To the Graduate Council:

I am submitting herewith a thesis written by Michael James Weis entitled "Research and Development of a New Heliport Lighting System with Implications for Further Research." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Aviation Systems.

Ralph Kimberlin, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

RESEARCH AND DEVELOPMENT OF A NEW HELIPORT LIGHTING SYSTEM WITH IMPLICATIONS FOR FURTHER RESEARCH

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Michael J. Weis
May 1996

DEDICATION

This thesis is dedicated to my wonderful wife and parents

Mrs. Joanne L. Weis

and

Mr. and Mrs. Wayne Weis

who have provided unending support throughout my life.

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Last, but certainly not least, I would like to acknowledge my wife, Joanne. She has been an inspiration not only in academics, but also in life.

ABSTRACT

In the past, the majority of helicopter precision instrument approaches were conducted to a runway utilizing the Instrument Landing System (ILS). Recent developments in the Global Positioning System will soon make it possible to shoot precision instrument approaches to every airport and heliport without the use of the ILS. This should greatly expand the roles in which helicopters are used today. To support the growth in precision instrument procedures that will accompany the expansion, a new heliport lighting system has been developed. The proposed lighting system is simple, compact, and affordable. It is composed of fewer lights than the previous systems, requires less space, and can be adapted to existing helipads.

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LIST OF SYMBOLS AND ABBREVIATIONS

AGL	Above Ground Level
ALS	Centerline Approach Lighting System
DH	Decision Height
DOT	Department of Transportation
FAA	Federal Aviation Administration
ft	feet
GPS	Global Positioning System
HALS	Helicopter Approach Lighting System
HILS	Heliport Instrument Lighting System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
MOLS	Mirror Optical Landing System
NAS	National Airspace System
nm	nautical mile
VASI	Visual Approach Slope Indicator
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

CHAPTER 1

INTRODUCTION

Advances in technology will soon make it possible to shoot precision instrument approaches to any heliport without the use of a land-based transmitter, such as the Instrument Landing System (ILS). Because a transmitter will no longer be required at every heliport, the cost of operating a heliport will be reduced, allowing for utilization of helicopters to their fullest potential.

The purpose of this paper is to propose a standard, affordable configuration of lighting to be used at a variety of heliport locations. This lighting system will provide helicopter pilots with the visual cues required to safely complete a visual approach to a helipad from the point in which the pilot emerges from the cloud ceiling on an instrument approach, or from the point in which a pilot acquires the pad when flying under visual flight rules (VFR).

A background section will be included which describes: the users of the system, the weather conditions in which the system will be used, and the technology the users will employ to navigate. Next, the required visual cues for a safe landing will be explored. Then, a review will be provided of the configurations that have been developed for this purpose, as well as discussions of the advantages and disadvantages of each. Finally, the proposed lighting configuration will be explored and suggestions will be provided for areas that, with further research, may further enhance the system or reduce its cost. This

thesis will not recommend types of lights or intensities that should be used with this configuration because they have yet to be determined.

CHAPTER 2

BACKGROUND

Helicopters are operated by various organizations: commercial, corporate, private, and government. These organizations use helicopters for a variety of tasks, including air carrier, executive transport, air ambulance, and law enforcement.

Most of these operations are conducted under visual flight rules (VFR), which is defined as rules that govern the procedures for the conduct of flight under visual conditions (Federal Aviation Administration, 1993). Visual meteorological conditions (VMC) is defined as meteorological conditions expressed in terms of visibility, distance from cloud, and cloud ceiling equal to or better than a specified minima (Federal Aviation Administration, 1993). In other words, operating under VFR is conducted when the cloud ceiling and visibility are great enough so the operations below the cloud ceiling can be conducted safely.

Many operators require the ability to operate when the cloud ceiling and visibility are below the minimums for VFR. Scheduled carriers need to operate in poor weather conditions in order to maintain a schedule and air ambulance services need this ability to save lives. Operation of off shore oil rigs require helicopters for the priority movement of parts for maintenance and people for crew changes. When crews are not rotated on schedule, morale goes down and costs go up. Other times, pilots may misjudge the weather and find themselves in poor weather conditions, requiring them to operate below minimums for VFR.

When the cloud ceiling and visibility are below the minimums for VFR, pilots can choose to operate under instrument flight rules (IFR). IFR is defined as a set of rules governing the conduct of flight under instrument meteorological conditions (IMC) (Federal Aviation Administration, 1993). IMC is defined as meteorological conditions expressed in terms of visibility, distance from cloud, and cloud ceiling less than the minima specified for visual meteorological conditions (Federal Aviation Administration, 1993).

Adams (1987) surveyed 200 operators and determined that only 50% operate IFR. Of all of the missions conducted within a period of one year, 25% were conducted under IFR. He also noted that the predominate factor causing IMC is fog, followed by low clouds, snow, and rain.

Today, the decision height for Category I precision approaches is 200 ft. The 200 ft decision height is chosen to provide pilots with 10 seconds from the decision height before contacting the ground, if the approach angle and speed are unchanged (Delucien et al., 1980).

According to Adams (1987), the FAA has recognized the low airspeed control capabilities of the helicopter and have certified the Sikorsky S-76 helicopter approaches to forty knots. By reducing the airspeed on the approach to forty knots, the ceiling minimums can be further reduced to 71 ft and still provide 10 seconds from DH to impact with the ground.

Additionally, advances in technology will soon provide us with the ability to safely conduct precision instrument approaches at practically any heliport. Warwick

(1995) reports that the Pentagon and the Department of Transportation (DOT) have agreed on the use of the Wide Area Augmentation System (WAAS) to provide this ability. The purpose of the WAAS is to augment the current Global Positioning System (GPS), so that it can be used as the primary source of navigational information. The WAAS provides the following three services: a ranging function, which improves reliability and availability; differential GPS corrections, which improve accuracy; and integrity monitoring, which improves safety (Enge & Dierendonck, 1995). The system is to be operational in late 1997, allowing the global-positioning system (GPS) to be used as a sole source for enroute navigation and non-precision approaches. The ability to conduct Category I precision approaches are scheduled to be phased in between 1998 and 2001 (Warwick, 1995).

This is good news for the aviation community. According to Loh (1995), this will provide for the standardization of precision approaches, missed approaches, and departure guidance for all 12,000 runways and more than 3,000 heliports in the United States National Airspace System (NAS). This will eventually reduce the number of receivers required for navigation of the different phases of flight, saving aircraft owners the expense of purchasing and maintaining the different receivers.

As helicopter operators gain the ability to conduct precision approaches to lower minimums at a variety of heliports, a standard instrument lighting system will become more important to guide pilots safely to the helipad.

CHAPTER 3

REQUIREMENTS OF A HELIPORT LIGHTING SYSTEM

When evaluating a heliport lighting design, it is essential to know what information pilots need and how they best receive that information. The purpose of this chapter is to describe the visual cues required by pilots and the means by which they receive them. The required cues will be presented in the order in which pilots need them.

Acquisition Lighting

The first cue required by pilots is upon breaking out of the clouds on the approach. First, pilots need to locate the pad. To help in the acquisition of the heliport, some sort of light source, such as a flashing strobe, is needed to distinguish it as a heliport. If pilots can identify the heliport immediately upon exiting the cloud layer, they can focus their attention on the heliport lighting system, and continue their approach visually. If they cannot immediately locate the heliport, attention must be given to the instruments to assure that they stay on glide slope and on course.

Attitude Information

To provide attitude reference, a horizontal line of lights could be used. This is important information, which aids pilots in keeping the wings level. Whittenburg, Vaughan, Havron, and Cavonius (1964) have guidelines for the length of a solid line of lights for attitude reference. They recommend a solid line of lights be long enough to

subtend a visual angle of 132 minutes. This corresponds to a line of lights 29 ft long at a distance of 761 ft. These distances were computed assuming a decision height of 100 ft, a twenty foot hover height over the pad, and a six degree glideslope. Having this information outside allows pilots to maintain their attention outside, eliminating the need to look inside for attitude information, again reducing pilot workload.

Line-up Guidance

The use of a longitudinal row of lights to provide line-up information would ensure obstacle clearance and proper approach path to the heliport. Whittenburg et al. (1964) provides guidelines for the length of solid lines of lights and the distance between two point sources of light. They suggest a solid line of lights subtend 19 minutes of visual angle. From a 100 ft decision height, a 20 ft hover over the pad, and a six degree glideslope, a line of lights needs to extend 34 ft from the far side of the pad to provide adequate lateral displacement guidance. Considering two point sources of light, the distance between the two should subtend at least nine minutes of visual angle, but may be separated by as much as 20 minutes. That relates to a distance between the two sources of at least 15.3 ft and no greater than 35 ft. Having this information outside eliminates the need to look inside for line-up information, further reducing pilot workload.

Glideslope Guidance

A visual glideslope system is important for two reasons. It provides obstacle clearance and a gradual approach to the helipad, keeping the pilot from having to make a

radical maneuver to get the helicopter safely on the pad. Glideslope information can be provided by a number of systems that are all adequate.

Some of the basic glideslope systems, such as the Visual Approach Slope Indicator (VASI), only give an indication of on glideslope, above glideslope, and below glideslope. These systems do not provide any rate information, which is the rate at which pilots approach the proper glideslope. This type of system is like driving a car with loose steering; it is a challenge to keep the car on the road. Pilots may tend to oscillate through the glideslope when using this type of system for the first time.

More complex systems, such as the Mirror Optical Landing System (MOLS), provide information on the distance the aircraft is off glideslope and information on the rate at which the aircraft is approaching the proper glideslope. These types of systems make it easy for pilots to maintain the proper glideslope.

Now that the pilot is on course and on glideslope descending to the helipad, information on distance to the pad and rate of closure is needed so that the pilot can decelerate to a hover over the helipad. The perception of distance and rate of closure comes from many cues that, when taken together, should provide adequate information to safely decelerate to a hover. Some of these important cues include: apparent foreshortening, retinal image size, optical expansion rate, optical edge rate, and optical flow rate.

Distance Estimation Information

The first visual cue that helps pilots perceive distance to the pad is apparent

foreshortening (Department of the Army, 1988). This refers to the apparent shortening of an object when viewed from a distance. An example of this would be the apparent shape of a circular lake when viewed from a distance. The lake appears to be oval at a distance, but as a pilot approaches the lake, the apparent shape changes from oval to circular. This is true for other geometrical shapes as well. The apparent shape of the helipad cues pilots as to the distance from it, and provides some guidance for deceleration. The circular shape of the helipad would also help pilots recognize changes in the approach angle. As a pilot goes below the glideslope, the pad shape would tend to flatten out into a more oval shape and as the pilot goes above glideslope, the pad would appear more round.

The second visual cue that helps pilots judge the distance to the pad is retinal image size (Department of the Army, 1988). Some perception of distance comes from the size of an image focused of the retina of the eye. As pilots approach a heliport, the retinal image size of the helipad increases. The brain perceives this as a reduction in the distance between the eye and the object. The retinal image size of the helipad continues to grow until the perceived size of the helipad approaches the actual size of the helipad, naturally cueing pilots to a reduction in distance and, hence, a need to decelerate.

Rate of Closure

The first cue, which gives an indication of rate of closure and signals pilots to decelerate, is known as Optical Expansion Rate (Andre & Johnson, 1993). Optical Expansion Rate refers to the rate at which the retinal image size of an object increases. As the helipad is approached at a constant speed, the size of the helipad image on the

retina expands at a faster rate (see Figure 1). In order to maintain a constant expansion rate, the rate at which the object is approached must be decreased. This is another cue that is naturally perceived by pilots, and signals them to slow down.

The second cue that gives rate of closure information is Optical Flow Rate. Optical Flow Rate (Andre & Johnson, 1993) is the angular velocity of surface elements in any one area of a field of view (see Figure 1). This velocity is proportional to vehicle velocity divided by the distance to the viewed surface. An example of this would be the speed at which the ground below flows through the chin bubble of a helicopter. As an aircraft descends, the speed at which the ground flows through the chin bubble increases. By maintaining a constant flow rate, a pilot can decelerate gradually to a hover.

The third cue that gives rate of closure information is Optical Edge Rate. Optical Edge Rate (Andre & Johnson, 1993) is defined as the frequency at which optical elements pass through some visual locale (see Figure 1). While the spacing between the lights is constant, the frequency of the lights through the chin bubble would be directly proportional to velocity. To give pilots an indication to decelerate, the spacing between the lights would have to decrease proportional to the distance to go to the pad. This would be useful if lights were below the approach path.

Helipad Lighting

Finally, after the pilot slows the helicopter to a hover over the pad, information is needed as to position over the pad. Depending on the size of the pad and the distance from the lights, it may be hard to perceive lateral, forward, or rearward drift over the pad.

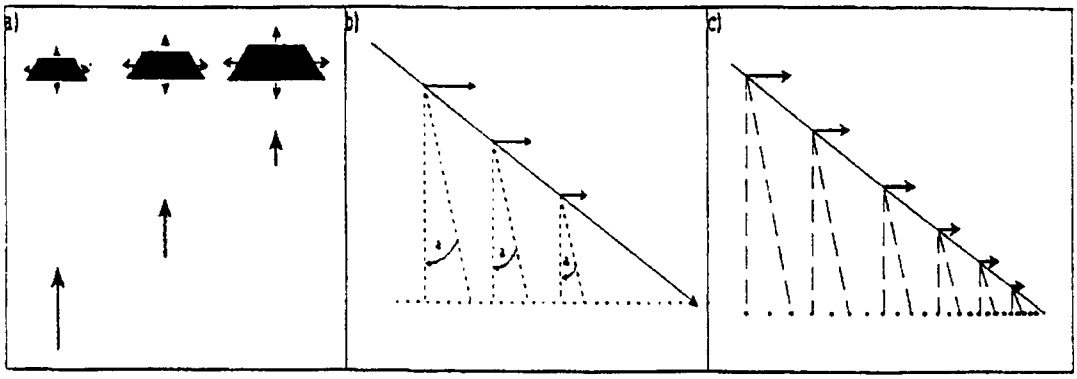


Figure 1. Optical variables useful for controlling deceleration. a) constancy of optical expansion rate requires speed to be proportional to distance to go; b) constancy of angular flow rate requires speed to be proportional to altitude; c) constancy of edge rate requires texture elements and speed to be proportional to distance to go.
Source: Johnson ,W. W. and Andre, A. D. (1993). Visual Cueing Aids for Rotorcraft Landings. Paper presented at Piloting Vertical Flight Aircraft: A Conference on Flying Qualities and Human Factors, San Francisco, CA

Additionally, in the final few feet of landing, pilots tend to look down at the pad to see how far they are above it. This diverts their attention away from the lighting system to the pad directly below, to which there may not be any visual cues.

There are three different types of lighting to be considered for the proposed helipad. The first is the perimeter lighting. The primary purpose of the perimeter lighting is to define the useable portion of the helipad.

The second type of lighting or marking is pad center lighting. It is used to identify the center of the pad, providing pilots with a reference when landing. This will help the pilots control drift, and may provide enough light for pilots to determine their height above the pad. The lighting could also be used to identify the helipad as such if the lighting is arranged in an H pattern.

The third type of lighting that may be required on the helipad is flood lighting. If the pad is dark and the microtexture is not visible, dim lighting will be required to

illuminate the microtexture. Microtexture is the small details on the pad such as rocks or cracks in concrete. Hoh (1985) states that "texture is clearly a key element of the visual scene when the task is to perform precise hovering". Hoh also notes that "most researchers agree that texture plays an important role in sensing translational rates in all three directions". As a result of his research, Hoh determined that hovering and low speed flight can be accomplished with a reasonable level of pilot workload and a relatively small field of view (38 degrees wide and 23 degrees high), if sufficient microtexture is available.

Hopefully, this chapter has given some insight into how pilots conduct an approach and what they look for when flying the visual segment of an instrument approach. These cues will be revisited later during the discussion of the proposed lighting configuration.

CHAPTER 4

PREVIOUSLY TESTED LIGHTING SYSTEMS

The idea of a heliport lighting system is not new; however, very little research has been conducted in this area. Several years ago, it was revealed that a standard heliport lighting system was nonexistent (Jones, 1984). Since then, ongoing research has been conducted to determine an effective design for a heliport lighting system that will provide guidance during precision and non-precision instrument approaches. Although most of the lighting systems designed have proven to be adequate, it is thought that a system can be designed that is more affordable, provides superior visual cues, and is compact enough to fit on a rooftop. A review and evaluation of some of these previous configurations will follow. Because specific reasoning for some of the design features are still unknown, questions will be raised and assumptions will be made to explain them.

Heliport Instrument Lighting System (HILS)

The Heliport Instrument Lighting System (HILS) evolved out of a need for an instrument lighting system to be used in conjunction with non-precision instrument approaches. HILS consists of four components: pad perimeter lights, front and rear approach lights, approach light wing bars, and touchdown area lights (see Figure 2).

The pad perimeter is lit by 115 watt omnidirectional amber lights that are elevated above the pad surface. The front and rear row of perimeter lights are composed of nine lights; the sides are only composed of five. According to Jones (1984), this somehow

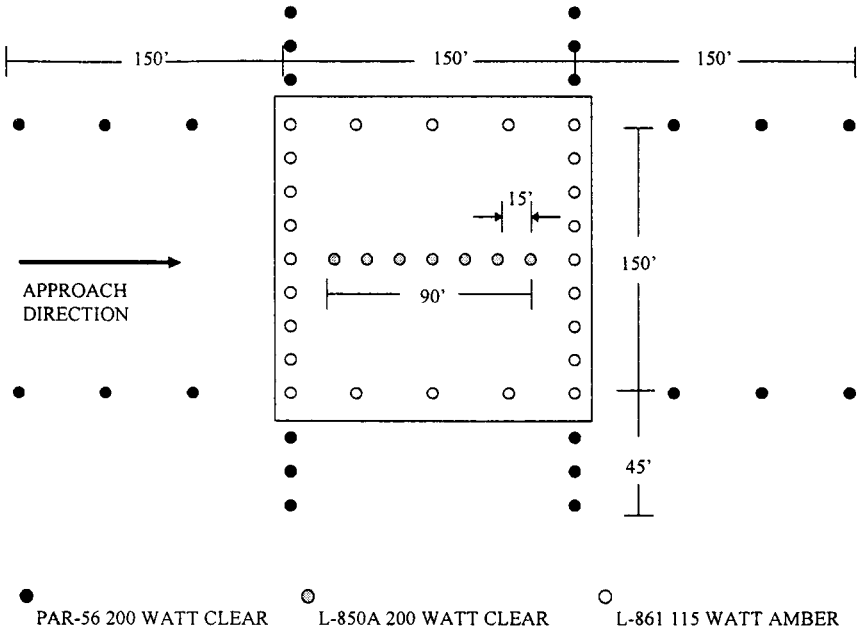


Figure 2. Configuration of the basic IFR lighting system
Source: Adapted from Hogan S. (1993). Heliport Instrument Lighting System (HILS) Report (DOT/FAA/CT-ACD330-93/3). Atlantic City Airport, NJ: Federal Aviation Administration

provided better visual cues, and was liked better by pilots than the front and rear row of lights containing only five lights. Jones also stated that it provided an enhanced visual presentation and definition of the front and rear edges of the pad.

The front and rear approach lights are extensions of the right and left side perimeter lights. They consist of two parallel rows of 200 watt clear unidirectional lights that extend 150 ft into the foreground and background of the helipad (Jones, 1984). Their purpose is to provide line-up information and, possibly, pad identification because it is in the shape of a pound sign (see Figure 3).

The approach light wing bars consist of two parallel rows of 200 watt clear unidirectional lights. They are extensions of the front and rear perimeter lights and

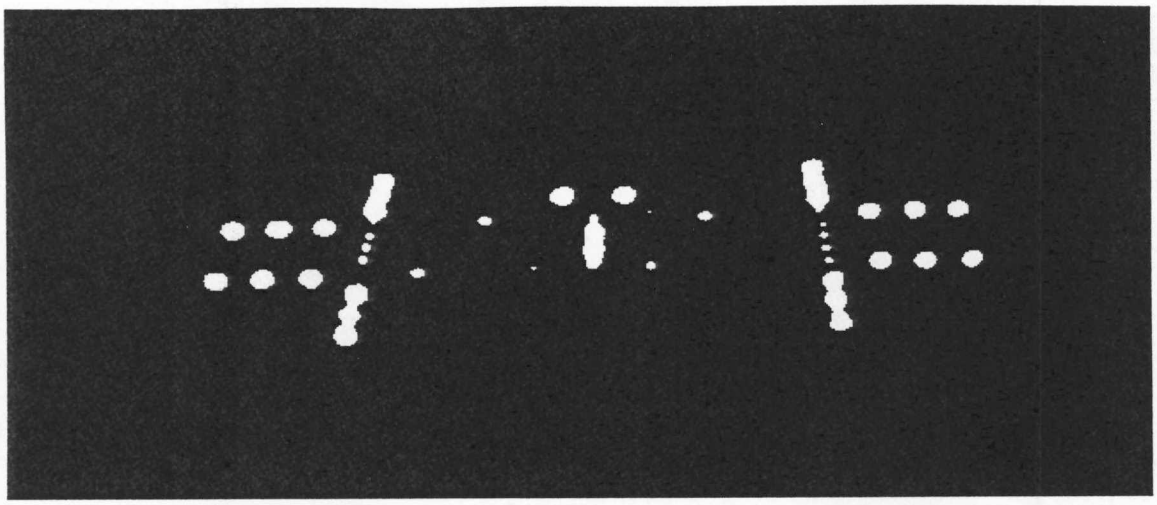


Figure 3. The basic IFR lighting system during an approach in a simulator
Source: Jones P.H. (1987). Simulation Tests of Proposed Instrument Approach Lighting Systems for Heliport Operations (DOT/FAA/CT-TN87/4). Atlantic City Airport, NJ: Federal Aviation Administration

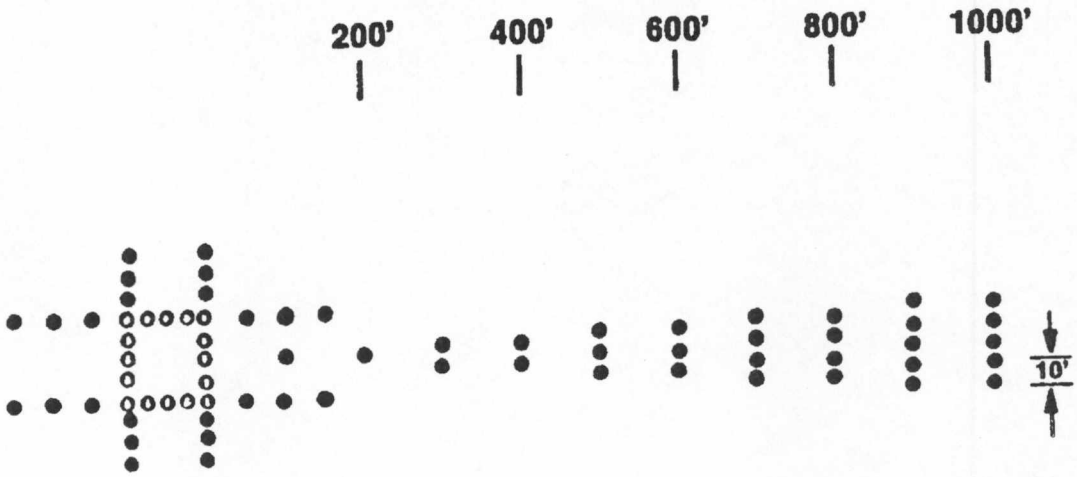
extend 45 ft to the right and left of the pad. Their purpose is to provide a visible horizon or roll guidance. Pilots believed that they provided more visual cues during the final portion of the approach, allowing for a more accurate judgment of rate of closure. Additionally, they provided information on pad location during cross wind approaches. At such time, the remainder of the lighting configuration may be masked behind the instrument panel due to the crabbing of the helicopter (Jones, 1984).

The final component of the HILS configuration is the touchdown area lights. It consists of bi-directional inset flush lights that are aligned with the landing direction. Its purpose is to provide final directional guidance and enough light to allow the pilots to observe surface definition (Jones, 1995). Because the lights are on the pad itself, they may be below the instrument panel of most helicopters when the helicopter is decelerating, thereby failing to provide line-up information during the flare.

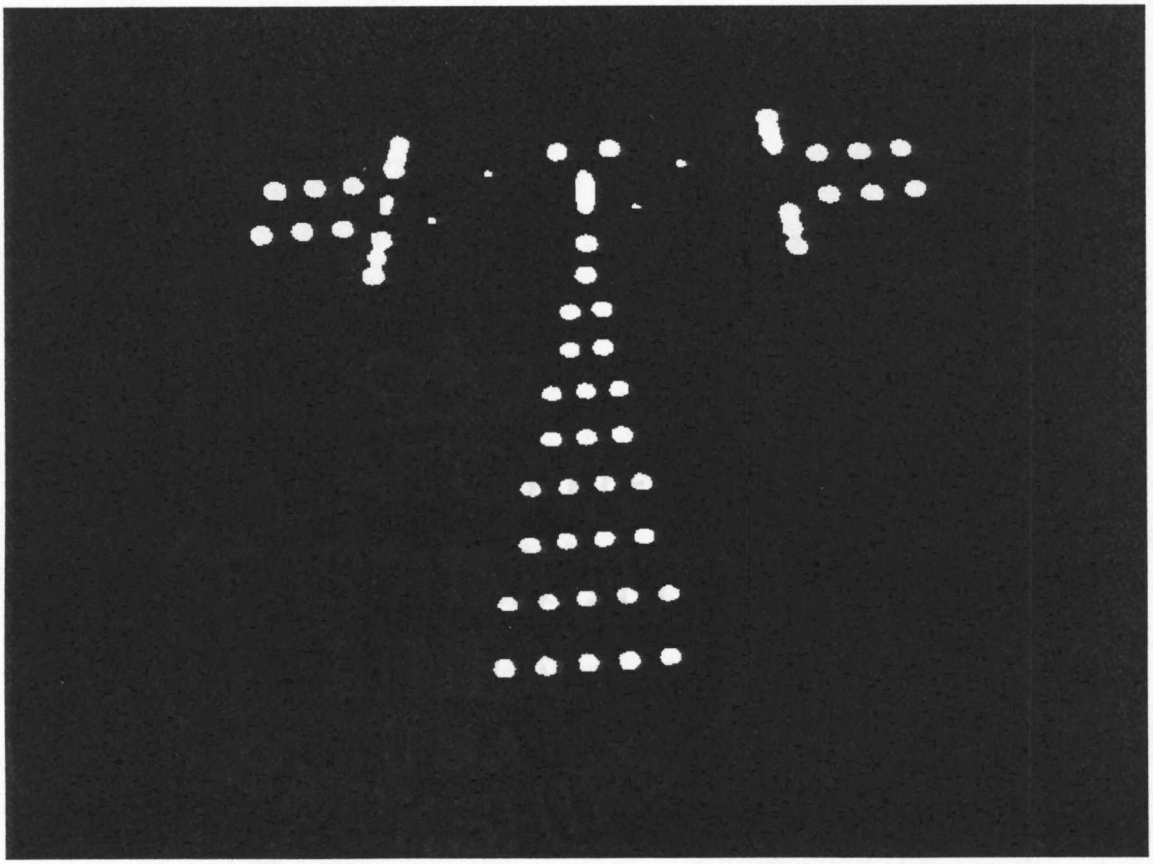
The HILS provides adequate visual cues to pilots; however, questions have yet to be answered about specific aspects of the design. The first question relates to the use of two parallel rows of lights versus one. It is possible that it provides an enhanced visual presentation, however, the use of one row of lights would cost less to construct, maintain, and operate while still providing an adequate visual presentation. The second question pertains to the use of a square helipad rather than a round one. The use of a round helipad would better distinguish it in the center of a city, where there is likely an abundance of lighted square rooftops. A round pad would also allow for easier interpretation of the apparent foreshortening visual cue and approach angle. The shortcomings of the HILS described above have provided great insight into the new design to be presented later.

Helicopter Approach Lighting System (HALS)

The Helicopter Approach Lighting System (HALS) is designed to provide a helicopter pilot with visual cues upon reaching the decision height (Billmann & Shollenberger, 1988). This lighting system consists of two basic components (see Figure 4). The first component is the HILS, just discussed in the previous section, and the second is the Centerline Approach Lighting System (ALS). The ALS consists of unidirectional high intensity light bars located in the approach zone of a heliport that are spaced at 100 ft intervals. The first light bar encountered by pilots on an approach is 1000 ft from the pad and contains five lights spaced ten feet apart. The number of lights in the rows decreases as they get closer to the pad, until there is only one light in the last row of lights. The overall view of the system appears as an arrow that points to the



(a)



(b)

Figure 4. Helicopter Approach Lighting System. (a) IFR approach lighting configuration, and (b) 1000 ft Approach Lighting System during an approach in a simulator
Source: Jones, P.H. (1987). Simulation tests of proposed instrument approach lighting systems for heliport operations (DOT/FAA/CT-TN87/4). Atlantic City Airport, NJ: Federal Aviation Administration

helipad. The ALS is intended to be added to the HILS at heliports in which there is available real estate in front of the pad. With the addition of the ALS, it is hoped that a reduction in landing minimums will be possible due to the increased visibility of the landing environment (Billmann & Shollenberger, 1988).

An extension to the ALS, which extends the approach lights and adds two more sets of wingbars, was tested. Since pilots may not have the heliport in sight upon breaking out of the clouds, the use of longer lengths of approach lights could be used to lead the pilot to the heliport (Jones, 1987). This would allow for lower visibility minimums. The extension of the ALS most liked by pilots was the 2400 ft approach lighting system (see Figure 5). The system uses the same 100 ft spacing between the row of lights that are composed of five high intensity lights. Additionally, two wing bars were added to the 1000 and 2000 ft row of lights to provide rate of closure information and roll guidance (Jones, 1987). All the pilots surveyed believed that the system was adequate or more than adequate.

This system may prove to be valuable for providing guidance to the heliport under low visibility conditions. The obvious drawback, however, is the need for excessive real estate to place the system. Another drawback that may prevent widespread use of the system is the extravagant cost, due to the large number of lights in the system.

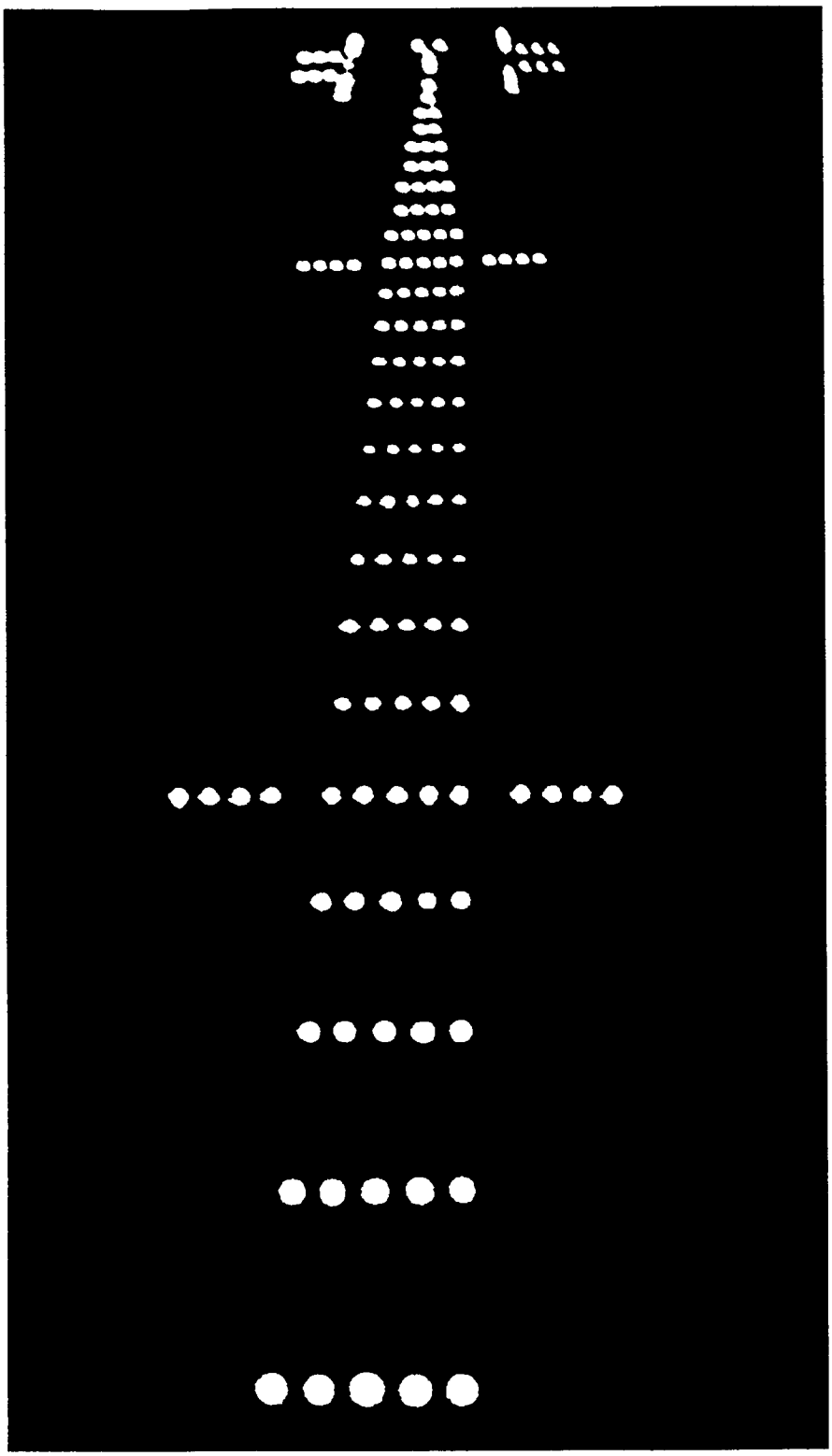


Figure 5. 2400 ft Approach Lighting System with wingbars during an approach in a simulator
Source: Jones, P.H. (1987). Simulation tests of proposed instrument lighting systems for heliport operations (DOT/FAA/CT-TN87/4). Atlantic City Airport, NJ: Federal Aviation Administration

CHAPTER 5

THE PROPOSED HELIPORT LIGHTING SYSTEM

This system has been designed primarily to provide visual cues to pilots flying precision instrument approaches. If a six degree glideslope is assumed, which crosses the pad at 20 ft and a 100 ft decision height, pilots will be at 761 ft horizontal distance from the pad when they are transitioning to the lighting system. Since precision instrument approaches will only represent a small portion of the total usage of the pad, an effort has also been made to design a lighting system that will support non-precision instrument and VFR approaches.

Acquisition Lighting

A flashing white strobe is used in the immediate vicinity of the helipad lighting system to set it apart from other lights in the area. Because of its vicinity to the pad, the strobe may need to be pilot controlled so that it can be turned off after the lighting system is acquired, preventing the strobe from creating a distraction to the pilots during the approach.

Attitude Information Lighting

A horizontal row of lights is used to provide a visual horizon. Two rows of three point source lights spaced at five foot intervals extend to the right and left of the three o'clock and the nine o'clock position of the pad. If a 100 ft pad is used, the two rows of

wingbar lights, if treated as one, would be 140 ft long (see Figure 6). According to Whittenburg et al. (1964), this is long enough to provide attitude guidance to a distance of 3646 ft (.6 nm). This would provide information far beyond the 761 ft needed for a precision approach, and would be helpful to pilots flying non-precision approaches as well.

Line-up Guidance

A row of four point source lights extend from the twelve o'clock position into the departure area to provide line-up guidance. The appendix shows views of the pad from a Sikorsky S-76 helicopter cockpit as the pad is approached on a six degree glideslope. This shows the importance of having the lights on the departure side of the pad. These lights are spaced 10 ft apart, providing a line of light 40 ft long, which is longer that the 34 ft recommended by Whittenburg et al. (1964). Additionally, two point source lights spaced 10 ft apart extend into the approach area from the six o'clock position. At a distance, the two longitudinal rows of lights, when taken together, would appear as two point sources. The 120 ft distance between them would provide line-up guidance to an even greater distance than 761 ft.

At heliports that have an obstruction or limited space in the departure area, a vertical line of lights can be used to replace or extend the longitudinal row of lights on the departure side of the pad. An example of this would be a pad built close to a building. Additionally, if the pad is on a building, a vertical row of lights can be placed, descending the side of the building on the approach side of the pad. This would provide strong line-

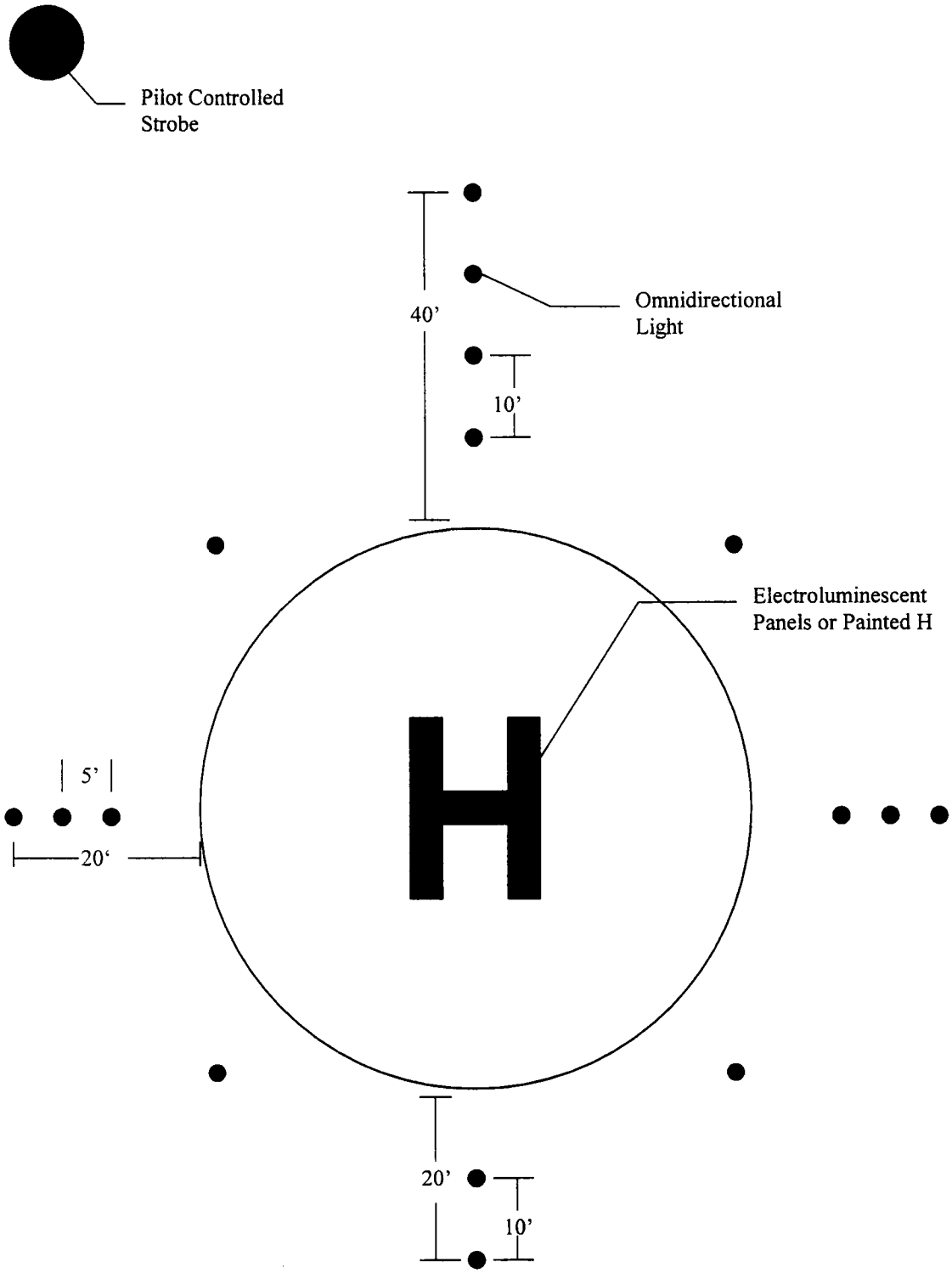


Figure 6. The proposed helipad lighting system.

up cues in a limited horizontal space (see Figure 7). This type of configuration would only be used when an obstruction already exists; it should not create an obstruction.

Glideslope Guidance

There are a wide variety of glideslope systems available today. Of course, the more expensive systems provide more information than the systems that are less expensive. All of the systems are adequate, and the determination of which system should be used is decided by the operator of the heliport.

Perimeter Lighting

The pad perimeter lighting is arranged in a circle, not only to define the usable portion of the helipad, but also to provide some usable visual cues to pilots on the approach. As described earlier, the round shape will appear oval at a distance. The apparent change in shape as the pilot approaches may provide approach angle cues and rate of closure cues as well. Additionally, the round shape will set it apart from other lighted rooftops that are square. Four lights are arranged around the pad at 90 degree increments starting at the two o'clock position. The diameter of the pad and lighting system should be in accordance with appropriate regulations.

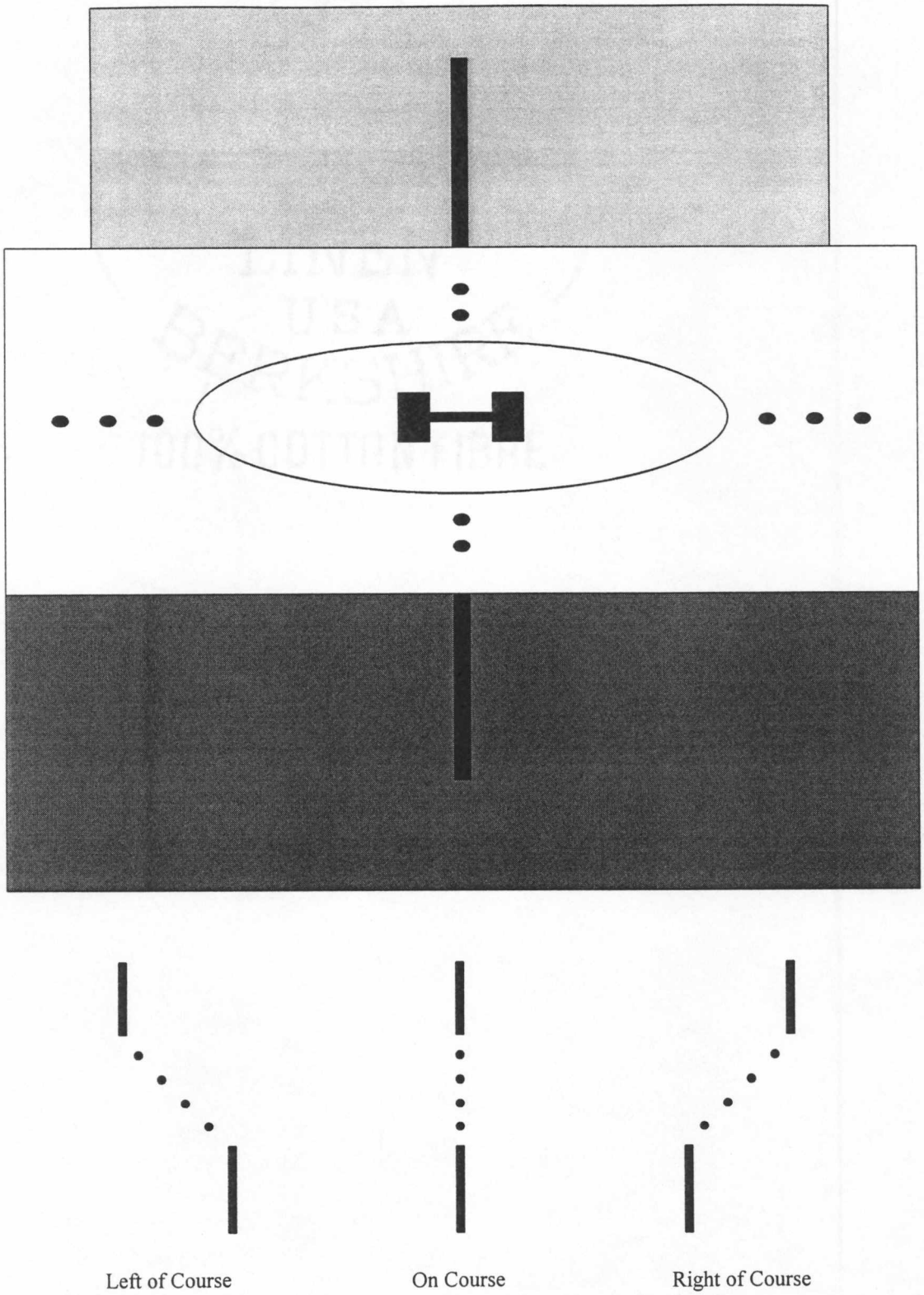


Figure 7. The proposed helipad lighting system with vertical light pipes.

CHAPTER 6

PRELIMINARY TEST RESULTS AND AREAS FOR FURTHER TESTING

The lighting configuration was assembled on the apron of closed runway 32 at Tullahoma Regional Airport, Tullahoma, Tennessee. Five subject pilots flew multiple approaches to the configuration in a Bell 206B helicopter on several nights. The sky was clear and the visibility was ten miles on all nights of testing. The pilots opinions and perceptions were recorded.

Acquisition Lighting

Pilots reported the ability to see the white flashing strobe, which flashed a Morse code H, at distances up to 10 nm, which they rated as excellent. As the pilots neared the pad, they reported that the light caused a distraction, which suggested the need for the strobe to be pilot controlled. Further testing should be conducted to determine the optimum intensity of the strobe, the rate at which the strobe flashes, and a possible method for pilots to control it.

Attitude Information Lighting

The horizontal row of lights was reported to be visible at distances up to 1.3 nm. This is far beyond the distance for which the system was designed, improving the lighting system's effectiveness for non-precision and VFR approaches. Some pilots commented

that the rows could be longer, either by adding more space between the lights or by adding more lights to the wingbars. Both of these recommendations should be further tested to determine if the change would improve the proposed system.

Line-up Guidance

The first few runs of the test were conducted using a longitudinal row of four green point sources spaced 5 ft apart on the departure side of the pad, and two amber point sources spaced 5 ft apart on the approach side. Additionally, a 20 ft long green light pipe, 8 inches in diameter, was placed vertically 20 ft beyond the lights in the departure area.

It was immediately recognized that the spacing between the longitudinal row of lights needed to be increased. After increasing the spacing to 10 ft, pilots reported the ability to receive useful line-up information at distances up to 1 nm. Later in the test, the two amber lights on the approach side of the pad were replaced with two green point sources. It appeared as if the amber lights were washing out the green point sources on the departure side of the pad. The change made the configuration appear to be more defined and useful for line-up cues at greater distances.

Pilots reported being able to see the light pipe at 1.5 nm. The line of light was easy to detect because there were no other light sources on the airport similar to it. Pilots must be sure not to confuse the vertical light pipe with the longitudinal row of lights because it would present an on course indication from all angles. Perhaps the light pipe should be shielded to allow light to be seen for 20 degrees on either side of the course.

Pilots also reported that the light pipe may only need to be 10 ft long, instead of 20 ft long. Further testing should be conducted to determine the appropriate length of the light pipe and lower cost alternatives.

Helipad Lighting

The use of electroluminescent panels were tested to determine their effectiveness for pad center lighting. Most pilots reported that the panels were not visible until on short final, but provided useful information once it was visible. Further testing needs to be conducted to determine if other types of lighting or reflective tape may provide the same information for much less cost.

Some dim pad flood lights were also tested to determine their importance to the lighting system. Pilots reported that the flood lights illuminated some of the microtexture, but did not add much to the available cues needed to land the helicopter. Further testing is needed to determine if pad flood lighting is required or if there is enough ambient light from the rest of the lighting configuration to provide the required visual cues.

CHAPTER 7

CONCLUSION

Past heliport lighting systems have been adequate for the limited use needed by helicopter operators. Recent advances in technology have enabled helicopters to be more widely used. The implementation of the Wide Area Augmentation System will provide the capability of precision instrument approaches with lower minimums to a great number of airports and heliports that previously had no instrument procedures. To support the growth in precision and non-precision approaches, a standard helicopter lighting system is needed.

Because of the diverse locations heliports now serve and the variety of organizations that operate them, a heliport lighting system must be simple, compact, and fairly affordable. Hopefully, this has been accomplished by the proposed lighting system. The configuration of the lighting system is very simple. It uses a the minimum number of lights to reduce cost and minimize space, without compromising the quality of the information received by pilots. The lighting system can also be easily adapted to the many existing square helipads.

Although great effort has gone into the research and development of the proposed lighting system, there is still much more to be done. It is necessary to determine the length and spacing of the wingbar and line-up rows of lights, so that they may provide clear attitude and line-up cues. Additional testing also needs to be conducted to determine the intensity, flash rate, and a means for pilots to control the strobe. Pad center

lighting or marking requires some research, as well. Finally, the color and intensity of the point source lights, which make up the lighting system, needs to be resolved.

While testing, it will be necessary to determine the effectiveness of the system by evaluating pilot performance. This information can be obtained by recording pilot comments, as well as the position of the aircraft relative to the proper approach path.

It is hoped that this proposed heliport lighting system will initiate further interest in heliport lighting issues. A standard heliport lighting system could provide support for the expansion of helicopter operations. Ultimately, it is possible that the standardization of heliports will make instrument flying more commonplace.

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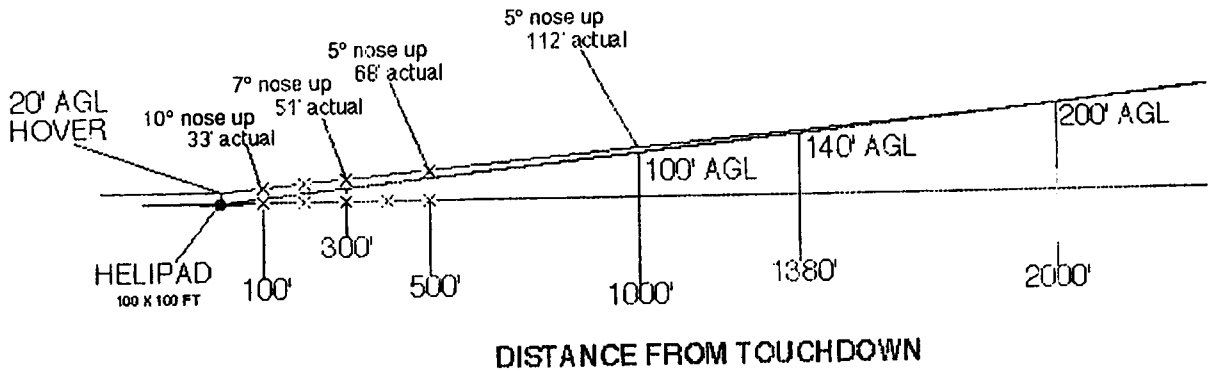
APPENDIX



6° APPROACH PROFILE

Figure A1. 6° approach profile
Source: Mr. Chris Jaran, Manager, S-92 Customer Relations, United Technologies, Sikorsky Aircraft

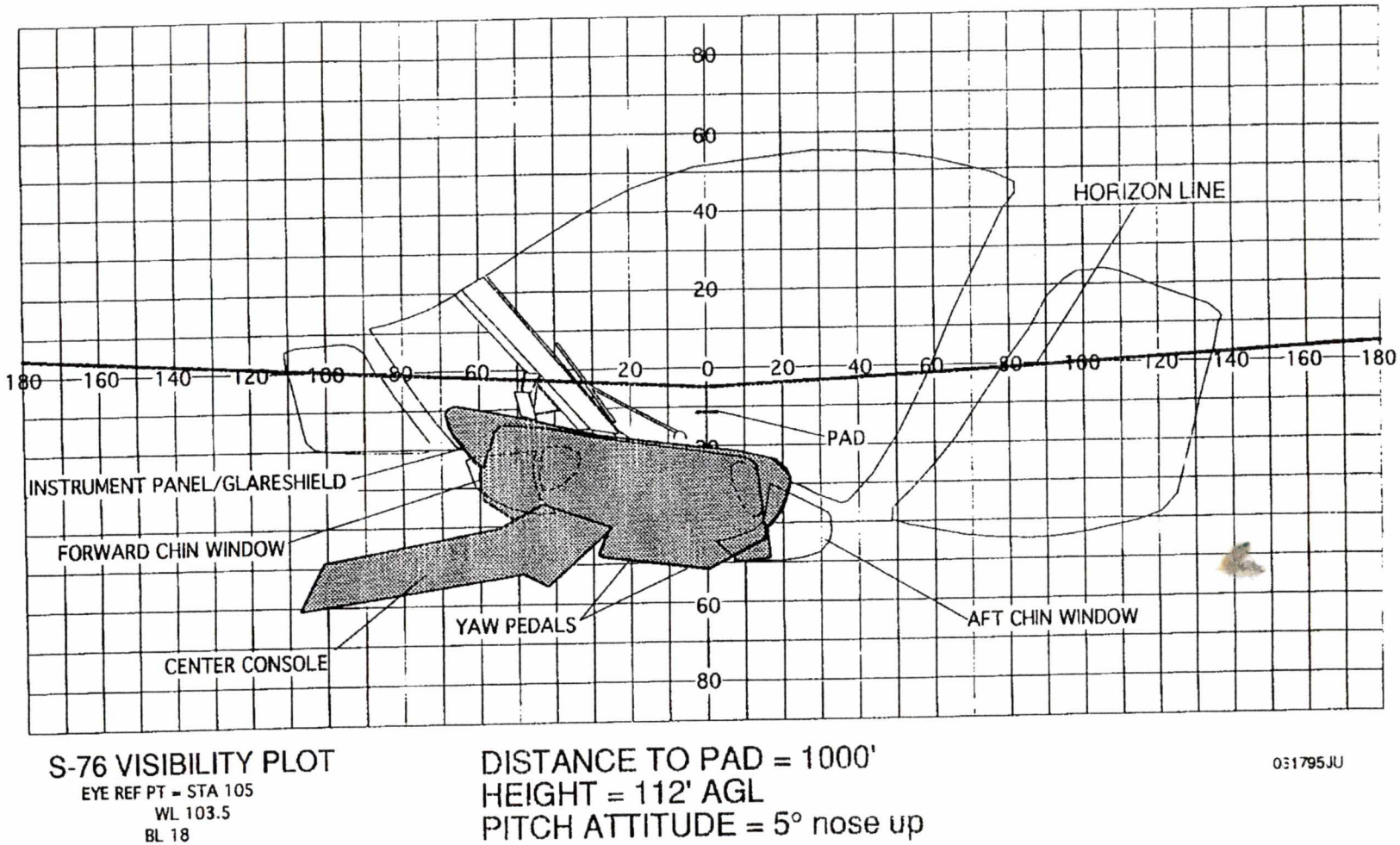
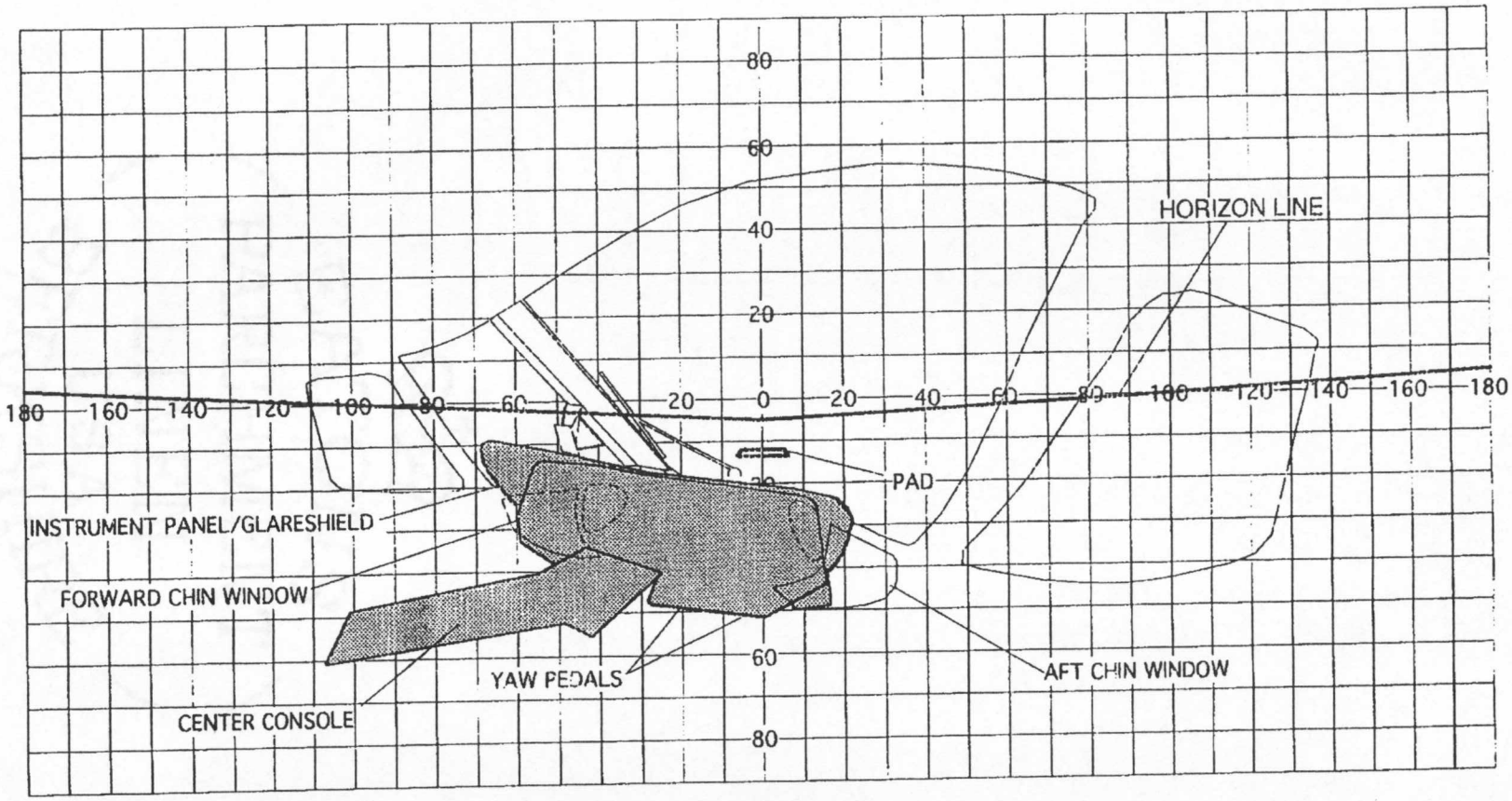


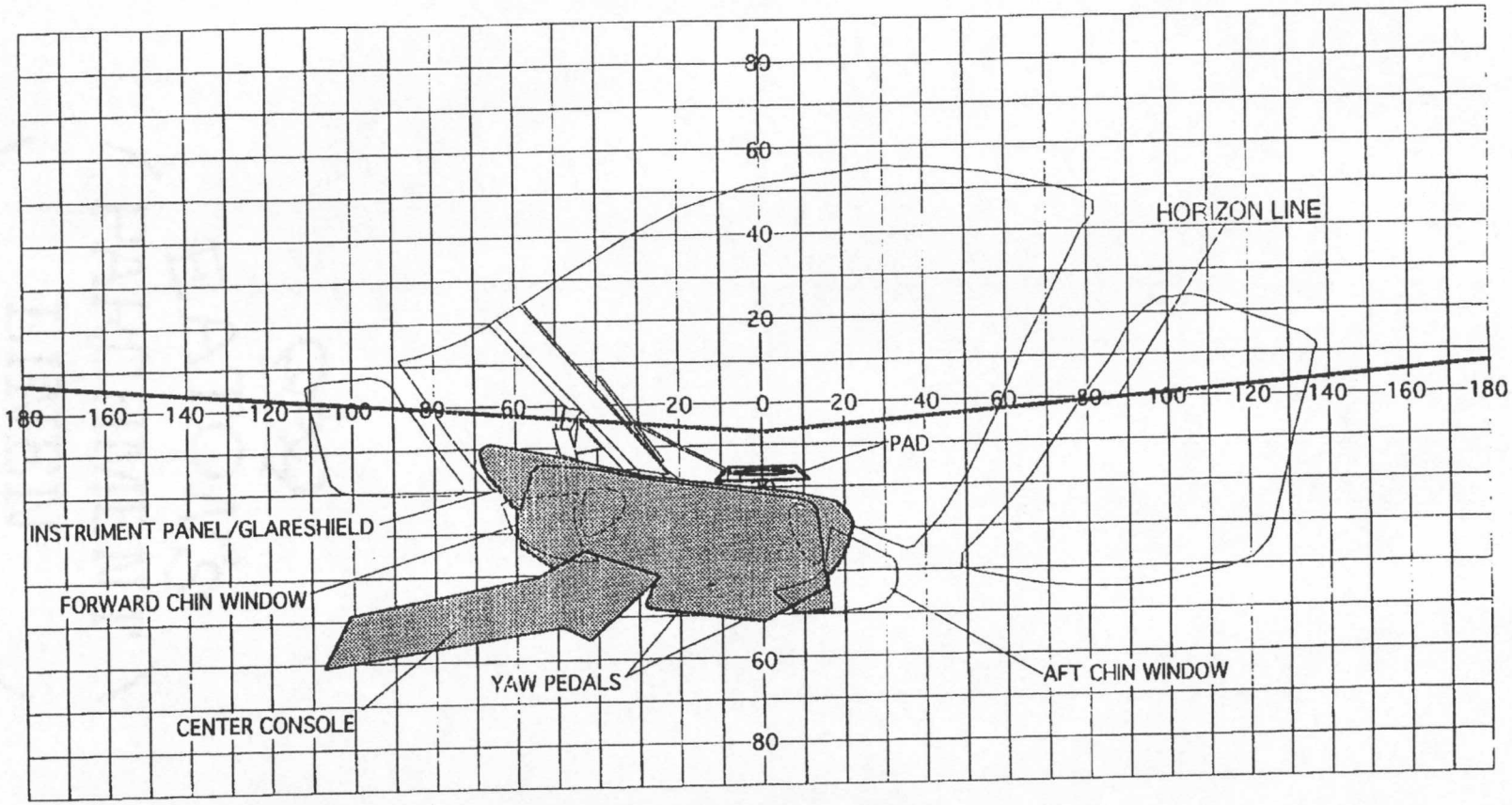
Figure A2. View from a Sikorsky S-76 helicopter on an approach at 112 ft AGL
Source: Mr. Chris Jaran, Manager, S-92 Customer Relations, United Technologies, Sikorsky Aircraft



S-76 VISIBILITY PLOT
EYE REF PT = STA 105
WL 103.5
BL 18

DISTANCE TO PAD = 500'
HEIGHT = 68' AGL
PITCH ATTITUDE = 5° nose up

Figure A3. View from a Sikorsky S-76 helicopter on an approach at 68 ft AGL
Source: Mr. Chris Jaran, Manager, S-92 Customer Relations, United Technologies, Sikorsky Aircraft



S-76 VISIBILITY PLOT
EYE REF PT = STA 105
WL 103.5
BL 18

DISTANCE TO PAD = 300'
HEIGHT = 51' AGL
PITCH ATTITUDE = 7° nose up

Figure A4. View from a Sikorsky S-76 helicopter on an approach at 51 ft AGL
Source: Mr. Chris Jaran, Manager, S-92 Customer Relations, United Technologies, Sikorsky Aircraft

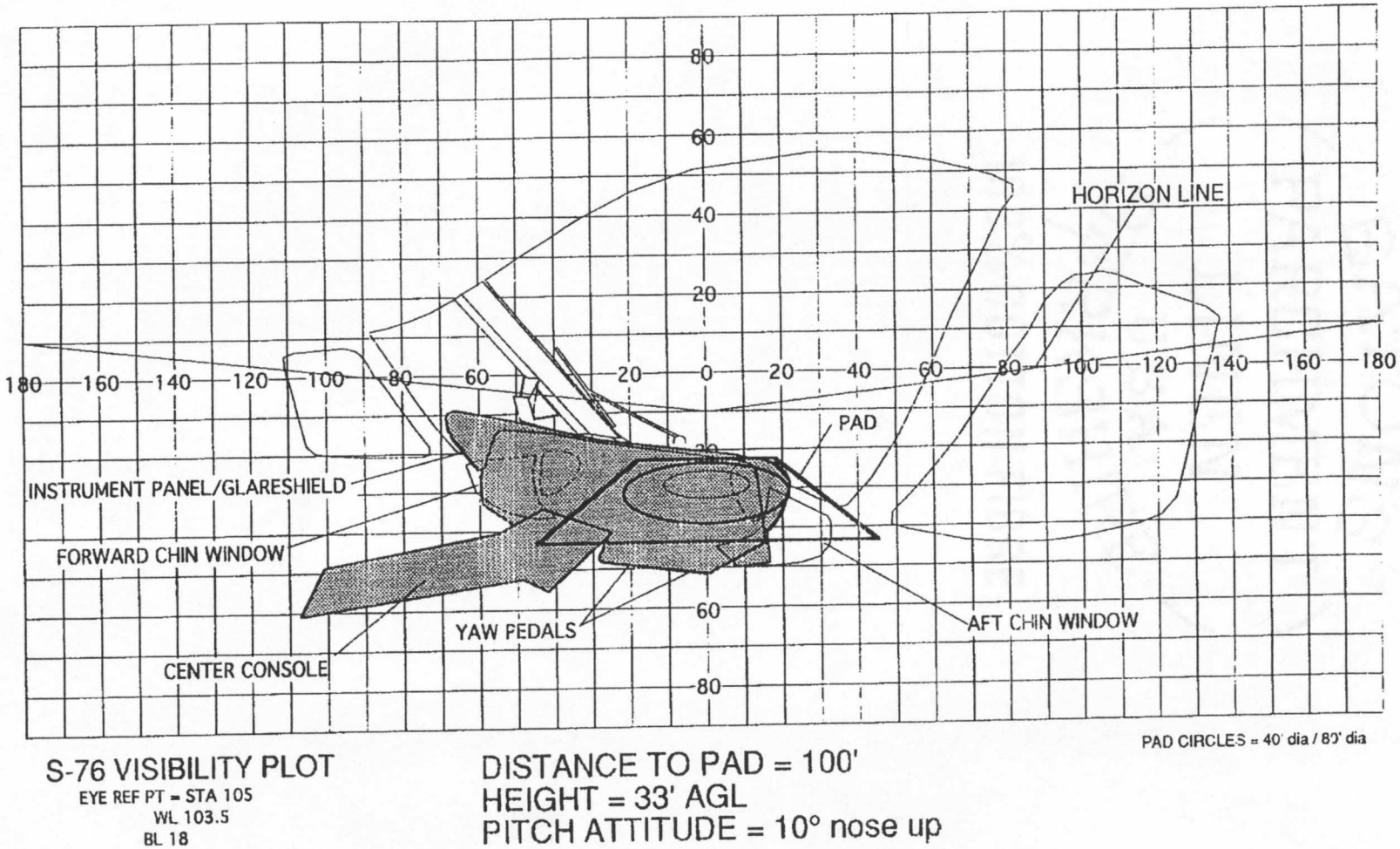


Figure A5. View from a Sikorsky S-76 helicopter on an approach at 33 ft AGL
Source: Mr. Chris Jaran, Manager, S-92 Customer Relations, United Technologies, Sikorsky Aircraft

VITA

Michael J. Weis was born in Dubuque, Iowa on July 31, 1970. At the age of 16, he attained the rank of Eagle Scout as a member of the Boy Scouts of America. Following graduation from high school at Highland Park High in Highland Park, Illinois, Michael joined the Army at the age of 18 to become a Warrant Officer and a helicopter pilot. Upon graduation from flight training in 1989, he served as a UH-60 Blackhawk pilot for four years. While assigned to Fort Benning, Georgia, Michael attended Columbus College in Columbus, Georgia, and was later assigned there in September of 1993 to complete a Bachelor of Science in Mathematics. In April of 1995 he was selected to attend further schooling at the University of Tennessee Space Institute where he is working on a Master of Science in Aviation Systems. Michael was also selected to attend the Naval Test Pilot School in Patuxent River, Maryland starting in January of 1997.