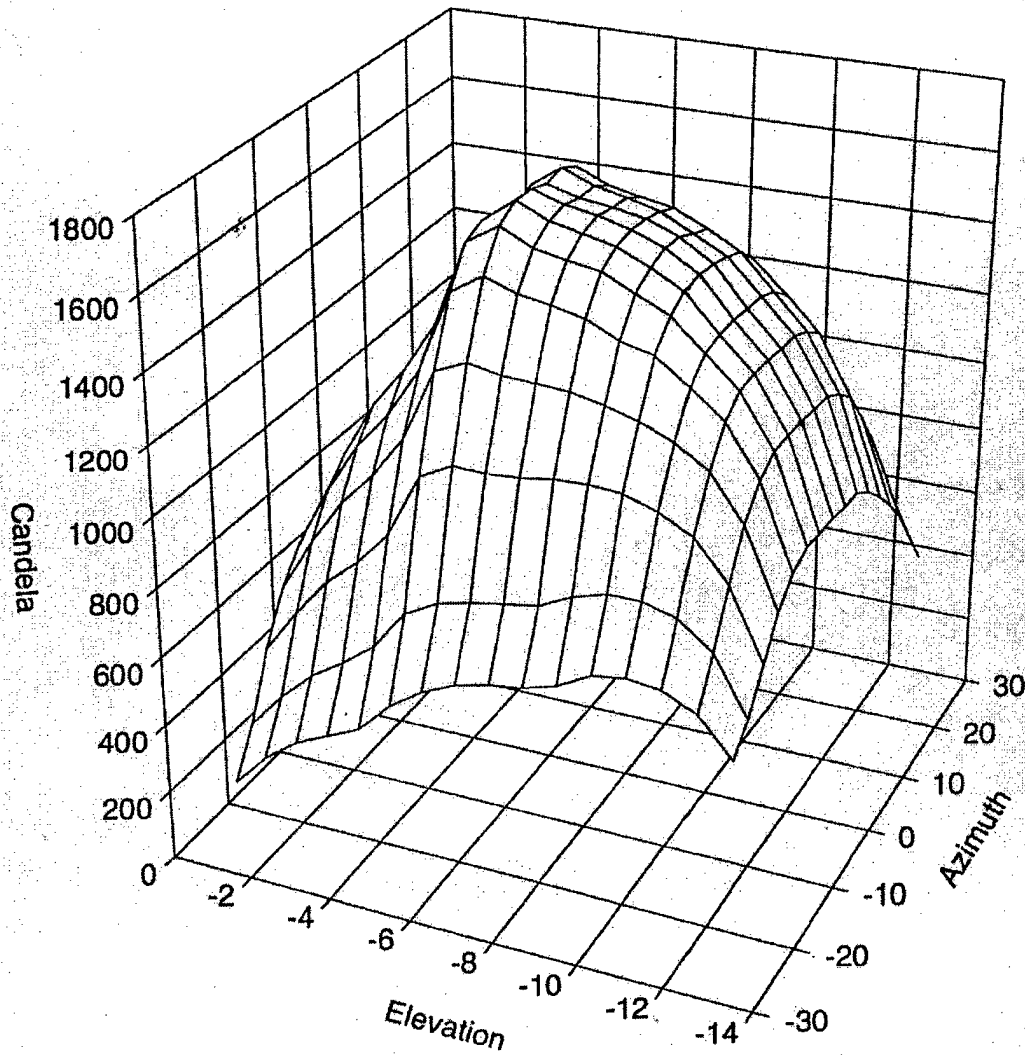


Figure 11 – Fiber Optic Center Line Light Intensity Distribution

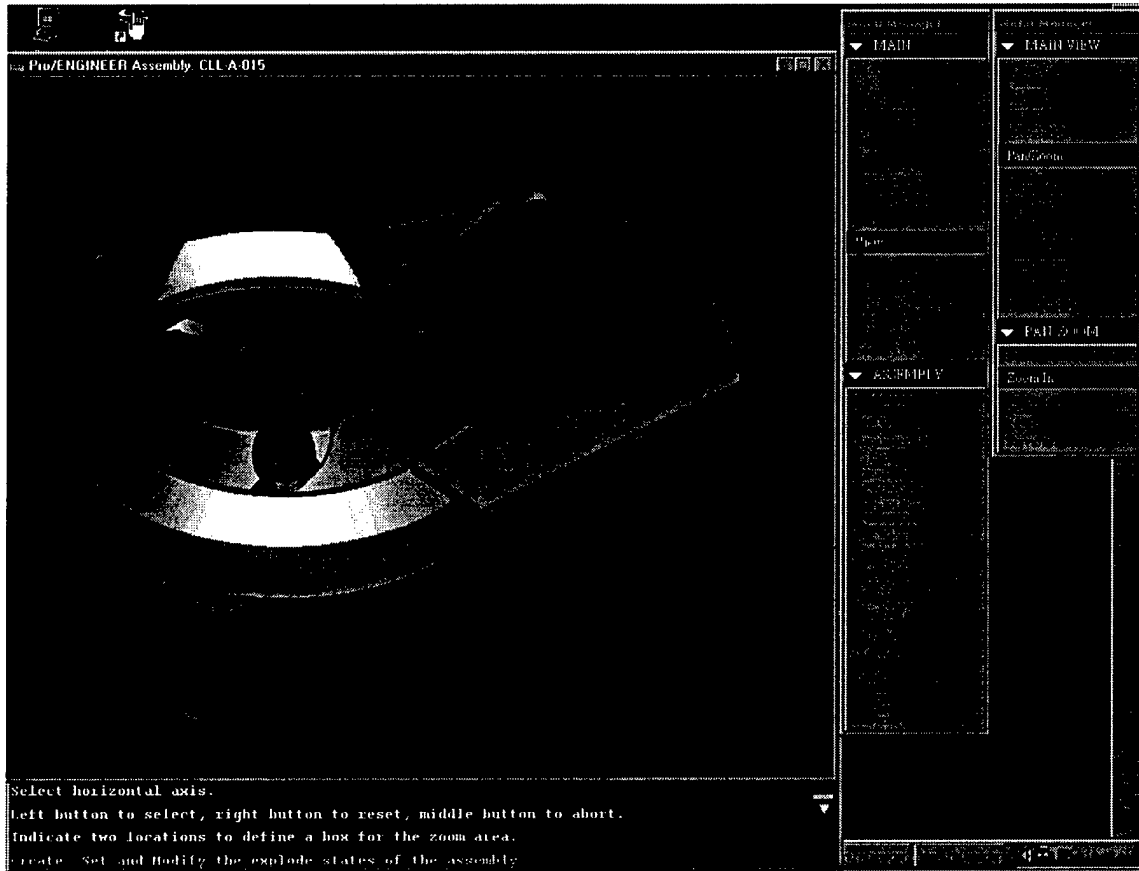


Figure 12 - Solid Model of Fiber Optic Centerline Light

TABLE 3 NVD CAPABILITY COMPARISON

DESCRIPTION	RADAR CROSS SECTION	NVD CAPABLE	MAINTENANCE	STATUS - NEW TECHNOLOGY REPLACEMENT
Deck Surface Flood	Large	yes, with filters	medium	
Deck Edge Light	Small	no (1)	high	
Overhead Floodlight	Large	yes, with filters	medium	
Homing Beacon	Large	no (1)	low	
Line-up Light	Very Small	no (1)	high	Underway
Ext. Line-up Light	Small	no (1)	low	
Vertical Drop Line Bar	Large	no (1)	medium	
Obstruction Light	Medium	no (1)	low	

Note 1) These lights are not directly NVD compatible but can be utilized with NVDs if they are sufficiently dimmed. The present dimmer does not allow for controlled dimming to these low levels. These lights have not been specified as required for NVD operations.

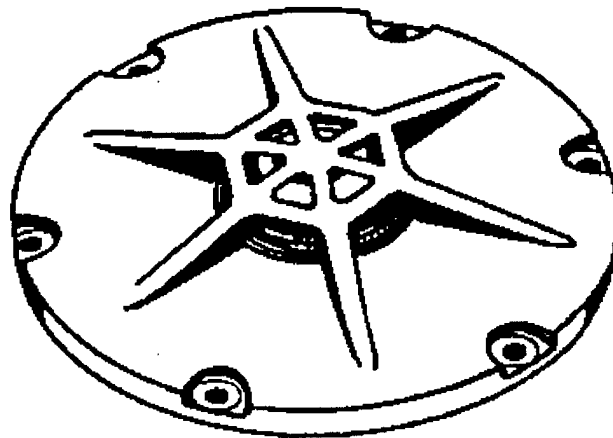
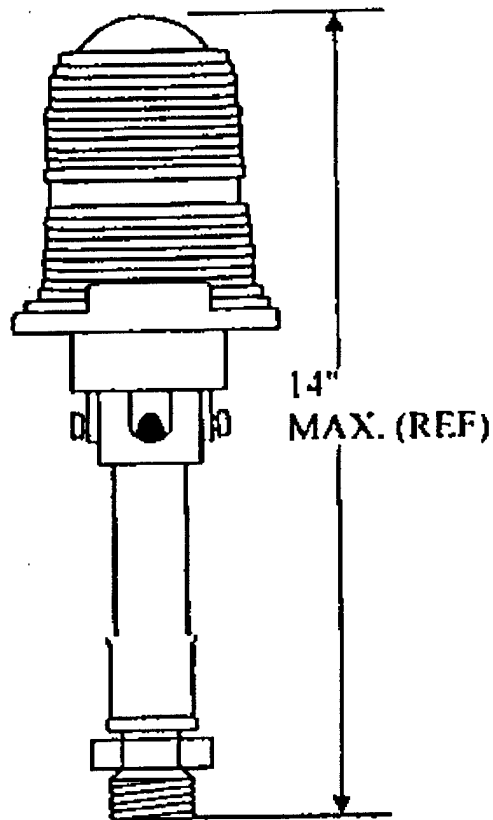
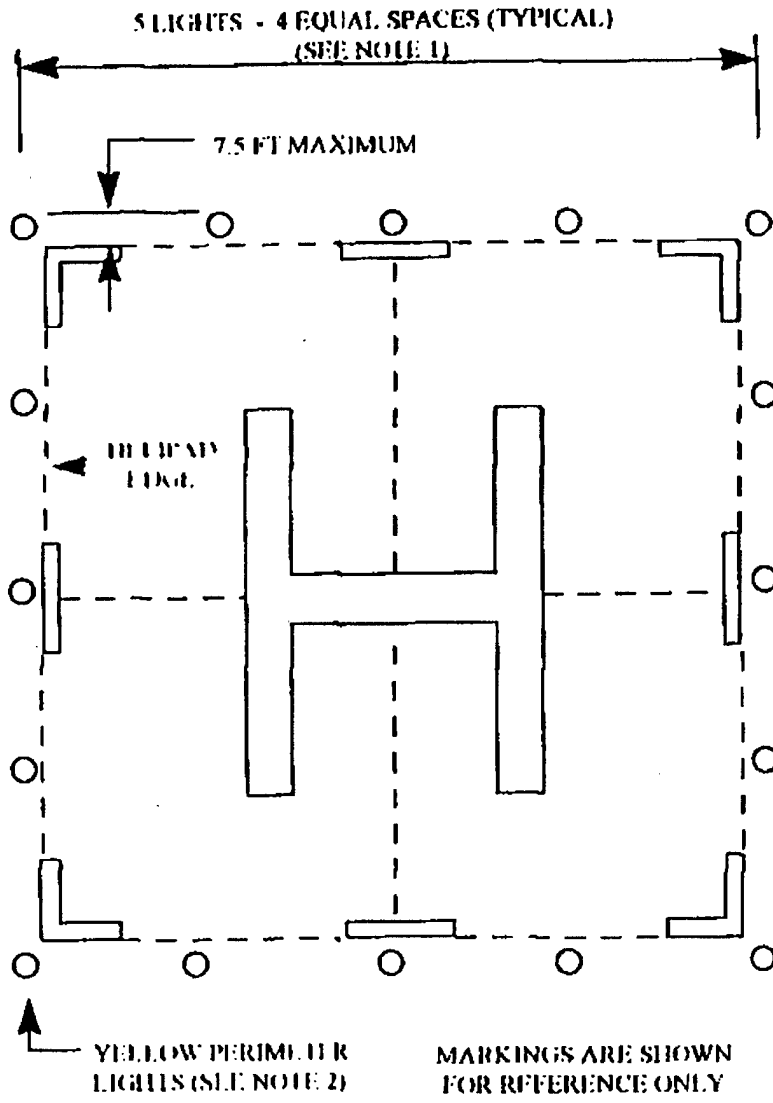


Figure 13 – Typical elevated perimeter/approach/landing direction light (type L-861) & Semiflush Helipad perimeter/approach/landing direction light (type L-852E)



NOTE 1: ALL FIXTURES SHALL BE THE SAME DISTANCE FROM THE HELIPAD EDGES, A FIXTURE SHALL BE LOCATED AT OR NEAR EACH CORNER. THREE ADDITIONAL FIXTURES SHALL BE EQUALLY SPACED BETWEEN THE CORNER LIGHTS ALONG EACH EDGE.

NOTE 2: THE COLOR EMITTED BY THE PERIMETER LIGHTS SHALL BE AVIATION YELLOW.

Figure 14 – Typical Layout of Helipad Perimeter Lights

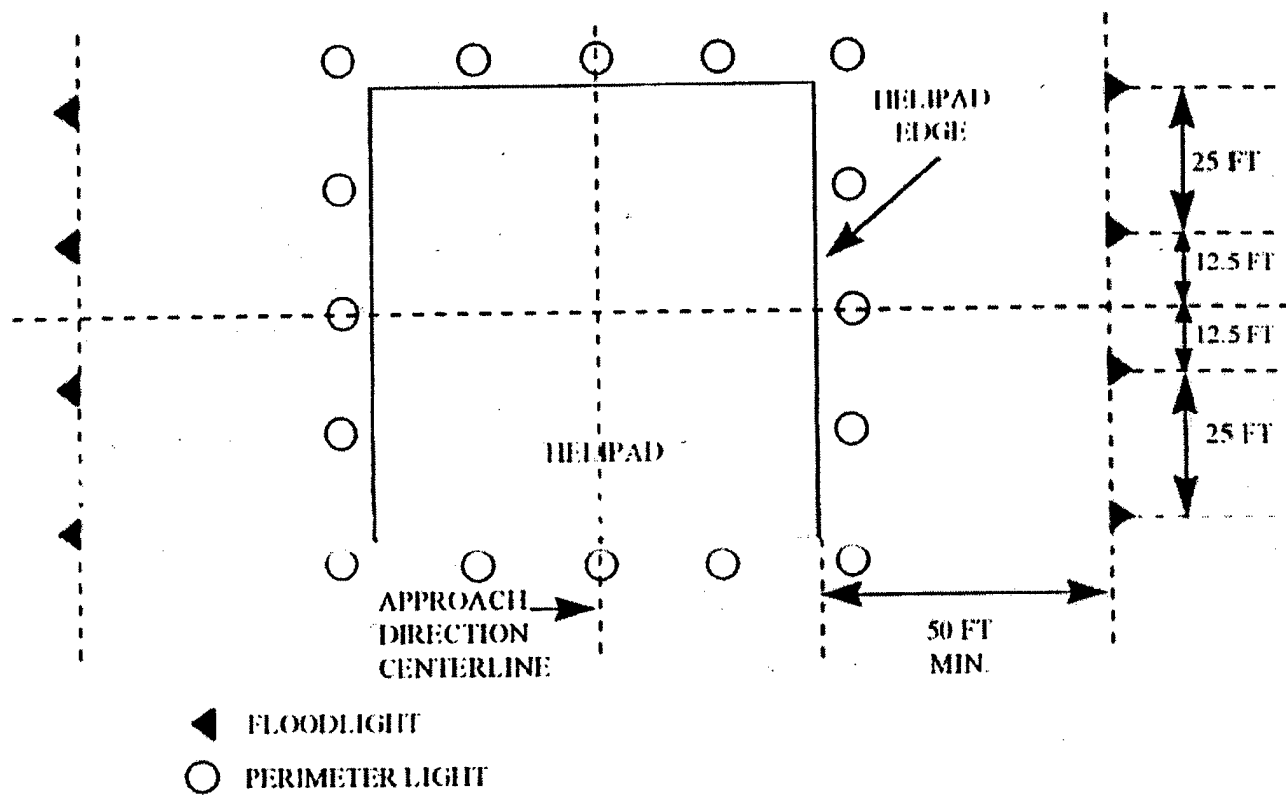


Figure 16 – Typical layout of Helipad Floodlights

Approach & Landing Direction Lights: These lights indicate the preferred direction to the helipad for helicopter approach and landing operations at night. The approach lights provide visual cues to the helicopter pilots for directional guidance along the designated approach path and landing direction to the helipad for landings. They are installed when it has been determined that the need to indicate a landing direction and approach is required. The helipad approach light system consists of a row of landing and approach direction lights installed as shown in **Figure 15**. These lights are usually the elevated type, except semiflush lights may be used in areas where helicopters with wheels may be taxing on the surface. The light emits an omni-directional beam. The following describes each system arrangement:

1. Landing Direction Lights – consists of a single row of six yellow lights outward from the helipad perimeter lights centered on the helipad in the established direction of the approach.
2. Approach Direction Lights – consists of two parallel rows of lights extending outward from the last landing direction light. Each row has five pairs of white lights.

Heliport Beacon: This visual aid is optional and not required for basic helipad installations. They are used for special operations or location requirements and require justification/permission to be installed. The heliport beacon provides identification for a lighted helipad or heliport when it is not closely associated with a lighted airfield. The heliport beacon shall alternately flash the colors white, green, and yellow. The white flash should be two closely spaced peaks. The flash rate shall be between 10 and 15 flash sequences per minute with the time between adjacent colors one third of the sequenced time. These beacons are usually the rotating type.

The beacon shall not be installed within one mile of an existing airfield beacon or useable runway. The heliport beacon shall be located not more than 1500 feet from the helipad or one of several pads. The beacon should be visible from any direction and should not be less than 50 feet above the ground level and the surface of the helipad. The axis of rotation of the beacon shall be vertical and the axis of the light beams shall be aimed not less than 5 degrees above the horizontal, with any light below the horizontal more than 1000 candelas. Light shields may be used to reduce intensity below the horizontal.

Helipad Floodlights: This visual aid is optional and not required for basic helipad installations. They are used for special operations or location requirements and require justification/permission to be installed. Helipad floodlights shall be used to illuminate the helipad surface at night to provide visual cues to the pilot for determining his height above the surface during the touchdown phase of his approach. The floodlights shall provide a uniform illumination of the helipad surface. When installed, the fixtures shall not permit any direct light to be visible above the horizontal. The fixture shall emit a narrow fan-shaped illuminating beam for which the axis of the beam shall be adjustable in elevation between 1 degree up and 5 degrees down from the horizontal.

The location of the helipad floodlights shall be as shown in **figure 16**. The floodlights shall be located not less than 50 feet from the edges on opposite sides of the helipad, parallel to and symmetrical about the centerline of the designated approach or approach

most frequently used for night landings. The number of lights and the spacing between lights may vary with the size of the helipad. The height of the fixtures shall not be more than 48 inches above the helipad surface. The fixtures shall be installed on a stable concrete foundation and mounted on frangible couplings. The axis of the beams of light shall be adjusted in azimuth and elevation to obtain uniform illumination of the helipad surface without having any direct light visible above the horizontal.

New Technology

A replacement for the centerline lights has been designed utilizing fiber optics to remote the light source to create a more robust design to withstand the harsh flight deck environment. This fixture allows lamps to be changed below decks and removes the lamp from the high shock environment thus greatly extending its life. In addition, the light pattern was optimized for the centerline requirement putting more light out at low angle to the pilot. See **figure 11** for the intensity distribution of the fiber optic light fixture and **figure 12** for the CAD solid model. While new technologies exist to replace the other lighting fixtures to overcome their shortcomings, no work is presently underway. However, high efficiency lamps, such as metal halides, and inexpensive plastic fiber optic light pipes are available that would allow cost effective custom illumination designs which would greatly reduce maintenance and provide more even deck illumination. Emerging technologies such as non-imaging concentrators and beam expanders also need to be examined as they have the potential to be used at the end of a fiber delivery system and provide customized lighting patterns that are secure and have little or no radar cross section as they can be made entirely of plastic. Other promising sources include LED point sources and arrays, electro-luminescent (EL) panels, encapsulated LED line lights, edge emitting fibers and arc sources.

Conclusions

This paper has presented a detailed description of lights used on navy helicopter landing platforms to provide visual cues for approach, landing, hover and deck operations. Visual cueing is a critical part of the approach and landing process and must provide clear unambiguous information on long range glide slope, lineup and closure rate to an approaching aircraft. Over the landing area, the lighting must be sufficient to allow the pilot to judge distance to obstacles and determine landing clearance and decent rate. In addition, the lighting must provide sufficient levels of illumination to allow deck personnel to perform their tasks safely and efficiently without interfering with the pilot's visual cues. The minimum lighting required depends greatly on the environment. No lighting is required for day VFR. In a clear night environment with a good horizon, a minimum of a centerline approach light and an outline of the deck would be sufficient. As conditions degrade and the task is made more difficult, as in the case of shipboard landings, the number or quality of cues must be improved to reduce pilot workload and increase safety. The lighting systems on US navy ships have evolved over a period of greater than thirty years to the system described above and is continuing to change following ever changing requirements.

Portable Lighting for US Marine Corps Expeditionary Airfields

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Support of Marine Corps aviation presents unique challenges. Unlike the Army and Air Force, whose primary aircraft are rotary-wing and fixed-wing, respectively, Marine Aviation is a composite mix of all aircraft types, including tilt-rotor and Vertical Takeoff and Landing (VTOL) aircraft. Therefore, the Expeditionary Airfield (EAF) concept must support operational scenarios as remote as grass landing strips, or as elaborate as an 8000-foot AM2 Mat runway with arresting gear, taxiways and other aircraft support areas. Each scenario has the potential for creating unique lighting requirements. The ultimate goal of an Expeditionary Airfield Lighting System is to accommodate the largest number of anticipated situations with the least amount of equipment. This paper will present the approaches taken by the EAF program to provide adequate lighting and marking for vertical flight operations, and provide a brief overview of the latest portable lighting equipment being used by the Marine Corps.

Vertical Takeoff and Landing Operations

One of the most varied aspects of the EAF program is the support of VTOL operations. The most common configuration employed by the Marines for VTOL support is a 96-ft by 96-ft expanse. Eight lights, spaced evenly about the perimeter of the VTOL expanse, are sufficient to support rotary-wing operations. The cockpit visibility limitations of the AV-8B Harrier necessitate the installation of additional hover reference cues. Presently, two separated cues are positioned inline, off each corner of the VTOL pad, forming a diagonal reference visible from all approach directions. International orange markers, similar to highway safety barrels, are deployed for daytime visibility, and a variety of portable lighting fixtures may be used at night. Although markings are not required at any EAF site, VTOL expanses are typically marked with broken perimeter lines and a centered 40-ft by 28-ft "H".

The inventory of US Marine Corps VTOL aircraft has for the most part remained unchanged since the 1970's. With the approaching introduction of the V-22 Osprey and the development of the Joint Strike Fighter, the EAF Team is committed to continually evolving its equipment and methodologies in order to provide the Fleet Marine Force with the most flexible, practical and advanced systems available.

Portable EAF Airfield Lighting Systems

Expeditionary Hardwire Lighting System

This is the oldest and most widely deployed system in the EAF inventory. Developed in the 1960's, and similar to civil airfield lighting systems employing constant current regulators and elaborate fixtures, this system has inherent limitations in the support of the

current EAF mission. The need to support three tiers of operations within 72 hours has led to the procurement of more expeditious systems utilizing newer technologies.

Expeditionary Lighting System (ELS)

A derivative of the Minimum Operating Strip Lighting Kit (MOSKIT) developed and first deployed by the Royal Air Force, ELS is a combination of the MOSKIT and the Supplemental Airfield Lighting Kit (SALKIT) trailers. The MOSKIT is a self-sufficient trailer providing runway edge lighting, runway approach lighting and glideslope reference. The SALKIT provides additional fixtures for taxiway lighting or supplemental runway lighting. Runway edge lighting is provided by the Omni-directional Runway Edge Light (OREL) which may be switched between one visual and two Night Vision Device (NVD) settings. The NVD settings are achieved by precisely under-powering the halogen lamp to produce a low level, near-infrared visual output. Inter-changeable lenses are provided to configure an OREL for runway (clear), taxiway (blue), threshold (red/green) or obstruction (red) lighting. Glideslope reference is provided by two separate Precision Approach Path Indicator (PAPI) systems. The tactical unit (TAC-PAPI) is identical to a FAA Type L-881 2-box PAPI, producing a "white-over-red" visual display. The NVD friendly PAPI (NVD-PAPI) is a 4-box system which uses filtered infrared light to produce a "steady-over-flashing" output to mimic its visual counterpart. The Uni-directional Approach Light (UAL) is provided for runway approach reference. The UAL is a high-intensity white light source, with no NVD setting. The UAL and TAC-PAPI are powered by one of two 2kW-diesel generators resident within the MOSKIT trailer. Rechargeable batteries power the OREL and-NVD-PAPI fixtures. All ELS fixtures may be controlled either manually or via a wireless remote control.

MOSKIT was first introduced to the US Marine Corps in 1992, and the first ELS successfully completed operational testing in March 1997. A production contract was awarded in March 1998.

Field Marker Lights (FML) and Infrared Marker Lights (IML)

Developed by the US Air Force and introduced into the EAF inventory in July 1996, the FML is a battery-powered lighting fixture with interchangeable plastic lenses. Clear, red, blue, green, yellow and infrared (IR) lenses are available to support virtually any airfield lighting requirement. The IR lenses are used exclusively to support NVD-aided operations. Control of the FML may be either manual, or through a separate wireless remote module.

The IML kit was developed by the Army in support of remote helicopter landing sites. Designed only to operate in the IR spectrum, the IML is an IR Light Emitting Diode (LED) powered by a standard 9-volt battery and is deployed attached to a mounting stake. Steady and flashing variants are now fielded by the US Marine Corps.

All FML and IML equipment is designed for tactical operations of short duration requiring minimal personnel support, and both have been used successfully to recover US Marine Corps helicopters and Harriers in both remote and urban environments.

Retroreflective Markers For Runway and Heliport Applications

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Technical Evaluation Engineering Division
Transport CANADA

1.0 Introduction

The current Canadian Air Regulations (CARs), applicable to aerodromes *, states in **Section 301.07 Lighting:**

*Aerodromes not requiring certification; not located within built-up areas of a city or town; or not serving a scheduled passenger service; or where it has been considered that certification would be in the public interest.

(1) Subject to subsection (2), where a runway is used at night, the operator of the aerodrome shall indicate each side of the runway along its length with a line of fixed white lights that is visible in all directions from an aircraft in flight at a distance of not less than two nautical miles.

(2) Where it is not practical to provide at an aerodrome the fixed white lights referred to in subsection (1) for reasons such as the lack of an available electrical power source or insufficient air traffic, the operator of the aerodrome may, if a fixed white light is displayed at each end of the runway to indicate runway alignment, use white retroreflective markers that are capable of reflecting aircraft lights and that are visible at a distance of not less than two nautical miles from an aircraft in flight that is aligned with the centre line of the runway.

(9) Subject to subsection (10), where a heliport is used at night for the take-off or landing of helicopters, the operator of the heliport shall illuminate the entire take-off and landing area with floodlights or

(a) where the take-off and landing area is rectangular, shall indicate the boundary with no fewer than eight fixed yellow lights, including one light at each corner, placed so that adjacent lights are not more than 13 m (42.5 feet) apart; or

(b) where the take-off and landing area is circular, shall indicate the boundary with no fewer than five fixed yellow lights placed so that adjacent lights are not more than 13 m (42.5 feet) apart.

(10) Where it is not practical to provide at a heliport the fixed yellow lights referred to in subsection (9) for reasons such as lack of an available electrical power source or insufficient air traffic, the operator of the heliport may use yellow retroreflective markers that are capable of reflecting aircraft lights and

that are visible at a distance of not less than two nautical miles from an aircraft in flight that is aligned with the approach path, if

(a) a light source is provided to show the location of the heliport; or

(b) where there is only one path for approach and departure, two lights are used to show the approach orientation.

The above regulation simply states an allowance for use of these markers as an alternative to conventional lighting, at non-certified aerodromes, without further elaboration as to the conditions of usage, such as a minima for flight (atmospheric) visibility. The only quantitative requirement is the acquisition distance of 3.7 km (2 nautical miles) which is applicable to both retroreflective markers and conventional low intensity perimeter lights.

In 1997 a report, submitted to Ottawa Headquarters, identified concerns for the use of retroreflective markers at two sites in Quebec Region; Chisasibi and Ile d'Entrée. These concerns arose out of an apparent lack of performance of markers at Chisasibi after about 2 years of installed service. The exact cause of the lack of performance is unknown although it is suspected that there may have been some chemical process that clouded the normally clear matrix of the reflective material. A detailed review was not possible, since the site had replaced the markers with conventional lighting, and the former were disposed of. Only a single marker could be found at site. One side of this marker was clouded, while the other was unaffected. There was no physical damage as might suggest abrasion. Since only one side was affected, it is apparent that whatever occurred it was of a directional nature. Albeit since the marker was not obtained directly from the runway, it is unknown as to whether the affect was limited to a particular position of the marker within the system. What was seen as of primary importance in this incident was not specifically that the markers had failed, nor the specific manner of failure, but rather that this had occurred within a relatively short time period. Because of this concern, a study of retroreflective markers was subsequently initiated and this evolved into a complete review of retroreflective marker performance in general.

It is to be noted that the prevailing paradigm for aeronautic ground lighting design has been to treat the light(s) or lighting as an enclosed visual aid system without regard for the type of aircraft. Even in cases where the light source is separate from the visual aid (e.g. externally illuminated signs) the source can be "fixed" and fully specified. For runway lighting the beam characteristic is defined by the runway dimensions and for approach lighting the objective is to produce a signal that adequately fills the flight path envelope within which there is a high probability of aircraft location.

Retroreflective markers, on the other hand, must be treated as an extended system which includes not only the marker on the ground, but also the aircraft from which illumination is actually obtained. This presents a certain difficulty, since the light on the aircraft can vary significantly in characteristics and is not spatially "fixed" as to have a design predictability.

Because the performance of retroreflective markers depends upon the components of the extended system, the scope of this report is an exploration of "factors" that may cause a reduction of the overall performance. Reference is made to the results of flight trials for a marker installation at the Alaska Malemute Drop Zone which took place in 1997, and this is taken as the base capability of markers with respect to the required acquisition distance of 3.7 km (2 nautical miles). The premise is that, if a factor can reduce marker performance, then this will result in some shorter distance of acquisition than realised in the Alaska trials. Since the results of the Alaska trials indicate marginal capability, under ideal conditions, the suitability of markers under non-ideal conditions is questionable.

It must be pointed out that the Alaska trials were conducted with a specific product and, to an extent, it is arguable that one should not make a general conclusion on this basis. However, it is also arguable that the product used for the trials is the best available on the market at present and therefore represents a benchmark from which conclusions of a general nature may be taken.

2.0 The Alaska Malemute Trial

In late October 1997, a retroreflective marker system was installed in a runway pattern at the Fort Richardson Malemute Drop Zone. The system consisted of a set of three sequenced flashing strobes at each end of the runway to provide alignment indication, two bars, each of three green/red markers of truncated pyramid shape to form the threshold indication, and a series of rectangular white markers to indicate the runway edges.

The threshold markers present a flat surface of about 3 ft² and the runway edge markers present a flat surface of about 2 ft². A form of passive reflective visual approach slope indicator (PASI) was also installed at one end. However, since approach slope indicators are not mentioned in the regulation, as a requirement for installed systems, its performance is not evaluated herein. Because the PASI has a much larger surface area, in comparison to the runway edge markers, care must be taken to ascertain whether the reported distance of acquisition is in relation to the PASI or to the runway edge markers.

The runway is located in a remote area and at night there is no background ambient lighting. A number of flights took place under conditions of unlimited visibility and the markers had been newly set so as to be without surface contamination.

The results of the trial, obtained from pilot assessment sheets and from discussion, are summarized in **Table 1** below. It is presumed that all values of reported acquisition are in units of nautical miles, although this was not indicated in most of the pilot comments. The text contained in the "Notation" column is a combination of pilot comments (in quotations) and pertinent information.

Table 1: Results of Alaska Malemute Trial

Company/Aircraft	Height	Acquisition	Notation
Security Aviation C-310R	2000 ft	2.5 miles (dimly) 2 miles (fully)	
FAA KingAir N15		1.5 to 2 miles *	"complete familiarization is required" * distance taken for comments on video
CAP C-206		2.5 to 3.0 miles (dimly)	100 watt landing light
Pen Air C-441	1200 ft	2 miles	"less if you turn final at lower altitude, approx 1 to 1 ½ miles" Landing light, #4553, 250 watts, 300,000 cd, 11 degrees horizontal and 12 degrees vertical
ERA Aviation DHV-6	500 ft	1.5 to 2 miles	"twilight, 250 watt lamps, one lamp burnt out"
FAA, Flight Stds PA-28-151	1100 ft	2 miles for PASI	closer for edge markers
FAA C-182	1000 & 700 ft	2.3 Nm	
FAA, Flight Stds DHC-6	1000 ft	2 miles	
Polaris Squadron DHC-2	400 ft	1.5 miles	"reflectors a bit dimmer for landing lights in the pulsed mode"
Birchwood CAP C-172		0.75 miles (for PASI)	wing mounted lights, PASI seen at 0.75 miles, runway markers at lesser distance
Birchwood CAP C-206	800 ft	1 mile	
HE Accesscom C-35 Beechcraft Bonanza	1500 ft	1.5 miles	
AAL-FSDO-03 C-150	500 to 700 ft	1 to 1.5 miles	PASI at 800 to 1000ft and 2 miles runway markers at 500 to 700ft and 1 to 1.5miles 100 watt lamps

There is a substantial variation in the reported acquisition distances and it is difficult to interpret the basis of this variation. In some cases it may be attributed to the distance of the light source from pilot eye, and in one instance to the loss of a wing light, and in another due to the use of a pulsed mode for the landing lights. There is also the aspect of the manner of approach that is not entirely clear from the information provided in the pilot evaluation sheet. That is, whether the observed acquisition distance is that for which markers first come into view for straight in approaches, or when they are visible simply because of being illuminated by aircraft lights upon turn from base leg to final within the traffic circuit.

A certain conclusion, for which there is some comfort in validity, can however be drawn from the flight inspection done by the FAA in a KingAir N15, since this was accompanied by a video taken during each approach. If one accepts the lower value (1.5 miles) of distance as being due to an unfamiliarity with the system (the FAA evaluation includes a comment that complete familiarization is required and training should be mandatory) then the acquisition might be judged at the higher value of 2 miles. This, however, is at the limit of the requirement in regulations. Thus, at best, one can say that the capability of the markers is marginal to the requirement.

3.0 Factors Affecting Performance

Given the results of the Malemute trial that the performance of markers is marginal to the required acquisition distance, the following factors are of importance. For purpose of classification, the factors are segregated with respect to "areas", as shown in **Figure 1**. That is:

(1) of the aircraft:

- the type of light source (lamp)
- the orientation of the light source
- the location of the light source with respect to distance from the pilot eye

(2) of the atmospheric condition

- flight visibility

(3) of the marker

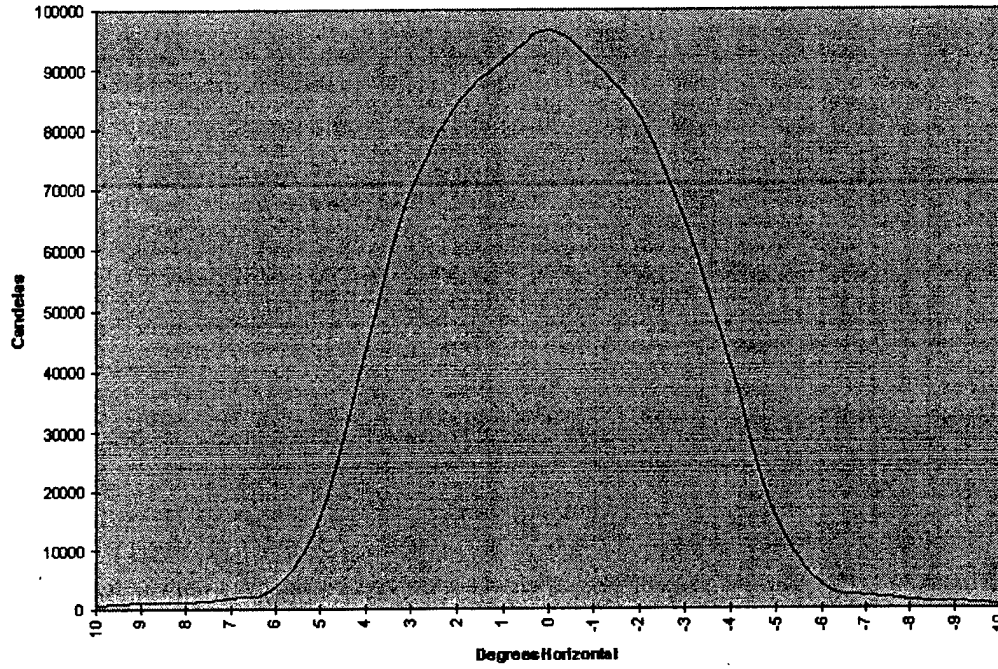
- type of reflective material
- shape and size of marker
- environmental affects obscuring of the reflective material such as frost, dew, snow, dirt, etc.
- physical deterioration of the reflective material such as by chemical action or blown gravel and sand.

3.1 Aircraft Area

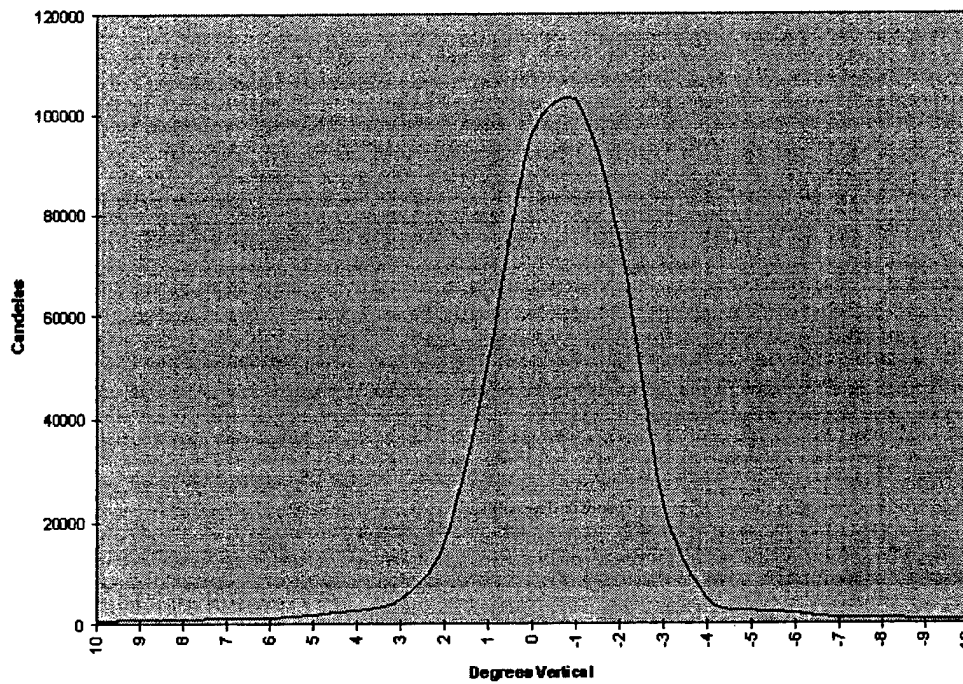
3.1.1 Type of Light Source. The retroreflective marker is a passive device and depends upon the light source provided on the aircraft. A lamp that is commonly used for general aviation aircraft and smaller commercial helicopters is the 100 watt #4509 lamp having a published peak intensity of 110,000 candelas and a beam spread of ± 5.5 degrees (total 11) horizontal and ± 3 degrees (total 6) vertical. Notation is made in the Malemute trials to the use of a 100-watt lamp for the Cessna C-206 and C-150. It is known that this lamp is used as well for the C-182, C-172 and C-150. It is also used for smaller commercial helicopters such as the Robinson R22 and R44. Thus the #4509 lamp might justifiably be considered as the "critical" lamp, simply because of its common usage.

The characteristics of the #4509 lamp are shown in the figures below for horizontal (zero degrees vertical) and vertical (zero degrees horizontal) cuts in the photometric distribution. The diagrams were produced from laboratory measured values without correction on the basis of lumen output. Also the vertical cut appears to have a higher peak than the horizontal, but this is due to the fact that the horizontal cut is along the zero degree vertical plan, and the peak for the measured lamp is offset at about 1 degree below this plane.

(a) Horizontal Distribution



(a) Vertical Distribution



The above diagrams are provided to illustrate the form of the beam and leads into a discussion on the difference in the manner of specification between that contained in the lighting industry's lamp catalogues and that in the ICAO Annex 14.

In the case of the industry specification, the beam spread is referenced to the peak and its range is determined by the point at which the intensity falls to one tenth of the peak. Thus the specification is simply a representation of the performance of available lamps.

In the case of aeronautical ground lights and Annex 14, there is a particular process by which the specification of photometric performance is determined. Rather than to relate the specification to what may be available, the characteristics (e.g. the isocandela diagram) are constructed from first principles. Beam spread is first selected on the basis of spatial geometry, and thereafter a value of intensity is determined for range and is specified for the spread of the main beam in terms of average intensity. Within this beam, the individual intensities are to not fall to less than half the average, nor rise (peak value) to more than 150 percent of the average. For example, a runway edge light has a required average intensity of 10,000 candela, with intensities within this main beam to be not less than half the average (5,000 candela), nor more than 1.5 times the average (7500 candela).

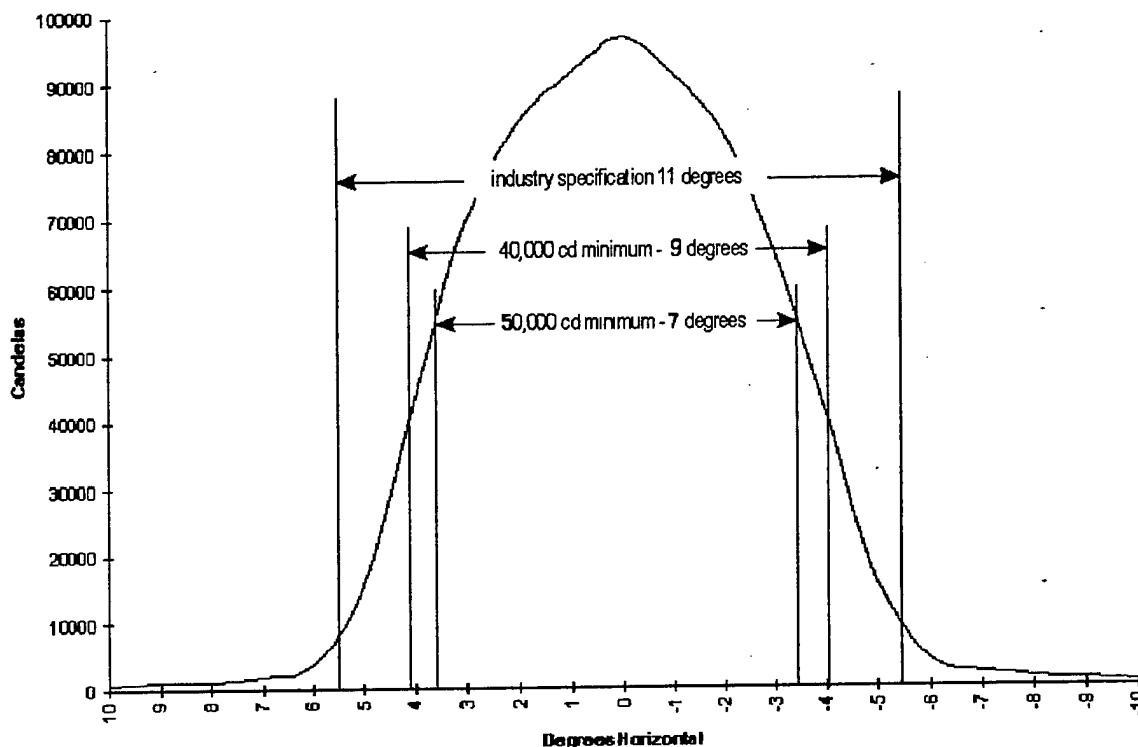
Since the retroreflective marker serves as a guidance aid for landing aircraft, its specification should follow the established practice, instead of the industry method. If the #4509 is the critical lamp, then its characteristics might be used as typical example. The peak intensity of 110,000 candelas must then fall within the prescribed tolerances and this is somewhere between an average intensity and a maximum of 1.5 times the average. Since the peak cannot be the average, it must then be closer to the maximum. Thus the average intensity would be at least more than $1/3^{\text{rd}}$ and not less than $1/2$ the peak, or between greater than 37,000 candela and 55,000 candela.

In other words, the ICAO specification does not represent what is available, but rather what is desired as to performance of the light fixture. It specifies a minimum average intensity within the required beam spread and limits are placed upon the allowable values of individual intensities within this beam. The latter is intended to obviate distributions that may have excessive peaks and valleys, so that there is a relative uniformity to this distribution.

Our consideration is that the peak intensity of 110,000 candelas of the #4509 lamp cannot be used as the minimum requirement, since this occurs at only one point within the distribution. Also, if an average intensity is to be used for the specification, then this exists for a much smaller angular subtense than that listed in the industry lamp catalogue.

The industry specification of the #4509 lamp gives a beam spread of 11 degrees horizontal. But this is to the extremities where the intensity falls to $1/10^{\text{th}}$ of the peak. If one follows the aeronautical ground light practice, the beam spread is actually much less. For example, as shown in the diagram below, if near 37,000 candelas (rounded to 40,000 candelas) is selected as the minimum intensity for the main beam, then the operational width is something of the order of 9 degrees or ± 4.5 . If 50,000 is selected as the minimum intensity, then the operational width is something on the order of 7 degrees

or ± 3.5 . Thus the beam width, for landing lights intended for aerodrome guidance aid application, is actually smaller than that published and the "system" is more sensitive to azimuth movement of the aircraft heading than is apparent in the industry specification. For example, if crosswind drift is of concern, the allowable tolerance for the heading is not ± 5.5 degrees, but rather something of the order of ± 4.5 or ± 3.5 degrees depending upon the selected minimum intensity.



In the case of helicopter use of retroreflective markers, the vertical spread is more importance than for fixed wing operations. The industry specification for vertical spread of the #4509 lamp is for 6 degrees ± 3 degrees spread to the extremities at which the intensity falls to $1/10^{\text{th}}$ of the peak. If 40,000 candelas is selected as the minimum for the main beam, the actual operational width of the beam is 4 degrees or ± 2 . Or if 50,000 candelas is the selected minimum intensity the spread is 3.5 degrees or ± 1.8 .

3.1.2 Number of Light Sources. One of the comments for the Malemute trial was a lesser expected acquisition due to the loss of a wing light. The lights on the subject aircraft were 250 watt, presumably at 300,000 candela peak. The number of lamps is a factor that should be taken into account. In fact, the availability of two lamps might be a base criteria for use of a retroreflective marker system, for purpose of redundancy, since there is no backup to the marker system other than the lighting on the aircraft. Although two-lamped aircraft may be taken as a constraint upon use of the system, a single lamp should continue to be the basis for determining acquisition distance.

It should also be noted that the output of the light source is not constant but decreases up to 20 percent with age [refer Illuminating Society of North America (IESNA) manual for lumen depreciation curves of multiple circuit lamps]. Thus the ability of the source to illuminate the marker should be weighed by a lumen depreciation factor. If 40,000 candelas average enable acquisition, then the minimum requirement for the lamp should be $40,000 * 1.2 = 48,000$ candelas.

3.1.3 Distance of the Pilot Eye to Light Source. The retroreflective marker returns light to the source on the aircraft and not the pilot. The degree to which the pilot can see the returned light depends upon the spread of this returned signal. In other words although the light is returned to the source, it should have sufficient spread so that a portion is available to a pilot eye located at some distance from the source.

The material commonly used for runway and heliport markers is that developed for roadway application and their performance is optimized for the relatively small angle between vehicle headlight and driver eye which may be less than a few feet. In the case of aircraft, a similar distance may pertain only to nose gear mounted lights. Many aircraft have wing mounted lights. The Dash 7 has a source to pilot eye distance in the order of 3.7m (12 feet). At least one aircraft type, with wing tip mounted lights, was measured to have a pilot eye to source distance of about 6m (20 feet).

The affect of source distance can be seen in **Figure 2** which illustrates a test conducted for an airside guidance sign also having retroreflective material. Photo (a) shows a high return of light for observation near to the position of the vehicle headlight. Photo (b) shows almost no return for only a small distance of offset.

The distribution of returned light from retroreflective material should also be taken into account in the case of further study of taxiway edge markers. A compromise may be necessary, since to optimize the amount of returned light may limit that available to the pilot's eye. It may be desirable to specify materials of a more diffuse reflectance.

It may be argued that a large source to pilot eye distance would subtend a relatively small angle when the aircraft is at the acquisition distance. Thus the affect of this source distance should not be a factor. However, at least one comment for the Malemute trial pointed out a lesser acquisition for the case of wing mounted lights. Also, the focus of Transport Canada regulations is upon the initial acquisition of markers at distance and does not yet go into the matter of how these markers might be used during flare prior to and after touchdown. A further comment of trials has been that the markers produce significant glare when illuminated from close distances. The Canadian military has considered an increase of spacing from 60m (200 ft) to 120m (400 ft). The affect of glare is something that also has to be considered helicopter applications, especially when the helicopter is in the final hover and snow on the pad is blown up as a cloud around the pilot.

3.1.4 Lamp Orientation. The output distribution of the #4509 lamp is relatively narrow for the industry specification and narrower still for aerodrome visual aid specification. This of course applies to the lamp itself and does not take into account the orientation of the lamp when installed in the lampholder on the aircraft.

In the case of the KingAir version with two nose gear mounted landing lights, these are orientated such their beams are individually angled outwards at 8.5 degrees from the aircraft heading. If the operational width of the lights is less than ± 8.5 , then there is a gap of some angular dimension in front of the aircraft, within which the amount of light may not be sufficient to provide acquisition. This may account for the lower distance of 1.5 miles reported for this aircraft in the Malemute trials. For example, if the necessary beam spread is ± 4.5 degrees, then a toe-out of the lamps at 8.5 degrees leaves a gap of about 8 degrees when the aircraft is aligned with the runway. This KingAir would then benefit from crabbing against a crosswind such that the heading is at least 8 degrees from centreline. The aiming of the lamps points out a factor in relation to the pilot's awareness of the aircraft landing lights. The common wisdom is that the pilot should maintain the aircraft on a heading that is aligned with the runway centreline. In part, that is the function of the fixed lights to be installed at each end of the runway. But for this KingAir version, with toed-out lamps, it may be best in order to obtain optimum illumination of the reflectors to approach the runway slightly to one side.

Alternatively, the aircraft manufacturer may also (confirmed for one manufacturer) design the aircraft's lighting system so that the beams of wing lights are toed-in so as to converge at some point in front of the aircraft. For small aircraft this may be of the order of 100 feet in front of the aircraft and a pilot eye to source distance of say 5 feet produces a toe-in angle of about 3 degrees. The light available to the retroreflective marker is then still within the beam spread. However, if wing tip lights are used and the pilot eye to source distance is then 10 feet, the toe-in is about 6 degrees and the available light is outside the beam spread.

The matter of light aiming for fixed wing aircraft raises a question as to how the extended system of marker illumination can be optimized if prevailing regulations apply to the airport itself and not to the aircraft. In brief, the specification can be developed for the marker, but not for the landing lights.

There are, however, some criteria for landing light aiming within the industry. For example, the Society of Automotive Engineers (SAE) has a published lighting practice, ARP693, which recommends a manner in which the lights are to be aimed. This practice states in article 3.1.2 (of ARP693 Revision C) that:

Aiming: It is recommended that adequate landing light aiming be provided to cover the following airplane attitudes:

- (a) Prior to touchdown, the pilot will start using the lights as he initiates the flare. The landing light shall be aimed somewhat ahead of the pilot vision limit, and along the glide slope.*
- (b) Before the point of touchdown is reached, the airplane is positioned in a nose up attitude and the centreline of the beam moves further down the runway relative to the pilots field of vision. At touchdown, it is desirable to provide illumination of the runway centreline and possible obstructions as far as 400 feet away from the pilot.*

(c) After touchdown, the nosewheel gradually drops to the ground and the airplane assumes a ground roll attitude. At this point, it is desirable to provide illumination of the runway centreline at least 300 feet away from the pilot.

The above criteria apply to vertical aiming of the landing lights. The distances specified for illumination are relatively large and more applicable to wide-bodied jets. For example, the ARP693 is used by Boeing in their landing light design. What is of interest is that this document addresses the provision of light coverage in the approach, touchdown, and ground roll attitudes. It also is based on the assumption that guidance is provided on the airfield by conventional lighting such that the purpose of the lighting is to illuminate the runway surface. Granted, it is not foreseeable that retroreflective markers would be used by this type of aircraft. However the existence of ARP693 indicates that, if specifications are to be developed for an extended system that includes the aircraft, then something of this nature would be necessary to guide design by aircraft manufacturers.

The orientation of landing lights is of particular importance for helicopters. Smaller commercial helicopters, such as the Robinson R22 and R44, have #4509 lamps aimed downwards at 7 and 18 degrees from the horizontal line of the aircraft, with the first lamp being used to light the helipad from a distance. When in cruise, this aircraft has a 5-degree nose depression that alters the landing light angle to 12 degrees. If one interprets the required acquisition distance as that for which a decision is made to proceed towards a landing, then the angle is too shallow to enable illumination of the helipad. If the height of initial approach is 304 m (1000 feet), the beam strikes the ground at a distance of 1.4 km in front of the aircraft whereas for the required distance the helipad should be at 3.7 km. It is to be noted that the operational vertical spread of the #4509 lamp is only about ± 2 degrees and therefore with lights fixed as mentioned above, the helipad would not be illuminated at the acquisition distance for the leading edge of the beam.

If the helicopter has forward aimed lights as in the case of the Astar, then with a 5-degree nose-down attitude, the beam strikes the ground at about 3.5 km and thus the helipad would be illuminated for the acquisition distance. But this then places a constraint in that forward aimed helicopter lights are required within the extended system of marker application.

Forward aimed lights, however, may pose a further problem once the helipad is seen and a decision is made to descent towards a landing. The helicopter then takes a nose-up attitude and the lights are directed above the helipad with the result of removing the illumination. Thus, a combination of lights may be required for acquisition and descent. But whatever the combination, as long as they are fixed, the pilot must maintain the orientation of the aircraft within a small tolerance, which may not be possible.

This discussion of lights on helicopters to illuminate helipad markers leads to the conclusion that such lights cannot be fixed and a basic requirement for the extended system is that the aircraft have at least one swivel landing light which can be orientated by the pilot in both horizontal and vertical directions. This is already the case for helicopters used in air ambulance service by the Ontario Ministry of Health.

It is apparent, from trials and experience, that the regulation does not reflect the reality by which retroreflective markers are actually used. A decision to proceed to a landing, with subsequent change in aircraft attitude, does not actually take place at the acquisition distance. Rather, the fixed lights (flashing lights in the case of the Alaska Malemute trial) are used in this manner. The pilot acquires the fixed lights and then proceeds to a landing until the markers are acquired at a much shorter distance. Also, although the regulation does not make mention of other aids, discussion with pilots, especially those of the air ambulance service, has given rise to comment in regard to use of GPS in the approach procedure.

3.1.5 Crosswind Compensation. As mentioned the beam spread of the #4509 lamp is published as ± 5.5 degrees and the actual operational width is likely somewhat smaller. A problem then presents itself with respect to the manner in which the pilot may compensate for crosswinds.

If the crosswind compensation is by "crabbing" the aircraft ... that is, to change the heading to vector against the wind, then the direction of the landing lights is also changed. Where landing lights are aimed forward and parallel with the centreline of the aircraft, crabbing can only be done to the operational width of the beam and still allow the markers to be seen. This would limit a change of heading to within perhaps 4.5 degrees, whereas crab angles of 10 degrees are not uncommon.

Crosswinds might also be accommodated by "slipping" the aircraft ... that is, to lower a wing and changing the aerodynamics ... so that the heading is maintained in alignment with the runway centreline. Although the landing light would be partially rotated by this manoeuvre and the intensity toward the runway reduced because of the elliptical pattern of the distribution, the affect would likely be much less than that occurring when crabbing the aircraft.

The factor of crosswinds illustrates the point that extension of the marker system is to a "platform" of lighting that is not constant as to enable predictability. If the acquisition distance specified in the regulation is a minimum at which the markers must be seen, then conformance is highly dependent upon the amount of crosswind and the manner of compensation. Also, since the markers are to illuminated at distance and maintained, the implication is that for crosswind compensation, the pilot is constrained to primarily utilize a slipping technique, from 3.7 km until touchdown whereas the more common practice is to crab at distance and change to slip just prior to threshold. This existence of this constraint emphasizes the need for a familiarity with the marker system, as commented by FAA in the Alaska Malemute trials.

3.2 Atmosphere

3.2.1 Flight (Atmospheric) Visibility. The present regulation simply states acceptance of retroreflective markers as an alternative to conventional lighting with specification only of the required acquisition distance. There is no mention of a condition of flight visibility under which these markers might be used.

It may, however, be seen as implied that the flight visibility would be that of VFR. Thus, for controlled airspace, the minimum flight visibility is 4.8 km (3 statute miles) and for uncontrolled airspace it is 1.6 km (one statute mile).

Trials of retroreflective markers have commonly taken place in good visibility. To our knowledge, no trials have been performed for reduced visibility.

In a rough fashion, one can at least obtain some indication of the significance of this factor and whether it is possible for pilots to acquire the retroreflective markers at the lower end of VFR flight visibility. This can be done by considering the marker to act as somewhat imperfect mirror. That is, the marker is essentially acting as a means by which the pilot is able to see his/her own landing light. A mirror, however, has the characteristic of placing a virtual image at a distance behind its surface that is equal to the actual distance in front. If the marker is to be seen at 3.7 km, the effect is placement of a virtual image of the landing light at a combined distance of $3.7 + 3.7 = 7.4$ km from the aircraft. But for controlled airspace the minimum flight visibility is based upon an inability to see lights beyond 4.8 km. Thus we run into an inconsistency. If the marker were a perfect mirror, then we would require that the pilot see the landing light at a distance which is greater than that for which he might see other lights in the surrounding area. Therefore, without testing, it is well apparent that the markers cannot be illuminated and seen at the lower flight visibility minima for VFR. And more so, since the marker is not a perfect mirror and is of a size which can capture only a minute portion of the entire beam that is directed towards it.

Although trials in reduced flight visibility have not been done, a limited test of marker capability was conducted by Transport Canada in the Spring of 1998. Unfortunately a portable visibility sensor was not then available and the test became simply a measurement of performance for a distance of 1 km between marker and light source. The visibility was subjectively estimated as greater than 6 nautical miles using two separate lighted reference points in the local area. What is of interest from this test was the finding that there occurred momentary reductions of luminous return of up to 30 percent. Some of this reduction of marker performance may be accounted for by a measurement tolerance for the instrumentation. But overall it is apparent that the major portion relates to atmospheric condition, perhaps to turbulence in the air, since all measurements were made with the marker, light source, and detector only a few feet above ground level. What this test points out is that even for what may be assumed to be near unlimited visibility, fluctuations in marker performance can occur and acquisition even if achieved at the required distance of 3.7 km would not necessarily be constant.

3.3 Local Phenomena

3.3.1 Degradation of the Sheeting Material. Retroreflective materials used in the construction of the marker can deteriorate over a period of time. Those installed at Chisasibi Airport in Quebec failed to perform after about 2 years of service. A system of heliport markers at Mattawa, Ontario were inspected and found to be damaged by gravel thrown by rotor downdraft. At Toronto International Airport, retroreflective taxiway edge markers were similarly abraded by the sand thrown by jet exhaust.

The degree to which a marker can be degraded by physical damage and still provide a suitable return signal is unknown. That this damage does occur points out the need for some form of inspection procedure at site, and therefore a means for measuring the available reflectivity. Such measurement means does exist in the form of a reflectometer. This device is essentially a hollow tube with a light source and detector together at one end. The other end of the tube is placed on the reflective material and a reading taken. Since the device is calibrated with samples of unused reflective material, a percentage indication of degradation can be obtained.

3.3.2 Surface Dimensions, Aspect Ratio and Shape. Marker performance also depends upon the active surface dimensions, aspect ratio (width to height) and shape. Obviously the larger the marker, the more the return of light to the aircraft. But the height of the marker is limited by standards for overall heights of aeronautical guidance aids installed at the runway edge. If the height is limited, then the only means of increasing size is to reduce the clearance provided to raise the marker above expected snow accumulation. It is not advisable to place the marker directly on the ground, since accumulated snow or drifted snow will obstruct light return and there will be a difference in the active size of the marker depending upon the season.

In any case, dimensions, aspect ratio, and shape are factors in performance. Since the aerodrome operator does not have capability to determine the actual suitability of a product, and it is unlikely that third party (laboratory) testing would involve repeated flight trials, it may be necessary for the aviation authority to at least provide guidance material as to minimum acceptable dimensions, aspect ratio and shape. How this might be done and the cost of doing so is unknown.

Transport Canada has developed a computer program for marker assessment, given a database of reflective material and critical lamp characteristics. The program allows one to input the various characteristics of a marker (size, shape, and aspect ratio) and the acquisition distance can be automatically calculated. The intent is to have a means of modeling so that may be possible to determine the marker performance without further flight trials. This computer program, however, is still in the process of refinement and further work is required to verify the calculation. One of the aspects that remains undefined is the possible difference in acquisition for a system of markers versus a single marker. We are intuitively aware that a system of many markers including the six or so of the runway threshold should be more conspicuous than may be suggested by treating only one marker.

3.3.3 Degradation due to Surface Contamination. The retroreflective marker can be subject to degradation due to surface contamination that obscures the return signal. Contaminants may be in the form of weather related conditions such as dew, frost, and snow cover. **Figure 3** shows the affect of frost on the return signal. **Figure 4** shows a condition of snow/ice cover. In addition, the surface may be obscured by grass clippings or dirt blown from the runway and surrounding strip area. A number of tests have been performed by Transport Canada in regard to weather contaminates. **Table 2** indicates testing performed on a marker with application of varying thickness of frost. This test was conducted by spraying the marker in a cold chamber maintained at minus 20 degrees Celsius. The lesser rate of degradation after application of 0.2 mm of frost may be due to

the addition of reflectivity from the frost itself. The table indicates that an initial thickness of frost of 0.1-mm thickness reduces the performance by almost 30 percent. Increased thickness of frost, which is not uncommon, eventually eliminates marker performance.

Table 2: Retroreflective Marker versus Frost Thickness

Frost Thickness mm (inches)		cd/m ²	Percent Reflectivity
0	(0)	11 800	100
0.1	(1/256)	8 500	72
0.2	(1/128)	4 500	38
0.4	(1/64)	3 800	32
0.8	(1/32)	2 780	24
1.6	(1/164)	1 103	9

Retroreflective Marker, Test Results

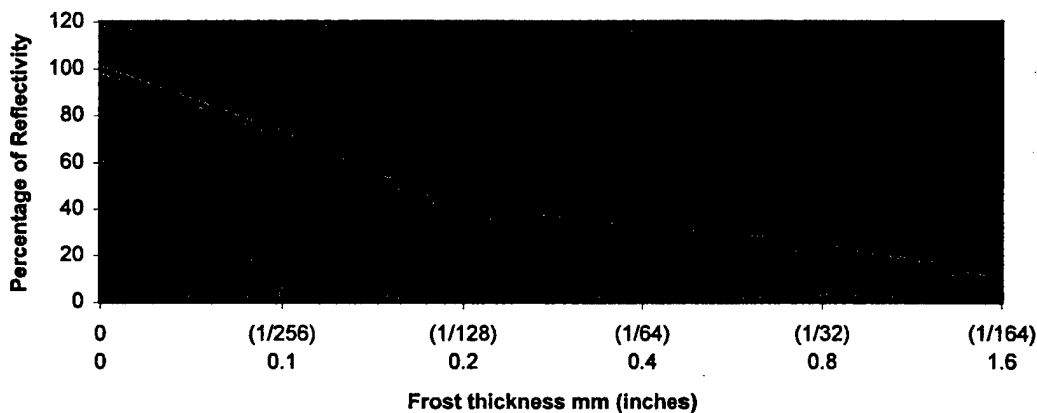


Table 3 below is a record of observations made for a heliport marker (refer Figure 4) during the Fall, Winter and Spring of 1997/98. All of the listed observations were subjective, except for incident 24 when a reading was taken with a spotmeter revealing a measured reduction of 50 percent. This incident and measurement gives an idea of the quantitative meaning of the subjective observation of “medium” performance reduction.

Table 3: Contamination Affect .. Heliport Marker

No.	Date	Temp	comment	Reduction
1	thr 2oct	-1	Frost	High
2	sun 5oct	8	Dew, high humidity	High
3	sat 11oct	0	Slight frost	High
4	sun 12oct	1	Slight dew	Low
5	sat 18oct	-1	Heavy frost, presence of morning fog	High
6	sun 19oct	0	Heavy frost, almost an ice quality	High
7	mon 20oct	2	Slight dew	Low

8	wed	22oct	-2	5cm of snowfall, marker covered with snow	Total
9	thr	23oct	-6	Some snow cover at top	Low
10	fri	24oct	0	Some snow cover	low
11	mon	27oct	-1	Snow cover, after fall of 20cm of snow	total
12	thr	30oct	-2	Frost cover	medium
13	mon	3nov	7	Dew, after heavy rain	low to medium
14	tue	4nov	1	Dew, slight fog in the area	low
15	wed	5nov	0	Frost	low to medium
16	thr	6nov	3	Slight coating of frost	low to medium
17	fri	7nov	0	Slight coating of dew	low to medium
18	fri	14nov	-2	Cover of snow - 5cm snow storm	total
19	wed	26nov	-7	Rain, freezing rain, then snow, road signs also covered	total
20	thr	27nov	-1	Snow cover of 26nov remaining on shadow side	total
21	fri	28nov	-7	Snow cover of 26nov remaining on shadow side	total
22	sat	29nov	-5	Snow cover of 26nov remaining on shadow side	total
23	sun	30nov	-5	Heavy frost, not associated with 26nov snow cover	total
24	tue	8dec	-12	Frost, performance reduction from 60cd/m ² to 30cd/m ²	medium
25	wed	18dec	-15	Frost	medium
26	thr	8jan	-5	Variable, ice storm, light penetrates thin clear ice	slight
27	mon	23mar	-7	Thin frost	medium
28	wed	25mar	-5	Thin frost	medium
29	sat	28mar	10	Remains of rain, cover of water	medium
30	thr	23apr	?	light frost	medium
31	wed	29apr	?	cover of dew	medium
32	mon	4may	10	remains of rain	medium
33	tue	5may	13	remains of rain	slight to medium

Table 3 shows that for the period from 2 October to 5 May, there were 33 incidents for which the performance of the marker was affected. In as much as these observations were not made on a continuous basis, there may have been additional incidents that were not recorded. However, of those listed, the number is about 13 percent of the days of the test over a period of 8 months. For incidents 20 to 22, the contaminant was the same as that for incident 19 which was a snow cover deposited on 26 November. Each additional day that this snow remained on the marker was counted as an incident, since it was considered the marker should be able to eliminate its contamination within a 24-hour period. This did occur on the sun side of the marker but not for the shadow side, facing northeast.

The observations of **Table 3** correlate with similar testing done for roadway signage in the mid 1960s for a sign array installed in Washington County, Minnesota (approximately 2000 feet from the Mississippi River) revealing the occurrence of dew or frost for 86 of the 234 nights of test period or an incident rate of 37 percent (Highway Research Record, publication 1254).

In the late summer and early Fall of 1998, a series of observations were made on a heliport marker to determine the affect of contamination solely by dew. Measurements were made by means of a spotmeter and the source was an automobile headlight. For each incident, at least three measurements were taken to obtain an average for the initial condition of the marker, then a second set of three measurements to obtain an average for

the marker when cleaned. The observations ceased when frost rather than dew was encountered. Frost at low temperatures cannot be easily removed from the marker and attempt at its removal by mechanical means damages the surface of the reflective material (This difficulty in removing frost should taken into account when considering the practicality of maintaining a system of markers on a runway). The entries of **Table 4** indicates that simple dew alone can significantly reduce the performance of the marker.

Table 4: Contamination Affect (dew), Heliport Marker

Date	Temp Celsius	Comment	Initial cd/m ²	Cleaned cd/m ²	Percent Reduction
1sep98	9	slight fine dew	45	70	36
7sep98		dew	165	394	58
8sep98		dew	51	55	7
14Sep98	6	dew	46	126	63
17-Sep-9	5	dew	34	78	56
29-Sep-9	1	dew	57.3	109	47.4
16-Oct-9	4	dew cover, fog in air	232	454.3	48.9

4.0 Summary, Conclusions, Recommendations

Results of the Alaska Malemute trial indicated that the performance of retroreflective markers is marginal under ideal conditions, with respect to the required acquisition distance of 3.7 km (2 nautical miles). For the non-ideal, there are a number of factors that may degrade the marker performance and further reduce the actual distance of acquisition.

The landing light on the aircraft, which is included in the extension of the marker "system", does not represent a source that might have design predictability. The beam of the selected critical lamp is relatively small in both horizontal and vertical directions implying a certain sensitivity with respect to movement of the aircraft. Also the beam may not be optimally used because of the manner of mounting on the aircraft to provide an aiming which is intended primary to illuminate the centreline of the runway upon landing with conventional edge lighting.

Trials have not as yet been performed to determine the usability of the markers to the reduced limits of VFR flight. However, it would seem obvious that the markers cannot be seen to these limits, since the limits themselves are based upon observation of lights in the surrounding environment. If these target lights that are used to determine flight visibility cannot be seen beyond 4.8 km (3 statute miles) then it is unlikely that the pilot will be able to see his landing light reflected over effectively twice the acquisition distance or 7.4 km (4 nautical miles).

Environmental factors such as contamination by frost and dew have been shown to cause degradation of performance of over 50 percent. However, the frequency of this contamination may perhaps be more important than the amount of degradation. A limited

study of observations, by Transport Canada, indicated that contamination, with varying degrees of degradation, occurred for about 13 percent of the days during the period of observation. It can be expected that this frequency would be even greater for particular location near to rivers or other bodies of water that can provide humidity. A similar study performed for on roadway signage for the Highway Research Board indicated a frequency of dew contamination of 37 percent of the days of observation. There is a device with which the site can measure the amount of degradation, however, the actual method has not been worked out. And in any case, such inspection may well be impractical for runway edge marker installations.

Because of the results of the Alaska Malemute trial and studies conducted by Transport Canada, it is concluded that the retroreflective marker system is not suitable as an alternative to conventional lighting. Thus, it is recommended that the existing regulation should be revisited to remove this alternative.

However, it is known that retroreflective markers do work. This has been shown by a number of trials under admittedly ideal conditions, and through experience from certain installations at non-certified aerodromes.

Therefore, it is further recommended that the revisiting of the regulation should be in a manner so as to identify retroreflective markers as a separate and different form of guidance system along with stipulation of appropriate limitations. For example, in the case of heliport application, it may be appropriate to stipulate the requirement of a swivel landing light.

In order to develop the revision of regulations, additional study should be conducted in order to properly define the above mentioned limitations.

FAA Heliport Lighting Research

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OVERVIEW

This paper discusses heliport lighting research performed for the Federal Aviation Administration (FAA) General Aviation and Vertical Flight Program Office (AND-710). The purpose of this research was to investigate cost-effective heliport lighting systems to support Global Positioning System (GPS) instrument approach procedures to heliports. This research was performed over a five-year period from 1994 through 1998. Science Applications International Corporation (SAIC) led the research team with support from the University of Tennessee Space Institute (UTSI).

The research effort was divided into several tasks:

Literature Search. Technical literature from prior research efforts was identified, reviewed and summarized in two technical letter reports, one discussing civil research and one discussing military research. The research team also investigated current FAA orders and lighting specifications applicable to airport and heliport lighting. The results of the literature search effort are not discussed directly, but rather are contained in appropriate technical sections of the paper.

Operational Requirements. Based on the literature search and contacts with helicopter industry representatives, the research team developed a set of operational requirements for helicopter instrument approaches to heliports. The investigation looked at special requirements needed for various types of heliports (e.g., public, private, ground level, rooftop, on-airport). The investigation also divided an approach into various operational actions that the pilot must perform.

Lighting Layouts. Based on the operational requirements, the research team identified several lighting layouts that could satisfy the requirements. These layouts consisted of various configurations of lights and types of lighting. The layouts differ depending primarily on the amount of space available at the heliport site.

Lighting Technology. Existing airport and heliport lighting is dominated by tungsten element, incandescent lighting technology. This technology has the benefit of being relatively inexpensive and widely available. Other lighting technologies may prove useful and advantageous at heliports. Some of these technologies have been available for many years, while others have become available only in the last few years. The investigation looked at advantages and disadvantages (both technical and cost) of the various technologies.

Tests and Demonstrations. The research effort included some initial testing with scale-model lighting layouts to look at pilot preferences. UTSI put together some promising layouts and technologies and performed a limited flight test effort at the airport in Tullahoma, TN. These initial tests showed promising results and the research team assembled a prototype lighting configuration and installed it at the NationsBank Southside Heliport in Atlanta during the 1996 Olympic Games. After the Olympic Games were completed, the prototype lighting system was moved to the United States Park Police heliport in Washington, DC. At this site, the research team demonstrated the prototype system to several government and industry representatives. In addition, the research team collected operational feedback from Park Police pilots.

Research Reports. The results of the lighting research are documented in four technical reports:

FAA/ND-98/1, Heliport Lighting – Technology Research

FAA/ND-98/2, Heliport Lighting – Configuration Research

FAA/ND-98/4, Heliport Lighting – U. S. Park Police Demonstration

FAA/ND-97/20, Evaluation of a Heliport Lighting Design during Operation Heli-STAR

These reports are available from the National Technical Information Service, 5258 Port Royal Road, Springfield, Virginia 22161.

LIGHTING SYSTEM REQUIREMENTS

FAA Requirements

Two lighting systems have FAA approval for use at heliports, the Heliport Instrument Lighting System (HILS) (**figure 1**) and the Heliport Approach Lighting System (HALS) (**figure 2**). These systems are included in several FAA Orders and Advisory Circulars as supporting operations at heliports. Specifically, the FAA's Heliport Design Advisory Circular (AC) (reference 1) recommends that HILS, with an enhanced perimeter lighting system, be installed to support non-precision instrument approaches. The guide also states that HALS, the enhanced perimeter lighting system, and HILS are "... necessary for a helicopter precision instrument approach procedure with the lowest minimums." The AC notes that, "The FAA is continuing its study of configurations for precision instrument approach lighting systems."

FAA Order 8260.37, Heliport Civil Utilization of Collocated Microwave Landing Systems (MLS) (reference 2) requires that "An operational HILS shall be mandatory for all MLS approaches to heliports. FAA Order 8260.42A, Helicopter Non-precision Approach Criteria Utilizing the Global Positioning System (reference 3), grants a ¼ mile visibility credit for HALS.

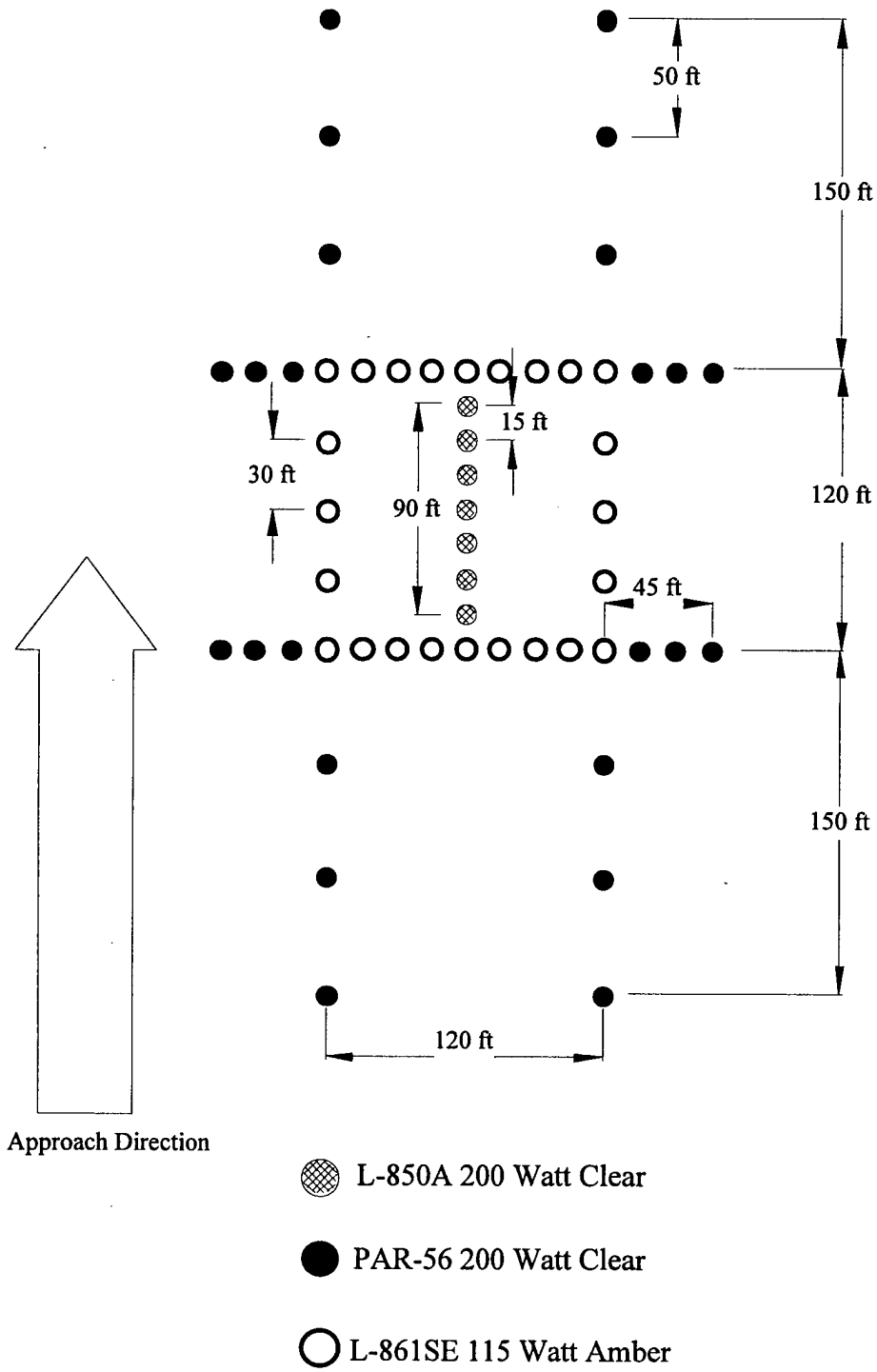


Figure 1 The Helicopter Instrument Lighting System (HILS)

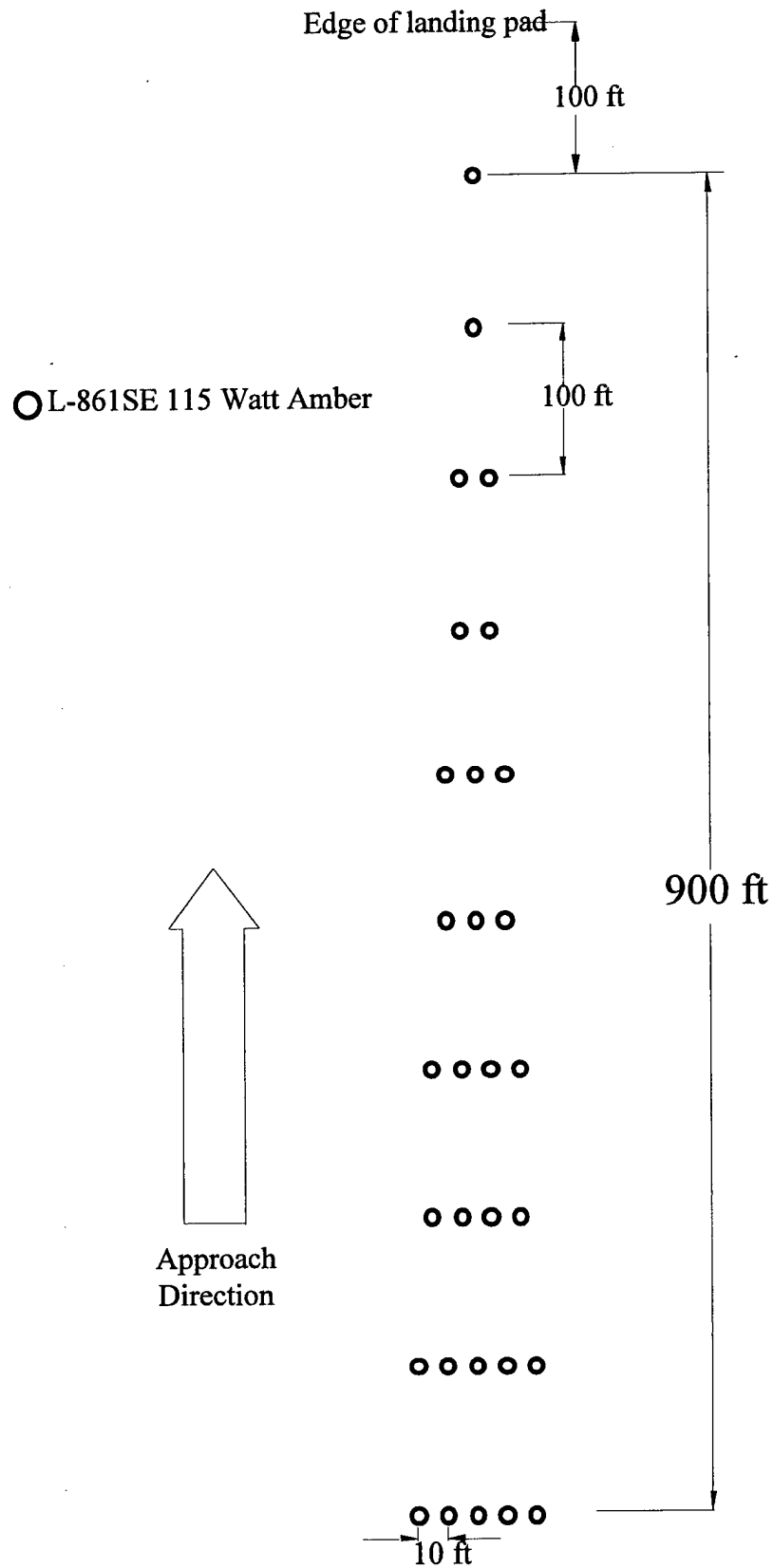


Figure 2 The Heliport Approach Lighting System (HALS)

The GPS non-precision approach order (8260.42A) recognizes the possibility of a HALS equivalent and authorizes a ¼ mile credit for its use. The growing number of GPS non-precision approaches will likely create a demand for a HALS equivalent. A possible HALS equivalent might use some form of "lead-in" lights that are visible to a pilot at the Missed Approach Waypoint (MAWP) or Decision Waypoint (DWP).

There are two basic problems with the HILS and HALS – space and cost. The HILS requires an area around the heliport 210 feet wide by 420 feet long; the HALS requires 1,000 feet in front of the heliport. Many heliports, particularly those located on rooftops, do not have space available to install either HILS or HALS. As shown in **figures 1 and 2**, the HILS, with enhanced perimeter lighting, has 55 lights and the HALS has 30 lights.

Two aspects of FAA lighting certification and documentation are worthy of note. The FAA publishes a list of approved lighting that can be purchased with Federal support, such as Airport Improvement Program (AIP) funds. In some cases, insurance companies and local and state officials have limited a heliport lighting designer's choices to this list of FAA-approved lighting. It is in the best interest of the industry to expand the FAA list of approved lighting in order to remove any barriers, however unintentional, to the introduction of new lighting technologies that may improve Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) heliport operations.

As the FAA develops and refines the requirements for heliport instrument lighting, care must be taken to develop technical descriptions as functional performance specifications that detail the required characteristics of the light output and not merely the characteristics of a light source. As lighting technology has advanced, there are several ways to produce a light output. Some of the current FAA lighting specifications characterize the lamp that is required to match up with a particular filter that will be used in the lighting system. It is possible that a colored light source could be substituted for the lamp and filter combination, but the colored lamp would not meet the current specification requirements. The approach lighting development described herein will help to avoid this trap by defining the required cues that must be provided to the pilot. This approach to developing specifications should aid introduction of new lighting technologies.

Public and Private Heliports

At private-use heliports, prior permission is required before landing. This allows heliport operators to control the training and proficiency of the pilots flying to and from the facility. Because the operator has this control, some alternatives to lighting might be suitable for guiding the pilot to the heliport. Some private heliports have developed a set of VFR course rules that provide guidance in the form of landmarks or specialized procedures. While adding flexibility to the choice of systems or procedures, such alternatives make it more difficult to accommodate visiting pilots who may be unfamiliar with the heliport.

Public heliports, however, must provide easily interpreted guidance and cues to a pilot who may be flying the approach to the heliport for the first time in the worst possible

conditions (IFR and/or VFR). Specialized lighting systems that require specific training would be difficult to implement at a public heliport.

Pilots could benefit from having more information on the standard procedures at heliports to which they may fly, whether public or private. Neither the FAA nor industry has developed any guidelines on the content, format, or accuracy of heliport information that should be provided to a pilot as an aid in preflight planning. At most heliports in the U.S., this information is not readily available. This is an area where Government/Industry cooperation and research might prove fruitful.

Heliport Groups

Heliports of many different designs are found in a large variety of environments and simplification is difficult. The groupings offered herein allow variation within each group. The heliport groups were picked to allow designers to work with generic heliports while designing subsystems that could be placed in such a way that uses the environment to maximize the cues provided to the pilot.

Rooftop. Rooftop heliports are often characterized by limited space, close proximity to the vertical surfaces of buildings or structures (such as parking garages), and a relatively high surrounding ambient light level. The pad itself may be dark in contrast to the surrounding city lights. These heliports are normally located in the midst of large numbers of point light sources on city streets, buildings, and signs.

Ground-level/off-airport. The largest grouping, ground level/off-airport heliports, includes many possible variations of ground-level heliports. This group is difficult to generalize. It can include a city-center heliport surrounded by tall, brightly illuminated buildings or a rural medical clinic's heliport surrounded by unlit or poorly lit streets and utility poles. A heliport in this group may have plenty of land available for the installation of lighting systems or it may be located immediately adjacent to a hangar, hospital, or passenger facility. A few ground-level heliports are located on piers or barges tied to piers and may be similar to rooftop heliports.

Ground-level/on-airport. This grouping differentiates a unique category of heliports with evolving requirements. Most on-airport heliports are currently not much more than a landing spot at an airport. Currently, approaching helicopters are typically merged with fixed-wing traffic and make the initial approach to the active runways. On final approach, the helicopter is redirected to complete the approach to the taxiway or may be directed to a helipad on the ramp. In these cases, the airport approach and runway lighting systems provide the required lighting cues. Lights that define the perimeter of the landing pad are typically the only lights uniquely associated with the heliport.

At some larger airports, non-conflicting helicopter traffic patterns have been developed that allow helicopters to approach, land, and depart the airport traffic area without using the fixed-wing traffic pattern during VFR operations. It is anticipated that in the near future, these non-conflicting approaches might be needed in IFR conditions to increase airport capacity. Future ground level/on-airport heliports are anticipated to require a

complete, dedicated lighting system that supports a helicopter-only instrument approach to, and departure from, the heliport.

Operational Requirements

The required lighting cues identified below are appropriate for IFR and VFR approaches. The visual segment of an instrument approach starts at the point in the approach where the pilot changes from an instrument scan to a visual scan. In low ceiling or visibility conditions, this can occur as late in the approach as the DWP or MAWP. A VFR approach can be initiated from a wide range of directions at some heliports. However, heliport approaches are often restricted by local traffic patterns and/or obstacles to one or more specific approach courses. These approach courses are most often defined by heliport operators and are disseminated to the pilots flying to the heliport via training, familiarization flights, and locally produced diagrams. A better means needs to be found to standardize the presentation and distribution of information that pilots need for safe approaches to, and departures from, heliports.

During an approach to a heliport, the pilot will have to acquire the landing environment visually, transition to a visual scan (if transitioning from an instrument approach), maneuver to a specific approach course, descend on a glideslope between 3 and 9 degrees¹, and proceed to a safe hover and landing. An optimal lighting system will provide all the information, in the form of visual cues, that the pilot needs to land the helicopter with an acceptable workload. These required external visual cues are:

- Visual acquisition of the landing environment, to include:
 - ◆ Identification as a heliport
 - ◆ Early acquisition in conditions of reduced visibility
- Lineup with the final approach course
- Closure rate to the heliport
- Horizontal reference (horizon)
- Glideslope that provides:
 - ◆ Relative altitude
 - ◆ Obstacle clearance
- Touchdown, which includes:
 - ◆ Transition to hover and hover position cues
 - ◆ Hover altitude and hover altitude rate cues

Not only are these cues required when approaches are going well (i.e., when the pilot is on-glideslope and on-course with a stabilized rate of descent), but these cues must also assist the pilot who is off-course and/or off-glideslope to complete corrective action. For an approach to a confined area such as a city center, visual guidance may be required to inform or warn the pilot when the aircraft is too far off course, off glideslope, or too fast to effect a safe landing.

¹Shallower or steeper glideslope angles are possible, but unlikely. Shallower angles are unnecessarily noisy and steeper angles are performance limited in many helicopters.

LIGHTING SYSTEM LAYOUTS

Acquisition Cues

A visual approach may actually be more demanding on the lighting system than an instrument approach. For a visual approach, the lighting system must provide acquisition cues that can be seen over a much broader area than required with the instrument approach.

The current Heliport Design Advisory Circular calls for an identification beacon flashing white-green-yellow pulses of light. The International Civil Aviation Organization (ICAO) standard is a beacon that flashes the Morse code "H" (four quick flashes). The beacon must be placed so that it will not interfere with pilot or controller vision. Thus, in the visual segment of an IFR approach, the beacon may not be the primary visual acquisition cue for the helicopter pilot. Other lighting components such as approach lights, perimeter lights, and glideslope indicators may provide stronger acquisition cues to a pilot on an instrument approach. These cues may not be as strong, however, if the pilot is displaced laterally and/or vertically from the final approach course, or if the helicopter is crabbed away from the approach course. In such cases, and in visual approaches, the beacon may play a stronger role.

Acquisition cues include:

- Rotating beacons: white – green – yellow at 30 to 45 flashes per minute
- Strobe beacons: four short white flashes for Morse code "H" (It is possible to flash the heliport identifier in Morse code in order to provide a stronger identification cue.)
- Heliport identifier markings ("H") outlined with electroluminescent (EL) panel or floodlight
- Radio controlled lighting: a lighting system that is actuated at the pilot's command will provide an enhanced acquisition and identification cue when activated
- Retroreflective: similar to pilot controlled lighting, since retroreflective markers are only visible when lit by the approaching helicopter's landing light
- Unique color (might also be used to further increase the conspicuity of a beacon)
- Unique characteristics: U. S. Coast Guard studies have shown that lines of light have higher conspicuity than point light sources in areas with high ambient light background
- Landmarks: many helicopter pilots navigate around their respective metropolitan areas by means of landmarks in the form of large, uniquely lit buildings or signs
- Configurations that use a combination of components may provide a unique system that stands out from the ambient lighting environment
- Extension of the landing environment toward the MAWP or DWP: currently HALS is the only FAA-approved heliport approach lighting system

Finally, acquisition also includes identification of the heliport as the intended point of landing. Identification has typically been provided by the combination of a geographical

position and an acquisition cue at night or in low visibility. Position can be provided by electronic navigation aids or visual location of landmarks. Additional identification cues are the standard heliport markings, e.g., "H." This marking can be lit at night with floodlights, or much more effectively outlined with EL panels.

Line-Up Cues

Most current heliports do not have approach or line-up lights. However, testing of the HALS system (reference 4) revealed improved lateral tracking performance with HALS approach lights over approaches without HALS. Without HALS, pilots turning to intercept the final approach course typically never reached the approach centerline with just HILS and enhanced perimeter lighting. Therefore, the research team believes that line-up lighting is a necessary part of a lighting system to support night instrument operations.

Extended line-up lights, either alone or paired with vertical lines of light (shown in **figure 3**), can produce effective line-up cues. However, there are some constraints on the location of line-up cues. Testing of helicopter instrument approaches to low minimums revealed that lineup lights in front of the landing pad were below the flight deck cutoff angle and were not visible for much of the approach (reference 5). Consequently, extended line-up lines (positioned beyond the landing pad) are recommended when possible. Vertical lines of light used in conjunction with shortened horizontal lines of light are possible alternatives at confined or rooftop heliports.

Glideslope Cues

Glideslope indicators of various combinations of colored, pulsing, or flashing lights have been used for years to provide the pilot with indications that the aircraft is either above, on, or below the desired glideslope. These cues require interpretation by the pilot: Glideslopes can be grouped into three general types:

- 1) Color and pulse-coded signals: indicates deviation from "on-glideslope" with combinations of colors and pulse rates
- 2) Alignment of elements: indicates deviations from "on-glideslope" with the misalignment of objects or lights
- 3) Geometric patterns: indicates deviation from "on-glideslope" with perspective of standard geometric patterns such as squares, rectangles and circles. Pattern can be oriented to appear "correct" (no perspective effects) when on-glideslope or to use natural perspective as with HALS.

Type 1 glideslopes are available from several manufacturers and are widely used at heliports. Type 2 glideslopes require a significant amount of area in the vicinity of the heliport and may not be sensitive enough unless the alignment bars can be elevated to heights of 15 or 20 feet. Type 3 glideslopes generally do not work well at heliports because the relatively small size of heliports makes these geometric cues very weak; the sensitivity very low. Also, the wide variety of shapes and sizes of heliports makes misinterpretation more likely.

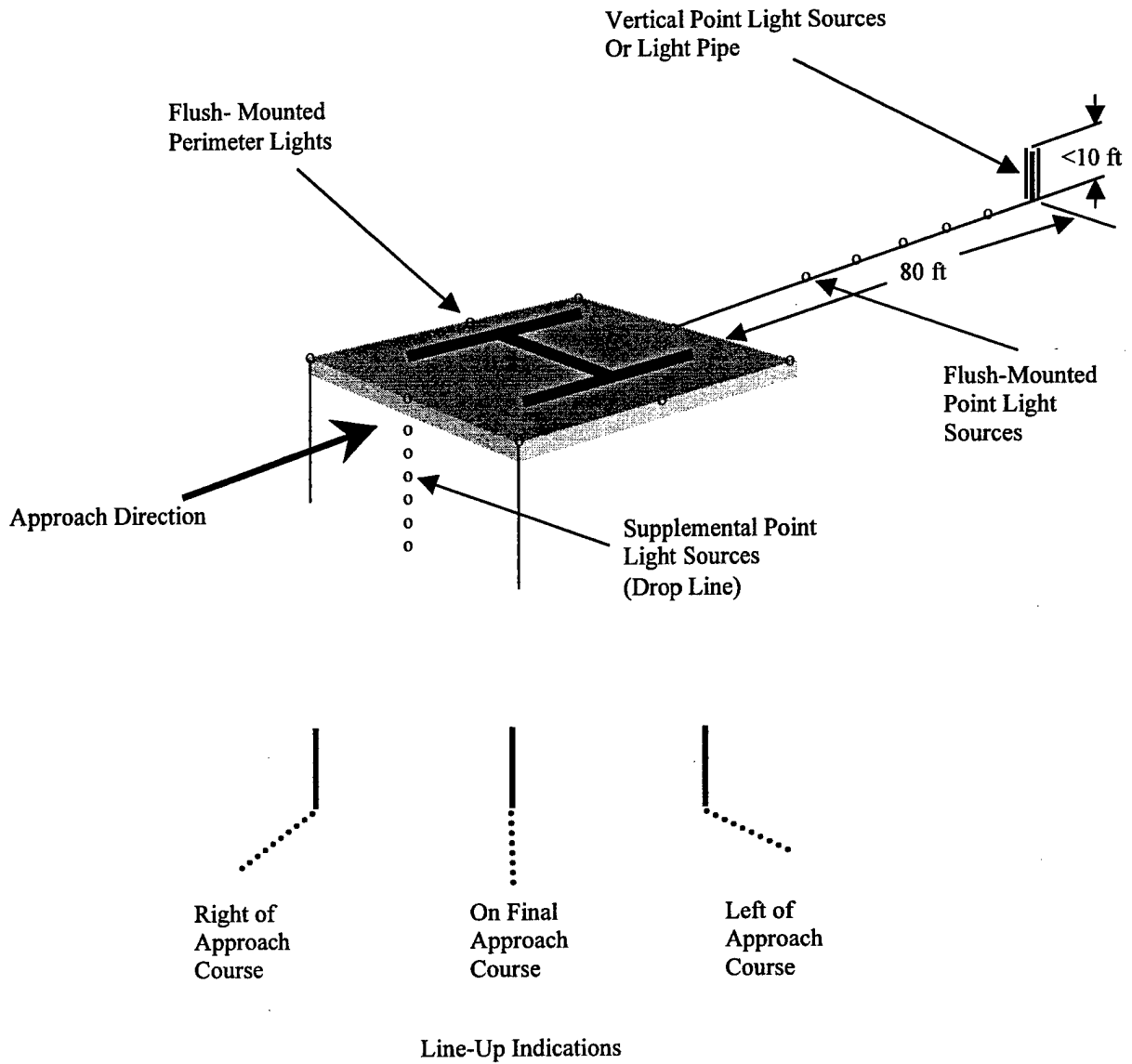


Figure 3 Rooftop Heliport with Vertical-Drop Line of Lights

Note: For rooftop heliports, a third line of lights extending vertically below the landing surface provides an even stronger, more easily interpreted line-up cue.

Horizon Cues

In the absence of a natural horizon, (something often encountered in approaches to very dark areas), the heliport lighting system horizon cue may become the most critical lighting cue. With no natural cue available, the pilot can easily misinterpret changes in contrast, caused by a shoreline or mountain range or distant city lights, as a horizon. In an urban environment, the large number of lights provides a relatively high ambient light level and a strong natural horizon, even under a solid overcast. Additional cues can be interpreted from both the vertical and horizontal surfaces of structures (which are often well lit). However, the relative strength of these urban horizon cues might be diminished in conditions of reduced visibility.

Horizon light cues can be combined with other lighting components. Approach lighting systems typically use rows of lights perpendicular to the approach path to enhance the visibility (more light) of the line-up cue and to provide a horizon cue. Perimeter light extensions and wing bars can provide the horizon cue in addition to enhancing optical expansion rate cues.

Closure Rate Cues

Closure rate becomes more difficult to determine in conditions other than clear daylight. In attempting to compensate for lack of closure rate information, pilots instinctively slow down. If the pilot slows down too much too early in the approach, the resulting increase in power required for level flight (on the backside of the power curve) can cause a significant loss of altitude. Equally troubling, if the pilot does not slow down early enough in the approach, a last minute deceleration may require an extreme pitch up attitude, and the landing area may be momentarily blocked from the pilot's view.

There are three important optical cues that a pilot can use to control closure rate during the visual segment of an IFR approach to a hover:

Optical Expansion Rate. Optical expansion rate is the relative rate of growth in size of the landing pad. This is proportional to the closure rate of the helicopter but independent of altitude. As the helicopter approaches the landing site, it appears to expand in size as the optical angle increases. The angle increases more and more per unit distance traveled toward the heliport as the distance decreases. Landing pad perimeter lights and extensions typically provide this cue.

Optical Flow Rate. Optical flow rate is the angular velocity of surface elements in any one area of the field of view. It is proportional to ground speed divided by the distance to the viewed surface. In an approaching helicopter, optical flow rate is best described as the angular velocity of features on the ground passing from the front to the back of the chin bubble.

Optical flow rate will provide closure rate cues if there is something to see passing below and behind the helicopter on the final approach. In a very dark environment, an approach lighting system with a long string of lights, such as HALS, can provide an optical flow rate

cue that reduces pilot workload and improves pilot control of closure rate. In an urban environment, the ambient light levels may illuminate terrain features sufficiently to be visible to the pilot along with street and building lights. Together, these will also provide an optical flow rate cue that will aid in closure rate control. Again, pilot experience is used to maintain the optical flow rate or apparent speed below some critical value.

Optical Edge Rate. Optical edge rate is defined as “the frequency at which optical elements pass through some visual locale (e.g., the lower portion of the windscreen).” The best example is the white lines passing out of view in front of an automobile moving along a well-marked road. In flight over lights with constant spacing, optical edge rate is directly proportional to ground speed. If the spacing between the lights is decreased in proportion to distance to the landing pad, maintaining a constant optical edge rate will result in a deceleration to zero ground speed.

Touchdown Cues

Fine-grained details such as blades of grass, the roughness of nonskid surfaces, or cracks in the landing surface are classified as “microtexture.” Lack of fine-grained detail can result in a substantial increase in the workload required simply to control the helicopter in a hover or in low speed flight close to the surface. Conditions that lead to a lack of microtexture include a smooth featureless surface, (e.g. still or dark water, poor visibility conditions, and/or an unlit surface).

Floodlights are used at many civil heliports to illuminate the heliport surface and surface texture. These fixtures must be carefully sized, shielded, and placed in order to avoid creating a glare and/or an obstacle hazard. Surface floodlights should be isolated on a separate lighting circuit that enables the dimming of these lights to match and blend with the other types of lighting in use. The Heliport Design Advisory Circular (reference 1) recommends maximum height of lighting fixtures based on the distance from the touchdown and liftoff area (TLOF). The surrounding land may require grading to allow installation of larger lighting fixtures.

LIGHTING TECHNOLOGY

Most lighting systems used to date have employed incandescent lights in one form or another. Two exceptions are Xenon flash tubes and EL lighting, although there may be others. The lighting at aviation landing sites has been primarily incandescent. Recent research efforts have reviewed alternative lighting technologies. Some of these technologies have been around for years and have not previously been used in the aviation field and some are relatively new technologies that have only recently become cost effective. A number of these alternative technologies show promise as potential components of heliport and vertiport lighting systems.

Point Light Sources

Incandescent Lights. Point light sources are characterized by a very bright point of light typically generated by a glowing filament or arc. These lights are often shielded from direct view of the pilot because of the negative impact on night vision adaptation and

because of the "after- image" effect. If a bright light is viewed directly, it often leaves an after-image on the retina that continues to be seen for several seconds or longer. If incandescent lights are not shielded, they are typically filtered with colored lenses, or directed away from the pilot. Exceptions to this are approach lighting systems where hundreds of 300-watt incandescent lights are aimed at the pilots of approaching aircraft.

Point light sources commonly used in aviation are tungsten filament and high intensity halogen incandescent lights. Halogen is used to slow the vaporization of the tungsten filament and increase the life of the lamp.

Light Emitting Diodes (LED). An LED is a semiconductor diode that emits light. By forward biasing an LED, the charge carriers (electrons and holes) can move across the semiconductor junction and release photons. Lenses are often used to focus and collimate the light beam. Depending on the type of semiconductor material used, the wavelength (color) of light emitted can range from the visible to the far-infrared spectrum. LED's can be manufactured to produce red, yellow, green, and most recently blue light. LED's have a typical output power of tens of microwatts and are grouped together to increase the total output.

For example, an LED replacement traffic light is brighter than the original incandescent lamp and uses only one-tenth as much energy. The LED's are more durable and have a much longer life than incandescent lights. LED's can be clustered together to produce a form-fit replacement for incandescent lamps or can be strung together in series that produce lines of light.

Lasers. Gas lasers are typically expensive to acquire and expensive to operate, thus they are not practical for use in lighting systems. There is also concern that high power lasers may cause eye damage to pilots.

A diode laser is based on LED technology, but it has two important differences when compared to conventional LEDs:

- 1) The operating current is much higher.
- 2) Two of the ends of the laser diode are aligned parallel to each other. These ends act as aligned mirrors that reflect the light back and forth and amplify it.

Recent advances in diode lasers are promising for aviation applications. Diode lasers are still more expensive than most other light sources, but may have advantages worth the added expense. Diode lasers have been used to provide the light source for a military glideslope indicator and localizer (line-up). The U. S. Navy plans to deploy these laser guidance systems on aircraft carriers to support fixed-wing operations.

Diffused Lighting Technologies

Light Pipe. The light pipe is a hollow tube with a reflective semi-transparent coating on the inside. A light is mounted on one end, with a filter (if color is desired). The light is reflected along the length of the tube, emitting a uniform light along its length. The light pipe provides a unique line of light that is easily identified in a high light density urban

environment. Furthermore, it uses only one light source. A mirrored film can be inserted to limit the portion of the circumference of the tube that emits light. This has the effect of both limiting the viewing angle of the light pipe and increasing the intensity of the emitted light (since the area of transmission is decreased). In the Atlanta and U.S. Park Police prototype lighting system, the light pipe was mounted vertically to provide acquisition, line-up, and hover cues.

Cold Cathode Lights. Cold cathode lights use a gas filament that tends to disperse the light in contrast to the hot metal filament of an incandescent light, which burns an after-image onto the retina. Consequently, the lights leave very little, if any, after-image, even after looking directly at the lights. The cold cathode lights are effectively monochromatic, and the lights tested in a prototype heliport lighting system had a greenish-blue color with a predominant wavelength of 512 nanometers. This wavelength (color) was selected to maximize the efficiency of the eyes' rods and cones at the low light levels encountered in nighttime aviation. Since these lights can be viewed directly without adverse effects on pilot vision, they were used to outline the perimeter of the landing pad and to provide illumination of the landing surface. The cold cathode lights have an added advantage in that they do not require dimming as the pilot got closer to touchdown. Thus, the same light intensity setting can be used to provide long-range acquisition cues and touchdown cues.

The cold cathode lights have advantages in power consumption and reliability. Typically, the cold cathode lights convert 65 percent of their power to light while 35 percent is lost to heat. Incandescent lights convert only 5 percent of their energy to light and 95 percent is lost to heat. The cold cathode lights also have a considerable maintenance advantage over conventional incandescent lights. The cold cathode lights have an approximate lifetime of 20,000 to 40,000 hours compared to a lifetime of about 2,000 hours for the incandescent lights.

Electroluminescent (EL) Lights. EL lighting uses phosphors to generate light by sandwiching a dielectric between two conducting surfaces. The result is a very thin, flat light panel that can be strengthened to allow it to be placed on landing and taxiway surfaces. Aircraft and ground vehicles can be taxied or driven over the panels. According to one manufacturer, the approximate life span is 28,000 to 45,000 hours. Intensity and the exact wavelength of the light are dependent on the frequency of the power source. A number of heliports throughout the U.S. are using such lighting. At both the high and low power settings, EL panels provide useful touchdown cues and the rugged, low profile installation makes EL panels very useful for illuminating heliport identification markings, taxiways, and parking areas.

Fiber Optics. Optical fibers are made from a clear material, such as glass or plastic. Two layers of material are used. Light travels through the core, which is surrounded by a cladding layer, keeping the light in the core. Because of differences in the refractive indexes of the layers, the cladding reflects light escaping from the core. This allows light to travel through the fiber for long distances, even if the fiber is bent. Recent advances in fiber optics manufacturing have produced fibers that are practical for aviation applications.

Two types of fiber optic lighting are available. End emitting fibers "pipe" light to a remote fixture, where a fitting on the end of the fiber can be used to replace a more traditional lamp. The advantage of "piping" light through optical fibers, is that the number of lights can be reduced and that the lamps can be located in a central, easy-to-access location, distant from the light output. This might be useful as a replacement for heliport lights that are difficult to replace (such as lights at the edge of a safety net overhanging the perimeter of a tall building). The other type of fiber optic is a side-emitting fiber that has a translucent outer cladding that emits light along the length of the fiber. These fibers can be used to form a solid line of light similar in appearance to neon signs.

Retroreflective Markers

Retroreflective surfaces reflect light back toward the light source so an external light source is required. In heliport applications this external light source is generally the helicopter's landing light. Retroreflective markers have been used in highway signs and are now being used in aviation as a passive lighting system. Such systems may be suitable for use in remote areas without electrical power. Some retroreflective markers can be seen at night from over 3 nautical miles in clear weather and can be arranged in the same patterns as point source lights. These markers are brightly colored to provide a daytime cue. The initial illumination of the pattern with the helicopter landing light provides a strong acquisition and identification cue similar to the initiation of a pilot-actuated lighting system. The unique character or appearance of the markers, when illuminated, is also an acquisition aid. The markers provide little surface illumination, however, since the majority of the light is reflected back toward the light source.

LIGHTING TESTS AND DEMONSTRATIONS

As a part of the project, the research team conducted several laboratory and field demonstrations of lighting components and systems.

Lighting Array Simulation (Scale Models)

In one test project the research team developed scale-model heliport lighting arrays and tested them in a dark room. The method used cardboard boxes to simulate the heliports with the lighting provided by miniature Christmas tree lights. The heliport arrays were laid out to a scale of ¼ inch equals one foot, which allowed viewing from scale distances of 2,600 feet in the room available. Three basic arrays were examined, with several variations in each case. Six helicopter pilots, with varying levels of flight experience, evaluated the arrays from 3, 6, and 9-degree approach angles. The results of the scale-model simulation were applied to the development of the prototype lighting system.

Mirror Optical Landing System Field Test

The objective of this test project was to compare a Mirror Optical Landing System (MOLS), developed by the U. S. Navy, with a commercially available glideslope system, the pulse light approach slope indicator (PLASI). The MOLS is a Type 1 glideslope that provides the pilot with an indication of angular displacement and rate of displacement

from the approach centerline. The error rate information allows the pilot to reduce the correction as the aircraft nears the "on-gldeslope" position.

The MOLS was located at the Erlanger Hospital helipad in Chattanooga, TN and aligned with the non-precision GPS approach to the helipad. Four Erlanger Life Force pilots then flew this system over a period of six months in a Bell 412 helicopter. Pilot surveys were conducted for 12 approaches (7 day, 5 night, with 4 of the total flown having a visibility of 5 nautical miles or less). Surveys of pilot opinions showed the MOLS to be superior to the installed PLASI system.

Discussions with individual pilots revealed a desire to have glideslope information located beyond the helipad with the guidance set to avoid obstacles to guide the pilot to a point above the heliport at 20 to 50 feet. The pilots would then fly beneath the glideslope to the helipad when a visual inspection of the landing area assured them that no obstacles were in their path.

Prototype Lighting System Tests at Tullahoma Airport

Several manufacturers expressed an interest in participating in the research effort by providing lighting components for field evaluation. From these components the research team developed and tested a prototype lighting system at UTSI. Initially, these lights were evaluated in a downtown environment. The color and characteristics of the cold cathode lights were so unique to the well-lit city environment that they were easily identified in the midst of a variety of traditional city lights. These unique characteristics also improved the ease with which the pilot maintained visual contact with the heliport environment (simulated during these tests) and significantly increased the amount of information provided to the pilot as compared to conventional incandescent heliport lights.

Atlanta Olympic Games Demonstration

The Helicopter Short-Haul Transportation Aviation Research Program, Operation Heli-STAR, was a joint FAA and industry initiative that applied advanced technology in a real-world operational setting. It was conceived as an innovative urban transportation system design, and it was created to meet the demands of the 1996 Olympics. Operation Heli-STAR provided an opportunity to perform research and development to yield valuable data that could support urban helicopter transportation systems, worldwide. As a part of Operation Heli-STAR, the FAA decided to evaluate the prototype lighting system developed by the research team.

The prototype system used a 20-foot light pipe, green cold-cathode lights, and EL panels. A semi-permanent installation, suitable for re-use, was built and installed at a temporary heliport at a commercial site that was named NationsBank Southside heliport. The prototype system enhanced the acquisition, line-up, closure rate, and touchdown cues. The site chosen for the evaluation allowed a single approach to a landing spot with obstacles on all sides. Ambient light levels were high in the city environment, and the same surrounding lights made conventional amber heliport lighting difficult to identify. During the three-week operational period, the weather was generally clear with good

visibility. No flights were flown to the demonstration heliport in low visibility conditions.

The plan of evaluating the prototype lighting system by large numbers of commercial pilots was not realized. Due to the long summer days and a limited night schedule, night traffic was minimal at all heliports. When the amount of cargo to be moved by air did not meet original estimates, the schedule was re-evaluated and the night flights to the NationsBank Southside location were eliminated. Security flights in the early morning, a few night cargo flights, and a few dedicated evaluation flights were the only flights that used the prototype lighting system. Pilot first impressions were all favorable, with the easily identifiable lights mentioned most.

U. S. Park Police Demonstration

After the evaluation in Atlanta, the FAA made the decision to move the prototype lighting system to the Washington, DC area for further evaluation. The U. S. Park Police heliport in the Anacostia section of Washington, DC was selected as the location. Since the prototype lighting system had not been thoroughly evaluated during Operation Heli-STAR, it was decided not to replace the existing Park Police Heliport lighting system. The prototype system was instead installed on a little-used parking pad that is set back a distance from the main landing pad.

Based on the experienced gained at Operation Heli-STAR, incandescent floodlights were not used in the Park Police installation. The cold cathode lights provided sufficient illumination, making the floodlights unnecessary. The EL lights, as configured in Atlanta, provided a good, low profile outline of the wooden landing pad at NationsBank Southside. Since the installation in Washington does not have a similar requirement to outline a landing pad, the EL lights were not used.

As the prototype system was installed, a diode laser system and a flashing acquisition beacon became available. These components were also installed and evaluated. The systems installed at the heliport were as follows:

- laser guidance (lateral and vertical) on the main helipad with conventional perimeter lights (**figure 4**)
- high intensity strobe beacon (flashing Morse code "H" , four quick flashes)
- light pipe and cold cathode lighting system (**figure 4**)
- glideslope indicator that used the "alignment of elements" concept (**figure 4**)

To encourage interest of local pilots, the availability of the prototype system was briefed at a local helicopter operator's association safety meeting and the pilots were encouraged to visit the site. The briefing was followed up with a letter invitation, written briefing, and evaluation forms. Unfortunately, only a few operators visited the site, and even fewer responded with written evaluations.

Because of the limited response, the emphasis was shifted to using the site to demonstrate the new technologies to FAA, military, and industry helicopter association officials. As new systems became available, they were installed, a limited evaluation was conducted,

and feedback was provided to the FAA and the manufacturer. At the conclusion of the evaluation, the Park Police pilots expressed a desire to have the cold cathode lights placed in operational service at their main helipad. The FAA recognized the benefits of having components of the prototype system available for long-term evaluation. In September 1998 the research team moved the cold cathode lights to the main helipad at the Park Police heliport. The lights remain in operation at this time.

CONCLUSIONS AND RECOMMENDATIONS

Lighting Requirements and Standards

As the FAA develops and refines the requirements for heliport instrument lighting, care must be taken to develop all resulting specifications as functional performance specifications that detail the required characteristics of the light output and not merely the characteristics of a light source. New ways to produce a light evolve as lighting technology advances. Developing specifications for the light source, rather than the light output, tends to inhibit innovation and technology improvements.

It is in the interest of industry to expand the FAA list of approved lighting in order to remove any barriers, however artificial and unintentional, to the introduction of new lighting technologies that may improve VFR and IFR heliport operations.

The public heliport, in general, has more demanding requirements than the private heliport. The public heliport must accommodate pilots with a wide variation in experience and skill. Private heliports can control who is permitted to use the heliport and can require specific training for pilots using the facility.

To some extent, heliport lighting designs are site and operations specific. One design will not work for all situations. Some manageable grouping of possible heliport types appears appropriate. Three types are proposed here: rooftop, ground-level/off-airport, and ground-level/on-airport. Guidelines should be developed to assist the designer in developing one or more cost-effective systems tailored for each of these groups.

The cues required for a safe instrument approach are: acquisition, line-up, glideslope, horizon, closure rate, and touchdown.

As the U.S. Park Police demonstration has highlighted, "local course rules" can be used to increase the safety of heliport operations. The VFR equivalent of an IFR approach chart is seldom available for public or private heliports. Such charts could provide pilots with "local course rules" including key heliport information. Such information could include: the azimuth of the heliport approach and departure paths, landmarks in the area, locations and altitudes of nearby obstructions, size and weight of the heliport's design helicopter, elevation of the landing pad, telephone number of the heliport operator, etc. A first step toward encouraging heliport designers, heliport operators, and state aviation authorities to develop and distribute such guidelines would be to develop guidelines on the content, format, and accuracy of such charts.

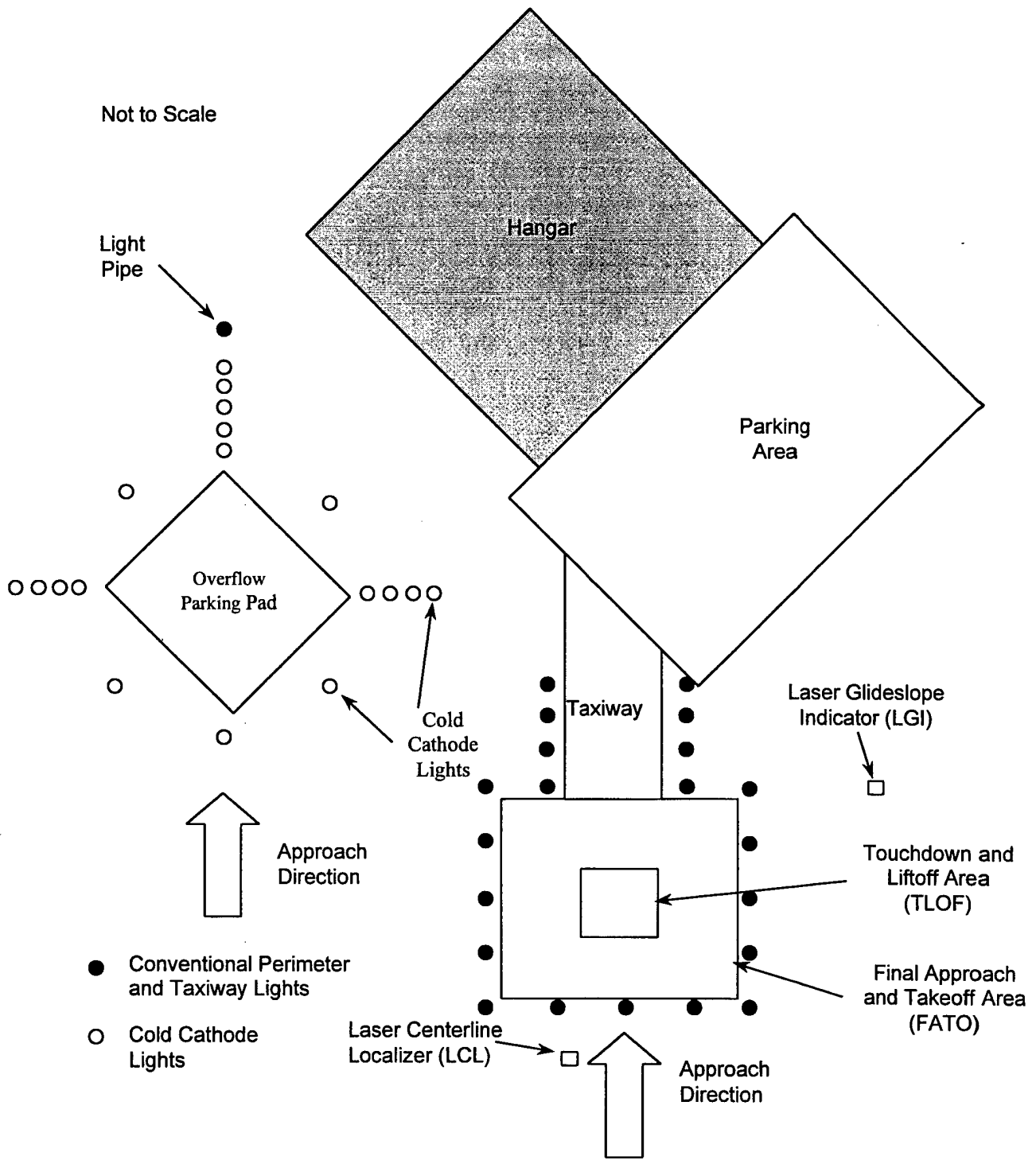


Figure 4 Prototype Lighting Layout at the U.S. Park Police Heliport

The ground-level/on-airport category is an important grouping in that it includes the emerging requirement for a lighting system to support vertical flight instrument approaches and departures that do not conflict with simultaneous airplane operations. These lighting systems must clearly differentiate the helicopter approach from the fixed-wing approach.

Lighting Component Conclusions

The pilots preferred the blue-green color of the cold cathode lights and the light pipe to the amber lights on the operational helipad. The blue-green color was very distinctive when contrasted with the white lights of the surrounding city. Much of the conventional incandescent lighting currently in widespread use in airport and heliport lighting blends into the city lights.

The pilots favored the light pipe and cold cathode prototype lighting system over the existing heliport lighting system, which consisted of amber heliport perimeter lights and taxiway lights. They found the light pipe and line-up light alignment cues very easy to interpret. The wing bars were useful in providing cues for horizon, fore and aft position of the helicopter over the helipad, and hover over the helipad. Some of the pilots also found the wing bars to be useful as an alignment cue when used in conjunction with the line-up lights.

The flashing acquisition beacon was very effective in locating the heliport amongst the many city lights. The pilots preferred the radio-controlled version of the beacon to the continuously flashing beacon because they were more confident of positive identification of their beacon when they initiated the beacon function. The radio-controlled version is likely more acceptable to residents and businesses located in the vicinity of the beacon, as well.

The FAA should investigate alternative early-acquisition lighting systems. Currently only HALS qualifies for a visibility credit for lighting and HALS is not suitable for installation at many locations. Lead-in lights that can be installed on top of buildings and above streets or highways are potential solutions.

It is possible that not all cues will require lighting augmentation at all sites. Natural cues may be sufficient at some sites. This determination will require careful analysis of the minimum requirements for each phase of the approach. A flight inspection process, flown in conjunction with the inspection of the instrument approach, will probably be required to certify the resulting lighting system. Before the FAA could adopt this policy, some practical and objective means must be found to define and determine when augmentation of a certain cue is not required at a particular site.

The most promising candidate lighting components and lighting systems should be tested in a variety of operational environments and under a variety of different weather conditions at different times of the year. If possible, test locations should be chosen that allow a wide variety of industry helicopter pilots to participate in this flight-testing.

FUTURE DIRECTIONS

So where do government and industry go from here? Basically, there are four choices:

Choice 1. Continue using the same FAA-approved lighting components and lighting systems. They are safe, relatively inexpensive (except for instrument approach lighting), components are readily available, and the lighting technology would remain based primarily on incandescent light sources. The benefit of this scenario is that relatively little needs to be done by either government or industry. The disadvantage is that this choice would tend to delay or eliminate any chance that technology could give us cheaper, more effective, more reliable lighting. This choice would also tend to limit operational benefits to helicopter operators because relatively few heliports have the space necessary to install FAA-approved heliport lighting to support instrument approaches.

Choice 2. Encourage new lighting technology by modifying FAA standards and specifications to define light outputs rather than light sources. This choice requires that FAA and the lighting industry do a considerable amount of work in updating the FAA's lighting standards and specifications. The benefit of this choice is that heliport operators would have alternatives in their purchase and operation of lighting components. The disadvantage is the time and costs required to develop new standards and specifications. Operational benefits at IFR heliports would still be limited because relatively few heliports have the space necessary to install FAA-approved instrument lighting systems.

Choice 3. Develop new heliport lighting systems and standards for IFR heliports. These new systems would need to be affordable to heliport operators and have much smaller footprints than the existing HILS and HALS. Benefits of this choice accrue to the IFR helicopter operators who presumably could optimize their IFR operations. Disadvantages are the cost, to both government and industry, of developing new IFR heliport lighting standards, and the risk of not being able to achieve lower IFR minimums. There are no assurances that an affordable, more compact lighting system will be able to achieve the performance necessary to reduce visibility minimums.

Choice 4. This choice is a combination of Choices 2 and 3. Choice 4 delivers maximum potential benefits in terms of encouraging new lighting technology and achieving maximum operational benefits to IFR helicopter operators. Choice 4 provides new or updated specifications and standards for lighting components, and it offers the possibility of producing smaller, more compact heliport lighting systems to support instrument approaches. However, Choice 4 also carries the largest cost to government and industry and the same risks of not being able to achieve lower IFR minimums that characterized Choice 3.

These choices need to be made primarily by helicopter operators and the lighting industry with input from government (FAA). It is industry's role to tell FAA what their heliport lighting requirements are. It is FAA's role to address industry's requirements by developing new or revised standards and specifications. It is the lighting industry's role to develop lighting components that will meet both the user's requirements and the FAA standards.

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APPENDIX E. LIGHTING MANUFACTURERS PAPERS

Cold Cathode Lighting for Heliports / Vertiports - A Paradigm Shift
Dr. Reynold Schmidt, Lightbeams

LEDline™ A Possible Aid for Pilots, for Lighting, Identification and Visual Queuing
at Heliports and Vertiports
Nick Hutchins, Hil-Tech International

Emergency Lighting
Dr. John Leverton

DISCLAIMER: The papers in this Appendix represent the opinions of the authors and of the organizations that they represent. These opinions are not necessarily consistent with FAA policy or plans.

COLD CATHODE LIGHTING FOR HELIPORTS/VERTIPTS A PARADIGM SHIFT

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Introduction

Cold cathode lighting is an old and well-understood technology. What this paper presents is the proposal of a new application for this well-accepted technology which has proven reliable and cost effective over many decades - for aviation landing lights. This significant advance in aviation lighting has been made possible by recent developments in solid state circuitry, by the creation of new phosphors for use in cold cathode lighting, and by extensive research in the medical science of spatial disorientation.

Bill H.R. 3463 "Airport Safety Act"

On March 12, 1998 Congressman James A. Traficant, Jr. introduced a bill entitled H.R. 3463, the "Airport Safety Act." The intent of this bill was to secure congressional support for the introduction of new airport landing light/ guidance technologies, which heretofore had received little, if any, focussed attention by the Federal Aviation Administration. The bill was strongly supported, amended and passed by Congress. The bill was included as an amendment to the Airport Improvement Program (AIP) as part of the Federal Aviation Administration's overall programs, and became effective on October 1, 1998. The amendment includes three major action items:

- The FAA is to conduct a study of the feasibility of requiring U.S. airports to install "Enhanced Vision Technologies" to replace or enhance conventional landing light systems over the next ten years. Enhanced vision technologies is defined by the amendment to include cold cathode lighting; laser guidance; ultraviolet, and infrared technologies.
- Makes installation of Enhanced Vision Technologies eligible for AIP funding.
- Requires the FAA to submit to Congress within 180 days of enactment of the Bill a schedule for certification of two of the most promising Enhanced Vision Technologies: cold cathode lighting and laser guidance systems.

Cold Cathode Lights

- **Components**

Cold cathode lights are made of hollow glass tubes sealed at both ends. Their internal surface can be coated with various phosphors, which when energized, emit different wavelengths of light. Electrodes (steel shells) are attached to each end of the glass tube. There is no filament, i.e. tungsten filament, in the tube. When electric energy is applied to the electrodes, a stream of electrons is generated which excites the phosphors to emit light energy (photons).

- **Color**

The color of the cold cathode light depends upon the presence or absence of phosphors, or mixtures of phosphors, in the glass tube. The blend of fluorescent chemicals (phosphors) used to coat the wall of the tube, and the mixture of gases introduced into the tube, determine the color (wavelength) emitted. Multiple phosphors and gases are available today which enables manufacture of a wide variety of wavelengths and colors of emitted light.

- **Temperature**

With the exception of the color red, cold cathode lamps have a very small amount of mercury contained in the lamp to aid in transmission of an electrical current through the lamp. Typically, low temperatures (below -20° F) cause a dimming of the cold cathode light output. This is due to the decrease in the vapor pressure of the mercury contained in the lamp. With the development of solid state circuitry, this problem has been eliminated. Lamps using pure neon gas only, which are red in color and do not contain mercury, are not effected by low temperatures.

- **Lamp Life**

The life of a cold cathode light is not appreciably affected by the frequency of turning the lamp on and off. This is due to the lack of a delicate filament and the presence of steel electrode shells which are immune to this problem. Cold cathode lights are noted for their long lamp life.

- **Flashing**

Because the cold cathode light lacks filaments, cold cathode lights provide excellent extended lamp life when used in the flashing mode vs. incandescent lights. The steel shell electrodes in the cold cathode light are not affected with repeated turning on and off, i.e. flashing, and lamp life is not appreciably affected.

- **Power Supply**

Until recently, cold cathode lights have required the use of conventional transformers to function. The average cold cathode light used in these applications requires

~3,000-6,000 volts to energize the light vs. 120V / 240 V for comparable incandescent lights. With recent innovations in solid state electronics, it is now possible to provide solid state circuits (solid state ballasts) which convert the 120V / 240V power supply to provide the power necessary for energizing the cold cathode light.

- **Solid State Ballasts**

Recently developed "smart" ballasts enable the manufacturer to program the ballast to perform tasks critical for aviation use:

- o Line voltage control - allows the use of unregulated power, a cheaper power source versus regulated power
- o Temperature control - allows operation of cold cathode lights in low temperatures
- o Flash rate - allows operator to set flash rates and "on" time as desired
- o Sequencing - allows operator to flash lights in a sequence, acting to guide pilots to a particular location, runway, taxiway, heliport, etc.
- o Candela - allows operator to set light output at desired levels

- **Retrofitting of Heliports/Airports**

Cold cathode lights, utilizing solid state ballasts, are ideally suited for retrofitting existing heliports/airports at a reasonable cost.

Cold Cathode Lighting - History of Aviation Applications

- **As Obstruction Lights**

The first neon cold cathode light was submitted for approval and certification to the FAA in 1962 by a principal of Litebeams, Inc. The FAA did not communicate with the principal regarding requirements for acceptance of cold cathode lighting by the FAA. Mr. Robert Bates, formerly of the FAA Engineering and Specifications Division, issued a notice of acceptance and approval to list the cold cathode neon obstruction light in the official FAA equipment list in 1979, 17 years later. According to Mr. Bates, the light had been burning at the FAA Technical Center since its submission in 1962. No standards under which the cold cathode obstruction light was formally accepted by the FAA were ever given. It was assumed the cold cathode light was judged in relation to incandescent lights in use at the time.

Beginning in the 1950's, this neon cold cathode light was installed at multiple airstrips, private heliports, private runways, etc. The light was installed in multiple industrial sites such as buildings, towers, refineries, etc., as both an obstruction light

as well as a marker light. The cold cathode light operates efficiently at the top of refinery towers where temperatures can reach 300⁰C.

Subsequent to receiving approval from the FAA to be included officially as an obstruction light, many commercial airports began to order small numbers of these units. One significant reason for this decision is based upon the fragility of the incandescent light's tungsten filament. The incandescent filament is vulnerable to the high frequency vibration created by jet engines, which result in filament breakage, and pre-mature lamp failure.

Presently Portland Airport, in Portland, Oregon, has converted almost all of its obstruction lights to cold cathode lights. San Francisco International Airport, in San Francisco, California, currently is beginning the retrofitting of their obstruction lights with cold cathode units.

- As Bridge and Pier Markers

The cold cathode obstruction light has been installed at multiple domestic and international locations for use as bridge and pier markers - near airports, heliports, waterways, and in other locations. In the State of California Cal Trans (California State Highway Department) has installed many of these lights throughout the state. Other states have followed the lead of Cal Trans, owing to the efficiency and reliability of the cold cathode light.

- As Heliport Lights

Similarly, cold cathode lights have been installed at multiple heliports, including rooftop locations. Recently, Mobile Petroleum Company installed a set of the new style green cold cathode lights on their rooftop headquarters in New Jersey. The FAA has been running a demonstration using green cold cathode lights since 1998, at the U.S. National Park Police Heliport, in Anacostia, Washington, D.C. These lights are now installed on a permanent basis. A demonstration videotape of the lights is available for interested parties.

- As Portable Runway / Taxiway / Heliport Lights

Portable cold cathode lights were designed to meet present FAA incandescent lighting standards for runways, taxiways and heliports with respect to candela and chromaticity. The initial models were tested extensively by the U.S. Marines and U.S. Air Force during 1989-1990. Pre-production models were purchased by the U.S. Marines and used in Operation Desert Shield and Desert Storm during 1990-1991, for marking ammunition and gasoline dumps. The models were fitted with infrared lenses, and were used continuously until the end of the war. Although scratched and battered, the lights did not break or fail to operate, and performed to the high standards set by the U.S. Armed Forces. As a result, the U.S. Air Force and U.S. Marines began purchasing these units for use at installations throughout the United States beginning in the early 1990's.

- Color

Cold cathode lamps can be controlled without the use of filters/colored lenses.

Night Vision Devices

Cold cathode lamps are compatible with night vision devices. Additional of special filters/lenses is not required prior to use.

- Spatial Disorientation

Cold cathode lamps minimize or prevent induction of spatial disorientation.

- Resistance to Damage from High Frequency Vibration Caused by Jet Engines

Because cold cathode lights lack filaments, they are not subject to failure due to high frequency vibrations generated by jet engines, a significant cause of pre-mature lamp failure with incandescent lights.

- Maintenance Requirements

Maintenance requirements for cold cathode lamps are low.

- Reliability

Reliability of cold cathode lamps is excellent.

- Initial Cost Factors

Initial cost for cold cathode lighting is moderate compared to comparable incandescent light units.

- Life Cycle Cost

Approximately 20% of comparable incandescent light units.

Safety During Helicopter Night Landing Operations: Increase Safety of Night Landing Operations of Helicopters by Reducing the Risk of Induction of Spatial Disorientation

- Explanation of Spatial Disorientation

An orientational illusion is a false perception of position, attitude, or motion, relative to the plane of the earth's surface. An example would be when the aircraft is turning to the right, when in reality it is flying straight and level. Spatial disorientation, commonly referred to as pilot vertigo, is restricted to that situation wherein the pilot not only has an orientational illusion, but also needs to have correct perception of

orientation for controlling his position, attitude, or motion. An example would be when the aircraft is approaching touchdown and false visual cues inform the pilot to bank his aircraft to one side resulting in an accident.

Spatial Disorientation (SD) is an Aeromedical Problem

Spatial Disorientation (SD) has long been a significant aeromedical factor contributing to both military and civilian aviation mishaps. ^(7,8) With increased research devoted to SD over the past 10-15 years, some definitive statements regarding the cause(s) of SD can now be made. SD contributes to, or is causative of, approximately 5-30% of military mishaps and about 2 -15% of civilian mishaps. Of those mishaps fatalities range from between 10-26% of all military mishaps and 14% of civilian mishaps. Accurate figures are difficult to determine due to differences in definitions of SD mishaps; because initially, many incidents are attributed to pilot error, and to the complexity of pursuing large numbers of accidents involved with this problem. ⁽¹⁴⁾ (Table 1). The research cited in this table does not specify the percent of fixed-wing vs. rotary-wing aircraft involved. Thus, it is not possible to state with certainty what percentage of mishaps listed in Table 1 will be addressed by newer, and improved lighting technology. After reviewing the pattern of incidents and accidents, it is clear that SD is a significant problem in aviation safety.

- Key Attributes of a Physiologically Compatible Landing Light

A light source operating within the range of 520 nanometers is thought to stimulate the retinal nerve cells (rods and cones) to 85% of their peak activity, creating the optimal color (green) to be perceived by the eye in low ambient lighting conditions ^(6,11,13) (Figure 1). With the introduction of a cold cathode lamp designed to emit light around 520 nanometers, it is now possible to provide an ideal light source designed specifically for maximum retinal efficiency. This is the first time in aviation history that a recommendation is made to employ a lamp which has been designed to be physiologically compatible with retinal physiology for use in landing aircraft.

Key attributes of physiologically compatible landing lights include: (1) constant candlepower (steady burn); (2) candela (uniform brightness); (3) chromaticity (uniform color in the range of 520 nanometers), and (4) cold cathode lamp.

- Use of a Physiologically Designed Landing Light

Use of specially designed ground lighting provides the helicopter pilot with adequate central visual cues; allows identification of microtexture; does not induce SD and, enables him / her to concentrate on obtaining the required peripheral visual cue information to safely land the aircraft.

- Current Landing Light Standards for Helicopters

For commercial airports or heliports, there is an FAA Advisory Circular, Heliport Design, AC 150/5390-2A, January 20, 1994, which addresses helicopter operations for commercial precision and non-precision approach operations. Although heliport lighting

is discussed, specifications for a light source are not discussed, vs. FAA lighting standards for runway, taxiway and obstruction lights.

Medical Emergency Sites for Helicopters

There are approximately 350 - 400 emergency medical services (EMS) flights daily or approximately 7,300 night flights per year. According to information received from David Harrington, Director, FAA Flight Standards Service on April 4, 1998, indicates a lesser number of night flights may be factually correct.

AUTHOR(S) MISHAPS	% AIRCRAFT MISHAPS	% FATAL AIRCRAFT
Nuttall and Sanford (one major USAF Air Command 1954-1956)	4%	14%
Moser (one major USAF Air Command 1964-1967)	9%	26%
Barnum and Bonner (USAF Mishap Data 1958-1968) [4679 major mishaps]	6%	15%
Barham (USAF 1969-1971)	6%	10%
Kellog (USAF 1968-1972) Proportion"	4.8-6.2%	"High
Gillingham and Page (unpublished data USAF 1979)	9.6%	18.4%
U.S. Army (study year(s) unavailable)	7.1%	N/A
U.S. Navy (study year(s) unavailable)	6.75%	N/A
Kirkham (General Aviation 1970-1975, total of 4012 fatal cases)	15.6%	14%
Kirkham (General Aviation 1978 - all general aviation accidents)	2.5%	The third most common cause
U.S. Navy Study 1980-1989	5.0%	N/A
U.S. Air Force Study 1989-1991	14.0%	N/A
Canadian Air Force Study 1982-1992	22.5%	N/A
U.S. Army Aeromedical Research Laboratory, Fort Rucker 1987-1995	30.0%	N/A

Table 1

Spatial Disorientation is a Significant or Causative Factor in Aircraft Mishaps

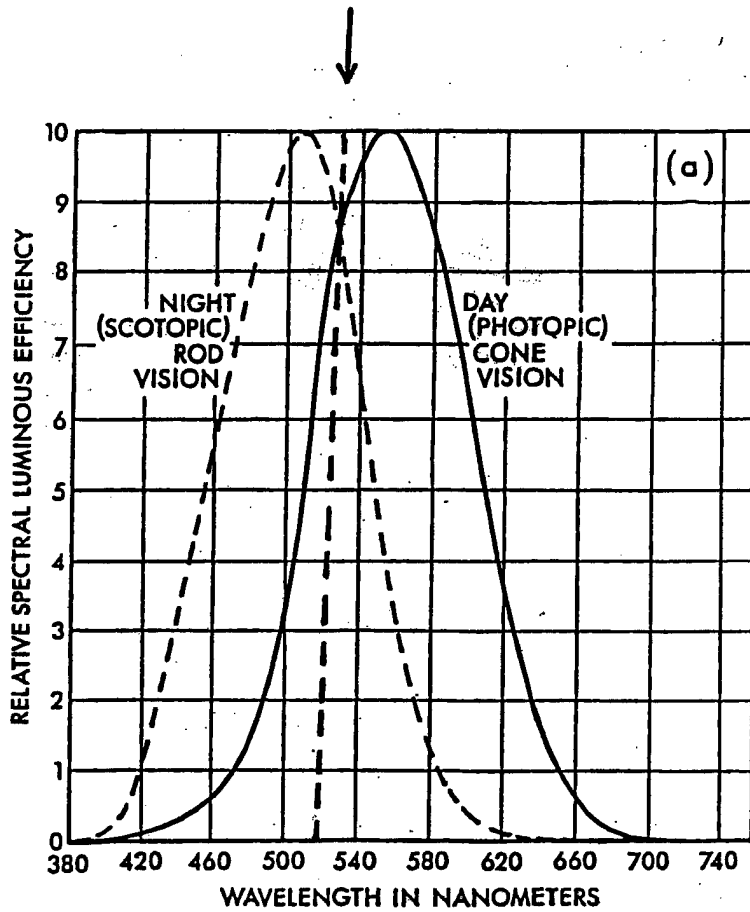


Figure 1. Relative Spectral Luminous Efficiency Curves for Photopic and Scotopic Vision, Showing the Purkinje Shift on the Wavelength of Maximum Efficiency

The FAA states clearly that medical emergency sites are not heliports (FAA AC 150/5390-2A). According to the FAA these medical emergency sites "may be identified with flags, markers, lights, flares, etc." The light sources used at medical emergency sites are classified by the FAA as "expedient lights."

- Relationship between Expedient Lights and Spatial Disorientation

It is possible to induce SD in the pilot through the use of various types of light sources. In a recent research publication, the FAA referred to light sources which are not certified as meeting FAA specifications to land aircraft as "expedient" lights.⁽⁹⁾ Such lights include "flares, vehicle lights, and other light sources."⁽⁹⁾ Use of these light sources, which also include strobes and flashlights, has an elevated probability of inducing SD in the pilot.

These light sources provide "point sources" of light, which can cause serious mishaps and fatalities. Expedient lights lack standardization in respect to steady burning (constant candlepower), brightness (candela), and chromaticity (color).

- Relationship Between Point Sources of Light, After Images and Spatial Disorientation

A point origin of light, such as a flare or an incandescent light which employs a filament to provide illumination, is interpreted by the eye as a "point source" of light. Such light sources emit high concentrations of light rays (radiant energy or photons) which impinge on the retina of the eye in a relatively small area, resulting in the development of an after-image (Personal Communication: Ralph Kimberlin, Ph.D., Associate Professor, University of Tennessee Space Institute, Tullahoma, Tennessee, September, 1995.)⁽¹⁹⁾

This phenomenon is created by the recovery of the retinal neurons (rods and cones) following their exposure to a concentrated light source. An after-image occurs when the retina is slow to recover or to remove the retinal image, even though the actual visual field has changed. This result is due to the time delay it takes for the retinal neurons (rods and cones) to "recover" (reconstitute their neurohumoral transmitter substance) from the light stimulus.

An example of this phenomenon is seen when one looks into a bright light, such as the sun or a flashlight, and then looks away. The light image of the sun or flashlight appears to remain, even though the person is looking away from this light source. A natural reaction to receiving this type of stimulus is for the individual to squint, thus narrowing the visual field in an effort to block out the intense light. This phenomenon is a primary contributor to the induction of SD when the helicopter pilot is focusing on such light sources while simultaneously approaching "touch down." The "after-images" created by such light sources can cause pilots to misinterpret their spatial orientation at the helispot.

- A Physiologically Designed Light Source Which Minimizes Induction of Spatial Disorientation - A Cold Cathode Lamp

Cold cathode lamps lack a filament and produce an even light output, which is not interpreted by the eye as a "point source". One can look directly at the cold cathode light and, when averting the eyes, can immediately perceive that no after-image is

created ⁽¹⁹⁾, and that one's night vision is unaffected by looking directly at such lights. No after-image is created because the light energy is evenly distributed across the retina; and, lacking a point of high concentration, the retina is able to recover quickly.

Cold cathode lighting is not a new technology, however, its application to landing aircraft is an innovation that results in improved safety of night operations. Cold cathode lamps produce a landing light that is comfortable to view and causes no after-image, and hence will not contribute to the induction of SD. Multiple examples of this light source exist in the neon (cold cathode) advertising signs in most cities, worldwide.

- The Optimum Color and Light Source For Helicopter Night Landing Operations
 - o Obsolete Selection Criteria

The FAA developed color (chromaticity) selection for airport lighting standards in the decade of the 1930s, based only on subjective factors. (Personal Communication: Robert Bates, Chief, Visual Aids Standards Branch, AAS-550, Airports Service, Department of Transportation, Federal Aviation Administration, Washington, D.C., April, 1990.) ⁽²⁰⁾ Scientific studies of eye physiology are being conducted, and the knowledge gained will be used to re-examine these criteria. Many of the lighting codes sponsored by the FAA are based upon tradition and international agreements and not upon retinal physiology, which is of paramount importance in preparing such standards.

Airports formerly were located away from the cities and sources of light pollution. As the cities have grown up around the runways and heliports, the importance of selecting the right color to enable the pilot to differentiate the runway or heliport from street lights is paramount in increasing safety during night-landing operations.

- o Scientific Selection of an Aviation Landing Light Based on Retinal Physiology

Previous research on retinal physiology ^(6,11) has identified the proper nanometer range for maximum retinal efficiency in the absence, or near absence of light. A light source operating within the range of 520 nanometers is thought to stimulate the rods and cones to 85% of their peak sensitivity, creating the optimal color green, which can best be perceived by the eye in low ambient lighting conditions. Light sources outside of this nanometer range are thought to be much less efficient in regard to retinal reactivity. ^(11,15)

Extensive research over the past three years with a cold cathode lamp, designed to emit light in the range of 512 nanometers, operating through a clear aviation lens, has been identified to be close to the ideal, non-point-source of light, designed to maximize retinal efficiency for night landing operations. The spectral luminous efficiency curves for cones and rods, as shown in Figure 1, were developed by the Commission Internationale de l'Eclairage, in 1924 for cones (photopic vision) and, in 1951 for the rods (scotopic vision). These assessments were made separately,

and may not reflect precisely the actual interaction between the rods and cones. In order to maximize retinal efficiency a light spectrum encompassing, to some extent, a range overlapping these two curves, is necessary. Additional research may clarify the physiological relationship between the neuroreceptors in this regard.

Over the past three years, repeated testing by multiple helicopter pilots, both military and civilian, reveals the eye apparently responds best to a light source operating in the range of 512 nanometers (Figure 2). Based upon the known factors of retinal physiology from the physiologic response of the rod cells in the retina, this finding is in consensus with present medical knowledge.

From a distance, light from a cold cathode lamp in the range of 512 nanometers, using a clear aviation lens, appears green, but is perceived by the eye with increased clarity as compared to an incandescent lamp in the range of 528 nanometers, the light emission range through a standard FAA green lens. A light operating in the range of 512 nanometers appears to be more easily identified in the surrounding "sea of lights" in an urban setting versus an incandescent lamp filtered through a green lens. Additional research is necessary to clarify these differences.

As a result of this physiological phenomenon, during night landing operations the pilot is never subjected to a bright, point source of light, but to a rather pleasant green light when viewed upon landing. No other light source can produce this effect. In this respect, this is a unique light. As a result, the potential for induction of spatial disorientation from this source of light is minimized or absent.

Standard airport heliport and runway lights utilize lenses which are optically designed to provide maximum light output for the pilot. However, the light source remains the incandescent lamp, which provides a point source of light.

- VFR Approaches at Night or During Inclement Weather Conditions Can Now be Made With Confidence

When landing in a "black hole" situation, for the pilot to land the aircraft safely, it is important for the pilot to have both central and peripheral visual cues. At night, peripheral visual cues are significantly reduced, or absent. A "black hole" can be defined as that situation where a pilot is attempting to land his rotorcraft with few, if any, visual cues, apart from the helicopter landing light itself.

When a helicopter pilot attempts a landing without adequate central and peripheral visual cues, a dilemma is created for the pilot as to how to simultaneously identify the helispot (the center of the helicopter landing zone where the aircraft is to land) and to "clear" (ensure the lack of physical obstructions) the entire helicopter landing zone itself. As a result, the total workload of the pilot can easily exceed 100 percent of capacity, a situation that significantly increases the probability for a serious error."⁽¹⁰⁾

While not all field operations require landing into a "black hole," nevertheless it is physiologically extremely difficult for pilots to repeatedly and safely land a helicopter into a "black hole" without using specially designed auxiliary ground lighting, due to the causative factors leading to the induction of SD.

Use of specially designed ground lighting provides the pilot with adequate central visual cues, and allows identification of microtexture; significantly reduces the probability for induction of SD and, enables the pilot to concentrate on obtaining the required peripheral- visual-cue information to safely land the aircraft.

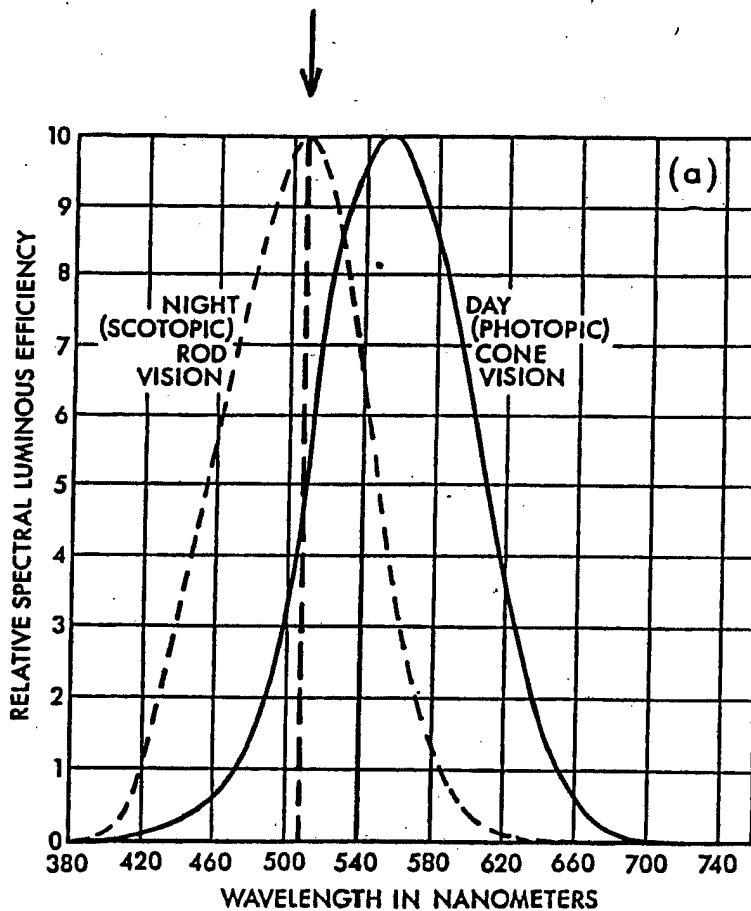


Figure 2. Relative Spectral Luminous Efficiency Curves for Photopic and Scotopic Vision, Showing the Purkinje Shift on the Wavelength of Maximum Efficiency

- Flight Safety - Human Factors

I agree with Sheridan and Young in "Human Factors in Aerospace Medicine" as to the importance of human performance enhancing system performance, in which "safety is intrinsic to system performance."⁽²¹⁾ "The majority of aviation accidents are attributed to operator (pilot) error. Close examination may reveal that the root cause goes back to a system design in failing to account for human capacity or limitations,"⁽²¹⁾ something especially true in the case of SD. The majority of aircraft mishaps due directly or indirectly to SD are usually classified initially as "pilot error". It is only after intense investigation and studies that the true nature of the underlying cause for the accident is discovered to be SD.

According to Gillingham in "The Spatial Disorientation Problem in the United States Air Force," published in the Journal of Vestibular Research: "SD wastes hundreds of millions of dollars annually and kills air-crew members. SD results primarily from inadequacies of human visual and vestibular sensory systems in the flying environment. The U.S. Air Force is conducting a three-pronged research and development effort to solve the SD problem. They are attempting 1) to elucidate further the mechanisms of visual and vestibular orientation and disorientation, 2) to develop ground-based and in-flight training methods for demonstrating to pilots the potential for SD and the means of coping with it, and 3) to conceive and evaluate new ways to display flight control and performance information so that pilots can maintain accurate spatial orientation."⁽⁷⁾

- o The Health Care Safety Paradox - American Medical Association Workshop 1997

In 1997 the American Medical Association, concerned about the rising number of incidents, accidents, and tragedies in the nation's hospital care system, conducted a workshop to determine the factors involved in compromising the safety of the patients, and the outcome of hospital treatment. The results were published in a report from a workshop on assembling the scientific basis for progress on patient safety entitled "A Tale of Two Stories: Contrasting Views of Patient Safety," available on the Web at: <http://www.npsf.org/exec/front.html>.

In the section entitled "Taking a 'New Look' at Systems Safety," the following observations were agreed to:

1. To improve the reliability and safety of our hospital care system, we need to continuously learn about the system.
2. To learn about the system, we need the ability to investigate and to understand the full story.
3. To obtain the full story, we need to move beyond asking who is to blame.

4. To move beyond blame, we need a culture that honestly talks about failure.

In the section entitled "The Promise of the 'Systems Learning' Approach," the following conclusions were reached:

1. Our present approach to safety in health care is too narrow.
2. What often appears as "human error" is, in fact, a much more complicated story.
3. "Safety" cannot be understood in isolation from all other aspects of health care.
4. Real progress in promoting patient safety will only be achieved in the system is understood.

Speaking as a physician interested in saving the lives of pilots, passengers, and crew personnel, the above summary applies to any "system," and in particular to the air transportation industry.

In a section containing questions and answers from attendees at the workshop the following is pertinent to this presentation:

Question: "Does the fact that pilots are at personal risk when flying have something to do with the success of the system? Is that a reason that you think this system might work much better in aviation than it might be made to work in medicine?"

Answer: "I believe that the reporting to this system (author's own explanation: NTSB, NASA Aviation Safety Reporting System (ASRS), FAA) is motivated not by the sense of personal risk that attaches to flying but rather from two major factors:

- (A) The sincere interest in improving safety by identifying hazards.
- (B) The sincere belief that the system to which they are reporting uses that information productively and deliberately to improve safety rather than simply as a means of counting failures."

The findings of the American Medical Association with regard to "systems safety" agree completely with Sheridan and Young's analysis of safety in the air transportation industry. The problem is the same: safety is a by-product of the system. Currently the American Medical Association uses as an example of a "system" to be emulated - the air transportation's safety guidelines. We need to continue to improve and support this system.

- Results of Using Physiologically Designed Ground Lighting

The use of specially designed ground lighting provides a "system" where "safety is intrinsic to system performance" and which conforms with the recommendations of Sheridan and Young's. ⁽²¹⁾ In addition, the use of specially designed ground lighting reinforces the pilot's acquired skill of visual dominance, a factor which is critical in avoiding induction of SD. ⁽⁸⁾ Placement of specially designed ground lighting, as contrasted to presently used lighting sources, provides the helicopter pilot with adequate central visual cues; allows the perception of translational cues required for the fine control of a helicopter; identification of microtexture; significantly reduces the risk of inducing SD; and, enables him to more easily obtain the required peripheral visual cue information for safe landing of the aircraft.

In the same manner, now that specially designed ground lights are available for landing aircraft, it is imperative that appropriate standards be developed for the use of proper ground-lighting sources to prevent or minimize the occurrence of SD in pilots of rotary-wing aircraft engaged in landings at night or in inclement weather ("system design"), thereby acting to prevent accidents, injuries, and fatalities.

Relationship Between the Global Positioning Satellite System and Spatial Disorientation

The Global Positioning Satellite System is now in place and operational. Its use by helicopter pilots will rapidly increase over time. Basic standards for rotorcraft use of GPS have already been drafted by the FAA. It is now possible, using GPS, for the helicopter pilot to fly directly to the HLZ via VFR or IFR, using this technology. When a helicopter pilot is flying under adverse weather conditions via VFR (visual flight rules), or IFR (instrument flight rules), the "cornerstone" for the induction of SD is created. Adverse weather conditions, in combination with the lack of adequate visual cues, are the "envelope" that leads to SD. The potential for induction of SD is increased when the pilot changes from IFR to VFR flight and begins final approach and landing maneuvers, especially when the environment at the proposed landing site is degraded or minimal; offers poor visual cues, and expedient or point source ground lighting is employed.

This phenomenon is documented by recent U.S. Air Force studies with fixed-wing aircraft. ⁽⁵⁾ It is reasonable to consider that this same phenomenon occurs with rotary-wing pilots as well, and this fact has been confirmed, on an informal basis, in discussion with numerous helicopter pilots over the past eight years. As these discussions were informal, occurred with both active and retired civilian and military helicopter pilots, in both face-to-face as well as via telephone conversations, this information is considered anecdotal. However, these discussions support the concept that the use of specially designed ground lights in these situations would greatly reduce the risk of induction of SD, and increase the safety of night landings.

- Light Efficiency of Cold Cathode Lighting

Laboratory tests reveal the cold cathode lamp differs significantly from an incandescent light with regard to light emissions using FAA lenses. Comparisons of 30W and 45W incandescent aviation lights, employing a standard omni-directional FAA green lens, with a light emission of 528 nanometers, and a cold cathode lamp

rated at 24W, with a light emission of 512 nanometers, using a standard omnidirectional FAA clear lens, is summarized in Table 2.

A significant drop in luminous intensity (candela) levels in the incandescent light sources occurs at approximately 10 degrees, dropping to 3-4 candela in the critical viewing range for the helicopter pilot. In the cold cathode lamp a small loss in candela is observed, beginning at 14 degrees, but never drops below 35 candela up to 20 degrees. The cold cathode lamp provides uniform light emission throughout the lens. No dimming of the cold cathode light is required upon short final approach (1/4 - 1/2 mile) and landing, as occurs with incandescent light sources. In addition, the cold cathode lamp provides excellent illumination of the helipad, virtually eliminating the necessity to use floodlights.

Approach Lighting Systems Symposium ALS '98: "Rethinking Approach Lighting Systems for the 21st Century"

In April 5-19, 1998, a symposium entitled "Approach Lighting Systems Symposium ALS '98: "Rethinking Approach Lighting Systems for the 21st Century" was held at Arizona State University in Mesa, Arizona. Co-sponsored by Arizona State University and the FAA, the above medical research information was presented. This information was subsequently published in Proceedings of the Symposium. The medical information presented in this paper received a Technical Paper Award of First Place.

Reduce Risk of Inducing Spatial Disorientation Using Physiologically Compatible Ground Lighting

The above medical information was submitted to The Journal of Aviation, Space, and Environmental Medicine for consideration for publication. This journal is presently the world's premier medical journal on these subjects. This medical information, after intense peer review, was accepted for publication by the Journal on September 3, 1998, to be published in the spring of 1999.

Conclusions

Specially designed ground lights for rotary-wing aircraft are being manufactured and sold in the U.S. These cold cathode lights have the characteristics necessary for proper ground lighting and include: (1) constant candlepower (steady burn), (2) candela (uniform brightness), and (3) chromaticity (uniform color in the range of 512 nanometers). Further they provide no point source of light, thus minimizing the risk for induction of SD.

Improved quality of ground lighting will reduce pilot workload in a critical phase of flight, and minimize the chances for induction of SD during night landing operations for rotary-winged aircraft. While figures for the occurrence of incidents or accidents secondary to SD for fixed wing aircraft are of greater magnitude than for rotary-winged aircraft, it is reasonable to institute preventive safety measures wherever and whenever possible.

Vertical Angle (in Degrees)	Luminous Intensity (Candela)		
	30W	45W	Cold Cathode 15W
20	3.0	4.7	35.5
19	3.2	4.5	36.9
18	2.9	4.4	38.0
17	2.8	4.4	39.3
16	2.9	4.5	40.6
15	2.9	4.9	41.8
14	3.1	5.3	42.8
13	3.3	5.6	43.6
12	3.6	6.1	44.2
11	3.8	6.8	44.6
10	4.1	7.5	45.0
9	4.6	8.7	45.3
8	5.2	10.5	45.5
7	6.2	12.9	45.7
6	7.7	16.1	45.9
5	9.7	20.4	46.2
4	12.3	25.5	45.8
3	15.2	32.6	45.3
2	18.9	43.4	44.6
1	25.3	56.9	44.2
0	34.6	68.9	43.9
1	43.4	74.7	43.4
2	47.0	72.1	43.1
3	45.5	63.9	42.6
4	40.1	52.3	NA
5	33.1	41.6	NA

Table 2. Comparison of Luminous Intensity Between Incandescent and Cold Cathode Aviation Lights

The configuration of the lights used or intense training will not eliminate the risk of SD; however, provision of specially designed ground lights will establish a preventive safety standard, and will not leave the possibility of the induction of SD “up to chance” or to “pilot error.” The use of specially designed ground lights provides a significant advance in aircraft safety for pilots, flight crews, passengers, and ground personnel.

Recommendations

1. Cold cathode lights specified to 512 nanometers should be certified for use in heliport/vertiport lighting systems.
2. Lighting standards in FAA air circulars for heliport/vertiport operations should be applicable to temporary and emergency heliports as well as to commercial heliports.
3. Use of the combination of cold cathode lighting systems with new laser guidance systems will likely provide a significant increase in safety of night landing operations.

Summary

- Spatial Disorientation has been primarily attributed to "pilot error" until now.
- To discover a heretofore unknown cause for the induction of spatial disorientation in pilots has required a diligent pursuit of the facts to discover the "root cause" for this phenomenon.
- A "Systems Approach" has now clearly identified a significant cause for induction of spatial disorientation in helicopter pilots - "Point Sources of Light."

NOW

- The final responsibility for implementing change in the "system" to protect helicopter pilots, crew, passengers and ground personnel rests with the United States Federal Aviation Administration.

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LEDline™
**A POSSIBLE AID FOR PILOTS, FOR LIGHTING,
IDENTIFICATION AND VISUAL QUEUING
AT HELIPORTS AND VERTIPOINTS**

Nick Hutchins, Hil-Tech International

Abstract

Present heliport standards call for a point source flood lighting, with or without perimeter lighting, electro-luminescent panels, or flush mounted inset lights. All these types of lighting have limitations, so combinations are often favored, with flood light systems being the key ingredient.

Floodlights are both high energy and (relatively) high maintenance and in emergency situations, without adequate power, do not function well if at all.

In bad weather at night, they are often not capable of adequately maintaining good ground contrast and can be a hindrance to pilots by providing glare. Critical pilot visual queues can be lost.

Identifying heliports can be difficult, since point source floodlights are similar to all the other yellow lighting around in cities. As international requirements specify that they be yellow, changing to other coloured lights, for distance identification, might prove difficult.

LEDline™

The LEDline™ system could be used for both vertiports and heliports and because of extreme low power requirements, could be battery backed up, in case of emergencies.

At night, the system would provide for highly visible ground markings, visual queuing and guidance (vector directions), to pilots, as good ground contrast is maintained in just about any weather.

The LEDline™ system is unlike any other typical point source lighting in cities or towns, as it is linear in format, therefore at night it looks completely different. The lighting system can be yellow or many other colours, however maintaining the yellow light colour would continue present international conventions and would be much simpler to achieve, as it would require minimal rewriting, or additions to current regulations.

Present Day Heliports, Some Limitations:

Present standards call for point source flood lighting of the heliport, and/or using low intensity perimeter lights, inset lights, electro-luminescent panels or a combination of these, with flood lighting systems being the key ingredient. The limitations of present systems appear to be well recognized, hence the variety of combination lighting solutions available, probably to try and overcome some of the perceived shortfalls. Whilst it is not my intent to go into all the ramifications of the different heliport lighting systems, I would like to focus a little on flood lights.

Floodlights normally have to be positioned away from the pad, to avoid being a hazard to the helicopter. In good weather, they normally provide excellent area lighting, so that the ground and its markings are easily seen, providing good vector queues for pilots. However, they have limitations. In bad weather, such lighting systems are often not capable of adequately maintaining good ground contrast and indeed can be a hindrance to pilots by providing glare. Pilots report that in certain conditions the heliport markings are difficult or impossible to see, thus floodlights can mask and hinder ground visual cues, creating "black hole landings".

In emergency situations, floodlights are high-powered energy devices requiring significant power and maintenance and, without adequate power, do not function well if at all. Since heliports are often required in emergencies, it is important that they function regardless of the local electrical grid.

A pilot hovering in a helicopter in rain has to view the heliport through the side windows just before he lands. In such conditions, (helicopters do not have windscreen wipers on the side windows), pilots have to strain to view the heliport through the glare from the point source flood lights reflected from each of the rain drops on windscreens. Needless to say it is difficult. This tends not to happen with linear sources.

In addition, floodlights suffer from being similar to every other light in a city, having a yellowish colour and being a point source. This means that pilots have great difficulty in identifying heliports from a distance, especially in light cluttered cityscapes.

There is another way and we feel we can be of significant help to pilots at heliports, vertiports and airports.

Potential Advantages of Flush Mounted, Linear LED Lighting Systems:

1. The LEDline™ lighting system is flush mounted, so it is not a hazard to helicopters and can be snow plowed without damage. This allows the system to not only outline the rectangular helipad, (hopefully in a dashed line fashion, so pilots get needed information if the helicopter is drifting), but also allows the light system to be safely installed within the pad. This guidance shows where the ground is so pilots are not landing into "black holes". Having a dashed line linear indicator rather than point sources, gives pilots more information on where they are within the helipad. It also increases the helipad

marking's visibility and safety, since the ground is marked and the maximum contrast ratios are maintained in just about all weathers.

2. The LEDline™ system is linear in format, therefore at night it looks completely different and is unlike any other typical point source lighting in cities and towns. Indeed a pilot viewing the heliport from a distance would see the whole pad pattern rather than just a light source. As such, the system should be much easier to spot than traditional lights. This tendency would be further pronounced if the system was of a different colour such as green.

The system might also be differentiated by having sections flash, perhaps to provide a lit indicator for a helicopter's standard approach. In this context some sort of "linear lighting design standard" could be developed, whereby a dashed linear line or cross could split the heliport and provide additional pilot vector information. This type of visual guide could extend some distance (to be decided and standardized), from the heliport/vertiport to provide an indicator both within and without the helipad. This should be extremely helpful in providing both surface and direction to pilots. Therefore in any city, the LEDline™ system should readily identify and differentiate heliports or vertiports against the clutter of all the other point source lights.

3. Present lighting standards are based on 1940's and 1950's filament bulbs, or arc lamp technologies and require significant maintenance and power to operate. This creates difficulties, as heliports are often based in difficult access areas with limited power availability. Indeed in emergency operations there may not be any power at all. In such situations, new lighting technologies such as LEDs are extremely helpful, as they are extremely long lived, and take minimal power to operate. Indeed they can, if necessary, be powered via car or truck batteries for emergencies, or at permanent sites be powered via mains, with battery back up, or in areas off the grid be powered via solar and/or wind generators, with batteries.

4. Another area where such linear lighting might be of help is to provide for increased safety for low flying aircraft/helicopters at airfields, heliports etc., where there are nearby overhead hydroelectric lines, or other obstacles. Here linear types of lighting could outline wires between hydroelectric towers, or be used to mark the towers and other obstructions. As an obstruction light, they could be made to act like a bulb to emit light in 360 degrees and be emergency backed up via the usual mains and batteries, or batteries with solar and/or wind generators.

Given the above, we would hope that the FAA would develop "operational parameters" as standards for similar types of products, and as part of "the research" that there be a specific program to evaluate the lighting in all weather conditions, rain, snow, fog etc. We would ask that, while such systems are being evaluated, that they be allowed for demonstrations of these "standards" at heliports and vertiports around the country.

Third Party Recognition: As recognition in the airport industry and from others, LEDline™ recently won the 1998 Technology Innovation Award from Aviation Week and Space Technology, 20th April 1998 issue. This award was given to HIL-Tech International Ltd., and 9 other companies, from a total of 90 nominated companies. Since

all the other winners appear to be multi-billion dollar, multi-nationals, we appear to be in excellent company. The August 1998 issue of Photonics Spectra recently did an article on LEDs and a picture of our system made the front page. World wide there is interest in the technology and its potential.

LEDline™ is used to make critical safety/guidance markings visible in just about any weather. This is particularly useful for airports, heliports and roads, where, by increasing the visibility of guidance markings in any weather, this reduces pilots and drivers' confusion. This should lead to a dramatic increase in safety and efficiency on airports, heliports and roads, as bad weather delays are minimized thus increasing the capacity of these facilities. Given the developed world's aging populations, the increased guidance provided will be of particularly importance for roads, just to maintain present safety standards.

Applications in the military range from marking paths through minefields, to bridges; from emergency exit and safety lighting of vehicles, ships, submarines, aircraft, helicopters, tanks, trucks etc., to building and warehouse exits; marking roads, airfields, helicopter landing pads, (both NVG and regular); drop zones; expeditionary airfields, bomb damage, follow-me lines, to lighting small places such as lockers, ammunition bins, or ship ammunition elevators, etc.

For helicopters, we believe that the system could be used as markings for the new vertiports, or as helicopter landing pads. As the emergency lighting within the helicopter, it could mark the exits, or outline the helicopter, making it far more visible at night in its search and rescue roll. LEDline™ could be placed at the end of the rotor blades for military formation flying for increased safety, and be used in a host of other areas from lighting instrument panels to providing semi-permanent light inside any boxes or containers on the helicopter.

LEDline™ is an extremely tough LED extrusion that can be inset into the pavement 6 mm (0.24 inch) below the surface, (so snowplows do not damage it). The system is placed some 25.4 mm (approximately 1 inch) into the surface of the concrete or asphalt apron, so that it is really a surface treatment of the road/taxiway/heliport and does not penetrate down to the road/taxiway/heliport bed causing structural damage.

The product is:

Tough: It has survived a direct loading test of 2.5 US short tons [some 5,000 pounds per square inch (psi), 38.6 megapascals (MPa) directly over a LED], and is chemically resistant to all the sorts of chemicals typically found on airfields, heliports, or roads. It has excellent weathering properties, [it meets American Society for Testing and Materials (ASTM) G 53, ASTM G 23 and ASTM E-96E] against ultraviolet light (UV), moisture or temperature (tested -67 F to +199 F, (-55 C. to + 88 C.)).

Submersible: The Canadian Navy successfully tested it at 35.6 F (2°C.) in seawater down to a depth of 300 m (1000 feet), some 430+ psi (3 MPa).

Energy efficient, and requires minimal power: The 8 lamps per meter system (brightest) takes 0.32 A per meter @12VDC = 3.84 watts per meter to run, the 4 lamp per meter system takes 0.16 amps (A) per meter @12VDC = 1.92 watts per meter to run, and the 2 lamp per meter system takes 0.08 A per meter @12VDC = 0.96 watts per meter to run. Thus the systems can be run off mains, mains and batteries, or via batteries and solar panels and/or wind generators. [A lamp consists of a circuit of 4 LEDs.]

Requires minimal maintenance: The red and yellow LEDs are rated, with a 90 percent confidence mean time between failure (MTBF), depending on ambient temperature, for 240,000 hours life @ < 95 F. (35 C.), or for 109,000 hours life @ < 131 F. (55 C.) if run at 70 milliamps (mA). We run them at 40 mA, which should extend their life.

Summary

In conclusion, we are asking for a new paradigm from the FAA, CAA or other authorities that specify airport and heliport lighting. A line is the simplest form of communication; it needs no language to interpret it. A straight line on the ground tells anyone that it is a line giving direction, the only question is which direction, and if you put an arrow at one end, you then know the direction. We can do this with light.

LEDline™ is appropriate technology for heliports, vertiports, and airfields and would ask that the FAA/CAA study the system at appropriate venues around the country, to develop standards and an "L" specification so heliports and airfields can routinely use it.

TEMPORARY/EMERGENCY HELIPORT LIGHTING SYSTEM

[Kleenkut Imageglow, UK]

Represented by Dr. John W. Leverton

Leverton Associates Inc.

The emergency services and private helicopter owners/heliport operators are often faced with the difficulty of providing guidance for helicopter operations in poor visibility or at night. This is particularly true in the United Kingdom (UK) where poor lighting is common in many locations even during the daytime in winter. A solution to this which is being evaluated in the U.K. is based on the Kleenkut "IMAGEGLOW" system.

The basic *Imageglow* lighting system has been incorporated into a material based portable/flexible helipad marking unit. Kleenkut manufactures the basic *Imageglow* lighting, but the design of the helipad lighting units has been developed by a separate company, which to date has limited their interest to providing a system for the U.K. emergency services. The system is robust and, when not in use, can be easily rolled up on a reel. As a result the same *Imageglow* lighting has also been incorporated in an "inertia barrier" for identifying "no go zones" in the event of emergencies at night. These barriers have been developed in conjunction with one of the U.K. leading automobile organizations and the U.K. Government Health and Safety Executive as part of a package of products designed to enhance road safety.

The *Imageglow* system uses a self-contained light source that is visible from up to 2000 feet: the *Imageglow* helipad is extremely robust and can be configured to any heliport symbols. When not in use, it can be rolled up and stored in a small, light carry bag for land based emergency services as well as being carried in helicopters. It has been designed to withstand the shock of being thrown from the air by aircrews and features integral flashing lights to help locate the kit. This enables land-based personnel to quickly identify safe landing sites at night.

The carry bag contains everything needed to set up the helipad on a variety of surfaces. On soft ground, a mallet and metal pegs enable it to be swiftly set up using the built-in eyelets. For use on hard surfaces, cords are attached to each corner allowing it to be securely tied down.

A variety of power options are available for the *Imageglow* helipad. A 9-volt battery can be used for flashing lights giving up to 38 hours of continuous use. For the helipad, a lithium battery can be used to provide a greater intensity of light. It can also be powered by mains power. The helipad can be produced in a variety of sizes using a range of different lights.

The particular *Imageglow* system highlighted in this paper is not currently available in the U.S. but the basic system could be made available to any manufacturer to develop a system similar to that being evaluated in the United Kingdom. This system would appear to offer major advantages for lighting/marketing emergency landing areas at night and to provide a simple system for use as a backup light for private use facilities or when night operations are very infrequent and temporary lighting is desirable.

Imageglow is the Trade Name of Kleenkut Imageglow Ltd: International Parents Pending

- ELECTROLUMINESCENT (EL) LAMP

- flexible
- flat or cord/' wire'
- thin
- cold illumination [no heat generated]
- wide range of colors (including white)

MAIN USE: ADVERTISING/SPECIAL EFFECTS

- CHARACTERISTICS

- nominal voltage/frequency 115v/400Hz [aircraft voltage]
- power: 6vDC to 110vAC [Examples-9v battery]
- increased voltage –increased brightness/decrease life
- increased frequency-increase life+some change in color/decrease life
- EL does not abruptly fail-gradual decrease with use

- CHARACTERISTICS

- temperature range: -50 to +65 Degrees C
- temperature stable
- main degrading impact – ultra violet (UV)
- maximum length 250m (800ft)
- can be incorporated in many materials including fabric

- CHARACTERISTICS

- static or flashing
- visible from 630m (2000ft)
- extremely robust
- can be configured to any symbol (e.g. H)
- life (currently) depending on use, exposure, UV etc-12 months – may be up to 2 years
- easy to setup and use

APPENDIX F. PANYNJ LIGHT-EMITTING DIODE (LED) HELIPORT LIGHTING DEMONSTRATION

DISCLAIMER: The material in this Appendix represent the opinions of the Port Authority of New York and New Jersey (PANYNJ) and of the pilots who responded to the questions on the PANYNJ evaluation sheet. These opinions are not necessarily consistent with FAA policy or plans.

1.0 BACKGROUND. On January 22, 1999, the Port Authority of New York and New Jersey (PANYNJ) installed light-emitting diode (LED) line lighting at the Downtown Manhattan Heliport (more commonly known as the Wall Street Heliport) in New York City. Over the next several months, the Port Authority solicited helicopter pilot evaluations of several configurations of LED lights. A daylight picture of the Wall Street Heliport is shown in Figure F1. Figures F2 and F3 show nighttime views of the installed LED lights.

Two LED line light components were installed at Wall Street. The first of these LED components was a double line of yellow lights on three sides of the TLOF. (Since this was a temporary installation, the PANYNJ was not willing to cut a slot in the surface of their concrete pier. Thus, nothing was installed on the fourth side of the TLOF since non-flush mounting of the LED lights would have precluded ground-taxi operations. If a permanent installation is made, presumably LED lights would be flush-mounted on this fourth side.)

The second LED component was a red X made up of LED line lights (each portion of the X was a single line of lights). This second component was installed in response to a suggestion from the United Kingdom (UK) Civil Aviation (CAA) authorities. UK authorities were looking for a lighting component, principally for offshore oil and gas rigs, that would indicate that the landing platform was closed.

By way of reference, the "standard" Wall Street Heliport TLOF lighting consists of elevated (approximately 12 inches high) yellow runway edge lights on three sides and flush-mounted lights on the fourth side (so that the helicopters may ground-taxi over them without concern). During the LED demonstration, these lights were operated at the lowest of five light levels. Blue lights marked the edges of the pier and the edges of the barge (an attached parking area). These blue lights were also operated during the LED demonstration.

The Wall Street facility is strictly a VFR heliport. It has no instrument procedures, however, in the New York City area, helicopters routinely operate in weather down to approximately 500 feet ceiling and 1 mile visibility. Thus, these pilot evaluations can be assumed to have taken place in weather of these weather minimums or better.

2.0 LED INSTALLATION. The LED line lights are designed to be installed in a slot [approximately 2.75 inches (70 mm) wide and 1.25 inches (30 mm) deep] cut in the concrete. This allows the lights to be installed flush with the top of the pavement. With such an installation, aircraft can ground-taxi and other vehicles can drive over the lights without damage. However, as discussed below, this is NOT how the LED lights were installed at Wall Street.

2.1 Yellow LED Edge Lights. Two lines of LED lights were installed approximately 4 inches apart. These TLOF edge lights were NOT mounted flush. Instead they were mounted on the top of the 9-inch "curbs" that are placed on three sides of the TLOF to keep the snowplow from running off the edge. No LED lights were installed on the fourth side.

When reviewing the results of this demonstration, it is important to keep in mind how the perimeter lights were installed. With flush mounting of the lights, there would be some effect on the low angle visibility of lights. If the slot in the concrete is cut too deep, this effect can be severe as was seen in a 1998 taxiway holding area demonstration at JFK Airport. At Wall Street, however, the LED lights were NOT installed in a slot cut into the concrete. Thus, it is probable that the visibility range of these lights was larger than what it would have been if the LED lights had been flush mounted.

Initially, both lines of yellow LED edge lights were blinked on and off (the lights were blinked off for approximately ½ second, 50 times a minute). Pilots found this VERY disconcerting and the PANYNJ quickly discontinued this configuration. Subsequently, the PANYNJ demonstrated three configurations of edge lighting. In the first configuration, the "inside" line of edge lights was steadily illuminated. In the second configuration, the "outside" line was blinked on and off. In the third configuration, the "inside" line of edge lights was steadily illuminated and the "outside" line was blinked on and off. These three configurations were demonstrated on alternate nights for several months. Then, at the start of April, the PANYNJ started using the third configuration ("inside" line of edge lights steadily illuminated and the "outside" line blinked on and off 50 times a minute) seven nights a week.

During the demonstration, there was some limited use of blink rates both faster and slower than 50 times a minute. This was done both for the edge lights and the red X.

2.2 Red LED X. The red X of LED lights was not flush mounted. Instead, it was laid directly on the concrete in the center of the TLOF and illuminated to indicate that the facility was closed. This very temporary "installation" was only done during the evening when it was dark. For testing purposes, a number of helicopters made approaches to the heliport during this time. Some of them made missed approaches and some of them landed on portions of the facility outside the TLOF. Since no aircraft were actually landed on the TLOF while the red X was in place, the temporary, non-flush mounting of the lights did not present a problem for ground-taxi operations. The red X was removed before PANYNJ employees went home for the night.

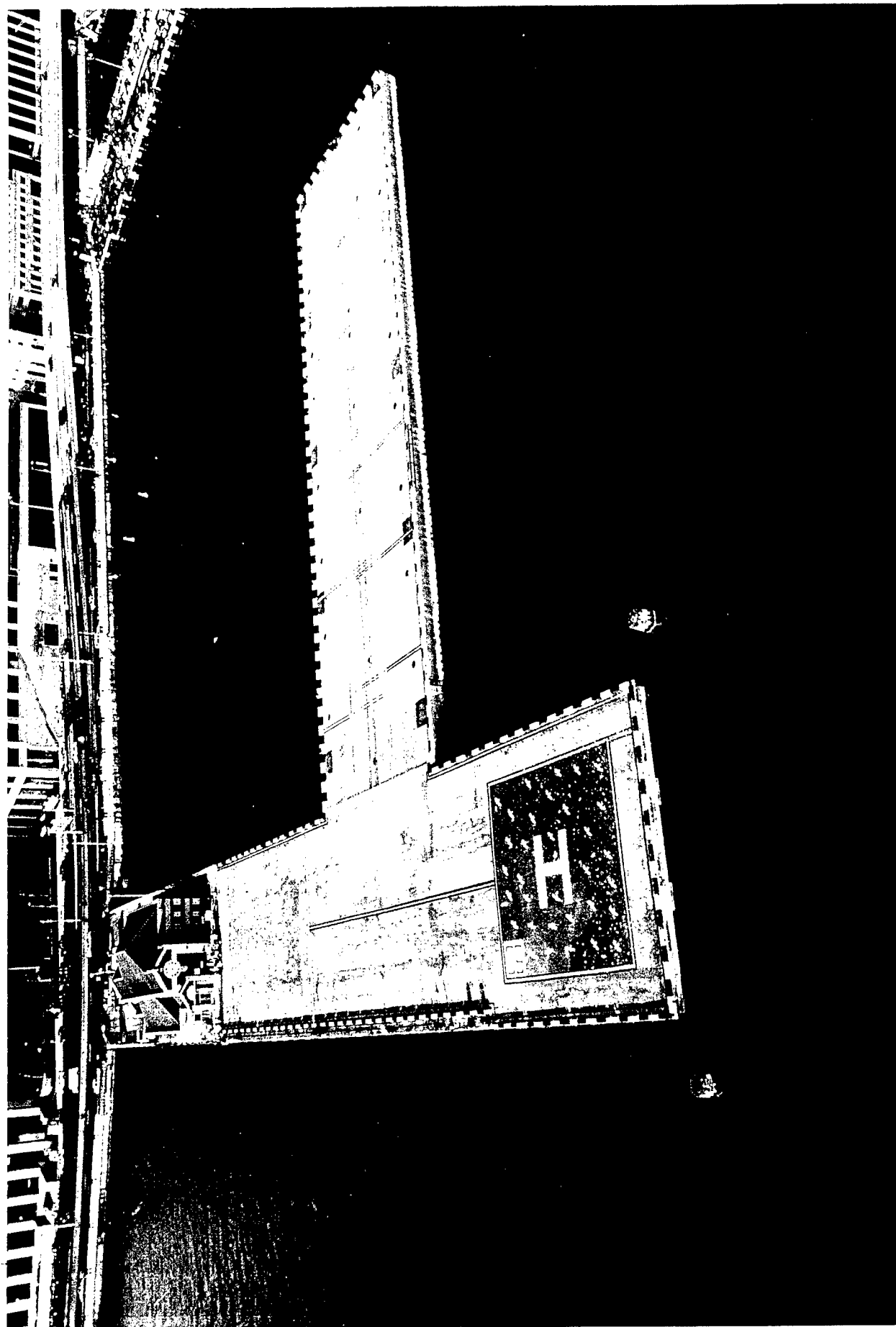


Figure F1. The Downtown Manhattan Heliport (Wall Street Heliport), New York City



Figure F2. The Wall Street Heliport Looking Upstream

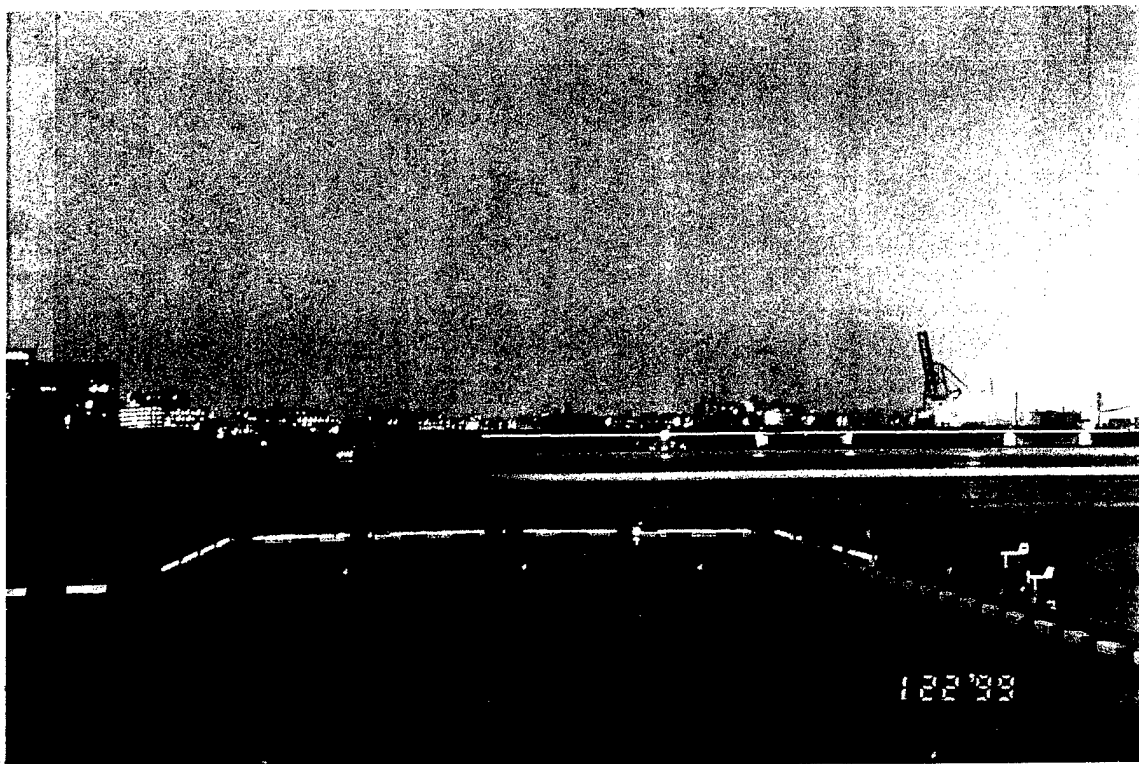


Figure F3. The Wall Street Heliport from the Terminal Building

When the red X was in place, it was operated in one of two fashions. On some evenings, the red X was blinked on and off (the lights were blinked off for approximately ½ second, 50 times a minute). On other evenings, the red X was steadily illuminated with no blinking.

3.0 HELICOPTER PILOT EVALUATIONS. Shown at the end of this Appendix are 31 evaluation sheets provided by various Industry pilots. These evaluations are shown in chronological order starting with a January 22 sheet and ending with a March 26 sheet. An additional 8 pilots provided limited verbal comments in late January and early February. [These comments, recorded by PANYNJ personnel, are shown at the end of section 4.11 of this Appendix.] All but 1 of the comments from these 39 pilots were positive with regard to the LED line lights. The 1 dissenting comment was verbal and the pilot provided no specifics on what he did not like about the LED line lights.

The Wall Street facility is strictly a VFR heliport. It has no instrument procedures, however, in the New York City area, helicopters routinely operate in weather down to approximately 500 feet ceiling and 1 mile visibility. Thus, these pilot evaluations can be assumed to have taken place in weather of these weather minimums or better.

4.0 SUMMARY OF PILOT COMMENTS.

4.1 Visibility Comparison. Comparing the LED line lights to the present Wall Street Heliport lighting, the pilots were almost unanimous that the LED line lights were better, that the heliport stands out better, and that the visibility from a distance was better.

4.2 Visibility Comparison During Rain, Snow, or Fog. The vast majority of pilots saw the LED line lighting during clear weather. Two pilots commented that the visibility of the LED line lights was better in fog than that of the present Wall Street lighting. One pilot commented that the visibility of the LED line lights was better in fog and rain than that of the present Wall Street lighting. [None of these three pilots reported the weather conditions during their observation of the LED lights.] A fourth pilot reported the weather as "CLR - +10 visibility" and yet commented that, in rain, snow, and fog, the visibility of the LED line lights would be better than that of the present Wall Street lighting. [Presumably, this pilot saw the LED lighting under a variety of weather conditions but made this written report when the weather was "CLR - +10 visibility".]

4.3 Guidance to Touchdown Area. Of 31 pilots, 19 indicated that the LED line lights provided better guidance to the touch down area than the present Wall Street Heliport lighting. Another 7 pilots said that it provided the same quality of guidance as the present Wall Street Heliport lighting. An additional 3 pilots said "not observed", "?", and "did not find". The remaining pilots did not comment on this issue.

4.4 Peripheral Cues for Actual Landing Area. Of 31 pilots, 19 indicated that the LED line lights provided better peripheral cues for actual landing than the present Wall Street Heliport lighting. Another 6 pilots said that it provided the same quality of guidance as the present Wall Street Heliport lighting. An additional pilot said "unknown". The remaining pilots did not comment on this issue.

4.5 Single Line Versus Double Lines of LED Lights. Of 31 pilots, 16 indicated that the single line of LED line lights provided the more helpful presentation [While it is not specifically addressed in the evaluation sheets, these 16 pilots are referring to a single line of steadily illuminated LED TLOF edge lights.]. Another 5 pilots indicated that the double lines of LED line lights provided the more helpful presentation [While it is not specifically addressed in the evaluation sheets, these 5 pilots are referring to a one line of steadily illuminated LED lights and a second line of LED lights line blinked on and off 50 times a minute.]. The remaining pilots did not comment on this issue.

4.6 Blinking the Lights – Effect on Conspicuity. Of 31 pilots, 22 indicated that blinking the LED line lights makes them more conspicuous. Only 1 pilot said that blinking the LED line lights does not affect their conspicuity. The remaining pilots did not comment on this issue.

During the demonstration, there was some limited use of blink rates both faster and slower than 50 times a minute. This was done both for the edge lights and the red X. However, pilots preferred a blink rate of 50 times a minute.

4.7 Problems with Blinking the Lights. Of 31 pilots, 2 indicated that blinking the LED line lights would create a problem for actual landing from a hover. Another 16 pilots indicated that it would not create a problem. The remaining pilots did not comment on this issue.

4.8 Meaning of the Red X. A number of the pilots did not see the red X, presumably because it was not “installed” and illuminated while they were in the vicinity of the heliport. Of the 14 pilots who did see the red X, they offered a variety of meanings for these lights. Of these 14 pilots, 7 indicated that it meant “don’t land” and another 2 pilots indicated that it meant “the heliport is closed”. However, 2 pilots indicated that it meant that they were too low on approach. Another 3 pilots indicated that it meant “obstruction”, “edge of heliport boundary”, and “perimeter of the pad”. [The rationale behind the answers of these last five pilots is unclear.]

4.9 Black Hole. Pilots were asked, “Do you ever feel like you are landing in a black hole?” Of 31 pilots, 4 answered “yes”. (Of these 4 pilots, 1 pilot indicated that the LED line lights eliminated this feeling. The other 3 of these 4 pilots indicated that LED lights did not eliminate this feeling.) Another 21 pilots answered “no”. The remaining pilots did not comment on this issue. None of the pilots indicated that the LED lights would create the feeling of landing in a black hole.

4.10 Visibility at Various Altitudes. Pilots were asked to estimate the maximum distance at which they could see the lights from an altitude of 500 feet, 1,000 feet, and 1,400 feet MSL. Initially, pilots misunderstood this question and the many of their answers were not useful. When this question was modified, the usefulness of pilot responses improved dramatically. A total of 16 usable pilot responses were received on this question:

At an altitude of 500 feet, 3 pilot estimates of the maximum visibility distance of the LED lights varied from 3 miles to “greater than 4 miles”.

At an altitude of 1,000 feet, 9 pilot estimates of the maximum visibility distance of the LED lights varied from 1/4 mile to "15 miles on a clear day". Of these 9 pilots, 7 pilot estimates varied from 1.5 miles to "greater than 5 miles". The meaning of 1/4 mile estimate is unclear since this pilot also reported 10-mile visibility. The meaning of the estimate "15 miles on a clear day" is also unclear but it is possible that the pilot may have viewed the lighting when the visibility was considerable less than 15 miles and that the 15 mile estimate was speculative.

At an altitude of 1,400 feet, 4 pilot estimates of the maximum visibility distance of the LED lights varied from 3 miles to "greater than 5 miles".

When reviewing these estimates, the reader should keep in mind that the LED line lights were not flush mounted. Thus, their visibility was probably greater than what it would have been if they had been flush mounted.

4.11 Pilot Comments. On the evaluation sheets, the pilots' comments were handwritten. For ease of reading, they are included here in typed form:

"A particular advantage would be to differentiate between the pad and the surrounding lights."

"Two approaches at 2130 hrs. Good visibility. Only noticed 1 row of amber lights on 3 sides. Didn't see red lights."

"Good system."

"Low perimeter lights and flashing LED's – is no good! Med perimeter, solid LED outside, flashing inside would be best."

"Hovering over the lights might be a bit distracting while they are blinking."

"The touchdown/landing area was closed at the time. We made our approach and landing to the transient spot. I am unable to give an accurate response to all of your questions at this time. I'll send another response after I have made a landing to the normal landing area (new lights)."

"Lights were outstanding."

"Blinking or flashing lights at night make the heliport stand out from the normal lights of the city."

"So far only saw in good weather; seems very good, flashing helped."

"Observed inside lights [editor's comment: the inside line of two lines of LED lights] steady and outside lights (lines) blinking – this was good!"

"No effect during daytime or low light. Excellent at night. Too much ambient light around heliport to create a black hole effect with or without the new lights."

“Visual reference improves 100 percent.”

“Anxious to evaluate during night landing and takeoff.”

“Encourage surface float lighting of touchdown zone. Arrival at 1800 hrs in darkness.”

“Did not land. Over area en route to/from the East 34th Street heliport. Liked the lights a lot.”

“It appeared that the [red] lights were not on for either landing. What are the red lights?”

“The lights are great!!”

“Seems to be a new kind of edge lighting. I didn’t get any new or additional guidance to pad, though.”

“The heliport landing zone stands out beautifully.”

“Due to the constant high amount of ambient light, not much difference is noted.”

“Blinking lights are a problem. Steady is better.”

The following are verbal pilot comments made during the late January/early February time period. PANYNJ personnel recorded these comments.

“Lights – both impressed. Very nice.”

“Landing – Flashing was not a problem.”

“Wow, the DMH Disco. Looks great.”

“The lights look good.”

“Why are you closed?” [radio call in response to the red X on the TLOF]

“Didn’t like it.”

“Looks pretty good.”

“The lights look good.”

5.0 COMMUNITY REACTION. While there is no residential housing in the immediate vicinity of the Wall Street Heliport, the facility has drawn complaints from Brooklyn across the East River. Specifically, the heliport beacon was removed some years ago in response to community complaints. No complaints have been received, however, in response to the installation of LED line lighting.

6.0 PANYNJ CONCLUSIONS. Shown on the following page is the September 15 letter from John J. McGowan, Manager of the PANYNJ Helicopter/Heliport Division. It speaks concisely as to their conclusions.

THE PORT AUTHORITY OF NY & NJ

Helicopter Maintenance Facility
121 B Billy Diehl Road
Teterboro Airport
Teterboro, New Jersey, 07608

(212) 435-6358/9
(201) 288-2761
(201) 288-0308 Fax.

September 15, 1999

Mr. Robert Smith
Federal Aviation Administration AND-740
800 Independence Avenue, SW
Washington, D.C. 20591

Bob
Dear Robert:

Enclosed are the pilot questionnaires that I used for the test LED Light installation at the Downtown Manhattan Heliport, New York City. The original form was revised to include the time and date of observation and to provide for a space to show distance one could see the lights at 500', 1,000' etc.

As you will see this is not a professional sampling effort but does, I think, get what we were looking for. The very first result was to eliminate both lines of LED's blinking at once. This ceased problems with pilots as the pad boundaries went from lit to dark. Also, based on the results we settled on one line blinking and one line steady as the presentation most pilots liked.

The results show an almost universal, the very negative response was from a pilot who thinks anything the Port Authority does is useless, liking of this system and that it is dramatically better than current standard design guide presentations. Some even rated them as 100% better.

I am available to answer questions on these responses and will continue to use this LED presentation at the DMH for as long as I can.

Thank you for organizing the conference and getting the industry started toward LED's as lighting standard.

Sincerely,

John
John J. McGowan
Manager
Helicopter/Heliport Division
Aviation Department

JAN. 22 1999

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-286-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey _____

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is:

Better Same Worse

Visibility in snow is:

Better Same Worse

Visibility in fog is:

Better Same Worse

Guidance to Touch Down Area is:

Better Same Worse

Peripheral cues for actual landing are:

Better Same Worse

Which presentation is most helpful:

Single line or Double line

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?"

Yes No

If yes, do these eliminate that?

Yes No

If not, do these create that?

Yes No

Estimate maximum distance you see these lights from an altitude of: 500'

1,000'

1400'

COMMENTS: A PARTICULAR ADVANTAGE WOULD BE TO DIFFERENTIATE BETWEEN THE PAD AREA AND SURROUNDING LIGHTS

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1/26/98

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is:

Better Same Worse Not observed

Visibility in snow is:

Better Same Worse "

Visibility in fog is:

Better Same Worse "

Guidance to Touch Down Area is:

Better Same Worse "

Peripheral cues for actual landing are:

Better Same Worse

Which presentation is most helpful:

Single line or Double line Only double observed

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

Not observed

If you saw the red lights what do they tell you?

Not observed

Do you ever feel you are landing into a "black hole?"

Yes No Not observed

If yes, do these eliminate that?

Yes No "

If not, do these create that?

Yes No "

Estimate maximum distance you see these lights from an altitude of: 500'

1,000' 1400'
15 mi on clear day

COMMENTS:

Good system

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-289-9308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1/26/99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line
 Blinking the lines makes them. More Same Less Conspicuous
 Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? DIDNT SEE RED LIGHTS

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: 2 APPROACHES AT 2130 HRS. GOOD VISIBILITY. ONLY NOTICED
1 ROW OF AMBER LIGHTS ON 3 SIDES

Please leave at any heliport or fax. Thank you.

Jay

1/27/99

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1/27/99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse
- Which presentation is most helpful: Single line or Double line
- Blinking the lines makes them: More Same Less Conspicuous
- Blinking the lines does, does not create a problem for actual landing from a hover.
- If you saw the red lights what do they tell you? Were To Low
- Do you ever feel you are landing into a "black hole?" Yes No
- If yes, do these eliminate that? Yes No
- If not, do these create that? Yes No
- Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: Low Perimeter lights AND Flashing LED'S - IS NO GOOD!
med Perimeter, Solid LED outside, Flashing inside would be best.

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1-28-99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? the red x would mean not to land

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: Hovering over the lights might be a bit distracting while they are blinking

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERIC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1-29-99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line
Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: THE DOWNTOWN/LANDING AREA WAS CLOSED AT THE TIME. WE MADE OUR APPROACH AND LANDING TO THE TRANSIENT SPOT. I AM UNABLE TO GIVE AN ACCURATE RESPONSE TO

Please leave at any heliport or fax. Thank you.

ALL OF YOUR QUESTIONS. AT THIS TIME I'll SEND ANOTHER RESPONSE AFTER I HAVE MADE A LANDING TO THE NORMAL LANDING AREA. (NEW LIGHTS) 235

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 1/30/99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:	<input checked="" type="radio"/> Better	Same	Worse
Heliport stands out:	<input checked="" type="radio"/> Better	Same	Worse
Visibility from a distance is:	<input checked="" type="radio"/> Better	Same	Worse
Visibility in rain is:	Better	Same	Worse
Visibility in snow is:	Better	Same	Worse
Visibility in fog is:	Better	Same	Worse
Guidance to Touch Down Area is:	<input checked="" type="radio"/> Better	Same	Worse
Peripheral cues for actual landing are:	<input checked="" type="radio"/> Better	Same	Worse

Which presentation is most helpful:	Single line	or	Double line
Blinking the lines makes them:	<input checked="" type="radio"/> More	Same	Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? RED X - CLOSED ?

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: 500' > 4 mi
1000' > 5 mi
1400' > 5 mi

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 30 JAN 99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? DON'T LAND

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: _____

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

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Date of this Survey 30 JAN 99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is:

Better Same Worse

Visibility in snow is:

Better Same Worse

Visibility in fog is:

Better Same Worse

Guidance to Touch Down Area is:

Better Same Worse

Peripheral cues for actual landing are:

Better Same Worse

Which presentation is most helpful:

Single line or Double line

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you?

DO NOT LAND

Do you ever feel you are landing into a "black hole?"

Yes No

If yes, do these eliminate that?

Yes No

If not, do these create that?

Yes No

Estimate maximum distance you see these lights from an altitude of: 500'

1,000'

1400'

COMMENTS:

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 30 JAN 99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? DO NOT LAND

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: _____

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 30 JAN 99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? DON'T LAND

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: _____

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 1/31/99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worst
- Heliport stands out: Better Same Worst
- Visibility from a distance is: Better Same Worst
- Visibility in rain is: Better Same Worst
- Visibility in snow is: Better Same Worst
- Visibility in fog is: Better Same Worst
- Guidance to Touch Down Area is: Better Same Worst
- Peripheral cues for actual landing are: Better Same Worst

Which presentation is most helpful: Single line or Double line *only saw single @ 160ft*

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? PERIMETER OF PAD

- Do you ever feel you are landing into a "black hole"? Yes No
- If yes, do these eliminate that? Yes No
- If not, do these create that? Yes No
- Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: LIGHTS WERE OUTSTANDING.

Post-it® Fax Note	7671	Date	2-1-99	# of pages	1
To:	JAY McGovern	From:			
Co./Dept.	PA of NY NJ	Co.			
Phone #		Phone #			
Fax #	201-288-0308	Fax #			

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

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Date of this Survey 2-1-99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse
- Which presentation is most helpful: Single line or Double line
- Blinking the lines makes them: More Same Less Conspicuous
- Blinking the lines does, does not create a problem for actual landing from a hover.
- If you saw the red lights what do they tell you? Dont land
- Do you ever feel you are landing into a "black hole?" Yes No
- If yes, do these eliminate that? Yes No
- If not, do these create that? Yes No
- Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: Blinking or Flashing lights up at night make the Heliport stand out from the normal lights of the city

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 2-1-99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse ?

Visibility in snow is: Better Same Worse ?

Visibility in fog is: Better Same Worse ?

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? X

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 4 MI 1,000' 6 MI 1400' ?

COMMENTS: So far only seen in good wx; seems very good; flashing helps.

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HELIPORT LIGHTING TEST

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Date of this Survey 2-1-99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is:

Better Same Worse

Visibility in snow is: DID NOT OBSERVE

Better Same Worse

Visibility in fog is:

Better Same Worse

Guidance to Touch Down Area is:

Better Same Worse

Peripheral cues for actual landing are:

Better Same Worse

Which presentation is most helpful:

Single line or Double line

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?"

Yes No

If yes, do these eliminate that?

Yes ~~No~~

If not, do these create that?

Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: OBSERVED INSIDE LIGHTS STEADY AND OUTSIDE LIGHTS (LINES) BLINKING - THIS WAS GOOD!

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HELIPORT LIGHTING TEST

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Date of this Survey _____

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: _____

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 2/5/99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? OBSTRUCTION

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: VISUAL REFERENCE IMPROVES 100%

TOM O'HUGO-WALL ST. HELICOPTERS, INC.

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey Feb 8, 1999

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: NA Better Same Worse
- Visibility in snow is: NA Better Same Worse
- Visibility in fog is: NA Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line
Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? didn't see them

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: encourage surface flood lighting of touch down zone
arrived at 1800 hrs in business

Please leave at any heliport or fax. Thank you.

S 76.B

HELIPORT LIGHTING TEST

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Date of this Survey 2-8-99 Time of Day 10PM
Approximate Weather CLR - +10 VISIBILITY

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line
Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? EDGE OF HELIPORT BOUNDARY

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of:

500' @ _____ miles; 1,000' @ 1/4 miles; 1,400' @ _____ miles

COMMENTS: DID NOT LAND - OVER AREA
ENROUTE TO/FROM E34 - LIKED THE LIGHTS
A LOT.

NAME: _____ COMPANY: _____

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

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Date of this Survey _____

Time of Day _____

Approximate Weather _____

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is: unk

Better Same Worse

Visibility in snow is: unk

Better Same Worse

Visibility in fog is: unk

Better Same Worse

Guidance to Touch Down Area is:

Better Same Worse

Peripheral cues for actual landing are: unk

Better Same Worse

Which presentation is most helpful:

Single line or Double line

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover. unk

If you saw the red lights what do they tell you? too low

Do you ever feel you are landing into a "black hole"? unk Yes No

If yes, do these eliminate that? unk Yes No

If not, do these create that? unk Yes No

Estimate maximum distance you see these lights from an altitude of:

500' @ _____ miles; 1,000' @ 4 miles; 1,400' @ _____ miles

COMMENTS: anxious to evaluate during night landing

and takeoff

NAME: Kushig Wood

COMPANY: Schering-Plough

Please leave at any heliport or fax. Thank you.

Jay

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Date of this Survey 2-11-99

Time of Day 0715 + 1215 EST

Approximate Weather UMC 1500M VIS, CAVU etc sunrise.

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is:

Better Same Worse

Heliport stands out:

Better Same Worse

Visibility from a distance is:

Better Same Worse

Visibility in rain is: UA

Better Same Worse

Visibility in snow is: UA

Better Same Worse

Visibility in fog is: UA

Better Same Worse

Guidance to Touch Down Area is:

Better Same Worse

Peripheral cues for actual landing are:

Better Same Worse

Which presentation is most helpful:

Single line or Double line

Blinking the lines makes them:

More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? What are these red lights???

Do you ever feel you are landing into a "black hole"?

Yes No

If yes, do these eliminate that?

Yes No

If not, do these create that?

Yes No

Estimate maximum distance you see these lights from an altitude of:

500' @ _____ miles; 1,000' @ _____ miles; 1,400' @ 1.5 miles

COMMENTS: I + appeared the lights were not on for either landing - what are the red lights???

NAME: _____

COMPANY: _____

Please leave at any heliport or fix. Thank you.

Jay

HELIPORT LIGHTING TEST

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Date of this Survey 2/11/99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: _____

Please leave at any heliport or fax. Thank you.

HELIPORT LIGHTING TEST

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Date of this Survey 3-3-99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: N/A Better Same Worse

Visibility in snow is: N/A Better Same Worse

Visibility in fog is: N/A Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: The Lights are great !!

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

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Date of this Survey 3-5-99

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

- Which presentation is most helpful: Single line or Double line
- Blinking the lines makes them: More Same Less Conspicuous
- Blinking the lines does does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

- Do you ever feel you are landing into a "black hole?" Yes No
- If yes, do these eliminate that? Yes No
- If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 2 mi. 1400'

COMMENTS: SEEMS TO BE A NEW KIND OF EDGE LIGHTING. I DIDN'T GET ANY NEW OR ADDITIONAL GUIDANCE TO PAD, THOUGH.

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are L.E.D.'s (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be accepted by the FAA as a standard for heliports/vertoports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0708. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 3/8/99 Time of Day 8:24 PM
 Approximate Weather clear, vis 10+ SM.

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful. Single line or Double line
 Blinking the lines makes them: More Same Less Conspicuous
 Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of:
 500' @ _____ miles; 1,000' @ 3 miles; 1,400' @ _____ miles

COMMENTS: The Heliport Landing Zone stands out
Beautifully

NAME: _____ COMPANY: _____

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 3/9/99 Time of Day 4pm

Approximate Weather VFR

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of:

500' @ _____ miles; 1,000' @ _____ miles; 1,400' @ _____ miles

COMMENTS: _____

NAME: _____ COMPANY: _____

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 3/11/99 Time of Day 1900

Approximate Weather NIGHT VFR

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line } ONLY SAW SINGLE LINE

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? DID NOT SEE RED LIGHTS

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of:
500' @ 3 miles; 1,000' @ 3 miles; 1,400' @ 4 miles

COMMENTS: _____

NAME: _____ COMPANY: _____

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The ERHC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 3-11-99

Time of Day 1930/2115

Approximate Weather CLR

Circle the responses you choose:

- Comparing this light source to present lights visibility to pilot is: Better Same Worse
- Heliport stands out: Better Same Worse
- Visibility from a distance is: Better Same Worse
- Visibility in rain is: Better Same Worse
- Visibility in snow is: Better Same Worse
- Visibility in fog is: Better Same Worse
- Guidance to Touch Down Area is: Better Same Worse
- Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? ?

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of:

500'@ _____ miles; 1,000'@ _____ miles; 1,400'@ 4 miles

COMMENTS: DUE TO THE CONSTANT HIGH AMOUNT OF AMBIENT LIGHT, NOT MUCH DIFFERENCE IS NOTED

NAME: _____ COMPANY: _____

Please leave at any heliport or fax. Thank you.

Jay

HELIPORT LIGHTING TEST

In conjunction with the FAA The Port Authority of New York and New Jersey is conducting a test of a new light source at the Downtown Manhattan Heliport (Wall Street). The lights being tested are LED's (Light Emitting Diodes). We are looking for pilot responses to these lights to determine if they should be adopted by the FAA as a standard for heliports/vertiports and possibly airports. Your responses are critical to this process. This is your chance to influence future standard. If you like them future testing will commence. If you say no the process will stop here.

The EREIC has been asked to conduct this survey of all pilots in the Northeast. Please fill out these short forms and turn them in at your New York City destination heliport or fax them to 201-288-0308. Different configurations will be presented so do these questionnaires as often as you can. Your input is vital.

Date of this Survey 3-26-99

Circle the responses you choose:

Comparing this light source to present lights visibility to pilot is: Better Same Worse

Heliport stands out: Better Same Worse

Visibility from a distance is: Better Same Worse

Visibility in rain is: Better Same Worse

Visibility in snow is: Better Same Worse

Visibility in fog is: Better Same Worse

Guidance to Touch Down Area is: Better Same Worse

Peripheral cues for actual landing are: Better Same Worse

Which presentation is most helpful: Single line or Double line

Blinking the lines makes them: More Same Less Conspicuous

Blinking the lines does, does not create a problem for actual landing from a hover.

If you saw the red lights what do they tell you? _____

Do you ever feel you are landing into a "black hole?" Yes No

If yes, do these eliminate that? Yes No

If not, do these create that? Yes No

Estimate maximum distance you see these lights from an altitude of: 500' 1,000' 1400'

COMMENTS: Blinking lights are a problem. Steady is better.

Please leave at any heliport or fax. Thank you.

Jay

APPENDIX G. ACRONYMS

AC	advisory circular
ADL	aeronautical data link
ADS-B	automatic dependent surveillance - broadcast
AEI	all engines inoperative
AFS	advanced flight simulator
AGARD	Advisory Group for Aerospace Research and Development
AGL	above ground level
AHS	American Helicopter Society
AIP	Airport Improvement Program
AND-520	FAA General Aviation and Vertical Flight Program Office
ASTM	American Society for Testing and Materials
ASW	anti-submarine warfare
C	centigrade
CAA	Civil Aviation Authority (UK)
CAD	computer aided design
CAP	Civil Air Publications (UK)
CARs	Canadian Air Regulations
cd	candela
CFIT	controlled flight into terrain
CIT	Cranfield Institute of Technology (now Cranfield University)
CNS	communications, navigation, and surveillance
COTS	commercial, off-the-shelf
CSM	conceptual simulation model
CTOL	conventional takeoff and landing
CVS	class of aircraft carrier (UK)
DERA	Defence Evaluation Research Agency
DH	decision height
DLA	designated landing area
DRA	Defence Research Agency (UK)
DWP	decision waypoint
EAF	expeditionary airfield
E-L	electro-luminescent
ELP	electro-luminescent panel
ELS	expeditionary lighting system
ELVIRA	extremely low visibility IFR rotorcraft approaches
EMS	emergency medical service
F	Fahrenheit
FAA	Federal Aviation Administration
FAATC	FAA Technical Center
FAR	Federal Aviation Regulation
FATO	final approach and takeoff area
FIS	flight information services
FDO	flight deck officer
FML	field marker lights
GA	General Aviation
GPI	glide path indicator
GPI	ground point of intercept
GPS	global positioning system
HAI	Helicopter Association International
HALS	heliport approach lighting system
HAPI	helicopter approach path indicator

HIGE	hover in ground effect
HILS	heliport instrument lighting system
Heli-STAR	helicopter short-haul transportation and aviation research (1996 Olympic Games, Atlanta GA)
HLZ	helicopter landing zone
HOGE	hover out-of-ground effect
HMD	helmet mounted display
HMSO	Her Majesty's Stationery Office
HPI	hover position indicator
HQR	handling qualities rating (Cooper – Harper)
HRP	heliport reference point
HRS	horizon reference system
ICAO	International Civil Aviation Organization
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
IFR	instrument flight rules
IGE	in ground effect
IMC	instrument meteorological conditions
IML	infrared marker lights
IR	infrared
KIAS	knots indicated airspeed
LCL	laser centerline localizer
LED	light-emitting diodes
LGI	laser glideslope indicator
LMS	large motion system
LSE/LSO	landing signal enlisted/officer
LZ	landing zone
M	meter
MA	milliamp
MAP	missed approach point
MAWP	missed approach waypoint
MLS	microwave landing system
MoD	Ministry of Defence
MOLS	mirror optical landing system
MOSKIT	minimum operating strip lighting kit
Mpa	megapascals
MTBF	mean time between failure
MTE	mission task element
NAM	Nederlandse Aardolie Maatschappij BV (Dutch Offshore Company)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAWC	Naval Air Warfare Center
nm	nautical mile
NTSB	National Transportation Safety Board
NVD	night vision device
NVG	night vision goggles
PANYNJ	Port Authority of New York and New Jersey
PASI	passive reflective visual approach slope indicator
psi	pounds per square inch
OEI	one-engine inoperative
OGE	out of ground effect
OREL	omni-directional runway edge light
PAPI	precision approach path indicator
PLASI	pulse light approach slope indicator

RAE	Royal Aircraft Establishment
RAST	recovery, assist, secure, and traverse
RN	Royal Navy (UK)
RSD	rapid securing device
SAE	Society of Automotive Engineers
SAIC	Science Applications International Corporation
SALKIT	supplemental airfield lighting kit
SD	spatial disorientation
SGSI	stabilized glideslope indicator
SHOL	ship/helicopter operating limits
STOL	short takeoff and landing
TTCP	The Technical Collaboration Process
TLOF	touchdown and lift-off area
UAL	uni-directional approach light
UK	United Kingdom
US	United States
USA	United States of America
USAF	United States Air Force
UTSI	University of Tennessee Space Institute
UV	ultra violet light
V	volts
VDC	volts direct current
VFR	visual flight rules
WISEQ	Visual Sequence (a mathematical modelling tool)
VMC	visual meteorological conditions
VTOL	vertical takeoff and landing
W	watts