Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2004/01

Enhancing Offshore Helideck Lighting - NAM K14 Trials

www.caa.co.uk

Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2004/01

Enhancing Offshore Helideck Lighting - NAM K14 Trials

January 2004

ISBN 0 86039 958 3

Issued January 2004

Enquiries regarding the content of this publication should be addressed to:
Research Management Department, Safety Regulation Group, Civil Aviation Authority, Aviation House, Gatwick Airport South, West Sussex, RH6 0YR.

The latest version of this document is available in electronic format at www.caa.co.uk, where you may also register for e-mail notification of amendments.

Printed copies and amendment services are available from: Documedia Solutions Ltd., 37 Windsor Street, Cheltenham, Glos., GL52 2DG.

List of Effective Pages

Contents

Foreword

The research reported in this paper was funded by the Safety Regulation Group (SRG) of the UK Civil Aviation Authority, and was performed by DERA Bedford (now known as QinetiQ Ltd). The work comprises a set of three dedicated flight trials, performed at the NAM K14 platform located in the Dutch Sector of the North Sea, aimed at investigating means of improving offshore helideck lighting. The project was commissioned in response to concerns that existed within the industry, and which were subsequently confirmed by the results of a questionnaire survey of the offshore helicopter pilot population reported in CAA Paper 97009.

This paper is based on the contractor's (QinetiQ Ltd) final project report ref. QinetiQ/FST/CSS/CR013344, but contains a more detailed analysis of the flight trials results subsequently performed by SRG's Research Management Department. All significant changes to the original report have been reviewed by and agreed with the contractor.

The CAA accepts the results of the study which have identified a number of ways in which offshore helideck lighting could be significantly improved. Following on from this work, further trials at an onshore site (Longside Airfield near Aberdeen) were performed during 2002 to evaluate refinements to the recommended system, try out some new ideas and investigate the effects of a helideck net on the lighting. These additional trials are to be reported in a separate CAA paper.

Safety Regulation Group

January 2004

Executive Summary

DERA Bedford (now QinetiQ) was tasked with conducting a series of flight trials on behalf of the Safety Regulatory Group of the Civil Aviation Authority to investigate means of improving offshore helideck lighting.

This report presents the results of flight trials that were performed on the offshore platform NAM K14B. This is a small, unmanned satellite located 5NM from the main K14 complex in the Dutch Sector of the North Sea.

The trials were conducted over a period of twelve months, between November 1998 and October 1999 using an S76 helicopter chartered from Bristow Helicopters Ltd (BHL). The trials team comprised CAA test pilots and observers, BHL pilots, a Norwegian CAA observer and DERA scientists.

The purpose of the flight trials was to assess new visual aids and alternative technologies that earlier tests and trials had indicated could provide improved visual cueing in the offshore environment.

A pilot has to perform many difficult tasks when approaching an offshore platform at night, including: -

- acquiring the helideck lighting patterns amongst the extensive cultural lighting on the platform;
- judging and controlling the closure rate of the aircraft to the helideck in the final approach;
- determining and controlling the aircraft's position in relation to the marked Touchdown Marking circle;
- determining and controlling descent rate using information from the surrounding environment.

Some of the piloting tasks are made more difficult by the problems of glare caused by stray light from misaligned light fittings installed to support aviation, or illuminate task and accommodation areas.

Potential aids for performing these tasks evaluated during the course of the research and covered in this report were: -

- changing the colour of the helideck perimeter lighting from yellow to green;
- highlighting the helideck perimeter with green Electro-Luminescent Panels (ELPs);
- highlighting the helideck perimeter with green Light Emitting Diode (LED) strips;
- highlighting the Heliport Identification Marking ('H') with green ELPs;
- highlighting the Touchdown Marking (circle) with yellow LED strips,
- shielding helideck-level floodlighting to reduce glare.

The experimental equipment was assessed during four phases of the approach and landing, which were defined as: -

- Helideck Acquisition.
- Final Approach.
- Hover.
- Landing.

The results of the flight trials show that changing the colour of the helideck perimeter lighting from yellow to green significantly increases the range at which the pilot visually locates and acquires the helideck amongst the platform lighting. Green perimeter lighting provides a strong colour contrast to the existing platform lighting. This change enhances the situational awareness of the pilot and promotes greater confidence in the conduct of the approach.

The ELPs evaluated as perimeter lights in the trial were not of an adequate luminance in the required viewing direction for the highly illuminated offshore environment. The trials pilots stated that they preferred point source perimeter lighting to area sources for the acquisition task. However, in the second flight, the addition of green LED strips to the perimeter pattern showed that this type of area source could provide additional information about the perimeter of the helideck.

The ELP ‘H’ superimposed on the Heliport Identification Marking was very successful in providing pilots with a visual aid to aim for when approaching the platform. Its shape, size and orientation in relation to the aircraft’s position provided effective cues to the pilot, such as approach angle and rate of descent. The cues provided by the ‘H’ were very effective until the aircraft moved across the deck into the hover position, when the ‘H’ disappeared from view below the helicopter.

The trials pilots recommended that the ELP ‘H’ be enlarged so that it would remain in view through to touchdown. An alternative solution that was identified was to highlight the Touchdown Marking circle with yellow LED strips placed around the inner and outer edges of the paint marking. These strips provided cues in the central part of the deck where the existing deck mounted floodlights were ineffective. The trial's results showed that, together, the LED strips and the ELP 'H' completely removed the ‘black hole’ effect caused by inadequate floodlighting.

The addition of the yellow LED strips around the edges of the Touchdown Marking circle was also found to provide useful textural cues. From the hover position, the individual LEDs could be seen and provided micro texture. The range at which the individual LEDs could be seen as separate light sources was constant and therefore provided a useful additional range cue to pilots in the final stage of the approach. Even when unlit, the raised profile of the LED strips on the circle provided textural cues.

The deck-level floodlights evaluated on the trial, either with or without hoods, hindered the acquisition of the helideck and dazzled the pilots during the final phases of the approach. They currently provide some useful cues in the hover and landing phases, particularly in combination with a helideck net, but if a net is installed the paint markings are obscured until the viewing range is small. The overall requirement for floodlighting to support helideck flight operations needs to be reassessed, bearing in mind their demonstrated limitations in providing the required visual cues.

From the results of the trials performed, the recommended equipment configuration to provide significantly enhanced cueing consists of: -

- Green perimeter lighting.
- Yellow LED strips defining the Touchdown Marking circle.
- Green ELP ‘H’.

If on grounds of cost, practicability or similar reasons a choice has to be made between the ELP ‘H’ and the LED strips, the trials pilots indicated that the LEDs defining the Touchdown Marking circle, would be the preferred option. The ‘H’ disappeared from view during the hover and landing phases of the approach, but parts of the LED pattern were always visible. However, it should be borne in mind that the lighting systems were evaluated in a limited and favourable range of weather conditions. The agreed preference is therefore for the provision of all 3 aids defined above.

The report recommends that the results of the flight trials be presented to the ICAO Visual Aids Panel (VAP) as a proposal to amend the current Standards and Recommended Practices for helideck lighting. The proposal should recommend the preferred configuration developed by the trials.

An in-service trial should be conducted to demonstrate the applicability of the proposed visual aids in a wider range of meteorological conditions and to a larger pilot population.

Also recommended is the development of a metric to quantify the photometric characteristics of LED strips, in such a way that equipment can be fully specified. This will allow the range performance of LED strip patterns in all visibilities to be predicted with confidence.

Abbreviations

1 List of abbreviations

BHL	Bristow Helicopters Limited
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
DERA	Defence Evaluation and Research Agency
ELP	Electro-Luminescent Panel
FAA	Federal Aviation Administration
FMC	Flight Management & Control Department
GPS	Global Positioning System
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
LED	Light Emitting Diode
MOD	Ministry Of Defence
NAM	Nederlandse Aardolie Madtschappij
NCAA	Norwegian Civil Aviation Authority
RLD	Rijksluchtvaartdienst
SRG	Safety Regulation Group
SLA	Safe Landing Area
UK	United Kingdom
USA	United States of America
VAP	Visual Aids Panel
VMC	Visual Meteorological Conditions
VFR	Visual Flight Rules
WP	Working Paper

2 Technical Abbreviations

cd	Candela
dc	Direct Current
ft	Feet
Hz	Hertz
kt	Knots
m	Metre
NM	Nautical mile
v	Volt
w	Watt

Enhancing Offshore Helideck Lighting - NAM K14 Trials

1 Introduction

1.1 Scope of report

DERA Bedford was tasked with conducting a series of flight trials on behalf of the Safety Regulatory Group of the Civil Aviation Authority to investigate means of improving offshore helideck lighting.

This report presents the results of the flight trials, which were performed on the offshore platform NAM K14B. This is a small, unmanned satellite located 5NM from the main K14 complex in the Dutch Sector of the North Sea.

The structure of the report is as follows. This section is intended to provide an introduction to the subject, together with an insight into the current operational practices and challenges. Section 2 provides the background to the project and an overview of the equipment evaluated. Section 3 describes the flight trial methodology. The data acquired during the flight trials is presented in Section 4. Section 5 contains a discussion of the results, with the conclusions in Section 6 and recommendations in Section 7. The references and acknowledgements are presented in Sections 8 and 9 respectively.

The appendices contain trial details and data. They also contain the results of photometric tests performed on the LED strips evaluated during the trials, and a collection of line pilot comments on current helideck lighting systems.

1.2 Visual Cueing Aspects of Offshore Approaches

1.2.1 General

The final approach and landing phases of all offshore helicopter operations are carried out by reference to visual cues that are mainly derived from the destination platform. On those occasions when an instrument approach procedure is in use, the latter stages of the operation still remain a visual task.

Visual aids, in the form of marking and lighting, are provided. These are generally in accordance with the Standards and Recommended Practices described in the ICAO Annex 14, Volume 2 (Heliports) [Reference 1] and CAA CAP 437 (Offshore Helicopter Landing Areas – Guidance On Standards) [Reference 2]. It is recognised that these aids do improve both the safety and regularity of operations. However, current operational experience and considerations related to the possible future reduction of operating minima through the use of DGPS approach guidance together indicated the need to review the existing provisions. A survey of offshore pilot views on workload and safety hazards was conducted [Reference 3]. Data from the pilot questionnaire used in that study is presented in Appendix E of this document. This provided strong support for research into enhancing the existing visual aids and assessing new technologies.

The CAA Safety Regulation Group therefore initiated a review of the visual cues at offshore facilities. The general objective was to identify any enhancements that could improve safety and/or operational capability. In particular, simplified helideck acquisition and orientation tasks were highlighted as being likely to benefit from enhancements. DERA was tasked with conducting this research.

1.2.2 Platform Location

The first visual task during an approach consists of finding the destination platform. The pilot performs the task by making a visual search. Inherent in the pilot's awareness from navigational aids on board the aircraft, and the position of the helicopter on the planned track, is an expectation of the likely direction and the time at which visual contact should occur.

However, small errors in navigation and the effect on helicopter heading of crosswinds can result in the platform not being in the expected position in the field-of-view. The problems that this can cause can be exacerbated when the time available for the search is limited. This situation is not uncommon where an instrument approach procedure is used in reduced visibility conditions, or where there are several similar platforms in a relatively small area.

By day, the task of making visual contact can be impaired by a low contrast between the platform and the background. At night, the contrast between the platform and the background is high, due to the various forms of lighting on the structure. The absence of the cultural or background lighting that occurs near built-up sites ashore is also beneficial to the search process.

1.2.3 Platform Identification

Wrong platform landings are inefficient and can be dangerous depending on the operational state of the helideck. Thus, once a platform has been located by a pilot it is necessary for it to be correctly identified. Offshore platforms are usually large and, in favourable viewing conditions, may be seen at ranges in excess of 10 km (5.4NM). In these circumstances, identification of the platform can be attempted by observation of its location in relation to other adjacent facilities and by reference to aeronautical charts.

The physical characteristics of the platform may be unique and may therefore further aid the pilot in the task. However, operational experience has shown that some form of sign or marking that is unique to each platform is required for identification to be certain in all cases. The range from which signs are conspicuous and legible is an important operational parameter [Reference 4]. If the whole approach is to be flown solely by using visual cues the location and identification tasks should be completed at a range in excess of 3.7km (2NM).

1.2.4 Helideck Location

Successful location and identification of a platform does not ensure that the pilot will be in visual contact with the helideck. The position of the helideck is not standardised. Since the final approach direction is strongly influenced by the prevailing wind direction, there will be occasions when the platform structure will totally obscure the helideck from the approaching aircraft. The visual location of the helideck is therefore of real concern to pilots, especially at night. This concern is often expressed in terms of a requirement for the helideck to be brightly lit at night so that it is conspicuous. The initial approach phase typically begins at a range of 3.7km (2NM) from the platform at a height of 500ft. At this point the pilot needs to make visual contact with the helideck as soon as possible. The helideck perimeter lighting currently in use is intended to be the cue that pilots use to acquire the deck. To be fully effective the lighting should enable the pilot to both locate the position of the deck and identify the outline shape.

1.2.5 Final Approach

Currently, all helicopter operations include a final approach phase that is flown with the aid of visual cues alone. In Visual Flight Rule (VFR) operations, the final approach may be considered to commence at that point where the pilot, having the helideck in sight, begins to adjust the flightpath in response to the visual scene. This in order that the helicopter can be safely flown to the hover whilst remaining clear of any obstacles. Typically, the descent may be commenced at a range of 1.8km (1NM). In Instrument Flight Rules (IFR) conditions, the final visual approach may only commence at the decision range, which may be as low as 1400m (0.75NM). During this phase of the approach, the pilot must decelerate the helicopter to the hover from an initial airspeed of approximately 60 to 80kt.

The two primary aircraft parameters to be controlled in the final approach are power and pitch attitude. The information from visual cues, in addition to the attitude cues required for this manoeuvre, are range, height and alignment in azimuth. Good range information is essential to ensure that the deceleration can be initiated at a point sufficiently early to avoid the need for a large pitch attitude change to achieve a rapid deceleration in the latter phases. Continuous range estimates are used to monitor the rate of closure so that incremental changes to the decelerating speed profile can be made. Height cues are used to monitor changes to the flightpath and are particularly important as the pilot manually schedules the power and pitch attitude changes that occur during the deceleration. Alignment cues in azimuth assist the pilot in the task of flying the track that will result in the helicopter reaching the desired hover position. All these essential cues are not as readily available offshore as they are at onshore sites, largely, because the foreground is relatively featureless, particularly so at night.

The primary, and at night the only cues are therefore those that can be derived from what the pilot can see of the platform. The helideck, as currently configured, is not a good source of cues in this phase of the operation. Peripheral cues are often non-existent until the very last stages of the approach, particularly at night. Even in good daytime visibility conditions, decelerating a helicopter over the sea with precision is not an easy task. In previous trials, the flight paths of commercial helicopters approaching the runway at Aberdeen were recorded. In this cue-rich environment, the flight paths were far more oscillatory than was anticipated. A similar experiment offshore would probably reveal similar or even greater variability.

One other area of visual cueing related to safety during the final approach that must be considered is that of helideck status. The helideck can already be in, or can assume a dangerous condition due to, for example, a gas leak. There is therefore a need for some form of status indication, particularly on unmanned installations. A CAA paper has examined this issue and proposes a visual aid to be used [Reference 5].

1.2.6 Hover and Landing

During these final phases which take place adjacent to, over and on the helideck, the pilot is aware of the need to monitor many safety issues. These arise from helicopter landing and performance characteristics and the need to stabilise the helicopter over the helideck and to then complete the landing.

From visual references, the pilot needs unambiguous indication of the boundaries of the helideck, the limits of the safe landing area (touchdown and lift off area: TLOF) and the location of all adjacent obstacles. In addition to this positional information the pilot needs to derive attitude and rate of change of attitude and position information in order to fine tune the helicopter's attitude and position and detect the onset of unwanted attitude or position changes. The detection of closure rate information during the landing is a particular example of the use of 'textural' cues, derived from small-scale objects, markings and lights on the helideck surface.

Positional cues are determined from the relative size and location of known features using foveal vision, and are derived from 'objects' that are several centimetres in extent. Rate cues can come from features such as surface roughness and small shadows on the helideck surface, and are sensed by peripheral vision.

The necessary cues can only be derived if the marking, lighting and floodlit surface texture are all conspicuous and legible. The presence of glare sources, windshield contamination from precipitation, accumulated dirt etc. all have a detrimental effect on the ability of the pilot to use the visual cueing environment.

Table 1 summarises the visual tasks and the associated visual cues/ aids currently available in each approach phase.

Table 1 Visual Cues Summary

Phase	Visual Task	Visual Cues/ Aids	Desired Range (km)
Platform Location	Search and detection	Contrast of platform against sea/ dark background Platform Lighting / Flare	> 10km (5.4NM)
Platform Identification	Observe defining features	Position of platform in relation to others Outline shape of platform Sign board (last resort)	10km (5.4NM)
Helideck Location & Identification	Search within platform structure	Shape of helideck Colour of helideck Luminance of helideck (floodlighting) Perimeter lighting	3.7km (2.0NM)
Final Approach	Detect helicopter position in 3 axes Detect rate of change of position Establish helideck status	Apparent size & change of size Apparent shape and change of shape Orientation and change of orientation of known features/ markings/ lights Status light system	1.8km (1.0NM)
Hover & Landing	Detect helicopter attitude, position and rate of change of position in 3 axes (6 degrees of freedom)	Known features/ markings Lights Helideck texture	30m

2 Background

2.1 General

Prior to the trials on the NAM K14B platform, a number of land-based and offshore flight trials had been conducted. The first of these was an onshore trial at Beccles Heliport. The lighting equipment initially chosen for evaluation was selected with a view to addressing existing known deficiencies, taking account of the results of trials performed for military applications. The equipment that was deemed likely to be operationally effective was then transferred to the NAM K14 platform. This platform has two helidecks, K14C and K14P (see Figures 1 to 3). K14P, being the stand-by helideck, was used to initially evaluate the equipment. A dedicated flight trial was conducted to assess the operational effectiveness of the visual aids. The trial on K14P resulted in a short list of equipment for evaluation in the final set of flight trials on the adjacent K14B satellite.

The flight trials on K14B were dedicated trials, consisting of a limited number of sorties over a period of 18 months. These trials involved BHL pilots, CAA pilots and observers, a Norwegian CAA observer, NAM personnel and DERA scientists. A large number of lighting configurations and several new technologies were evaluated in a closely controlled and well documented manner, to ensure that meaningful comparisons could be made between the various configurations and technologies. The trials were expected to take some time to complete, so a semi-permanent installation was required. Figure 4 shows a side view and Figure 5 a plan view of the platform. Figure 6 indicates the trials equipment locations on the platform.

Between November 1998 and October 1999, three flight trials were conducted.

The objectives of the trials were to evaluate aids that, based on the earlier tests and trials, would potentially improve safety by:

i) increasing the conspicuity of the helideck by changing the colour of the perimeter lighting;

ii) increasing the conspicuity of the helideck by the application of alternative technologies for perimeter lighting;

iii) enchancing the visual cueing environment on the helideck by lighting the ‘H’ and the circle on the TLOF by the application of new technologies;

iv) reducing glare by modifying or removing the floodlighting.

The various visual aids evaluated during the trials are described in the following paragraphs.

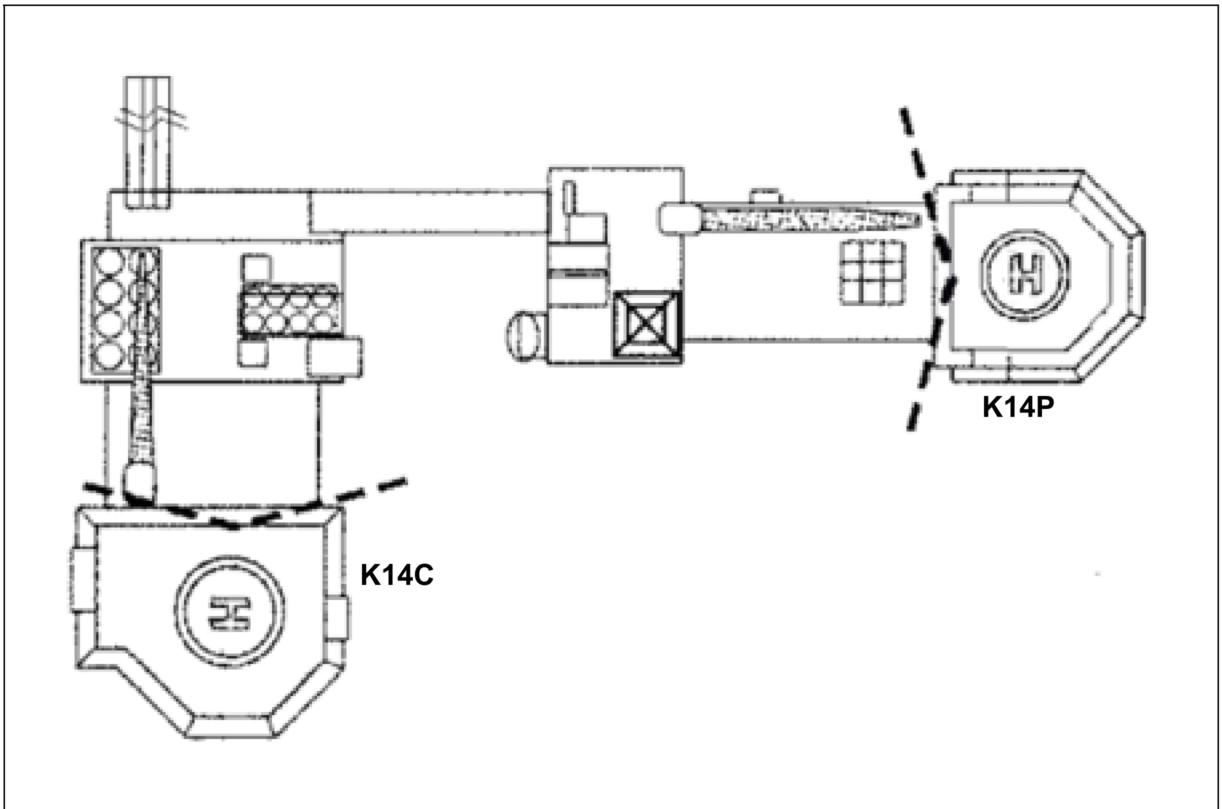

Figure 1 Plan View of K14C/ P Complex

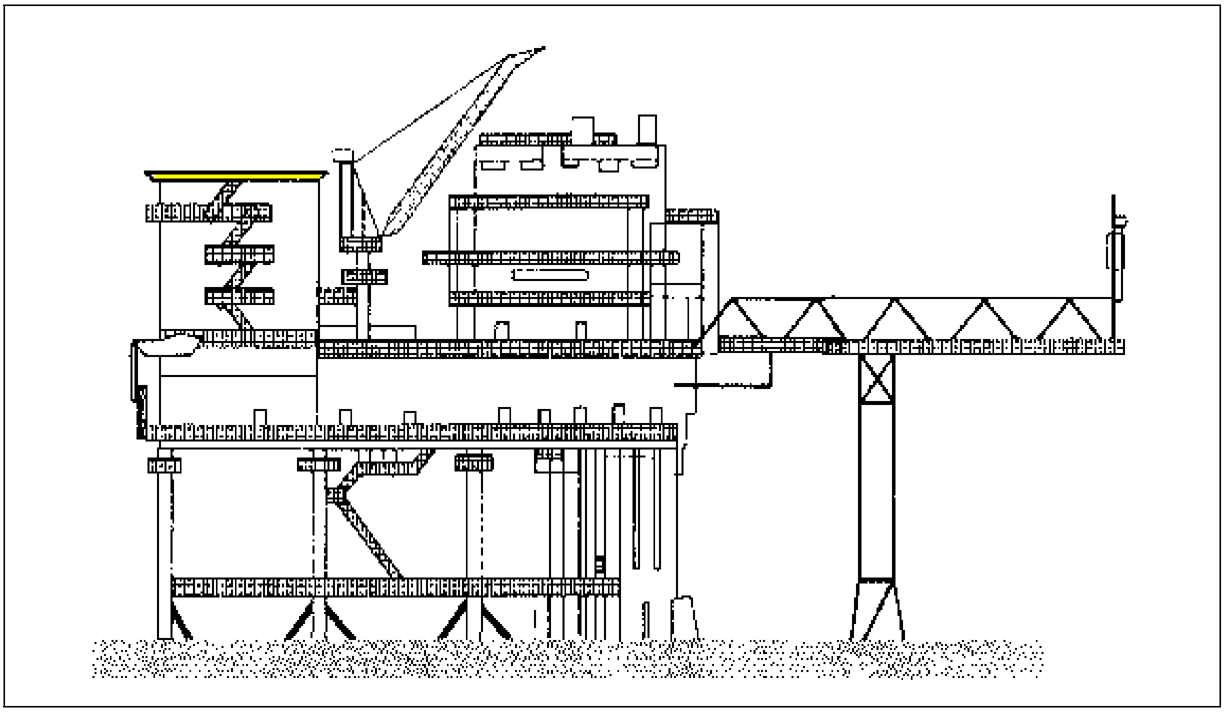

Figure 2 Side View of K14C

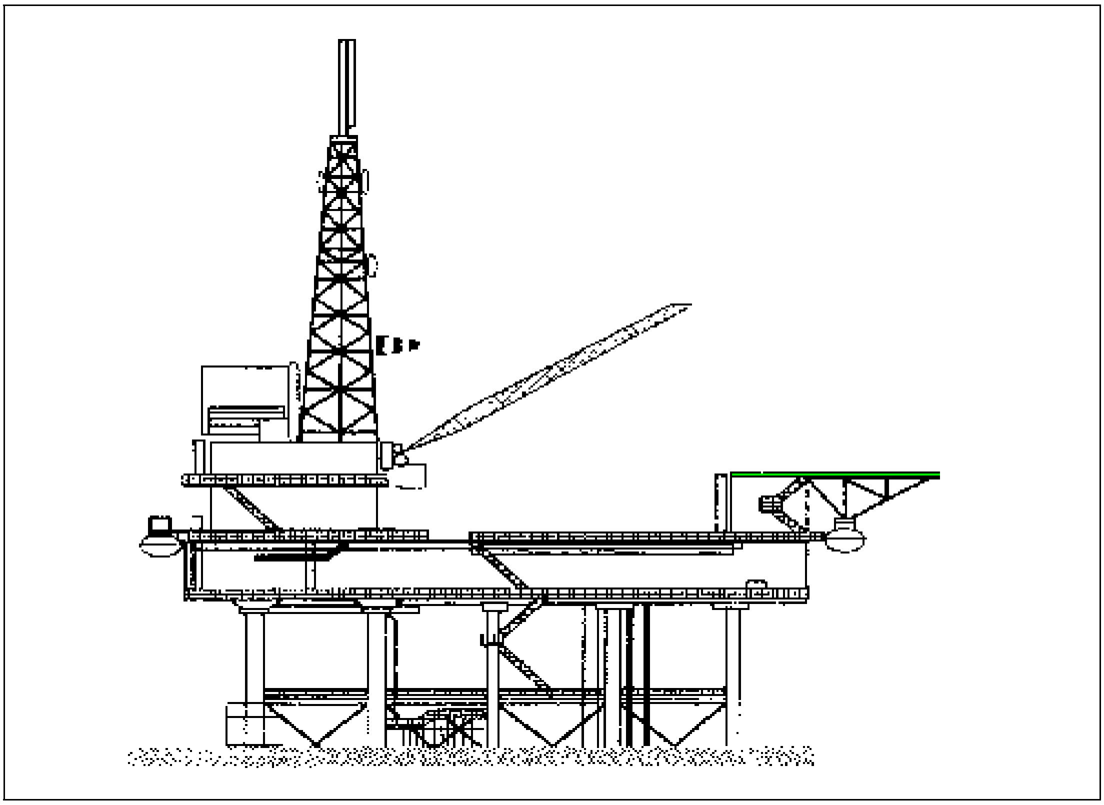

Figure 3 Side View of K14P

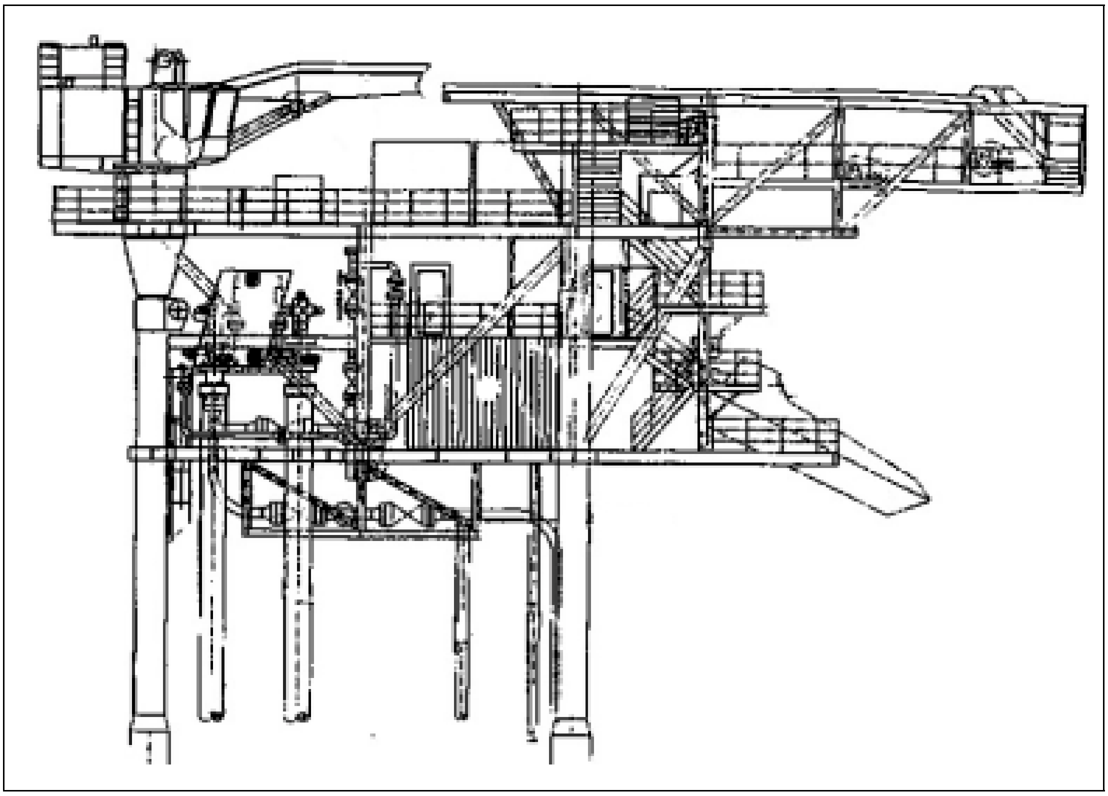

Figure 4 Side View of K14B

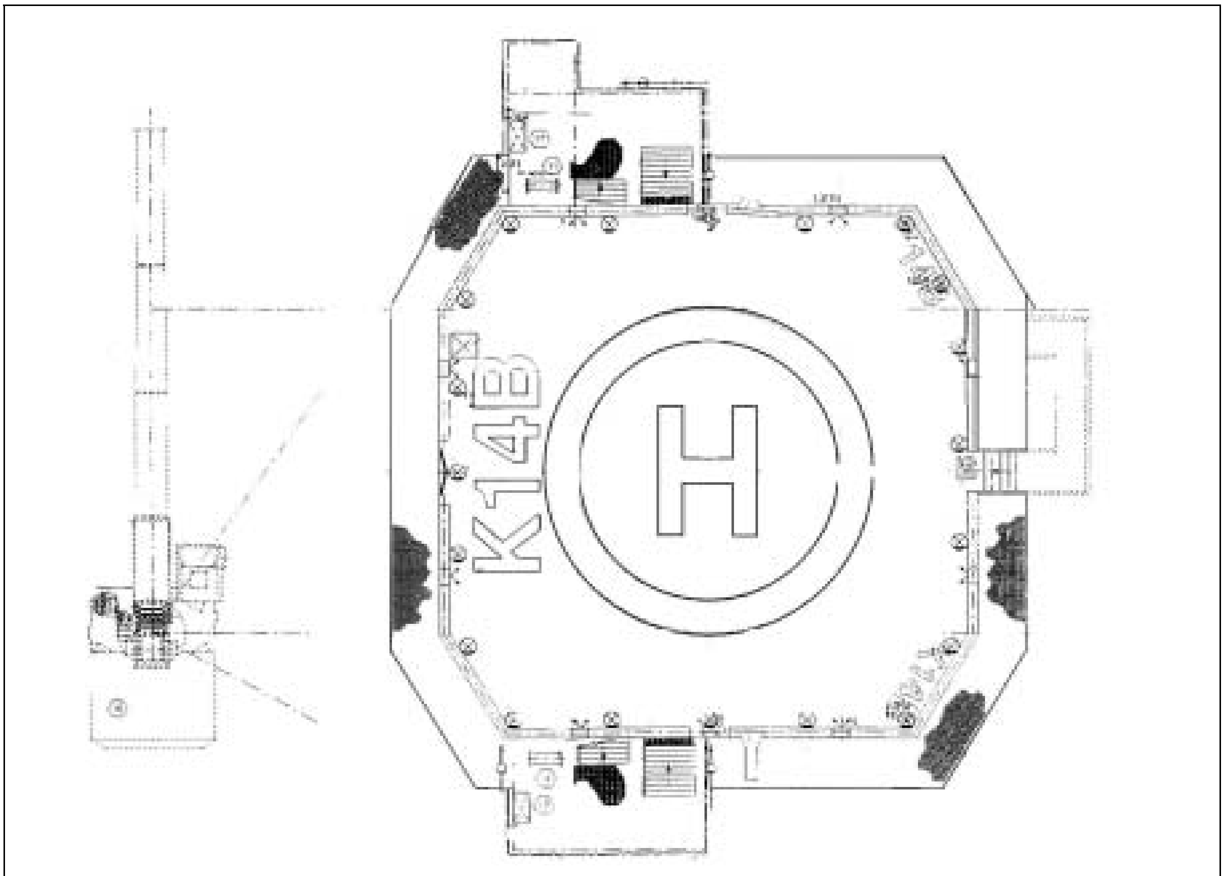

Figure 5 Plan View of K14B

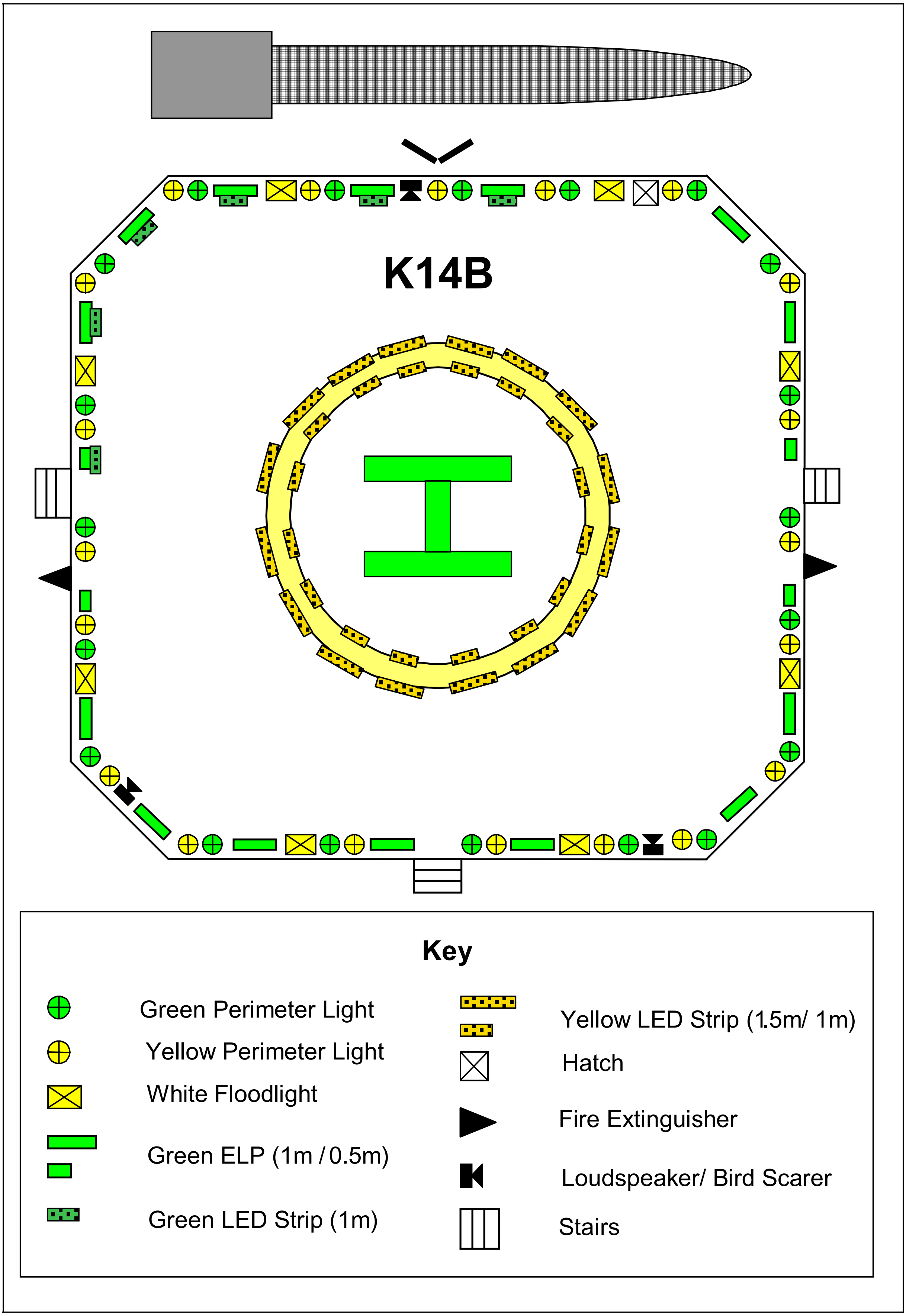

Figure 6 Experimental Equipment Locations on K14B

2.2 Green Helideck Perimeter Lighting

To be consistent with airfield taxiway edge lighting, all helideck perimeter lighting should be blue. This is not implemented, however, due to the ineffectiveness of low intensity blue lights in the high cultural lighting environment of offshore platforms.

The original specification for helideck perimeter lighting therefore comprised alternate yellow and blue lamps. Around 1990, the specification was changed to all yellow lights to overcome the conspicuity problems caused by the relatively low intensity of the blue lamps. Since the change was made, however, the colouring of the non-helideck floodlights and platform cultural lighting has become predominantly yellow due to the increased use of high pressure Sodium lighting. The resulting lack of colour contrast between the helideck and cultural lighting adversely affects the conspicuity of the perimeter lighting. This causes pilots problems when performing the initial visual acquisition of the helideck.

To address this issue it was decided to change the colour of the helideck perimeter lights to green. Such a change is within normally understood criteria for the colours of visual signals, green generally indicating a safe environment. In practical terms, the colour change can easily be achieved, at low cost, by substituting green filter material for yellow within each fitting. The light output with the green filter in place was found to be sufficient for the purposes of the trial.

Green was chosen for evaluation as the new perimeter lighting colour following the earlier dedicated trial on K14P. Green and red 210-degree sector lights had been evaluated on K14P, and pilots had commented that the green sector lighting was very conspicuous. No green lighting is currently used on offshore platforms and it was therefore concluded that green perimeter lighting should be investigated. In addition, it is known that green is one of the easiest signal colours for the eye to detect.

Prior to green lighting being evaluated on K14B, the yellow lenses in the perimeter light units on K14P were changed to green. This was a straightforward low cost replacement and enabled some evaluation of the concept prior to the dedicated trials. From the initial comments, it became obvious that the green lighting was worth evaluating in more detail on K14B. The green lighting formed part of an in-service trial on K14P. Pilots from Bristow Helicopters operating from Den Helder (Netherlands), completed questionnaires comparing the trial green lighting on K14P and the existing yellow lighting on K14C. The results are given in Appendix C.

To enable a direct comparison between the existing yellow and trial green perimeter lights during the dedicated trial, an additional circuit of green lighting was installed on K14B. These additional units were supplied by the manufacturer of the existing perimeter lighting. The units were evaluated as supplied during the first two flight trials. Prior to the third and final trial, the lamps were changed from 60 w incandescent bulbs to the more efficient 20w fluorescent lamps used in the yellow lights. This improved the colouring of the lamps, approximately doubled the amount of light flux and thus increased the intensity of the light output.

The green perimeter lights are omni-directional, and they require a power supply of 220 v – 240 v 50 Hz. They are an identical unit to the yellow lights that have a published intensity of 25cd and comply with CAP 437. The lights are shown in Figure 7.

2.3 Green Perimeter Electro-Luminescent Panels

Electro-Luminescent Panels (ELPs) are a particular form of the luminescent panels described in ICAO Annex 14 Vol. 2. They have been extensively tested as a pilot visual aid by DERA in the military environment, where they have been successfully used to provide enhanced final approach, hover and landing cues for ship-borne helicopter operations. Based on this experience, DERA recommended that this technology be applied to the provision of enhanced cues at offshore facilities. In particular, it was expected that suitably sited luminescent panels would provide perception of the size, shape and orientation of a helideck.

Evaluations during military flight trials, and subsequent in-service experience, have demonstrated that ELPs provide cues that are particularly suited to the task of supporting helicopter operations on small facilities such as helidecks. An ELP is an evenly illuminated luminescent area light source of significant size with established dimensions. The lit area has well defined straight edges and corners. Patterns of these lights can be deployed that demonstrably provide many more usable cues than can be obtained from a comparable pattern of conventional point source lights.

For example, because the panels have a standard size and shape pilots can deduce important range and orientation information from them. Apparent changes of the rectangular shape of the individual panels as the helicopter is manoeuvred can provide powerful position and rate cues at short range. The often slow but significant changes to position that can result during cross-wind or turbulent conditions in the hover can be more readily detected by reference to the sensitive cues that the panels can provide. At longer range, any change to the perceived shape of the complete pattern of ELP can provide similar cues.

Another important operational benefit that results from the use of luminescent panels is seen in conditions where precipitation adversely affects the ability of the pilot to derive cues from deck-mounted aids. Visual cues can be affected in a variety of ways. These include reduction in visibility (caused by atmospheric attenuation), contamination of the windscreen by water droplets (which causes the lights to ‘bloom’), or by the masking of deck markings that occurs whenever water lying on the deck reflects the floodlighting. In all these circumstances, a pattern of ELPs can continue to provide normal cues where point-source lights or markings generally do not.

The ELPs used had an average luminance of 65cd/ m^2 in a direction normal to the surface. The panels were either 1, or 0.5m long depending on location and are shown in Figure 8. They were powered using a static inverter that converts 115 v 50 Hz to 115 v 400 Hz.

During earlier onshore trials at Beccles Heliport, a number of ELPs were deployed in a horizontal pattern on the 'mock' helideck. Evaluation of this pattern was repeated during the K14C trial. Pilots reported that the acquisition range of this pattern was less than would be usable during the approach phase. Since, in this configuration, the panels were viewed at a very shallow angle, this result was not wholly unexpected (see Figure 9).

In an attempt to identify any potential that ELPs might have in providing useful cues at long range, the subsequent trial on K14B used panels mounted on the arms of an inverted ‘V’ frame. Frames of this configuration were installed around the perimeter of the helideck. Approaching pilots were therefore able to view the panels at an angle that was close to the normal (see Figure 10).

2.4 Green Electro-Luminescent Panel ‘H’

The luminescent ‘H’ is designed to assist the pilot in locating the helideck on the platform, and to provide visual cues in the centre of the helideck where the helideck mounted floodlighting is frequently ineffective (the so called ‘black-hole’ effect).

The concept of an illuminated ‘H’ was first trialled at Beccles Heliport, and was subsequently evaluated during the K14P trial and found to be very effective in providing useful additional cues. The ‘H’ was located on top of, and had the same dimensions as, the Heliport Identification Marking (‘H’) on the helideck. The trials pilots noted the additional cueing that was provided as the aircraft moved across the helideck into the hover position. The luminescent ‘H’ provided the pilots with an area to aim for, and also provided lateral cueing and descent rate information.

During the earlier trials, the ELP ‘H’ had consisted of a single line of ELPs over the paint mark. Pilots’ comments suggested that the ‘stroke width’ should be increased to show a ‘filled’ ‘H’ having the same dimensions as the painted ‘H’. This suggestion was implemented for the K14B trial. An ELP manufacturer was commissioned to fabricate an ‘H’ that could withstand the weight of an S76 helicopter landing on it. It was installed over the painted ‘H’ on the helideck and powered via armoured cabling.

The ELP ‘H’ had an average luminance of 100cd/ m^2 normal to the surface. The ‘H’ was approximately 2m in width and 3m in length with a stroke width of 0.3m, and had the same power supply requirements as the perimeter ELPs. Figure 11 shows the ELP ‘H’ installed on the deck.

2.5 Light Emitting Diode strips

Light Emitting Diode (LED) technology has progressed significantly in recent years. Not only has the intensity increased, but also the viewing angle and lifespan have both been improved. These improvements have allowed LEDs to be used in many new applications, one of these being transparent plastic strips encasing a single row of equidistant LEDs (see Appendix D for details). For the equipment used during the trial a group of 4 LEDs is defined as a lamp by the manufacturer. The strips were originally designed as an alternative to taxiway lights at airports. They were subsequently used experimentally as an alternative form of perimeter lighting at Manhattan Heliport, New York, USA, where they have also been used in the form of a cross to indicate when the helideck was not operational. The strips have the characteristic of ‘lit paint marks’ and have been evaluated for use on highways in Canada.

It was decided that the LED strips would be worth evaluating in the offshore environment. The strips evaluated during the dedicated flight trials on the K14B contained 8 lamps per metre (32 LED's/metre), the brightest format available. The intensity of these strips could easily be reduced by lowering the supply voltage; the intensity of lower specification strips could not have been increased.

As part of the second dedicated flight trial, green LED strips were temporarily installed around one quarter of the helideck perimeter to evaluate the concept of a green LED perimeter. The evaluation was limited to only one part of the perimeter by the amount of green strip available from the manufacturer at the time.

For the trial, the LED strips were attached to the ’v’ frames above the perimeter ELPs facing inwards towards the helideck. The purpose of these strips was, again, to provide additional perspective cueing to the pilot. The LED strips seen from a distance appear as a panel of light, but as the viewing range decreases, the individual LEDs become visible and the strips appear as a series of point sources.

Prior to the third dedicated flight trial, two broken circles of yellow LED strips were installed around the inner and outer edges of the painted yellow Touchdown Marking circle in the centre of the helideck. These were intended to provide additional cueing required during the approach phase by providing the pilot with an aiming point. During the landing phase the LED pattern was intended to increase the position and height cueing, which was expected to be particularly useful once the ELP ‘H’ had disappeared from view beneath the aircraft. It was anticipated that the LED strips would also help to improve the textural cueing from the deck that is reduced when a helideck net is not fitted.

Whilst the LED strips were expected to be effective, there are no agreed international standards for the photometry of systems that consist of arrays of closely spaced light sources. All light patterns currently in use as landing aids consist of individual point sources. These are spaced such that the overall photometric performance of the type of light unit used to make the pattern defines the intensity of the pattern at all operational ranges. Photometric testing of point sources uses well-established techniques.

Current lighting specifications can therefore be defined and compliance verified. This is important both for procurement activities and for the purposes of safety regulation. If LED strips are to be adopted for operational use, it is imperative that a suitable means be developed to describe and measure the light output characteristics of the equipment. Tests should be performed in a way that is generic, practicable, repeatable, and demonstrably related to the manner in which the LED strips are used to provide visual cues.

Whilst recognising the issues raised in relation to photometric specification, it was considered feasible to plan flight trials using the available LED lighting. A programme of work to establish a meaningful method of characterising the performance was recommended to run concurrently with the flight trials. Exploratory photometric tests using equipment and techniques already applied to LED lighting systems used in road transport were conducted and are described in Appendix D.

The green LED strips require a 17 v dc power supply whilst the yellow LED strips are supplied by 12 v dc. The green strips used on the perimeter and inner yellow strips used on the circle were 1m in length while the outer yellow strips on the circle were 1.5m long. The strips are shown in Figures 12 and 13.

2.6 Floodlights and Hoods

CAP 437 states that “the landing area should be floodlit if intended for night use. The floodlighting should be arranged so as not to dazzle the pilot”.

The floodlights installed on K14B are mounted at deck level on the perimeter of the helideck. They are aimed slightly below the horizontal to illuminate the surface of the helideck, in compliance with the requirements of CAP 437.

The floodlights, fitted with a 50w halogen lamp, provide a peak intensity of 8,000cd at an angle of ± 20 degrees in azimuth. Between ± 2 degrees in elevation the intensity is at least 2000cd with a peak of 8000cd on the 0 degrees axis. At greater angles the lights emit significant amounts of light in directions that coincide with the flight path of approaching helicopters, and at pilot eye height when the helicopter has landed on the helideck (see Figure 14).

Due to the lamps being misaligned either at installation or during service or maintenance, the floodlights are often a source of glare to the pilot. This problem is exacerbated by the vertical beamspread of the floodlights which, for a typical installation, allows the emission of light intensities above the horizontal that are significantly greater in magnitude to those used in the adjacent perimeter lighting.

During an approach, the initial problem caused by the floodlights occurs while acquiring the deck. At this point the helicopter is only at a small angle above the horizontal in relation to the lights. Consequently, the brightness of high intensity floodlights is sufficient to reduce the conspicuity of the much lower intensity perimeter lights. This degrades the cues that should be available to the pilot at this stage to help determine the location of the helideck within the platform. As the approach continues, at shorter ranges the floodlights become a glare source that not only causes discomfort to the pilot, but which can also be disabling. Both types of glare should be avoided in any floodlighting system design. Discomfort glare makes seeing uncomfortable for the pilot and, in the limit, may cause watering or involuntary closing of the eyes. Disability glare causes a loss of image contrast sensitivity through stray light being scattered within the eye.

In an attempt to combat the problems caused by glare from the floodlights, an experimental hood was evaluated. The design of the hood was determined by the geometry of the pilot's eye position relative to the floodlights with the helicopter on the helideck. This is considered to be the limiting condition, being both the closest viewing range and the shallowest angle of elevation relative to the floodlights during the approach and landing. With the floodlights correctly aligned, the hoods should ensure that the pilot is unable to the see the light source during the latter stages of the approach and the landing. Laboratory tests showed that by trying to design the hood to be effective at angles less than 7°, the illuminance on the deck was reduced to unacceptable levels. The physical size of a hood required for angles less than 7° would also be unacceptable, as it would infringe upon the Safe Landing Area (SLA).

Figure 15 shows the deck level floodlight illuminating a surface.

Figure 16 shows the floodlight from the same viewing angle with the addition of a hood.

Figure 17 shows the geometry of the hood fitted to the floodlight.

Figure 7 Green Perimeter Lights

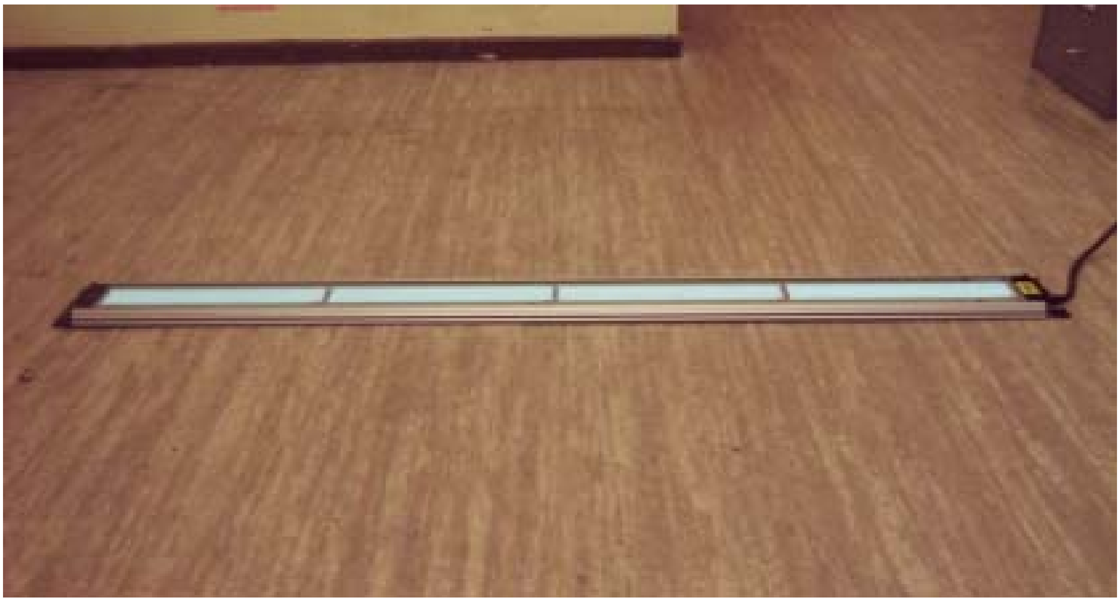

Figure 8 Green Perimeter ELPs

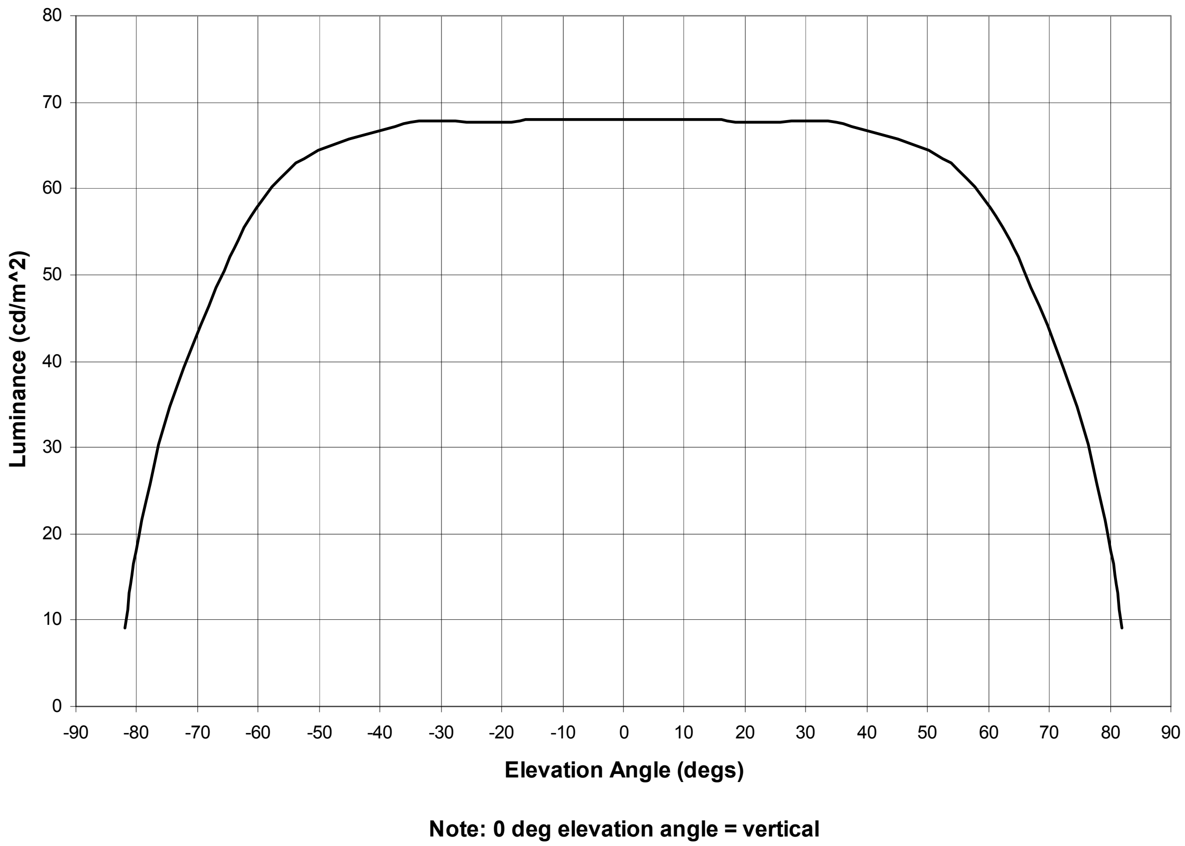

Figure 9 Light Output from an ELP

Figure 10 V Panel

Figure 11 Green ELP 'H'

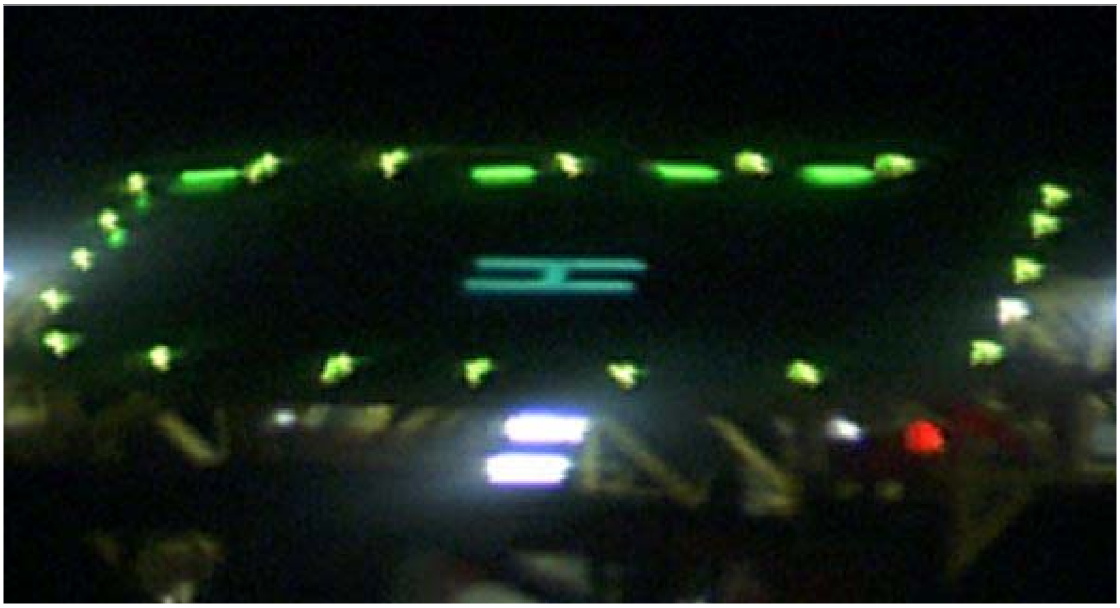

Figure 12 Green Light Emitting Diode Strips as Perimeter Markers

Figure 13 Yellow Light Emitting Diode Strips around the Touchdown Marking Circle

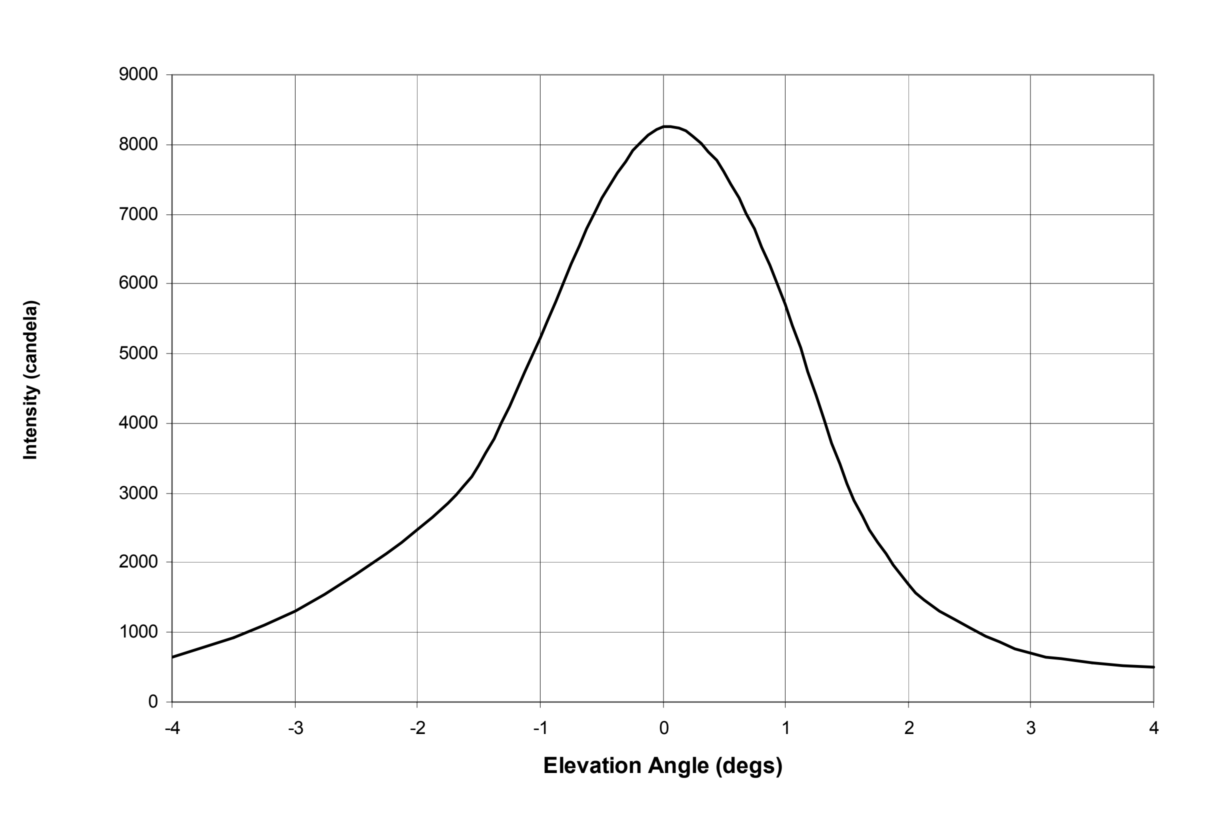

Figure 14 Beam Spread of Typical Floodlight

Figure 15 Floodlight Without a Hood

Figure 16 Floodlight With a Hood

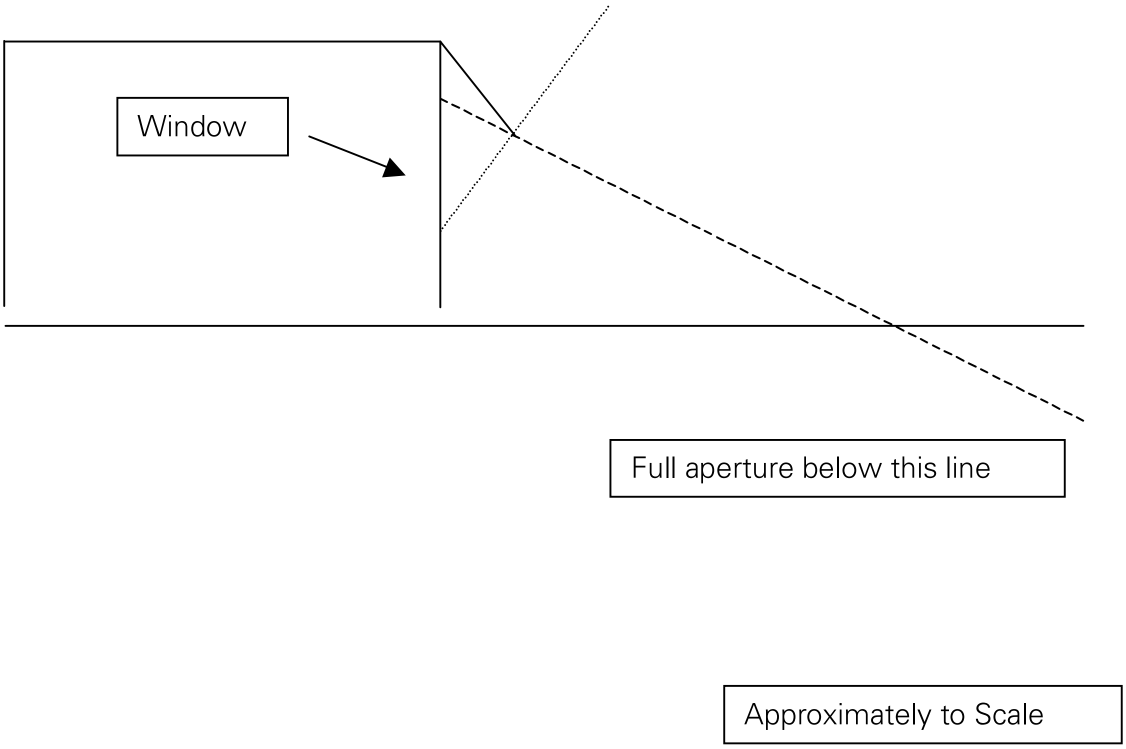

Figure 17 Floodlight Hood Geometry

3 Flight Trials

3.1 General

Three flight trials were conducted between November 1998 and October 1999. All the trials were conducted using a Sikorsky S76 Helicopter chartered from Bristow Helicopters Ltd (BHL), and based at North Denes Heliport, Norfolk, England. All flight trials were conducted at night, and took place at the NAM K14B platform.

Clearly defined configurations of lighting equipment were established before each flight to ensure that meaningful comparisons between various cues and technologies could be made. This approach required that the lighting configuration could be readily switched to activate particular aids or combinations of aids. It was also desirable to make all the test observations in weather and ambient light conditions that were as near as practicable to being the same, although operational constraints make this difficult to achieve in practice.

The test methodology and the data collection were subject to a structured planning approach. To facilitate this it was important that, wherever possible, the evaluations would be carried out by qualified test pilots and flight test observers. In practice this latter requirement was met by the use of a small sample of aircrew drawn from the CAA, BHL, Norwegian CAA, NAM and DERA.

The NAM K14B platform was chosen for the trials because it presents many of the visual cueing problems that the research was intended to address. It is a small satellite platform where pilots are known to have difficulty in determining the orientation of the platform in general, and the helideck in particular. In reduced visibility conditions, where no horizon can be seen, these problems are even worse. In these circumstances pilots report that, due to spatial disorientation, all sense of perspective can be lost making it very difficult to plan and execute the approach. Precipitation and the presence of guano on the deck surface exacerbate the problems.

Based on the results of earlier trials it was decided that the dedicated experimental trials would evaluate aids expected to:

a) Improve the conspicuity of the helideck by changing the colour of the perimeter lights from yellow to green.

b) Improve the conspicuity of the helideck by the use of alternative lighting technologies; in particular ELP and LED lighting.

c) Improve the visual cueing environment, especially for the final approach, hover and landing by the use of ELP and/or LED lighting.

d) Improve the visual cueing environment by reducing glare through the modification or removal of the floodlights, and show that if some or all of the new lighting outlined in a), b), and c) were to be adopted for future operations, then deck floodlighting would no longer be necessary.

The first trial took place on 29th November 1998. Visibility was about 9km (5NM), and the cloud base was at or above 500 ft. The wind direction was 070 degrees, with a speed of 10kt. There was a small amount of intermittent drizzle throughout the trial. The moon provided some ambient lighting. A BHL pilot captained the aircraft from the right hand seat and a CAA test pilot flew from the left. The aircraft approach heading to the platform was 070 degrees.

The second trial was conducted on the 25th April 1999. The visibility was again 9km (5NM) but the cloud base was at 5000ft. The wind direction was 050 degrees and the wind speed was 20kt. There was a slight mist, which caused the scene to appear hazy. A BHL pilot captained the aircraft from the right-hand seat, and another flew the aircraft from the left-hand seat. The aircraft approach heading was 055 degrees.

The third and final flight trial was conducted on 17th October 1999. There was no cloud and a half moon. Visibility was more than 18km (10NM). The wind speed was 25kt at 090 degrees. The aircraft approach heading was 090 degrees. A BHL pilot captained the aircraft from the right hand seat and a CAA test pilot flew from the left.

3.2 Methodology

Prior to the first trial commencing at K14B, approaches were made to K14C and K14P to document the current procedure for landing on an offshore helideck at night. These approaches are described in Appendix A.

3.2.1 K14B Flight Trials

The Global Positioning System (GPS) fitted to the helicopter was used to obtain range information. The approaches were each flown using the same standard profile as far as was possible in the absence of vertical guidance. The purpose of this procedure was to allow valid comparisons of the results obtained from the various approaches to be performed. Runs normally commenced from a range of (3.7km) 2NM and a height of 500ft. The final approach started at 1.85km (1NM), 350ft. The hover phase began when the aircraft was 5ft to 10ft above the helideck.

Prior to each trial, operational data was recorded on the pro-forma shown in Appendix B Section 1.1. During the flight, the pilot was asked to state the range, height and speed at acquisition of the helideck, and then at acquisition of the various lighting technologies under evaluation. The pilot was also asked to report any significant changes in aircraft heading or speed and wind speed or direction. Throughout each run, the pilots were prompted by the DERA Trial Manager to provide general information about the visual aids being assessed.

Each run was separated into four phases; helideck acquisition, which encompassed platform location and identification and helideck location; final approach which included the descent and deceleration; the establishment of the hover; and the landing manoeuvre.

Once the aircraft had landed safely on the helideck, the pilot was asked to provide ratings for the presentation and workload associated with each phase. The ratings are subjective but provide a relative measure between candidate lighting configurations.

The presentation rating scale was designed to acquire data on the quality of the information presented by the lighting aid under test; covering such issues as conspicuity, comprehensibility and overall suitability for the task.

The workload scale was used to obtain a measure of the pilot's perception of the level of effort required to use a particular aid or combination of aids.

The rating systems comprised a scale of 1 to 10. The baseline test configuration of yellow perimeter lighting and floodlights, being the current standard lighting configuration, was ‘pegged’ at a value of 5 for both presentation and workload to provide a defined datum. For the presentation scale, a low rating (below 5) indicated that its appearance was worse than the baseline. An improved appearance received a higher rating (above 5). The scale was inverted for the workload ratings. A low rating (below 5) indicated that the approach was easier to complete. A higher rating (above 5) indicated a higher workload to fly the aircraft using the available visual aids. The ratings were elicited from the pilot using a ‘post run’ questionnaire and recorded on a pro-forma together with any comments, as shown in Appendix B Section 1.2.

All the rating scale information provided by the pilots was recorded using a tape recorder. Written notes were also made. Additional runs were conducted to obtain video and still pictures of the helideck. After each flight trial, a de-briefing of the pilots was conducted to gain additional pilot comments and generally discuss the conduct and results of the trial.

3.3 Lighting Configurations

Table 2 (below) summarises the various light equipment configurations that were evaluated during the flight trials. The configuration column contains a unique identifier for each equipment combination. This corresponds to the identifiers used on the ratings diagrams (Figures 18 to 25). The equipment associated with each configuration is indicated by an asterisk in the corresponding column. Some combinations were assessed repeatedly; some were evaluated only once.

Table 2 Overall Summary of Trial Lighting Configurations

Config.	Floodlights	Floodlights with Hoods	Yellow Perimeter Lights	Green Perimeter Lights	Green Perimeter ELPs	Green Perimeter LEDs	Green ELP 'H'	Yellow LEDs Circle
(a)	*		*					
(b)	*			*				
(c)			*				*	
(d)				*			*	
(e)					*		*	
(f)	*				*		*	
(g)	*			*	*			
(h)				*	*		*	
(i)			*		*		*	
(j)	*			*			*	
(k)				*				
(l)				*	*			
(m)				*		*	*	
(n)	*			*	*		*	
(o)						*		
(p)	*			*				*
(q)	*			*			*	*
(r)				*				*
(s)				*			*	*
(t)		*	*					
(u)		*		*				

3.4 Objectives of Each Run

3.4.1 First Trial

The overall objectives of the first flight trial were to evaluate the operational effectiveness of various forms of lighting to delineate the helideck perimeter, and the use of green ELPs to highlight the Heliport Identification Marking 'H'.

The evaluation of the performance of various lighting systems, both with and without the presence of the deck-level floodlighting, was also part of the trial plan. Results were to be related to the cueing changes produced at night by the various aids during the four defined phases of the approach and landing. The helicopter searchlight was to be used throughout all approaches except where stated otherwise.

Table 3 Equipment Configurations Planned for the First K14B Flight Trial

Run	Configuration	Floodlights	Yellow Perimeter Lights	Green Perimeter Lights	Green Perimeter ELPs	Green ELP ‘H’	Comparisons tested	Comments
1	(a)	✓	✓				Change of colour of perimeter lights	Baseline of existing standard equipment
2	(b)	✓		✓				Baseline of proposed perimeter lighting
3	(c)		✓			✓	'H' in lieu of floodlighting	‘H’ as a positioning / textural cue with existing perimeter lighting
4	(d)			✓		✓		‘H’ as a positioning / textural cue with proposed perimeter lighting
5	(e)				✓	✓	ELP only with / without floodlight	ELP technology only
6	(f)	✓			✓	✓		Effects of floodlights on ELP technology
7	(l)			✓	✓		ELP & perimeter lights with / without floodlight	Complete green perimeter lighting
8	(g)	✓		✓	✓			Effect of floodlights on complete green perimeter lighting
9	(h)			✓	✓	✓	All ELP technologies with yellow or green perimeter lights	Complete suite of green helideck lighting
10	(i)		✓		✓	✓		Contrast of yellow perimeter lighting with ELP technology
11	(j)	✓		✓		✓		Adding during flight on basis of initial assessments.

The equipment configurations to be evaluated in the first test flight are summarised in Table 3.

Run 1 was effectively a calibration exercise for all phases of the remaining runs, since it demonstrated the current cueing environment against which the cueing provided by the new lighting aids was to be compared.

By changing only the colour of the helideck perimeter lights for Run 2 from yellow to green, a direct comparison could be made. This would establish the magnitude of any improvement in operational performance that could be expected if such a modification were to be implemented on existing helidecks. Benefits were particularly expected in the helideck acquisition phase. For this test, it was assumed that the current floodlighting would be retained.

During Runs 3, 4 and 5 the usefulness of a green ELP ‘H’ located over the deck paint marking was evaluated, particularly in relation to the latter stages of the approach, hover and landing manoeuvres, where positional and rate cues are of particular significance. These tests were carried out with the floodlighting extinguished.

During Runs 3, 4 and 5, three options for lighting the helideck perimeter were added to the pattern in turn. This enabled an evaluation of the ELP ‘H’ when surrounded by various forms of perimeter lighting. It also provided further data on the relative merits of yellow and green perimeter lighting, and tested the effectiveness of green ELPs as a means of lighting the helideck perimeter.

By raising the ambient lighting levels on the helideck surface, floodlighting will have an adverse effect on the conspicuity of all other lighting in the vicinity. This effect of reduced contrast can be expected to be more prominent in the case of lights that have low luminance values such as ELP. Having configured the previous runs without floodlights, it was therefore decided that the effect of floodlighting on the ELP based aids should be tested (Run 6).

A similar test was programmed for Runs 7 and 8 where the impact of floodlighting on the two alternative means of providing green perimeter lighting was to be assessed. The data obtained was to be related particularly to the helideck acquisition task.

Runs 9 and 10 were designed to evaluate the effectiveness of the ELP aids, supplemented by either yellow or green perimeter lights.

Before the trial it was suggested that the combination of lighting that might be found to provide the best overall cueing would consist of floodlighting, green perimeter lighting and the green ELP ‘H’. This configuration was designated as Run 11.

During the trial period, it was decided that, due to various flight time constraints and lessons learned, Runs 7 and 10 would be deleted from the schedule.

3.4.2 Second Trial

The purpose of the second trial was to repeat the evaluations of some of the more promising lighting configurations flight tested during the first trial, but with different pilots in order to broaden the basis on which conclusions could be drawn.

In addition, green LED strips had been installed around one corner of the helideck. An objective of the trial was thus to compare the different forms of green perimeter lighting available (‘normal’ perimeter lights, LED strips and ELPs) individually, and in various combinations.

Hoods, designed to reduce the glare produced by floodlights were also to be available for evaluation. In the event, however, the hood design was found to be insufficiently robust to withstand the rotor downwash and the corresponding runs were abandoned.

Table 4 Equipment Configurations Planned for the Second K14B Flight Trial

Run	Configuration	Floodlights	Yellow Perimeter Lights	Green Perimeter Lights	Green Perimeter ELPs	Green ELP 'H'	Green LED Strips	Comparisons tested	Comments
1	(b)	✓		✓				Change of colour of perimeter lights	Baseline of proposed perimeter lighting
2	(a)	✓	✓						Baseline of existing standard equipment
3	(j)	✓		✓		✓		Repeat tests of configurations of interest from first trial	Green perimeter lights and ELP 'H' with floodlights
4	(d)			✓		✓			Green perimeter lights and ELP 'H' without floodlights
5	(h)			✓	✓	✓			Green perimeter lights and ELP 'H' with green perimeter ELPs
6	(k)			✓				Comparison of combinations of green perimeter lighting and ELP 'H'	Green perimeter lights only
7	(l)			✓	✓				Green perimeter lights with green perimeter ELPs
8	(m)			✓		✓	✓		Green perimeter lights with green LED strips and 'H'
9	(e)				✓	✓			ELP only
10	(o)						✓		Green LED strips only

The equipment configurations evaluated in the second test flight are summarised in Table 4.

Runs 1 and 2 were planned to address the same issues as were addressed by the corresponding runs in the first trial.

Runs 3 to 5 comprised repeat tests of configurations of interest from the first trial, and evaluated the effect of adding either floodlights or green ELP perimeter markers to the configuration comprising green perimeter lights and the ELP 'H'.

Runs 6 to 10 were planned to evaluate various combinations of green perimeter lighting, with and without the ELP 'H'.

3.4.3 **Third Trial**

After the completion of the second trial a number of changes and additions were made to the equipment fitted to the helideck of K14B.

The main objective of the third trial was to assess the benefits of outlining the Touchdown Marking circle with strips of yellow LED lighting as a means of enhancing cues for the final approach, hover and landing phases.

Another objective was to evaluate the floodlight hoods to determine their effectiveness in reducing glare. The hoods had been strengthened following the second trial.

The green perimeter lights used in the first and second trials were significantly different to the yellow perimeter lighting, although nominally of the same optical performance. The yellow lights used fluorescent light sources, while the green lights used incandescent sources. Between the first and second trials the output of the green lights deteriorated noticeably. In order to restore the light output of the green lights, and to ensure a proper comparison, the green lights were re-lamped with fluorescent sources for the third trial.

The configurations planned for the third test flight are summarised in Table 5.

As in previous trials, Runs 1 and 2 were designed to allow a direct comparison of the helideck location cues provided by yellow or green perimeter lighting.

Runs 3 to 5 represent three credible combinations of LED strips and ELP 'H' that were considered to be candidates for further evaluation. Runs 6 to 8 were the same as the three previous runs except for the absence of floodlighting. It was expected that comparisons of the results from Runs 3 to 5 with Runs 6 to 8 would establish whether floodlighting is necessary if alternative lighting cues are available in the middle of the deck. Data from these six runs was also intended to investigate the influence that floodlighting might have on the effectiveness of various aids.

In Runs 4, 5, 7 and 8 the use of yellow LED strips to define the outline of the Touchdown Marking circle was to be evaluated. This lighting was intended to enhance the cueing environment during the final stages of the approach, hover and landing. In particular, it was expected to be useful once the ELP 'H' had disappeared from view below the helicopter in the hover.

The final runs, 9 and 10, were designed to evaluate the effectiveness of hoods in reducing glare caused by the deck-level floodlighting.

During the execution of the trial, it was decided to repeat Run 7 with the helicopter landing light switched off, thereby depriving the pilot of the cueing that this light can provide during the hover and landing. This formed Run 11, the final run of the trial.

Table 5 Equipment Configurations Planned for the Third K14B Flight Trial

Run	Configuration	Floodlights	Floodlights with hoods	Yellow Perimeter Lights	Green Perimeter Lights	Green ELP 'H'	Yellow LEDs	Comparisons tested	Comments
1	(a)	✓		✓				Change of colour of perimeter lights	Baseline of existing standard equipment
2	(b)	✓			✓				Baseline of proposed perimeter lighting
3	(j)	✓			✓	✓		Combinations of green perimeter lights green 'H' and yellow LED, with floodlights	With floodlighting
4	(p)	✓			✓		✓		With floodlighting
5	(q)	✓			✓	✓	✓		With floodlighting
6	(d)				✓	✓		Combinations of green perimeter lights green 'H' and yellow LED, without floodlights	No floodlighting
7	(r)				✓		✓		No floodlighting
8	(s)				✓	✓	✓		No floodlighting
9	(t)		✓	✓				Effect of floodlight hoods	Baseline with hoods
10	(u)		✓		✓				Modified Baseline with hoods
11	(r)				✓		✓	Effect of aircraft landing lamp	Per Run 7 but without aircraft landing lamp

4 Flight Trial Results

4.1 General

The three flight trials described in Section 3 of this document evaluated a range of lighting equipment (described in Section 2), with the aim of providing improved visual cueing during all four phases of the approach to, and landing on, helidecks at night in VMC. The trials strategy involved a comparison between solutions and, where possible, a quantitative measure of relevant parameters.

In this section, rating data obtained from the debriefing forms is presented and analysed. The rating scales used were devised to elicit pilot comments in a structured manner. Although they cannot be regarded as validated tools for measuring performance levels, the information that they provide is considered to be a valid means of assessing the relative merit of particular visual aids or combinations of aids. The analysis reported in this section is based primarily on the comparison of ratings from pairs of runs (within each trial only, to avoid effects of individual pilot opinion and any other inter-trial differences), where the only difference between the two lighting equipment configurations is the feature under consideration. The comparisons used and the corresponding features evaluated are detailed in Table 6.

Table 6 Ratings Comparison Matrix

Group	Configs	Trial(s)	Runs	Comparison
1	(a) & (b)	T1, T2, T3	1 & 2, 2 & 1, 1& 2	Yellow vs. green perimeter lights
	(c) & (d)	T1	3 & 4	
	(t) & (u)	T3	9 & 10	
2	(b) & (j)	T2 & T3	1 & 3, 2 & 3	ELP 'H' (no/yes)
	(l) & (h)	T2	7 & 5	
	(k) & (d)	T2	6 & 4	
	(g) & (n)	T1	7 & 9	
3	(c) & (a)	T1	3 & 1	ELP 'H' vs. floodlights
	(d) & (b)	T1, T2, T3	4 & 2, 4 & 1, 6 & 2	
	(h) & (g)	T1	8 & 7	
4	(r) & (s)	T3	7 & 8	ELP 'H' (with yellow LED circles) (no/yes)
	(p) & (q)	T3	4 & 5	
5	(b) & (p)	T3	2 & 4	Yellow LED circles (no/yes)
	(b) & (q)	T3	2 & 5	Yellow LED circles & ELP 'H' (no/yes)
	(b) & (r)	T3	2 & 7	Yellow LED circles vs. floodlights
6	(d) & (h)	T1	4 & 8	Green ELP perimeter markers (no/yes)
	(k) & (l)	T2	6 & 7	
7	(e) & (f)	T1	5 & 6	Floodlights (no/yes)
	(d) & (j)	T2 & T3	4 & 3, 6 & 3	
	(k) & (b)	T2	6 & 1	
	(h) & (n)	T1	8 & 9	
	(r) & (p)	T3	7 & 4	
8	(a) & (t)	T3	1 & 9	Floodlight hoods (no/yes)
	(b) & (u)	T3	2 & 10	

The transcripts of the in-flight pilot commentaries were also used to support and supplement the analysis of the rating data, and are presented in Appendix B. In addition, since the range from which a particular visual aid provides meaningful cues is an important indicator of operational effectiveness, data gathered on this aspect is presented and reviewed.

4.2 **Range data**

A summary of the range data acquired during the three flight trials is given in Table 7. This data was obtained under a variety of ambient weather conditions but, in all cases, the meteorological visibility was at least 9 km (5NM) and the helicopter was clear of cloud.

Ignoring the Trial 2 results where the intensity of the green perimeter lights was degraded, the green incandescent perimeter lighting consistently produced the greatest identification ranges (2.0 to 2.5NM), typically 1.25 to 2.0 times the range of the existing yellow perimeter lights (Trials 1 & 3 Run 1 vs. Run 2, Trial 1 Run 3 vs. Run 4, and Trial 3 Run 9 vs. Run 10). This enhancement of the helideck acquisition range enables the requirements of Table 1 to be met. Perimeter lighting using other technologies did not produce ranges sufficient for the helideck acquisition task.

For the descending, deceleration of the final approach phase the pilots initially used the shape of the helideck to derive cues, transferring to in-deck cues as soon as practicable. For this phase, the green perimeter lights had a greater initial useable range than the yellow perimeter lights, and the absence of floodlights increased the range at which the deck shape became apparent (Trial 1 Run 8 vs. Run 9, Trial 2 Run 4 vs. Run 3, and Trial 3 Run 7 vs. Run 4). In general, the shape of the deck outline was seen by the time that the pilots had commenced their descent at a range of 1NM.

For the third trial yellow LED strips delineating the inner and outer edges of the Touchdown Marking circle were added to the lighting pattern. During the descent this pattern had a typical acquisition range of 1.1km (0.6NM). At this range pilots could use the perspective of the standard-size circle to derive essential height (relative to the helideck), and closure rate cues. This information is not readily derived from the irregular shape of the helideck perimeter, and paint markings are not apparent until ranges of approximately 0.25km (0.15NM). Thus, the improved lighting aids generally provided more useful information, and provided it earlier in the final approach phase than is currently the case.

As the helicopter enters the hover phase at a range of 100ft (30m), the cues should already be adequate for the pilot to assess the orientation of the aircraft in terms of landing direction, and in establishing a stable hover over the landing area. The ELP ‘H’, having a typical range of 0.5km (0.3NM), initially provided many of these cues, but moved out of view as the aircraft translated over the helideck into the hover position. The Touchdown Marking circle also provided the cues required, but remained in view providing good positional and attitude cues.

For the landing phase all the deck mounted visual aids could be clearly seen, except for the ELP ‘H’ which was obscured from view below the helicopter. At this range the individual LEDs in the Touchdown Marking circle LED strips could be seen as discrete sources providing micro-texture information.

Table 7 Range Data (nautical miles)

	Run No	Rig	Deck Visible	Deck / Circle shape / shape	Yellow Perimeter	Green Perimeter	Green ELP Perimeter	Green LED Perimeter	ELP H	Yellow Circle Visible	Deck Texture
Trial 1	1	5+	1.0	0.5	1.5						0.13
	2		1.5	0.8		2.5					
	3		1.0	0.8	2				0.6		
	4		2.0	1.1		2.5			0.4		
	5			0.4		1.8			0.4		
	6								0.4		
	7		2.0	0.5		2+			0.4		
	8		2.0	0.8		2+	0.6		0.2		
	9		1.75	0.6			0.2		0.3		
Trial 2	1	2			1.7						
	2	2		0.75		1.75					
	3	2		0.8		1.5			0.4		
	4		1.3	1.0		2.0			+ 0.3		
	5			1.0		1.8	0.1		0.3		
	6			0.6		(1.0)					
	7			0.7		(1.0)	0.1				
	8					(1.0)		+ 0.2	0.3		
	9							0.2	0.3		
	10			0.7				0.9			
Trial 3	1	2		0.9	1.4						
	2			1.1		2.5					
	3					2.5			0.3		
	4			0.4		2.2				0.4	
	5			0.6		2			0.4	0.6	
	6			0.5		2.5			0.4		
	7			1.1		2				0.8	
	8			0.9		2			0.4	0.7	
	9			0.7	1.0						
	10					2					

NOTE: Where no data is shown for a Run this is either because the aid was not being evaluated during that Run or occasionally the pilot did not provide the data.

4.3 Helideck Acquisition Ratings

Because the helicopter was normally flown downwind for a distance of at least 2NM (3.7km) prior to the commencement of each run, a relatively large data base relating to the helideck acquisition task was obtained during the trials. However, in Trial 2 where the final approach, hover and landing cues were principally being tested, no acquisition data was obtained for a number of the approaches. The helideck acquisition ratings for presentation and workload for all three trials are summarised in Figures 18 and 19 respectively, and are presented in the manner in which they were analysed in Table F1 in Appendix F.

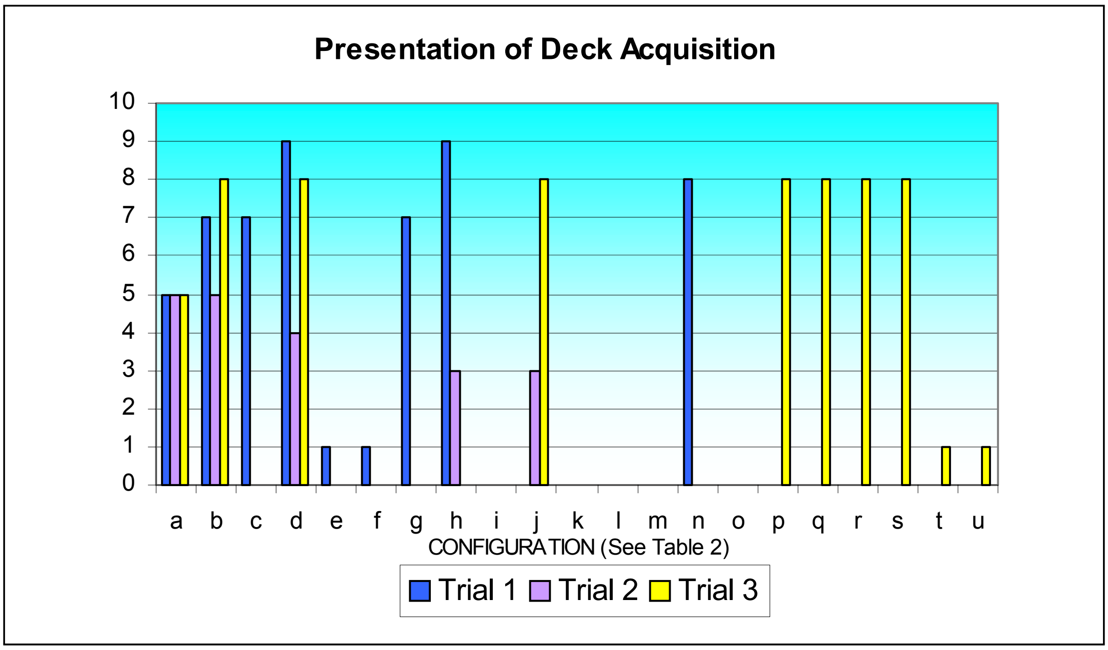

Figure 18 Helideck Acquisition Workload Ratings

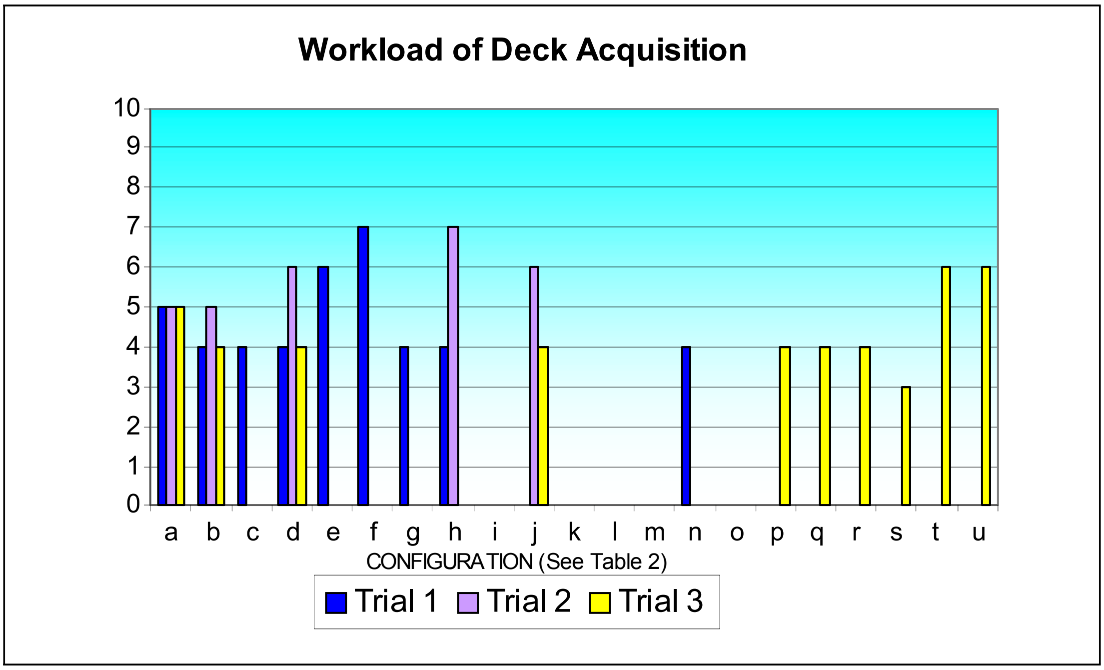

Figure 19 Helideck Acquisition Workload Ratings

The primary visual aid for helideck acquisition is the perimeter lighting. In all three trials, the yellow perimeter lights (configuration (a)) and green perimeter lights (configuration (b)) were directly compared for this task. In Trials 1 and 3 the green perimeter lights were consistently rated as providing a clearly better presentation and reduced workload in comparison to the existing yellow lights. The ratings for Trial 2, however, indicate no improvement but this is considered to be due to degradation of the lamps fitted to the green perimeter lights during the 7-month period between Trials 1 and 2. This degradation was noted at the time of the trial, and the incandescent lamps were subsequently replaced with the same fluorescent lamps fitted to the yellow lights for Trial 3.

The other configurations which may be used to directly compare the yellow and green perimeter lighting are (c) with (d) in Trial 1, and (t) with (u) in Trial 3. The former indicates an improvement in changing from yellow to green perimeter lights, the latter indicates no change. There is no obvious explanation for the unexpected ratings from Trial 3, and it is noted that the ratings for configurations (t) and (u) are significantly lower that for configurations (a) and (b) respectively (see ratings for the trial runs listed in group 8 in Table F1). The only difference between the two sets of results are normal floodlights, and floodlights with hoods. The geometry of the hoods was such that, at the ranges concerned, they would have had no effect on the amount of light seen by the pilot. It can only be surmised that the floodlight hoods were, in some way, significantly influencing the pilots' opinions.

In addition to configurations (b) and (c), which have already been considered above, all the configurations awarded better ratings for presentation and/or workload than the baseline of yellow perimeter lights and floodlights without hoods (Trial 1 configurations (d), (g), (h), (n), and Trial 3 configurations (d), (j), (p), (q), (r) and (s)), were associated with configurations containing green incandescent perimeter lights. When used without any other form of perimeter lighting (Trial 1 configurations (e) and (f)), the ELP perimeter markers proved inadequate for the task. When used in combination with green incandescent perimeter lights (Trial 1 configurations (d) and (h)), the green ELP perimeter markers made no difference to the ratings for this phase.

The only other factor considered likely to affect helideck acquisition is the presence of floodlights. Direct comparisons can be made using the ratings data for group 7 in Table F1. Overall, these suggest a small improvement in acquisition ratings in the absence of floodlights. Further evidence of the negative effect of floodlights lies in the comparison of the ratings for group 3 in Table F1. These comparisons indicate the relative merit of the ELP 'H' and the floodlights. Overall the presentation ratings for the 'H' were moderately better than for the floodlights, but the workload ratings were virtually unchanged. Since the ELP 'H' was not visible at helideck acquisition range, it can be concluded that the overall improvement in the acquisition ratings are due to the absence of floodlights rather than the presence of the ELP 'H'. As noted above, the addition of hoods to the floodlights produced unexpectedly poor ratings.

Thus on the basis of the ratings data presented in Figures 18 and 19, it can be seen that the use of green incandescent perimeter lights significantly enhances helideck acquisition compared with current provisions. There is also evidence to suggest a modest improvement in helideck acquisition with the deletion of the floodlights. No other change to the standard helideck lighting had a significant effect. These conclusions are supported by the pilot commentaries given in Appendix B.

4.4 Final Approach Ratings

During the final approach phase the pilot requires cues to enable him to control the flight path and speed of the helicopter. With reference to Table 1 in Section 1 of this report, the perimeter lighting, the Touchdown Marking circle LED strips and the ELP 'H' were all expected to help provide the cues required. The final approach ratings for presentation and workload for all three trials are summarised in Figures 20 and 21 respectively, and are presented in the manner in which they were analysed in Table F2 in Appendix F.

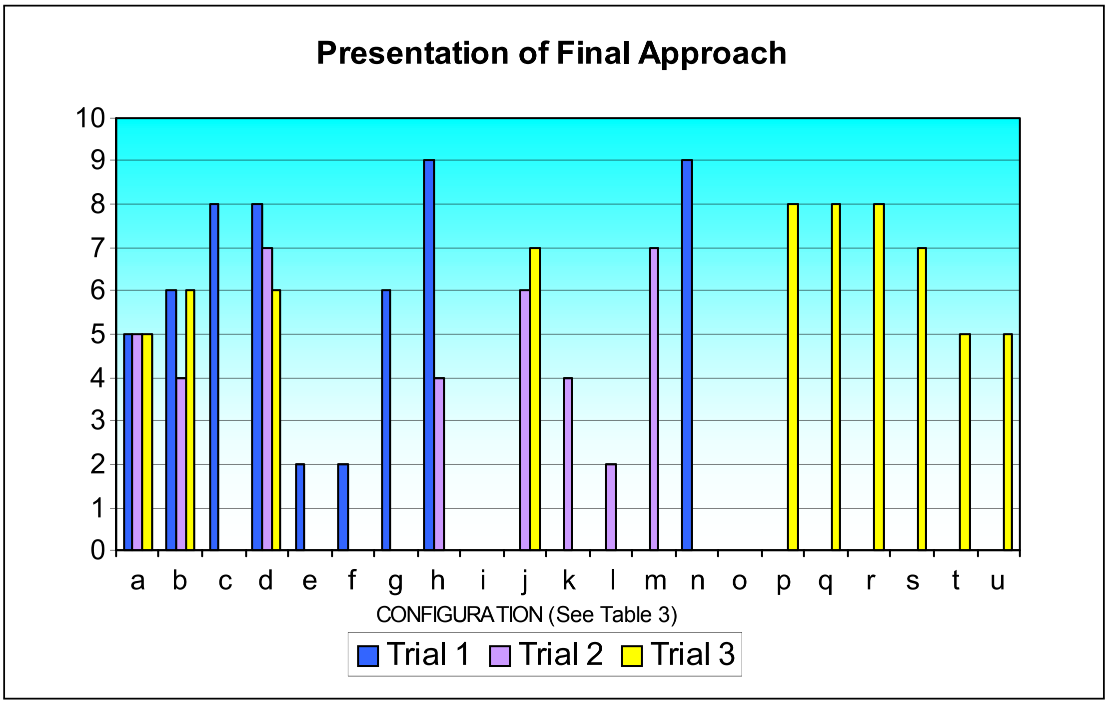

Figure 20 Final Approach Presentation Ratings

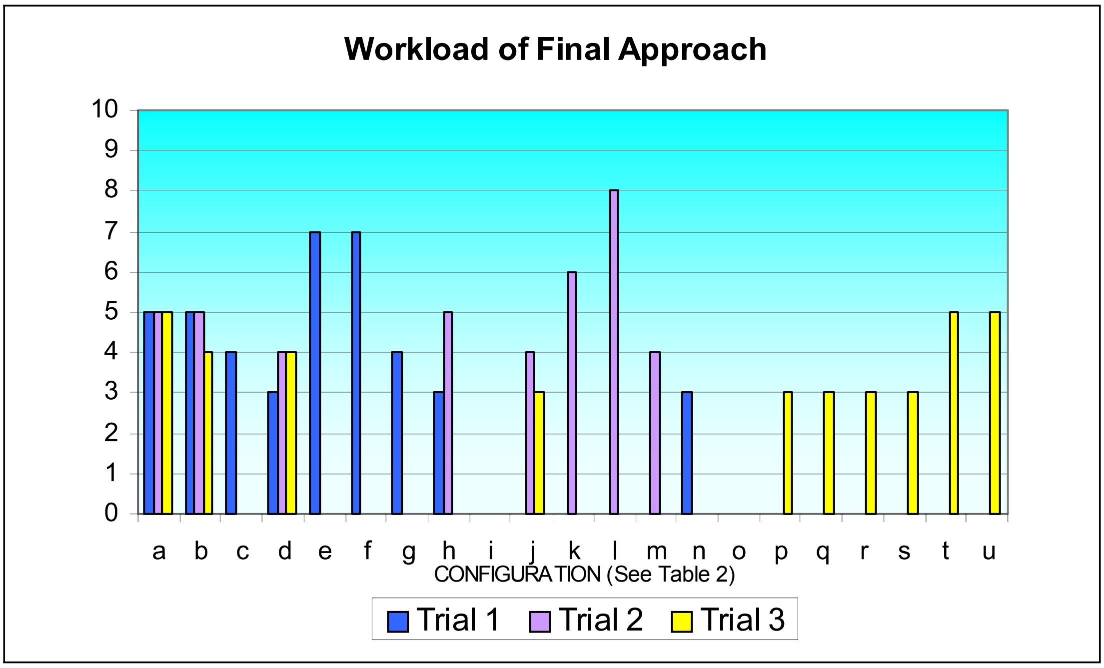

Figure 21 Final Approach Workload Ratings

As regards the perimeter lighting, comparison of the ratings for group 1 in Table F2 indicates virtually no difference between the yellow and green incandescent lighting. This is to be expected, since the change in colour essentially only affects conspicuity which is not an issue once the helideck has been acquired. When used with no other form of perimeter lighting, the corresponding ratings data (configurations (e) and (f)) indicates that the ELP perimeter markers were inadequate for the task. Furthermore, the ELP perimeter markers had little or no positive effect when used in conjunction with incandescent perimeter lighting (see ratings for the trial runs listed in group 6 in Table F2). From the pilot commentaries in Appendix B, this is most likely due to their relatively low intensity. Although no direct rating comparisons are available, the good ratings awarded for configuration (m) in Trial 2 do indicate a positive result for the green perimeter LED strips when taken with the favourable pilot commentary for Trial 2 Run 8 in Appendix B.

The effect of adding the green ELP 'H' to effective perimeter lighting (i.e. ignoring configurations (e) and (f)) can be deduced from the ratings for group 2 in Table F2. The ratings indicate a consistent and significant improvement. Furthermore, comparison of the ratings data for group 3 in Table F2 all indicate that the ELP 'H' consistently provided better cueing for this phase of the approach than the floodlights. However, looking at the use of the ELP 'H' in conjunction with the Touchdown Marking circle LED strips (see ratings for the trial runs listed in group 4 in Table F2) shows a lack of improvement over that provided by the Touchdown Marking circle LED strips without the ELP 'H'. With reference to Table 7, this result is most likely due to the greater range of the LED strips.

The addition of the Touchdown Marking circle LED strips for the third trial was particularly successful, as indicated by comparison of the ratings for configurations (b) and (p) for Trial 3. The improvement in the ratings was the same when used in conjunction with the ELP 'H' (compare configuration (b) with (q) for Trial 3) which, in view of the non-positive result for the ELP 'H' mentioned above, again demonstrates the benefit of the Touchdown Marking circle LED strips. Finally, comparison of the Trial 3 ratings for configurations (r) and (b) indicate that the Touchdown Marking circle LED strips outperformed the floodlights.

Inspection of the ratings for group 7 in Table F2 indicates that, overall, the floodlights had no effect. From the range data reviewed in Section 4.2, it was expected that the effect of the floodlights in decreasing the range at which the deck shape became apparent would have an adverse effect on the ratings. One possible explanation could be that the reduced range of the cues provided by the helideck shape was compensated by the presence of other cues, e.g. the ELP 'H'. For this phase of the approach, the addition of the floodlight hoods had no effect.

For the final approach phase, the ratings data presented in Figures 20 and 21 shows that the provision of lit in-deck patterns noticeably improves the cueing, and can result in reduced levels of workload. The most effective visual aid was the Touchdown Marking circle LED strips, closely followed by the ELP 'H'. The current standard, which relies on markings illuminated by floodlighting, is clearly inferior. The colour of the perimeter lights and the presence of floodlights (with or without hoods) had no significant effect. Although supported by only limited data, the pilot commentary indicates favourable results for the green perimeter LED strips.

4.5 Hover Ratings

For the hover task, the key aids were expected to be the Touchdown Marking circle LED strips, and the linear perimeter lighting (ELP perimeter markers and green perimeter LED strips). While the purpose of the floodlights is to provide cues for the hover and landing, in-service experience had suggested that their usefulness would be limited. It was hoped, however, that the addition of the hoods to the floodlights might improve their performance. The hover ratings for presentation and workload for all three trials are summarised in Figures 22 and 23 respectively, and are presented in the manner in which they were analysed in Table F3 in Appendix F.

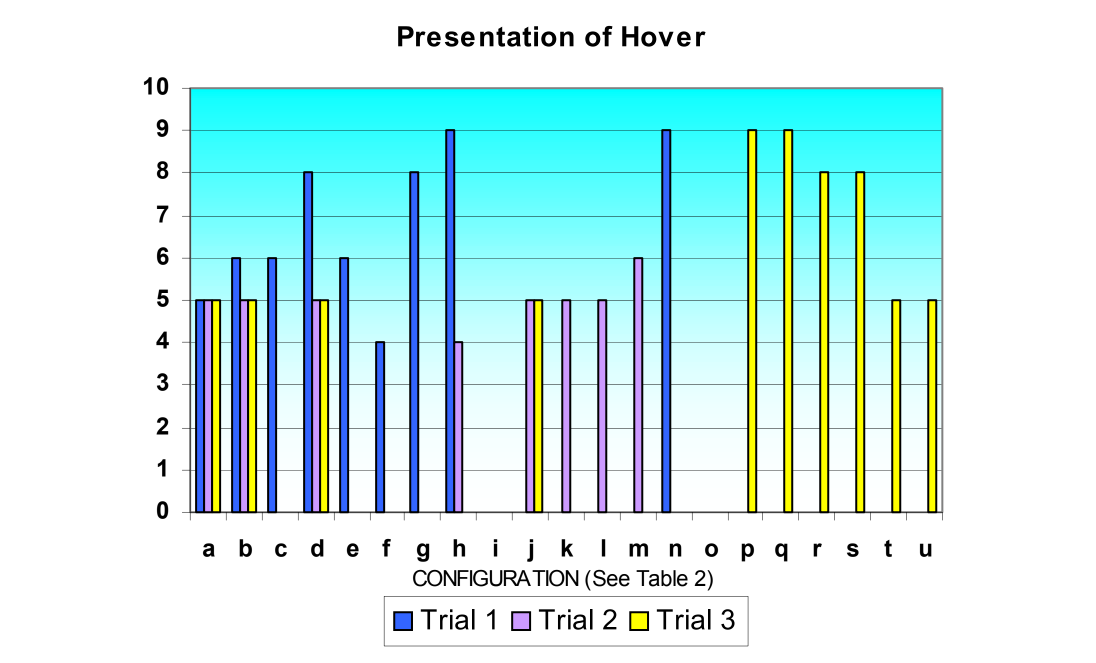

Figure 22 Hover Presentation Ratings

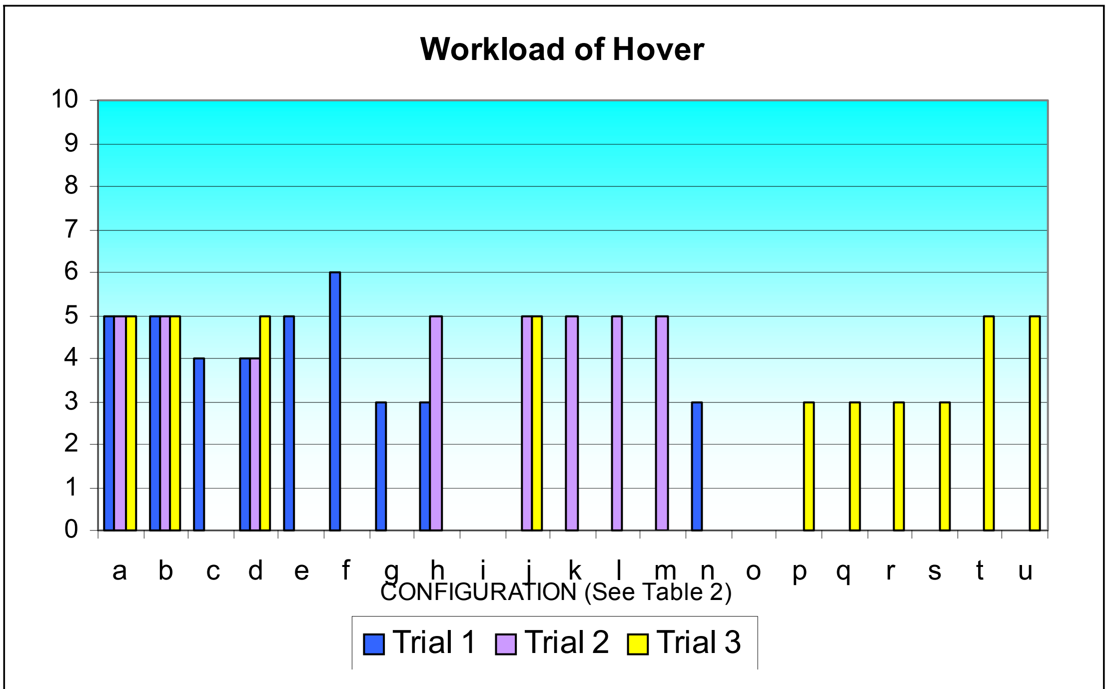

Figure 23 Hover Workload Ratings

The colour of the incandescent perimeter lighting had very little effect on the presentation ratings and no effect on the workload ratings (see ratings for the trial runs listed in group 1 in Table F3). This result was expected for the same reasons as for the final approach phase (see Section 4.4). With reference to the ratings for group 6 of Table F3, the ELP perimeter markers provided only a very slight improvement. The ratings for configuration (m) for Trial 2 indicate a positive result for the green perimeter LED strips, which is supported by the pilot commentary in Appendix B. The improvement in the rating is, however, not as great as in the case of the final approach phase, but this could be due to the additional benefit provided by the ELP 'H' which would not feature during the hover phase (see below).

As regards the lit in-deck patterns, as expected the ELP 'H' made no significant difference being largely obscured from view below the helicopter (see ratings for the trial runs listed in groups 2 and 4 of Table F3). Comparison of the ratings data for configurations (b) and (p) for Trial 3, however, indicates a significant improvement from adding the Touchdown Marking circle LED strips. This is reinforced by comparison of the ratings for configurations (b) and (q) for Trial 3 which, since the effect of the ELP 'H' can be largely ignored, effectively represents a second data point for evaluating the effect of adding the Touchdown Marking circle LED strips. Furthermore, comparison of the ratings for configurations (b) and (r) for Trial 3 demonstrates the supremacy of the Touchdown Marking circle LED strips over the floodlights.

Turning to the floodlights, the ratings data for group 7 of Table F3 confirms that they provided virtually no benefit. In fact, the ratings data for group 3 of Table F3 suggests that the floodlights were less beneficial than the ELP 'H' which, for most of the hover phase, was out of view below the aircraft. The fitting of hoods to the floodlights made no difference to the ratings (see ratings for the trial runs listed in group 8 of Table F3).

Overall, the ratings data presented in Figures 22 and 23 shows that the only visual aid that had any impact on the ratings for the hover phase was the Touchdown Marking circle LED strips, where a significant improvement was seen. No other visual aid had any significant effect apart from the green perimeter LED strips which were well received by the pilots.

4.6 Landing Ratings

The aids intended to provide the visual information during the landing were identical to those for the hover, i.e. the Touchdown Marking circle LED strips and the linear perimeter lighting (ELP perimeter markers and green perimeter LED strips). Once again, it was hoped that fitting hoods to the floodlights would improve their usefulness by reducing glare which, by virtue of the geometry and close proximity, is at its worst during this phase. The landing ratings for presentation and workload for all three trials are summarised in Figures 24 and 25 respectively, and are presented in the manner in which they were analysed in Table F4 in Appendix F.

The presentation ratings for Trial 1 improved slightly with the change in colour of the incandescent perimeter lighting from yellow to green (see ratings for the trial runs listed in group 1 in Table F4). No significant difference was expected for the same reasons as for the hover and final approach phases. With reference to the pilot commentary in Appendix B, however, it is suggested that the reason for the better ratings could have been the lower glare from the green lights which was quite noticeable at close range. The ELP perimeter markers had no effect on the ratings (see ratings for the trial runs listed in group 6 in Table F4), and neither did the green perimeter LED strips (see ratings for configuration (m) for Trial 2).

Again, as for the hover phase, the ELP 'H' made no significant difference being obscured from view below the helicopter (see ratings for the trial runs listed in groups 2 and 4 of Table F4). The Touchdown Marking circle LED strips provided a significant and consistent improvement in both presentation and workload ratings as evidenced by the ratings data for group 5 of Table F4.

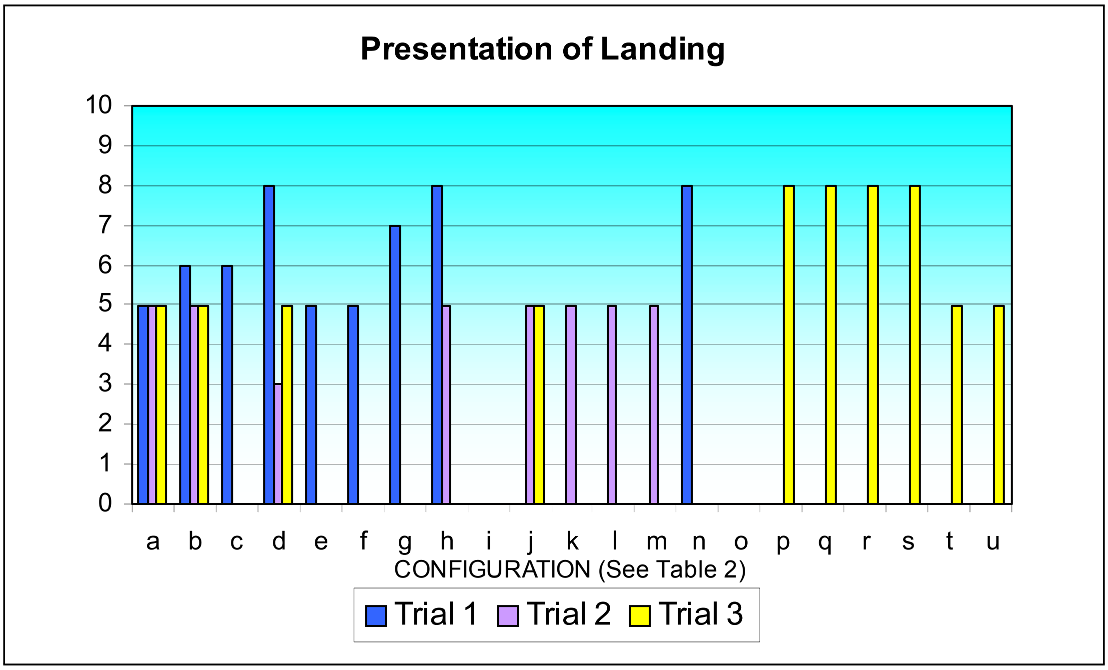

Figure 24 Landing Presentation Ratings

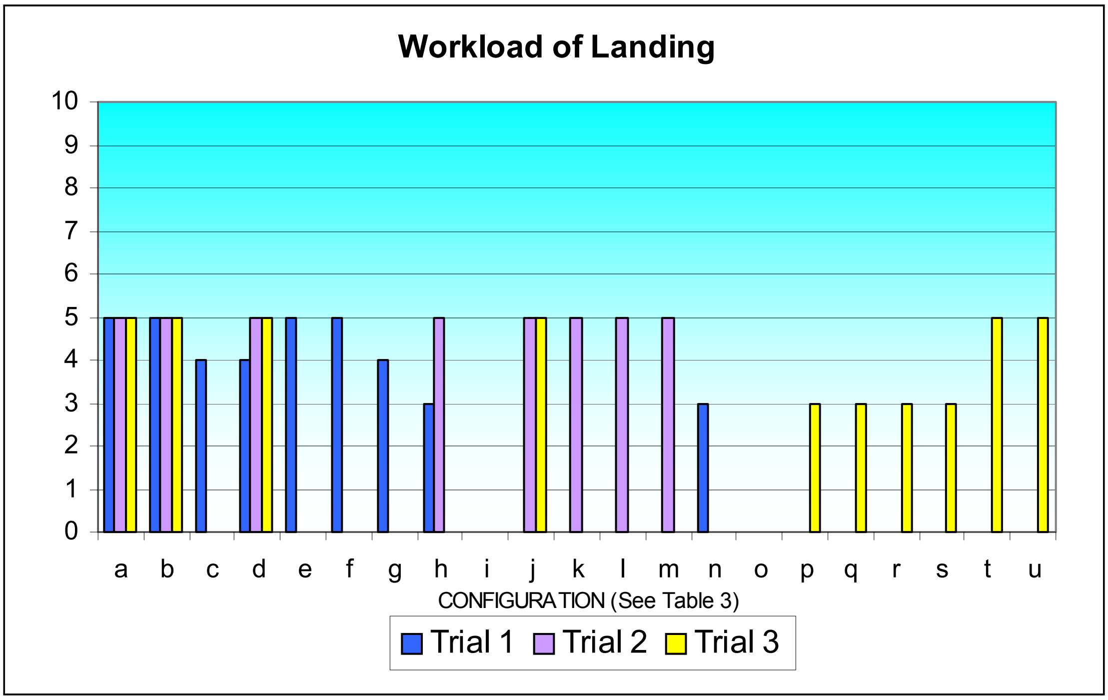

Figure 25 Landing Workload Ratings

Inspection of the ratings for groups 7 and 8 of Table F4 indicates no overall benefit of adding the floodlights either with or without the hoods. Furthermore, the ratings for group 3 of Table F4 indicate a moderate overall decline in ratings for floodlights relative to the ELP 'H' even though the 'H' is out of view during the landing. With reference to the pilot commentary in Appendix B, it is surmised that the negative effect of the floodlights is due to glare.

Overall, the ratings data presented in Figures 24 and 25 indicates that the Touchdown Marking circle LED strips was the only visual aid to have any significant effect, and provided a notably better cueing environment for the landing. Otherwise, the only other result worthy of note is the ineffectiveness of the floodlights.

5 Discussion

5.1 General

Throughout the trials, each run began at a range that was well below the range at which the pilot would normally have made visual contact with and identified the platform using on-board navigation systems to facilitate the task. The time available for the flight trials was thus totally dedicated to the 4 approach phases that were the subject of the research. The tasks of platform location and identification were not addressed during this project.

In the following discussion, each of the visual aids evaluated is assessed in terms of the cueing it provided during the 4 approach phases. Finally, an assessment of the overall package of visual aids required to fulfil operational requirement stated in Section 1 is presented. Figures 26 and 27 summarise, respectively, the current cueing environment and the enhanced cueing environment that can be provided by adopting the package of visual aids identified from the analysis of the flight trials results.

5.2 Green Helideck Perimeter Lighting

The ratings data and pilot comments clearly indicate a significant improvement in cueing during the helideck acquisition phase by changing the colour of the perimeter lights from yellow to green. This is particularly impressive given the significantly lower intensity that results from the lower efficiency of green filters. The results indicate that the green helideck perimeter lighting enabled the operational requirement for helideck acquisition stated in Section 1 to be met.

As might be expected, the change of colour had no effect during the final approach and hover phases, but a slight improvement was evident in the landing phase. This is believed to be due to the lower intensity of the green lights and consequent reduction in glare, which is at its greatest during the landing phase due to the viewing geometry and close proximity. It should be noted, however, that the intensity of green perimeter lights if used in service would probably need to be increased to cater for the full range of operational meteorological conditions.

5.3 Green Perimeter ELPs

The green perimeter ELPs were demonstrably inadequate for the helideck acquisition task, and had no effect on the ratings for either the final approach or landing phases of the approach. A slight improvement was, however, evident during the hover phase. The main problem with this visual aid is considered to be the relatively low intensity of the ELP, which results in a lack of detectability at longer ranges and a lack of conspicuity against the other helideck lighting at shorter ranges.

5.4 Green ELP 'H'

The ELP 'H' had no impact on the helideck acquisition task, and does not meet the operational requirements for either the final approach, hover or landing phases stated in Section 1. This is due to the low intensity of the ELP, and the fact that it was out of view below the helicopter during the hover and landing phases. However, it should be noted that, at 3m x 2m x 0.3m, the 'H' used for the trial was significantly smaller than the normal standard of 4m x 3m x 0.75m, and a larger 'H' may well have proven more effective. An 'H' formed from higher intensity light sources such as LEDs might

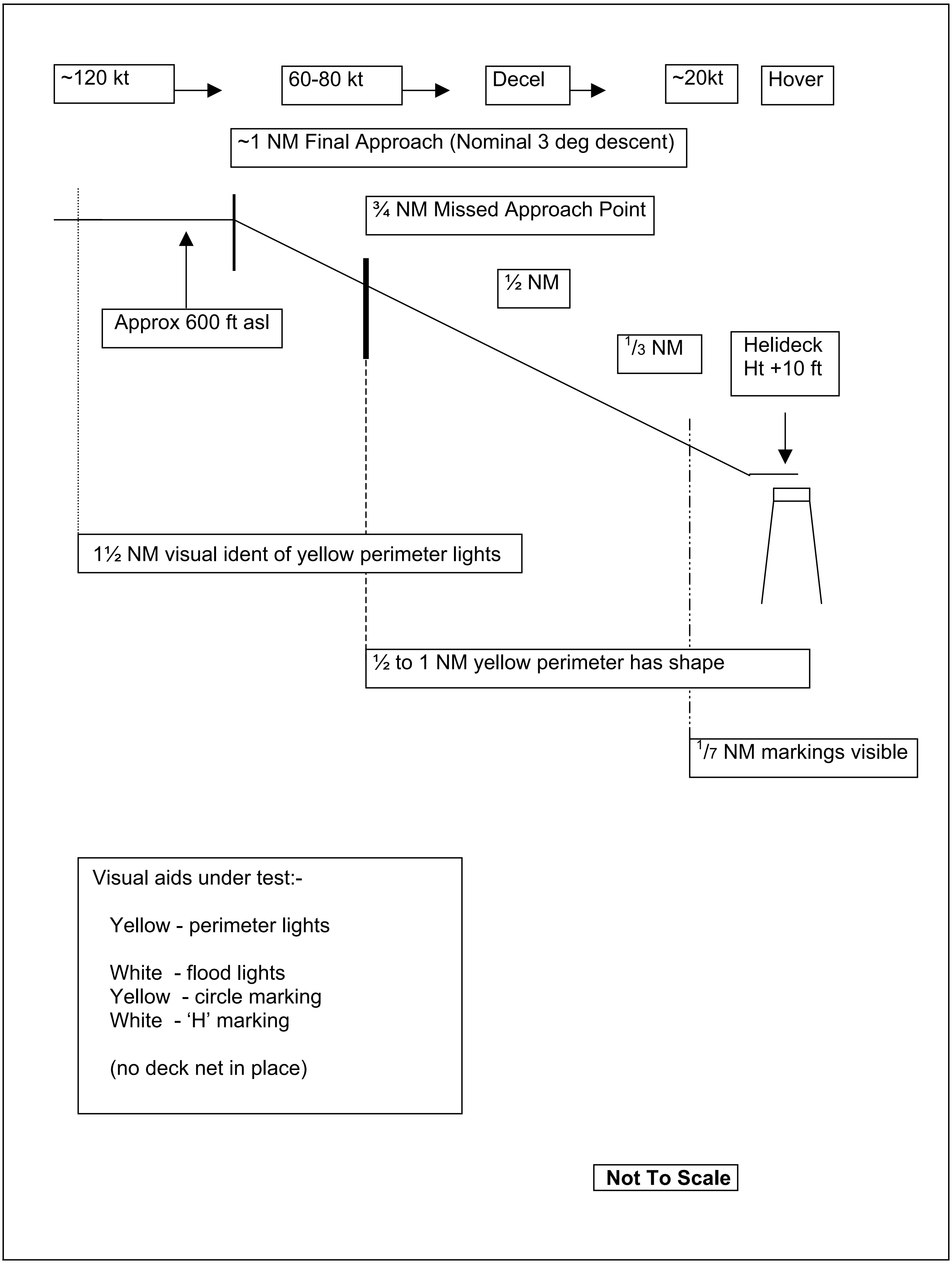

Figure 26 Current Cueing Environment

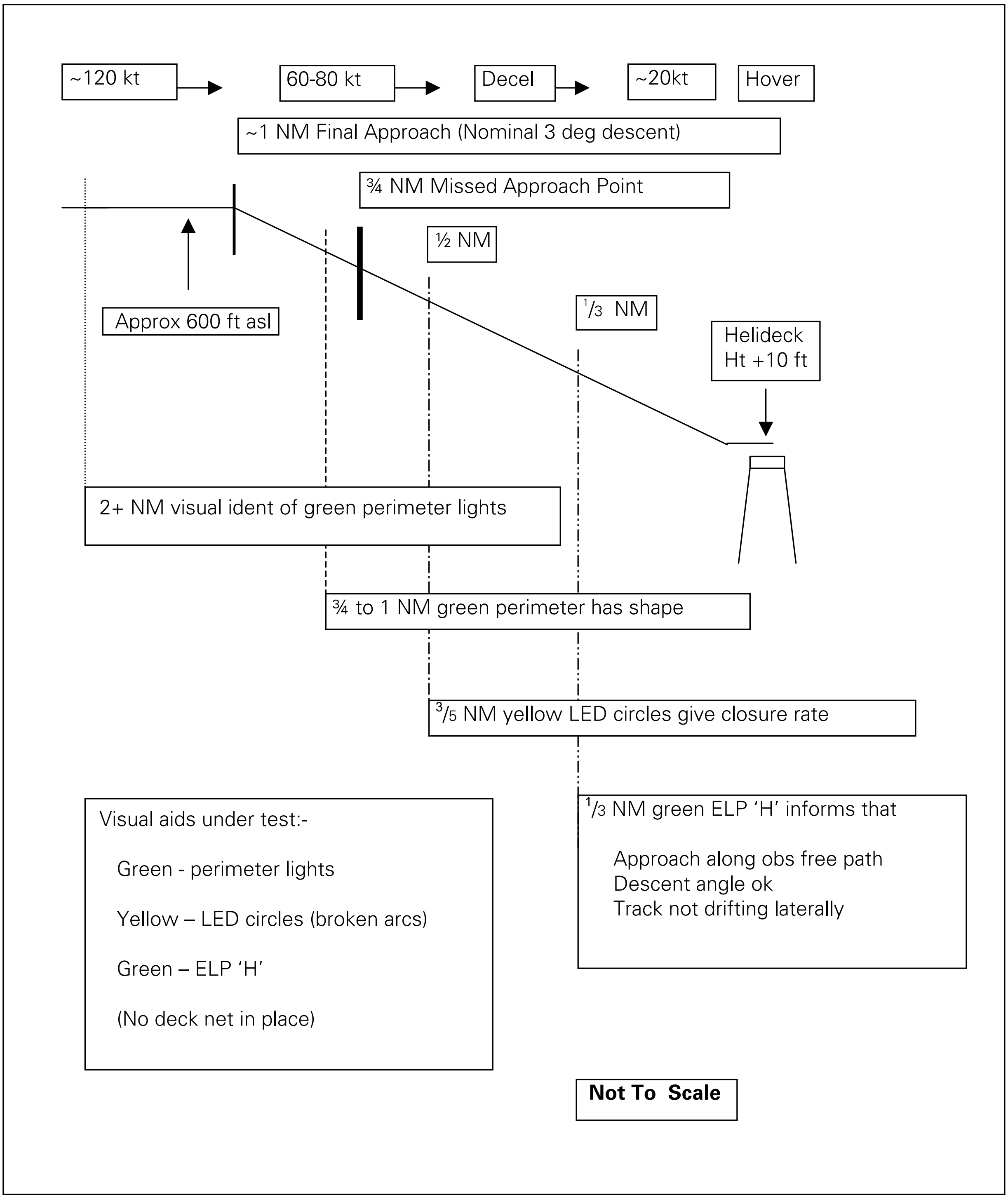

Figure 27 Proposed Cueing Environment

also have fared better, which could also address the other disadvantages of ELPs of high initial cost and relatively short service life.

Nevertheless, in the absence of the Touchdown Marking yellow LED strips, during the final approach the ELP 'H' consistently provided significantly better cueing than the floodlights of the current standard and was well received by the pilots. The greater performance of the 'H' is accredited to its higher intensity (100 cd/m^2 vs 65 cd/m^2) and its location in the centre of the helideck where it is relatively dark and where the pilot's attention is focussed during the final approach. It should also be noted that the 'H' was the only aid which provided a heading reference (relative to the obstacle free sector) and that, due to the nature of the ELP light source, it does not suffer from the 'blooming' generated by point source lighting on cockpit transparencies that are contaminated with rain drops or scratched.

5.5 LED Strips

The yellow LED strips around the Touchdown Marking circle significantly enhanced the cueing in all but the helideck acquisition phase, where the range of the helicopter from the helideck is significantly beyond the range of the aid. A useful, if unintentional feature of this aid was the change in appearance of the strips from lit bars to lines of individual point sources from the entry into the hover onwards. This provided a useful range cue towards the end of the approach, and textural cues equivalent to those provided by a helideck net during the hover and landing phases. In addition, because of its standard size and shape, the benefits of this aid would be further enhanced if widely implemented.

The results indicate that the yellow LED strips around the Touchdown Marking circle enabled the majority of the operational requirements for the final approach, hover and landing phases stated in Section 1 to be met. At (typically) 0.6NM, the acquisition range of the aid for the final approach phase was less than the desired range of 1.0NM, and no heading reference is provided as a result of the axial symmetry of the pattern.

The green perimeter LED strips also showed promise but, since their intensity is insufficient for helideck acquisition, it is considered more advantageous to locate yellow strips around the Touchdown Marking circle.

5.6 Floodlights and Hoods

Overall the floodlights, with or without hoods, had a mildly detrimental effect on the cueing provided by the helideck lighting. At longer ranges their high intensity, relative to the perimeter lights, reduced the conspicuity of the helideck shape and hence impaired the acquisition of the helideck to some extent. During the final approach, hover and landing phases the floodlights provided no benefit. This was not unexpected as the ineffectiveness of low level floodlights in illuminating either the paint markings or the surface of the helideck, apart from the area immediately in front of the lights, is generally well known. There was also some evidence of a negative effect due to glare during the landing phase which, again, is consistent with in-service experience (see Appendix E).

The ineffectiveness of the floodlight hoods was unexpected. An alternative, and possibly more effective means of reducing glare would be to use louvers. Given the overall performance of the floodlights, however, a better solution might be to simply delete them.

5.7 Overall Package

Taking account of all the results, pilot comments and operational experience it is considered that the operational requirements for all four approach phases stated in

Section 1 might be met using a combination of green incandescent perimeter lights, yellow LED strips around the Touchdown Marking and a green ELP 'H', as shown in Figure 28. The green perimeter lights fulfil the operational requirements for the helideck acquisition phase and the early stages of the final approach phase. The yellow LED strips and ELP 'H' together meet the operational requirements for the middle and later stages of the final approach phase, and the hover and landing phase.

The foregoing is based on trials performed by a limited number of pilots and in a very limited range of favourable metrological conditions. It is considered likely, for example, that the intensity of the green perimeter lights would need to be increased to ensure that the operational requirement would be met in worst case metrological conditions. It should also be borne in mind that a significant number of helidecks are fitted with a helideck net which would cover the Touchdown Marking circle and the 'H'. Simple geometric considerations (20cm mesh size, 2cm rope diameter) suggest that little or none of the LED circles or 'H' would be visible at viewing angles below 6 degrees, and the effectiveness of the aids could be reduced at higher angles.

Figure 28 Preferred Equipment Configuration

6 Conclusions

It is concluded that: -

- The green incandescent perimeter lighting, despite being of lower intensity than the yellow, substantially increased the acquisition range of the helideck. As a result, the pilots' confidence was increased and workload was reduced during the early stages of the approach. The improved performance is attributed to the enhanced colour contrast with the platform cultural lighting.
- The luminance of the perimeter ELPs evaluated was inadequate in the viewing direction to be used as an acquisition aid. Even with all other deck lighting switched off, the ELP had insufficient luminance for the task.
- The green ELP 'H' co-located with the Heliport Identification Marking significantly enhanced the cues during the latter stages of the final approach, but became obscured below the helicopter during the hover and landing.
- The yellow LED strips, installed as 2 broken circles coincident with the inner and outer edges of the Touchdown Marking circle, provided significantly enhanced cueing for the final approach, hover and landing compared with the cues provided by floodlit markings. The LED strips provided texture on the surface of the helideck even when they were unlit.
- The floodlights, with or without hoods, degraded the usefulness of the other visual aids during the acquisition of the helideck.
- The floodlights did provide some useful textural cues in the hover and landing phases, but other visual aids evaluated during the trials provided significantly better cues for a larger proportion of the approach and landing.
- The addition of floodlight hoods had no effect on the difficulties caused by the floodlights during the approach to the platform, and no beneficial effect in the hover and landing.
- As a result of the trials it is concluded that the preferred equipment configuration to provide significantly enhanced cueing is:-

  a) green incandescent perimeter lighting,

  b) yellow LED strips defining the Touchdown Marking circle, and

  c) green luminescent Heliport Identification Marking ('H').
- The preferred equipment configuration needs to be evaluated by a larger sample of pilots.
- The preferred equipment configuration needs to be tested in the full range of operational meteorological conditions. The effects of water contamination of the cockpit transparencies on the cues derived from the lighting (LED strips in particular) need to be evaluated, and the adequacy of the intensity of the aids in conditions of reduced visibility should be established.
- The preferred equipment configuration needs to be evaluated with a helideck net fitted to establish the extent of any degradation of the cueing provided and, if appropriate, any additional provisions required.

7 Recommendations

It is recommended that: -

- The results presented in this report, supplemented by any additional data available from other evaluations, should form the basis of a proposal to the ICAO VAP to amend Annex 14, Volume 2. The proposal should recommend that ICAO adopt: -

  a) green incandescent perimeter lighting,

  b) illuminated Touchdown Marking circle using LED, or equivalent, strip lighting, and

  c) illuminated Heliport Identification Marking ('H'), using luminescent panel, or equivalent lighting

  as the standard lighting recommended for helidecks intended for use at night.
- An in-service trial be conducted to demonstrate the applicability of the proposed visual aids in a wider range of meteorological conditions, and to expand the pilot sample size.
- Further trials be conducted to evaluate the effects of a helideck net on the proposed visual aids.
- The requirements for floodlights be reviewed.
- Test methods to assess the photometric characteristics of LED strips be developed to enable specifications to be published and equipment compliance verified.

8 References

1 ICAO Annex 14, Volume II - Heliports

2 CAA Civil Aviation Publication 437 - Offshore Helicopter Landing Areas – Guidance On Standards

3 CAA Paper 97009 - Questionnaire Survey of Workload and Safety Hazards Associated With North Sea and Irish Sea Helicopters Operations

4 CAA Paper 92006 - Offshore Platform Identification Signs

5 CAA Paper 98003 - Specification For An Offshore Helideck Status Light System

9 Acknowledgements

Bristow Helicopters Ltd, England

- Dave Reid

Trial Pilots: -

- Henry Boyt
- Andy Broadbent
- Dave Cameron
- Gemma Chillcott
- Guy White
- Gabriel Barton

Civil Aviation Authority, Norway

- Ornulf Lien

Nederlandse Aardolie Madtschappij (NAM), Head Office, Netherlands

- Wietse Stuiver
- Dave Casson

Nederlandse Aardolie Madtschappij, K14 Platform, Netherlands

Offshore Installation Managers: -

- Peter Post
- Ton van de Klundert

Trial Personnel: -

- Ed Bleeker
- Martin Dantuma
- Gustaaf de Wolf
- John Okkerman
- Ad Verberne

Rijksluchtvaartdienst, Netherlands

- Ton Fransen
- Sanne Vermeulen

Appendix A Approach and Landing on K14 (Pilot Commentary)

1 General

Approaches and landings were performed to both the K14C and P helidecks. This was done in order to gain an appreciation of how pilots use the available visual cues to conduct these operations at night, and to compare landings on decks with and without nets. The pilots provided a commentary during the landings, which was recorded and used to form the basis of this appendix. Some of the phraseology used reflects that used by the pilots in their commentaries.

2 Landing on K14C

The K14C is a large helideck with a small area outside of the Safe Landing Area (SLA). The helideck has yellow perimeter lighting and helideck level floodlights. There is little superstructure in the immediate vicinity of the helideck to provide visual cues. The helideck is illustrated in Figure 2 in the main body of this report.

The pilot started the final approach phase, by looking through the windscreen in the direction of 'half past two'. As the aircraft approached the platform, the pilot picked out any cues that were available to monitor the closing speed. At this point, the appearance of the platform superstructure as illuminated by the platform lighting, together with the reflections from the sea and the changing shape of the pattern formed by the helideck perimeter lights, all provided information about the closure rate and the orientation of the helideck.

As the aircraft moved closer, the 'scene' was established. The aircraft was positioned so it could 'slide down' an imaginary line to the helideck at a constant approach angle. The aim was to keep the helideck in the same position in the windscreen as it got bigger. The pilot continued this process until the aircraft was 10ft above the helideck.

Once in a stationary hover, the pilot's attention transferred to the hover references and he was now looking at the helideck close to the aircraft. Scanning through the windscreen from 'half past ten' to 'half past two', the pilot monitored the external environment while checking the cockpit instrumentation. At this stage, the pilot was using the texture provided by the helideck net to assess the aircraft's height and position over the helideck. The main textural cues emerge during the period just before the hover where subtleties of the net structure and the material of the net become apparent. At night most of these cues are picked up by the aircraft's landing lights. From recognition of the grid form to realisation of an imperfect grid form to identification of the rope to awareness of knots to seeing the twists of the rope etc, all provide valuable textural cues. As soon as the shadows formed by the rope and landing lights can be seen to be moving (i.e. when getting closer to the hover), all these factors become doubly meaningful at night. In the final descent from the hover, depth perception, rate of closure and fore/aft and lateral positioning cues are the main benefits provided by the net. Moving shadows are a significant source of cues.

The net provided a standard, known grid, and the texture within the rope increased depth perception cueing. Cues were produced by the floodlights in illuminating parts of the net and creating shadows. The shadows moved as the aircraft's height or position altered. The helicopter finally made a gentle landing on the helideck.

3 Landing on K14P

This helideck is the lesser-used helideck on the platform. Green perimeter lighting had been installed alongside the helideck level floodlights, but no deck net was fitted. The superstructure of the platform adjacent to the helideck provided some information to the pilot. K14P is illustrated in Figure 3 in the main body of this report.

The pilot flew the approach as to K14C and, again, established the ‘scene’. As the aircraft descended over the helideck, the floodlights provided some texture around the outer part of the helideck. The pilot’s workload had increased, as there were fewer cues due to the lack of a net. The painted ‘H’ and the Touchdown Marking circle could not be seen.

The helideck appeared as a black hole. The only height information came from the green perimeter lights, which became the focus of the pilot’s attention. The aircraft then made a quick landing on the helideck.

Appendix B Examples of K14B Flight Trials Pro-forma and Questionnaire and Pilot Comments

1 K14B Trial Proformas

1.1 K14B Operational data (To be completed by DERA)

Run .... Date ....

Aircraft type .... Pilot ....

Approach heading ....

Pre run

Time (GMT)

Cloud base.. Visibility (km) ....

Wind speed (knots) .... Wind direction ....

Ambient light	**Twilight**	**Night/ Moon**	**Night/ No Moon**
Precipitation	**None**	**Rain**	**Snow**

Post run

Time (GMT)

Cloud base.. Visibility (km) ....

Wind speed (knots) .... Wind direction ....

Ambient light	**Twilight**	**Night/ Moon**	**Night/ No Moon**
Precipitation	**None**	**Rain**	**Snow**

Checklist

Existing helideck level floodlights	☐
Existing yellow helideck perimeter lights	☐
Trial green helideck perimeter lights	☐
Helideck perimeter Electro Luminescent Panels	☐
Electro luminescent 'H'	☐

1.2 Pilot Comment And Rating Proforma

Helideck Acquisition

Platform acquisition range ....

Helideck acquisition range ....

Presentation		Workload	

Comment	

Final Approach

Presentation		Workload	

Comment	

Hover

Presentation		Workload	

Comment	

Landing

Presentation		Workload	

Comment	

Ratings

Presentation	**Workload**
1 = poor	1 = not effortful
10 = excellent	10 = very effortful

1.3 K14B 'Post run' questionnaire

Task:

- Start approach at a range of 2NM from the platform.
- Fly a standard approach to the helideck.
- Establish a stable hover over the 'H' with the landing light on.
- Land aircraft.

Helideck Acquisition

- At what range is the platform acquired?
- At what range is the helideck acquired?
- Give a mark from 1 – 10 for presentation compared to the baseline.
- Give a mark from 1 – 10 for workload compared to the baseline.

Final Approach

- Does the configuration provide relative aircraft altitude information?
- Does the configuration provide closure rate information?
- Does the configuration require a modification to be made to the approach technique?
- Give a mark from 1 – 10 for presentation compared to the baseline.
- Give a mark from 1 – 10 for workload compared to the baseline.

Hover

- Does the configuration provide descent rate information?
- Does the configuration provide lateral/ longitudinal helideck position information?
- Give a mark from 1 – 10 for presentation compared to the baseline.
- Give a mark from 1 – 10 for workload compared to the baseline.

Landing

- Give a mark from 1 – 10 for presentation compared to the baseline.
- Give a mark from 1 – 10 for workload compared to the baseline.

General (to be answered after landing)

- Is the positioning of the equipment suitable?
- Is the intensity of the equipment suitable?
- Does the internal cockpit lighting alter the effect of the configuration?
- What effect would environmental changes have on this configuration?
- Does this configuration increase/ decrease workload?
- Is configuration better/ worse than existing lighting?
- Does this configuration provide a good overall situational awareness?

Comments to be noted at all stages

2 1st Flight Trial (Pilot Comments)

2.1 Introduction

The objectives of the first offshore flight trial at K14B on 29th November 1998 were to evaluate the benefits to be obtained from using green perimeter lighting and Electro Luminescent Panel (ELP) lighting for the acquisition of, approach to and landing on an offshore helideck. Landings were also performed on two additional helidecks, K14C and K14P, which are located on the main complex.

All runs were conducted with the aircraft searchlight switched on instead of the landing light, as this was the preferred practice of the Right Hand Seat (RHS) pilot. All distances quoted are in nautical miles (NM), heights in feet (ft) and aircraft speeds in knots (kt).

The BHL pilot who was commanding the aircraft occupied the RHS while the CAA pilot sat in the Left Hand Seat (LHS). The CAA pilot was the primary commentator, being a qualified test pilot. The statements in the following section are all based on the pilot comments recorded during the trial.

2.2 K14B Configurations

Approaching the K14B the pilots complained that at 0.5NM they could not see any helideck lighting, so they performed a fly-by to investigate. It transpired that only the green Electro Luminescent Panels (ELPs) around the perimeter and covering the 'H' had been switched on. When the pilots saw the ELPs, they thought that they provided excellent cues. The intensity was assessed as being acceptable in the latter stages of the approach to K14B, but a bit dim initially. The pilots liked the shape of the helideck produced by the perimeter mounted ELPs. The main cue gained was perspective, which was provided mainly by the ELP 'H'.

The aircraft landed to allow the additional personnel to disembark from the aircraft for the duration of the trial. All the lighting circuits were operated to check functionality prior to starting the first run. Each complete run took about 10 minutes from take off to landing.

Run 1 – Yellow Perimeter Lights and Floodlights

The cloud base was no less than 500ft, visibility approximately 5NM, and wind direction 070 and 10kt. The cloud screened the moon and it was not raining. K14C/ P could be seen clearly from the satellite, which is 5NM away.

The approach was started at a range of 2.2NM, at an airspeed of about 80kt. A straight-in approach to the platform was made; the pilots could see the yellow perimeter lighting of the helideck against the white platform lighting, but it was not very conspicuous. The aircraft slowed to 50kt and the pilots began to determine the helideck orientation but found it was difficult to define the shape.

The aircraft was at a height of 300 ft, which meant that the viewing angle which determines the width of the ellipse created by the helideck perimeter lighting was initially too small. At about 0.5NM the oval shape started to appear. As the aircraft was closing to the helideck at about 40kt, though the platform structure gave good closure rate cues the helideck did not. The aircraft then moved over the helideck and landed. All through the run the aircraft landing light was switched off but the searchlight, which was steerable, was left on. After landing, the next run configuration was called for to allow the equipment configuration to be switched on and checked while the pilots were completing the questionnaire.

The pilots stated that the platform acquisition range would probably be 5NM if the approach started further out, as visibility for the test period was good. They positively located the helideck from 1 to 1.5NM away. The RHS pilot knew in detail what cues were being sought, hence the RHS pilot located it before the LHS pilot. The pilots could see the yellow perimeter lights, but no shape. They used the platform rather than the helideck itself to gain the main closure rate cues.

It was not until 0.125NM from the platform that the pilots really concentrated on the helideck and used that for closure and height cues. Once the aircraft was within 100ft of the platform the LHS pilot had to work hard to get the lateral/ longitudinal position over the helideck. Both pilots were happy with the intensity of the perimeter lighting.

To enable this run to be used as the baseline for all the other configurations, scores of **5** were given for the **workload** and **presentation** ratings for all four phases of the approach and landing.

Run 2 – Green Perimeter Lights and Floodlights.

The approach was made from 2.5NM. The aircraft searchlight was on throughout the run. The green perimeter lights could be seen as soon as the approach was started. The helideck was definitely separated from the other platform lighting, which was red and white. The pilots both agreed that the location of the helideck was obvious.

At a speed of 60kt and just under 1.5NM away, the helideck was very clearly visible. The helideck shape started to appear at about 1NM. This time the aircraft approached the helideck at a height of about 400ft. This meant the oval created by the helideck lighting pattern was much more obvious. At 0.75NM there was a definite shape appearing. The floodlights interspersed with the green perimeter lights stood out obviously as being associated with the helideck; they also helped to produce closure rate cues.

Both pilots agreed that the acquisition of the helideck was much quicker hence, for the **acquisition** phase, a score of **7** was awarded for **presentation** and **4** for **workload**. The **approach presentation** was much better and was given a **6**, with a **workload** of **5**.

When the aircraft was close to the helideck, the visual cues were found to be not too dissimilar to those provided by the yellow perimeter lights with the floodlights on. Some texture was gained from the helideck. The green lights were picked out easily and the shape was seen sooner at 0.75NM rather than 0.5NM for the yellow lights. The pilots could differentiate the helideck from the platform. The RHS pilot liked the green lighting better than the yellow, as it was easier on the eye. Both pilots stated that the green lights did not dazzle them as the yellow lights did. For the **hover,** a score of **6** was awarded for **presentation** and **5** for **workload**. For the **landing**, the **presentation** received a score of **6** and a **workload** rating of **5**.

This configuration was better initially, and the pilot gained more helideck orientation and shape information. It was stated that depth perception was improved because of the white lights on the superstructure below the green lights on the helideck. This also helped with lateral/ longitudinal definition.

Run 3 – Yellow Perimeter Lights and Green Electro-Luminescent 'H'

The searchlight was angled downwards as there was a lot of moisture in the air and it can present a source of glare. From 2NM at a height of 500 ft and an airspeed of about 80kt, the helideck perimeter lighting could be seen, but mainly because the pilot now knew where to look in relation to the overall view of the platform. At just under 2NM the green 'H' could not be seen.

The helideck was picked up quite easily at about 1NM range but the pilot was still unsure of its shape or size. At just under 1NM there was still no visual contact with the ‘H’ but, with the aircraft at a height of 450 ft and an airspeed of 60kt, it was noted that the oval began to “open out”. The pilot then started to receive good rate cues from the oval. By 0.4NM the ‘H’ became visible. As the aircraft moved closer to the helideck in the final stages of the approach, the ‘H’ began to produce good depth perception cues. As the aircraft moved over the helideck, the ‘H’ disappeared from view. The aircraft then landed.

For this approach, the helideck was seen from 2NM. The lack of floodlights improved the ability of the pilots to see the helideck as the floodlights hindered both pilots on the two previous runs. Both pilots preferred to have no floodlights as they impeded early acquisition of the helideck shape. This is because the floodlights effectively camouflage the perimeter lights amongst the other platform lighting, and the pilots could not identify the helideck.

The final approach phase was deemed to start from the point when the ‘H’ was seen. During the final stages of the approach, the ‘H’ became a very valuable cue as it provided very good closure rate information; the pilots both commented that they used the ‘H’ a lot. They would both prefer a larger ‘H’ to allow even more information to be derived from it. This was because it was positioned exactly where the RHS pilot was looking and so he was scanning the edge of the ‘H’ continually and was totally focused on it. It was a very important feature.

For the **acquisition** phase, the **presentation** rated **7** and **workload 4**. The **presentation** was much clearer on the final **approach** than the previous runs and was rated **8** with the **workload** rated **4**. The ‘H’ was lost under the aircraft as it crossed the helideck to land. The lack of textural cues on this helideck was not good.

During the **hover** over the helideck before landing, the pilots awarded a score of **6** for the **presentation** of the configuration and **4** for the **workload**. The **same ratings** were also given for the **landing** phase.

Both pilots agreed that the lack of floodlighting on the helideck helped, by not adversely affecting, the pattern of the perimeter lighting. The ‘H’ did not become useful until 0.75 to 0.5NM away. There was a window of opportunity for looking at the ‘H’ and good cueing was gained within it. Both pilots were much happier without the floodlights as the ‘H’ gave much better perception of height, position, closure rate, etc.

Run 4 – Green Perimeter Lights and Green Electro-Luminescent ‘H’

The weather conditions remained the same as for the previous runs. The pilots commented that, through conducting a series of approaches, they felt that they were quickly becoming experts at landing on this helideck.

At 2.5NM from the platform, the pilots could make out the helideck against the rest of the superstructure. The green lighting was very dominant at 2NM. Both pilots thought that the green lighting was so much better than the yellow lighting because it made the helideck location more obvious. At a height of 500 ft and an airspeed of 80kt, the aircraft made a good approach with the pilots receiving good depth perception cues. At just over 1NM the helideck took on a definite shape.

At 0.4NM and a height of 300 ft the ‘H’ came into view. By 0.3NM and at a height of 250ft the pilots had locked onto the ‘H’. The ‘H’ then gave excellent information on depth perception, range and rate of closure. Again, they commented that they would prefer the ‘H’ to be bigger. (The ‘H’ is the same size as the painted ‘H’ on the helideck, which was smaller than normal - 3 m x 2 m as opposed to the more usual 4 m x 3 m). The aircraft then moved over the helideck and landed.

The final approach was deemed to have commenced from the point on the approach when the 'H' was seen. There was a period during the approach when the pilots received very useful information from the helideck, especially rate of closure and height. If the 'H' was larger, the pilots would have this information for longer. At 0.4NM the 'H' gave a very good angular perspective of the approach, but it was short lived. It cannot be used as a landing aid as it is out of view below the aircraft during this phase.

The 'H' on the final approach was definitely better than the floodlights but the pilot still had difficulties in obtaining textural cues from the helideck. The 'H' was a more usable cue as it did not have the glare problems associated with the floodlights. This increased the pilots' confidence as everything could be seen and there were no sudden changes in the visual cueing environment.

During the **acquisition** phase, a rating of **9** was awarded for the **presentation** and a rating of **4** for the **workload**. A rating of **8** was given for the **presentation** of the helideck during the **final approach** phase with **3** as the **workload** rating. For both the **hover** and **landing**, scores of **8** were given for **presentation** with **4** awarded for **workload**.

Both pilots commented that they thought this to be the best configuration evaluated so far.

Run 5 – Green Perimeter ELPs and 'H'

For this run, the moon had come out slightly and the pilots could see the sea.

At about 2.7NM, the pilots could not distinguish the helideck but they could see the superstructure. At 1.85NM the green lighting was visible but it was not obvious as a helideck. It was quite disturbing for the pilots not to be able to see the helideck so they concentrated on the white platform lights. At 1NM out there was still no helideck and therefore the pilot had no depth perception.

From 0.7NM the pilot could see the helideck but could not make out its shape. The brightest cue was the 'H' which, at 0.4NM, was beginning to appear. The pilot had to overshoot this approach due to the lack of closure rate information as the lighting was so dim. It was not until the last minute that the pilot realised the aircraft was approaching the helideck excessively fast and the approach was abandoned.

The pilot then tried to approach the helideck again. At approximately 1.5NM the aircraft turned back towards the platform. At 1.3NM, there were no real depth cues from the small amount of green lighting. The cueing was not very good as the pilot was still having trouble deriving the relevant information. The pilot was locating the helideck but there was no shape at 0.7NM. At 0.4NM, the helideck shape was acquired but it was very dim while the 'H' was dominant. The pilot was receiving good information from the 'H' while at an airspeed of 40kt. Good helideck perimeter cues were obtained as the shape of the helideck was well defined. In addition, there was no glare as there had been with the floodlights.

The helideck was still lacking some textural cues but the 'H' did give the pilots more to look at. The perimeter ELPs needed to be brighter. It was still difficult to land the aircraft the second time round because of the lack of textural cues. This configuration demonstrated the importance of the perimeter lights. As the perimeter ELPs and the 'H' were of different intensities, the helideck lighting provided useful depth perception and rate closure information. Both pilots were expecting this run to be the best in terms of usable visual cues and were surprised by the outcome.

The rating given during the **acquisition** phase for the **presentation** was **1** and **6** for the **workload**. For the **final approach**, a **2** was given for **presentation** and a **7** for

workload. The **presentation** of the **hover** was rated **6** and **5** for the **workload** while the **landing** was rated **5** for **both** the **presentation** and **workload**.

The aircraft returned to K14C to refuel after run 5. The wind, had by now, increased to about 10 to15kt.

Run 6 – Floodlights, Green Perimeter ELPs and 'H'

The aircraft approached the platform on the same heading as before, i.e. 070. At 2NM out, at a height of 500 ft and an airspeed of about 80kt, the pilots could see the platform but not the helideck. At 1.5NM, there was still no helideck information. At 0.75NM, the floodlights were having the effect of washing out the green perimeter ELPs and distorting the shape of the helideck. The pilot had to adjust the speed of the aircraft due to the lack of closure rate information. The 'H' could be seen but the helideck orientation could not be judged. The approach presentation was worse than the previous run and the workload was quite high due to the noticeable lack of closure rate information.

In the final stage of the approach at about 0.4NM, the 'H' became a major source of visual cues. At 0.25NM, the deck shape was still not obvious. It is very important that the pilot knows the shape of the helideck as the continuity of the shape is used for descent path information. At one point, the helideck looked skewed which confused the pilot. The pilots felt that the ELPs needed to be nearer to each other to make the pattern more obvious. Again, the pilots commented that the floodlights distorted the green perimeter lighting and caused glare.

Due to the glare problem from the floodlights, the **presentation** rating for the **acquisition** phase was **1** with a **workload** of **7**. This meant that the **final approach** also scored poorly for **presentation** with **2** and, again, a **workload** score of **7**. The **presentation** for the **hover** rated **4** with **6** for the **workload**. For the **landing**, both the **presentation** and **workload** scored **5**.

Run 7 – Green Perimeter Lights, Green Perimeter ELPs

This run was not flown.

Run 8 – Green Perimeter Lights, Green Perimeter ELPs and Floodlights

The helideck was recognisable at 2NM at a height of 500ft and an airspeed of 80kt. At 1NM the pilots could just make out the shape of the helideck. A definite shape was starting to be defined at 0.75NM. The floodlights were, once again, degrading the shape of the helideck. With the aircraft slowing down to about 40kt, from 0.5NM the helideck was providing good cues.

The platform was obvious at 2NM mainly because of the green perimeter lighting and the floodlights. The white floodlights masked the shape of the helideck, however, and prevented optimum cueing during the final approach. The floodlights were more useful when the aircraft was hovering as they were providing textural cues. Lack of textural cues is a problem on the K14B helideck. The perimeter ELPs were seen at 0.6NM and the 'H' at 0.4NM. On landing, the green perimeter lights did not glare, but the floodlights did a little.

The RHS pilot preferred to use the aircraft searchlight to light the helideck initially and then use the helideck level floodlights. The lack of the 'H' did not help the textural cueing environment.

The rating of the **presentation** for the **acquisition** phase was **7** with a **4** for **workload**. For the **final approach** stage the **presentation** rated **6** and the **workload** **4**. As the pilot was receiving good cueing from the helideck, the **hover presentation** rated **8** and the **workload 3**. The **landing** rated a **7** for **presentation** and a **4** for **workload**.

Run 9 – Green Perimeter Lights, Green Perimeter ELPs and 'H'

From 2NM the helideck could be distinguished. At 1NM at a height of 500ft and an airspeed of 60kt the helideck shape was starting to form. At 0.8NM a definite shape was appearing. At 0.65NM, the helideck shape looked good and was better without the floodlights distorting it. Good depth perception and speed cues were gained. The perimeter ELPs and 'H' appeared at about 0.2NM but the green perimeter lights dominated and provided the most cues. Good depth perception and rate of closure cues made the approach and landing a lot easier. During the hover, the 'H' illuminated the helideck very effectively, but its usefulness was degraded as it disappeared from view under the aircraft.

This configuration was good but more textural cues were needed. The pilots were impressed by this configuration and rated the **presentation** for the **acquisition** phase with a **9** and a **4** for the **workload**. The **final approach** and **hover** both scored a **9** for **presentation** and a **3** for **workload**. The rating of the **presentation** for the **landing** was reduced slightly due to the lack of textural cues but still gained an **8**, and a **3** for **workload**.

Run 10 - Yellow Perimeter Lights, Green Perimeter ELPs and 'H'

This run was not flown.

Run 11 – Green Perimeter Lights, Green Perimeter ELPs, 'H' and Floodlights

This run did not form part of the original trial plan and was added during the trial. It was decided to include this configuration after the comments made regarding lack of textural cues during the previous run. At 1.75NM a definite acquisition of the helideck was made. The green perimeter lights outlined the helideck very well. From 1NM the helideck was obvious but the shape was still uncertain. From 0.6NM the helideck shape became much more obvious. The 'H' and perimeter ELPs could be seen from 0.3NM, it looked very good and there were good textural cues alongside the floodlights. As the aircraft was coming into the final hover, the cues looked very good and the pilot was very confident about landing on the helideck. The pilots stated that even in the rain they would be happy landing with this configuration.

Again, the 'H' was lost under the aircraft as it moved over the helideck. The floodlights were providing good textural cues during landing, but the pilots thought that these could be better generated by other equipment.

During the approach, the floodlights destroyed the shape of the helideck but, because the helideck was covered in guano, during the hover and landing they did provide sufficient textural cues.

The pilots stated that this was the best configuration that they had seen for this helideck, but commented that they would still like to see better textural cues during the landing phase.

The textural cues from the floodlights were very good in the hover and did not dazzle the pilots too much as they were trying to land, but the landing was spoilt by the sharpness of the floodlights.

This run gained the best ratings with an **8** for the **presentation** in the **acquisition** phase and a **4** for **workload**. During the **final approach** the **presentation** gained a **9** and the **workload** a **3**. These ratings were also given to the **hover** phase. The **landing** scored an **8** for **presentation** and a **3** for the **workload**.

On completion of Run 11, the NAM personnel rejoined the aircraft for the return journey to K14C. The pilot commented that K14C/ P was a welcoming sight after flying to the small satellite. The green perimeter lights installed on K14P stood out well against the cultural lighting. The NAM platform personnel disembarked from the aircraft and the remainder of the trials team continued back to North Denes, UK.

2.3 Summary of lighting configurations and ratings

The lighting configurations evaluated during the 1st flight trial are summarised in Table B1, and the corresponding presentation and workload ratings in Table B2.

A baseline of 5 was allocated to Run 1. The higher the rating of the presentation, the more effective the configuration. This is inverted for the workload ratings, with a higher score representing an increased workload for the pilot.

Table B1 Equipment Configurations for Trial 1

Run	Config.	Flood lights	Yellow Perimeter Lights	Green Perimeter Lights	Perimeter ELPs	ELP H
1	(a)	✓	✓	-	-	-
2	(b)	✓	-	✓	-	-
3	(c)	-	✓	-	-	✓
4	(d)	-	-	✓	-	✓
5	(e)	-	-	-	✓	✓
6	(f)	✓	-	-	✓	✓
7	(l)	-	-	✓	✓	-
8	(g)	✓	-	✓	✓	-
9	(h)	-	-	✓	✓	✓
10	(i)	-	✓	-	✓	✓
11	(n)	✓	-	✓	✓	✓

Table B2 Trial 1 Ratings

Run	Config.	Helideck Acquisition		Final Approach		Hover		Landing	
		Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work Load
1	(a)	5	5	5	5	5	5	5	5
2	(b)	7	4	6	5	6	5	6	5
3	(c)	7	4	8	4	6	4	6	4
4	(d)	9	4	8	3	8	4	8	4
5	(e)	1	6	2	7	6	5	5	5
6	(f)	1	7	2	7	4	6	5	5
7	(l)	-	-	-	-	-	-	-	-
8	(g)	7	4	6	4	8	3	7	4
9	(h)	9	4	9	3	9	3	8	3
10	(i)	-	-	-	-	-	-	-	-
11	(n)	8	4	9	3	9	3	8	3

3 2nd Flight Trial (Pilot Comments)

3.1 Introduction

The second K14B flight trial was conducted on 25th April 1999. The aircraft used for the trial was a BHL Sikorski S76B flown by two BHL pilots. A CAA pilot was present but did not fly the aircraft. This unfortunately reduced the comments that the CAA pilot was able to make, as his view from the aircraft was restricted. The comments included here are those of the BHL pilots.

All approaches were made from 055; the wind speed was 20kt with a direction of 050. The cloud base was 3000 ft. Visibility was 5NM (K14C could be seen from K14B) but there was no moon due to the haze. There was no visible horizon. As for the 1st trial, the baseline scores (i.e. for Run 2) were set at 5, although configuration (b) was actually evaluated first as problems were initially experienced in setting up the lighting for the baseline configuration (a).

The first part of the trial comprised repeat runs, with different pilots, of the more successful configurations from the first trial. The second part of the trial (i.e. from Run 6 onwards) was to assess a number of different configurations of perimeter lighting during the final stages of the run. All of these runs were therefore started from 1NM range.

3.2 Lighting Configurations

Run 1 – Floodlights and Green Perimeter Lights.

The run was started from 2NM at a height of about 500ft and an airspeed of 90kt. The complete platform could be identified from 2NM away. The green perimeter lights could be seen from 1.75NM and a height of 450 ft but they were not forming a pattern. At 1NM away there was still no real depth perception gained from the lighting. At 0.75NM and a height of 400ft, the helideck was conspicuous and could be recognised as such.

The pilots felt that the green perimeter lighting did not give as many useful cues about the shape of the helideck as the standard yellow perimeter lights, which gave a better circle.

For the **acquisition** phase, both the **presentation** and **workload** scored **5**. The **presentation** for the **final approach** rated **4** and the **workload** rated **5**. All ratings for the **hover** and **landing** scored **5**.

The baseline configuration (a) could now be set up. The pilots commented that it would have been better if the trial had started with the yellow perimeter lights of the standard helideck lighting.

Run 2 – Floodlights and Yellow Perimeter Lights

The pilot could see a line of red lights in the area of the platform; these were the obstacle lights on the crane. This information helped to locate the helideck. At 1.7NM and a height of 480ft, a flat circle of yellow lights could just be made out. By 1.4NM out with an airspeed of 80kt, a clearer definition of the helideck was visible. It could be distinguished from the rest of the platform.

As this was the baseline run all phases rated **5**. The pilots felt that their workload was slightly less than for Run 1.

Run 3 – Floodlights, Green Perimeter Lights and Electro Luminescent 'H'.

From 2NM and a height of 500 ft, the red obstacle lighting of the crane and the white floodlighting could be seen but there was no definite image of a helideck. At 1.7NM the helideck mounted floodlights could be distinguished from the existing platform lighting. At 1.5NM and a height of 450ft the green perimeter lighting could be seen but still no definite shape could be determined. At 0.8NM, the green perimeter lighting on the helideck could be seen but the white floodlights were degrading the cues provided by it.

The ‘H’ could be seen from 0.4NM and a height of 300ft. The pilots stated that although the ‘H’ looked good and was useful, in the hover and landing stages it disappeared under the aircraft. This was when they needed it the most. When landing the aircraft, the pilots commented that they did not look at the helideck lights but that they looked down onto the helideck surface.

They thought that the source of the green perimeter lights appeared smaller than that of the yellow lights.

For the helideck **acquisition** phase, the **presentation** scored only a **3** and the **workload** a **6**. The **final approach presentation** rated a **6** and the **workload** a **4**. The **hover** and **landing** phases both rated **5** for the **presentation** and **workload**.

Run 4 – Green Perimeter Lights and ELP ‘H’

The K14C could still be seen from K14B. The visibility had therefore not changed significantly, although it was still hazy.

At 2NM and a height of 500 ft, a few green lights could be seen near to the bright red lights of the crane. There was no definition but it was known to be the helideck. The rest of the platform was brighter than the helideck. By 1.3NM the green lighting was more obvious but the definition of the helideck was poor. At 1NM, the perimeter lighting started to form a shape but it was not a definite circle. At 0.9NM and a height of about 450ft, a definite green helideck was located.

The pilots stated that they did like the green perimeter lights with the ‘H’, but they thought the green lights needed to be brighter. During the hover, the pilots commented that the helideck was much darker. The platform lighting below the helideck was bright, and overpowered the green perimeter lighting.

Again, as the aircraft moved into a hover above the helideck, the ‘H’ disappeared under the aircraft. The pilots stated that from about 0.3NM and a height of 300 ft the ‘H’ was a useful, distinct cue. The pilots had been discussing the ELP ‘H whilst the aircraft was refuelling and decided that they were favourably impressed by the ELP ‘H’ as an aid.

The **rating** given to the **presentation** for the **acquisition** phase was **4** with a **6** for the **workload**. The **presentation** for the **final approach** was **7** and **4** for the **workload**. The **presentation** for the **hover** rated a **5** with a **4** for the **workload**. The **landing** phase **presentation** rating was **3** with a **5** for the **workload**.

Run 5 – Green Perimeter Lights, Helideck Perimeter ELPs and ELP H

At 1.8NM, a green glow could be seen coming from the area of the helideck but there was no definite pattern. This had not changed at 1.5NM, but by 1NM there was a definite shape to the perimeter lights. At 0.5NM, a height of 350ft and an airspeed of 60kt the ‘H’ could not be seen. By 0.3NM and a height of 300ft it was visible although it was not obvious that is was an ‘H’. By 0.2NM, a height of 300ft and an airspeed of 60kt the shape of the ‘H’ was clear.

During the hover phase of the run, the pilots commented that the ELPs located around the perimeter of the helideck made no contribution to the visual cueing. They were not acquired until 0.1m and a height of 150ft. The landing light was switched on in the final stages, as the searchlight would normally be used during the approach.

The pilots both said that they liked the 'H' but that when they needed the cues it provided it was out of sight below them. They also stated that their personal preference was for the floodlights to be switched on and that they did not experience glare problems. They personally had few problems acquiring the helideck with the floodlights on. During the hover the perimeter ELPs could not really be seen; they were not noticed until the aircraft was on the helideck.

For the **presentation** for the **acquisition** phase, a score of **3** was given with a **7** for the **workload**. For the **final approach presentation**, a rating of **4** was given with **5** for the **workload**. The **presentation** for the **hover** rated **4** with a **5** for the **workload**. Both the **presentation** and **workload** of the **landing** rated **5**.

Run 6 – Green Perimeter Lights

At 1NM and a height of 450 ft the helideck could be vaguely distinguished. At 0.6NM the pilot could only see the front edge of the helideck. At 0.5NM and a height of 350ft the circle formed by the perimeter lights was well defined and "very crisp".

During the hover, the pilots were asked to state what cues they were using to land the aircraft. They said that they just looked at everything around them and that they used what was there. Once on the helideck they both agreed that the green perimeter lighting was not as harsh as the yellow, but that was because they were too dim. They both stated that they would accept flying to a platform that had green helideck perimeter lighting as long as it was brighter.

The **presentation** for the **final approach** stage rated **4** and the **workload** rated **6**. Both the **presentation** and **workload** scores for the **hover** and **landing** rated the baseline **5**.

Run 7 – Green Perimeter Lights and Perimeter ELPs

At 1NM and a height of 480 ft, most of the green perimeter lights could be seen although not as a complete circle. At 0.7NM, a height of 450ft and an airspeed of 70kt a definite helideck shape could be seen. Both pilots said that it looked a clear, concise helideck. They confirmed that the perimeter ELPs made no useful contribution as they were not bright enough and the viewing angles were too shallow to be seen from normal operational distances. They were not seen until 0.1m and a height of 160 ft.

A comment made by the pilots was that when they were approaching the helideck and the heading of the aircraft was oscillating slightly, the helideck appeared to move round. They said that it was the ELPs that appeared to make the helideck spin. This effect was very disorientating and the ELPs distracted them. This increased the pilot workload, which was reflected in the ratings.

The **presentation** for the **final approach** phase rated a **2** and an **8** for the **workload**. The **presentation** and **workload** for both the **hover** and **landing** rated **5**.

Run 8 – Green Perimeter Lights, ELP 'H' and Green Perimeter LED Strips

At 1NM away, the helideck could be seen but it was not well defined. By 0.7NM, a distinct shape had appeared and the circle formed by the perimeter lighting was obvious. At 0.5NM and a height of 400 ft, the 'H' could be seen in the centre of the helideck but it appeared as a diffuse area of light rather than a distinct shape. At 0.3NM the 'H' became a definite shape in the middle of the helideck.

Both pilots commented that when they saw the LED strips on the helideck their attention was drawn to them, and that they provided useful information about the shape of the helideck. They thought that this combination of equipment was the best so far. During the final approach at about 0.2NM and a height of 250ft, the pilots commented that the perimeter LED strips certainly helped provide cues about the closure rate of the aircraft and the descent angle.

It was unanimously agreed that the LEDs were much better than the perimeter ELPs as they were a “crisper, cleaner green”. They also preferred them as the individual LEDs could be seen at short range through the extruded strip, which provided more short range, fine texture due to the resulting dotted line rather than the continuous lines of the ELPs. The LEDs made the ELPs look “wishy-washy”. The presentation of this configuration was much better and this was reflected in the ratings.

The **presentation** for the **final approach** phase rated **7** and a **4** for the **workload**. The **hover presentation** was **6** with **5** for the **workload**. Both the **presentation** and **workload** of the **landing** phase rated the baseline score of **5**.

Run 9 – Perimeter ELPs and ELP ‘H’

From 1.2NM, the helideck area was a black hole; no lighting could be seen. When the aircraft was at 1NM and at a height of 500ft from the helideck there was still no definition to the helideck. From 0.8NM, still no lighting could be seen. At 0.4NM and a height of 400 ft, lighting could be seen on the helideck but there was no real definition. The ‘H’ could only be seen as a diffusely lit area but showed the location of the helideck amongst the platform’s cultural lighting.

At 0.2NM, a height of 300ft and an airspeed of 50kt, the perimeter ELPs were becoming more obvious and a pattern was beginning to emerge. The helideck was visible to the pilots, however they were not happy completing the run without sufficient helideck lighting, and an overshoot was performed. No ratings were given for this configuration.

Run 10 – Green LED Strips

At 0.9NM, green lighting could be seen on the helideck. By 0.7NM and a height of 400ft, a definite shape to the helideck had appeared and by 0.3NM, at a height of 400ft and an airspeed of 60kt the lighting strips had become very bright.

The pilots both commented that, with just a quarter of the helideck perimeter covered, the LED strips gave more useful cues than a complete set of helideck perimeter ELPs. They both commented that it was unfortunate that the whole helideck could not be lit like this for the trial. Both of the pilots really liked the LED strips and supported their use.

They thought that the colour was much more easily differentiated than that of the ELPs, and that the LEDs gave a “much sharper” view of the helideck. They also preferred the fact that the strips comprised point sources rather than extended light sources, since this provided micro texture at short range.

An overshoot was performed again for this configuration, as landing on this platform was not possible due to the reduced perimeter lighting. The pilots thought that the lighting presented was a significant improvement to the cueing environment, even though a completely illuminated perimeter was not available for the test. No ratings were given for this configuration.

Additional Run – Approach To K14P

Following Run 10 the aircraft returned to K14C/ P. Due to the prevailing wind direction the aircraft was unable to land on K14C and therefore had to land on K14P. This gave the pilots the opportunity to compare the green perimeter lighting on K14B with the green perimeter lighting on K14P.

From 2.5NM away K14P could be seen. At 1.7NM away, the helideck could be seen quite clearly but it was still lacking complete definition. The floodlights were distorting the cues gained from the perimeter lighting. By 0.7NM there was a definite helideck pattern visible.

The pilots commented that the cultural lighting on the platform was far too bright and was drawing their attention away from the helideck. The pilots liked the green perimeter lighting installed on the helideck, as it appeared to be brighter than the lights on K14B. During the hover and landing phases of the run, the floodlights were far too bright and distracted the pilot whilst landing the aircraft.

3.3 Summary of lighting configurations and ratings

The lighting configurations evaluated during the 2nd flight trial are summarised in Table B3, and the corresponding presentation and workload ratings in Table B4.

A baseline value of 5 was allocated to Run 2. The higher the rating of the presentation, the more effective the configuration. This is inverted for the workload ratings, with a higher score representing an increased workload for the pilot.

Table B3 Equipment Configurations for Trial 2

Run	Config.	Flood lights	Yellow Perimeter Lights	Green Perimeter Lights	Perimeter ELPs	ELP H	Green LED strips
1	(b)	✓		✓			
2	(a)	✓	✓				
3	(j)	✓		✓		✓	
4	(d)			✓		✓	
5	(h)			✓	✓	✓	
6	(k)			✓			
7	(l)			✓	✓		
8	(m)			✓		✓	✓
9	(e)				✓	✓	
10	(o)						✓

Table B4 Trial 2 Ratings

Run	Config.	Helideck Acquisition		Final Approach		Hover		Landing	
		Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work load
1	(b)	5	5	4	5	5	5	5	5
2	(a)	5	5	5	5	5	5	5	5
3	(j)	3	6	6	4	5	5	5	5
4	(d)	4	6	7	4	5	4	3	5
5	(h)	3	7	4	5	4	5	5	5
6	(k)	-	-	4	6	5	5	5	5
7	(l)	-	-	2	8	5	5	5	5
8	(m)	-	-	7	4	6	5	5	5
9	(e)	-	-	-	-	-	-	-	-
10	(o)	-	-	-	-	-	-	-	-

4 3rd Flight Trial (Pilot Comments)

4.1 Introduction

The final flight trial was conducted on 17th October 1999. The aircraft used for the trial was a BHL Sikorsky S76B. The CAA test pilot flew from the left-hand seat. Since the previous trial in April 1999, a number of changes had been made to the lighting equipment installed on the helideck.

a) The green perimeter light units were relamped with the same flourescent sources as the yellow perimeter lights to restore the output intensity and improve the colouring.

b) Extruded plastic strips containing yellow Light Emitting Diodes were installed. These were of the same type as the green LED strips that had been evaluated in the second trial as perimeter lighting. The yellow strips were installed around the inner and outer edges of the Touchdown Marking circle to form two concentric broken rings, each made up of sixteen strips.

c) Metal hoods were fabricated for installation on the floodlights in an attempt to address the problem of glare.

d) Although not actually removed, the perimeter ELPs were not evaluated during this trial.

The objectives of this trial were therefore both to repeat certain of the previous runs with a third flight crew, and to evaluate the changes and additions to the lighting equipment.

At the start of the trial there was a half moon and no clouds. The wind was approximately 25kt from a direction of 090. Visibility was more than 10NM. As before, the baseline scores were set to a value of 5. The aircraft landing light was on for all the runs unless stated otherwise in the following paragraphs.

4.2 K14B Configurations

Run 1 – Floodlights and Yellow Perimeter Lights

Although there was a half moon, the evening was quite dark and many textural cues normally available from the sea were not present. The aircraft started its approach from 2NM on a heading of 090 and at a height of 650ft. The platform was located immediately. At this stage the helideck could not be seen, but the red obstacle lights on the crane, the white platform lighting and the flashing beacon were visible. The pilots commented that the white floodlights were blending with the yellow perimeter lights and a definite helideck shape could not be determined. At 1.4NM and a height of 500ft, the yellow perimeter lighting started to appear. This could be seen as a flat line of yellow lights.

By 1.1NM and a height of 400ft the line was starting to split and the near and far edges could be distinguished. By 0.85NM, the pilots were convinced that what they were looking at was the helideck. There were no problems with the floodlights at this stage. At 0.25NM a slight blurring of the yellow and white floodlights on the far side of the helideck became apparent. The two floodlights facing the aircraft were seen to be degrading the information from the yellow perimeter lights.

Once the helideck was acquired, the available lighting did not offer any other information to the pilot. The left-hand seat pilot was unsure of the speed of the aircraft as only very limited closure rate cues were available, which made the aircraft appear to be travelling faster than it was.

This run was given baseline ratings of **5** for the **presentation** and **workload** for all phases of the approach and landing. Pilots commented that this landing was easier than a standard baseline operation as the LED strips on the helideck improved the cueing even though they were not switched on.

Run 2 – Floodlights and Green Perimeter Lights

The aircraft turned onto the approach at a range of 2.5NM and a height of 600ft and the pilots could instantly identify the helideck. Both pilots stated that the improved acquisition range of the helideck resulting from the use of the green perimeter light greatly increased their confidence during the approach.

As the aircraft progressed into the final approach phase, the pilots commented that although the platform lighting was not causing them problems the floodlights on the right hand side of the helideck were obscuring the perimeter lighting. At 1.22NM and a height of 500ft two strips of green lights could be seen. By 1.05NM, the helideck shape was starting to form an ellipse, which improved the closure rate and angular information that the pilots received. By 0.5NM, the helideck perimeter lights formed a very distinctive shape. As the aircraft approached at a range of 0.41NM, the floodlights were no longer a problem as the 'look down' angle had steepened. The aircraft moved into the hover position; the green perimeter lights provided no more information than the yellow perimeter lights at that range. Overall, the pilots much preferred the green perimeter lighting.

For the **presentation** for the **acquisition** phase a rating of **8** was given. The **workload** rated **4**. The **final approach presentation** rated **6** and **4** for the **workload**. Both the **presentation** and **workload** of the **hover** and **landing** phases rated a **5**.

Run 3 – Floodlights, Green Perimeter Lights and ELP 'H'

The aircraft turned onto the approach at 2.5NM and a height of 650ft and, again, the green perimeter lighting was instantly recognisable even though the floodlights were still degrading their effect. By 0.8NM, 480ft the elliptical shape of the helideck perimeter lighting was appearing. Both pilots commented that it was comforting to know the location of the helideck even if the true shape was not obvious.

By 0.33NM and a height of 300ft, the 'H' had appeared, but could only be seen by the pilot in the right hand seat. The LHS pilot's view of the 'H' was adversely affected by the floodlights as one unit sat directly above it. During the final approach phase at 0.11NM and a height of 200ft, the pilots were using the angular information provided by the 'H' and the elliptical shape formed by the perimeter lights. This produced a good perspective of the helideck enabling the position of the aircraft relative to the helideck to be judged.

The pilots commented that they felt secure during the last 100ft of the descent to the helideck as the closure rate cues were improved greatly compared to the standard lighting system. This configuration also helped the pilots orientate themselves over the helideck.

As the aircraft moved into the hover and was positioned over the helideck the 'H' was lost from view under the aircraft. During the landing phase, the cues previously obtained from the 'H' were unavailable, but their comment "if you can't see it you're in the right place" summed up their enthusiasm.

Previously, the only source of aspect information was the ellipse formed by the perimeter lights. The pilots stated that the ELP 'H' was providing that information and they liked the concept of having a large illuminated green 'H' in the middle of a dark helideck.

As the aircraft returned to K14C (which has yellow perimeter lighting) to refuel, both pilots commented that it would be very useful to have the illuminated 'H' on this helideck. This gave a clear indication that that both pilots rated the ELP 'H' highly as an aid.

The ratings for the **acquisition** phase were good with **presentation** getting **8** and the **workload 4**. The **presentation** for the **final approach** rated **7** and the **workload 3**. Again, the **presentation** and **workload** for the **hover** and **landing** rated **5**.

Run 4 – Floodlights, Green Perimeter Lights and Yellow LED Strips

It was starting to turn slightly cloudy at this stage of the trial but the visibility was still 10NM. The aircraft started the run from 2.2NM and 600ft. As the aircraft turned onto the approach, the green perimeter lights were instantly recognisable. The floodlights were still obscuring the full effect of the perimeter lights and the shape of the helideck, but the perimeter lights still stood out well due to the colour contrast between them and the rest of the platform lighting.

The aircraft maintained height during the approach and the pilots commented that the steeper aspect improved the cues gained from the lighting. When viewing the helideck from a lower height, the platform lighting reduced the effectiveness of the helideck lighting. The platform cultural lighting also threw ambient light onto the sea. This, together with some illumination of the platform superstructure, helped provide closure rate information to the pilots.

During the final approach phase, the circle became obvious at a range of 0.4NM and a height of 400ft. The floodlights on the right hand side of the helideck reduced the level of cues provided by the LED strips. At 0.18NM and a height of 250ft, the circle looked "excellent". The gaps between the LED strips gave useful information about the rotation of the aircraft in relation to the helideck. The LED strips also produced information on relative elevation as the pilot could make a judgement based on the apparent flatness of the circle. Both pilots liked this feature of the visual cues.

As the aircraft moved over the helideck into the hover at a height of 30ft, the individual LEDs in the strips could be seen. The strips then appeared as strings of point sources with the benefits this brings in terms of textural cues. The LED strips also improved the pilot's confidence as they highlighted the helideck markings. The strips were rated as being comparable to a net in terms of providing texture, with the strips being the preferred means.

The right hand seat pilot stated that, for a split second, the view of the Touchdown Marking circle is lost as the aircraft moves into the hover. During the landing phase, the ability to clearly see the landing circle increased the confidence of the pilots. It was noted that the helideck floodlights merged with the platform lighting directly below the helideck. Both pilots said that the platform lighting was useful as it highlighted the superstructure. Although it provided additional information about the scene, they said that there should be a definite gap between this lighting and the helideck floodlights.

The rating for **presentation** for the **acquisition** phase was **8** with **4** for the **workload**. The **final approach presentation** rating was **8** and **3** for the **workload**. The **presentation** of the **hover** rated a **9** with **3** for the **workload**. **8** was given for the **landing presentation** and **3** for the **workload**.

Run 5 – Floodlights, Green Perimeter Lights, ELP 'H' and Yellow LED Strips

The approach heading changed slightly to 110 degrees due to a change in wind direction.

The green perimeter lights were seen as soon as the aircraft turned onto the approach at 2NM and a height of 600ft. Once again, their effect was degraded by the floodlights on the far side of the helideck. By 0.62NM, the perimeter lights had opened into a definite ellipse and the LEDs were also visible. By 0.41NM and height of 500ft the LED circle was very distinctive and the 'H' could be identified. The floodlights were affecting the conspicuity of the 'H'. The two systems are not compatible. By 0.24NM, the ELP 'H' was an obvious cue. During the final approach, the 'H' surrounded by a yellow circle emphasised the black centre of the helideck confirming that the pilots were flying to a helideck.

The left-hand seat pilot was not sure that the 'H' did actually enhance the situation compared to having just the LED strips, thought that the scene looked quite surreal and wondered if there were too many colours involved. The right hand seat pilot liked the combination of the 'H' and LED strips, but disliked the floodlights.

Again, the 'H' disappeared from view as the aircraft moved over the helideck into the hover position. The circle was then used during the landing to obtain closure rate information and judge the aircraft's position over the helideck.

The rating for **presentation** for the **acquisition** phase was **8** with **4** for the **workload**. The **final approach presentation** rating was **8** and **3** for the **workload**. The **presentation** for the **hover** rated a **9** with **3** for the **workload**. A rating of **8** was given for the **landing presentation** and **3** for the **workload**.

Run 6 – Green Perimeter Lights and ELP 'H'

By this time in the trial there was a small amount of cloud in the sky, which occasionally obscured the moon thereby reducing the ambient light level.

The aircraft turned onto the approach at 2.25NM and a height of 550ft and the green perimeter lights could be instantly seen. With no floodlights obscuring the perimeter lighting, the green lighting was very obvious and distinctive. The pilots commented that they preferred the helideck with no floodlighting. The floodlights acted as beacons and attracted the viewers' attention to the helideck, but both pilots commented that they preferred to acquire the helideck a little later and not use the floodlights.

At 0.5NM the shape formed by the perimeter lights started to 'open up' into a clearly defined helideck shape. The lack of floodlights also improved the helideck definition. During the final approach, the 'H' appeared in view at 0.38NM and a height of 450ft. This helped the pilot judge the angle of approach to the helideck. The 'H' looked very distinctive against the blackness of the helideck centre. The pilots were reassured to see the 'H' at this point in the approach.

Approaching the hover, the 'H' was of very significant benefit. Again, all useful information was lost as the aircraft moved over the 'H' and landed. The pilot commented that, at this stage in the landing, the cues gained form the LED strips were missed. The right hand seat pilot used these more than the left-hand seat pilot. The pilots' were agreed that the ELP 'H' on its own was not as good an aid as the LED circle.

Cueing lost by not using the floodlights was replaced by using the steerable aircraft landing light on the nose of the aircraft. The undercarriage-mounted landing light was fixed.

The **presentation** rating for the **acquisition** phase was **8** and **4** for the **workload**, while the **final approach presentation** rating was **6** and the **workload 4**. The **presentation** and **workload** ratings for the **hover** and **landing** phases were all **5**.

Run 7 – Green Perimeter Lights and Yellow LED Strips

The aircraft started the approach from 2NM and a height of 500ft and the green perimeter lights were instantly recognisable. At 1.05NM and a height of 500ft the helideck was described as "looking very good". The green colour of the perimeter lights was very distinctive. At 0.8NM, the LED circle could be seen. It produced a good perspective of the helideck at this range and allowed descent path information to be derived by the pilot.

During the final approach, at 0.42NM and a height of 400ft, the aspect of the helideck could clearly be seen from the Touchdown Marking circle. This information is not always obtainable using just perimeter lighting as helideck shapes and sizes vary significantly. The pilots described the circle of known size as "something to latch on to". The cueing was enhanced significantly during this phase by the LED strips. Closure rate information and perspective were particularly enhanced.

Again, during the hover, the pilots temporarily lost sight of the strips but, once they had re-acquired them, the aircraft landing light supplemented the LED strips by filling in detail. The pilots both commented that with the LED strips they had a higher confidence in their ability to estimate the pitch and fore/ aft position of the aircraft. They were of the opinion that they could manoeuvre over the helideck with confidence. Both the pilots commented that the LEDs and perimeter lights provided a better combination of cues than the 'H' and perimeter lights.

The presentation rating for the **acquisition** phase was **8** and the **workload 4**. The **presentation** rated **8** and the **workload 3** for the **final approach, hover** and **landing** phases.

Run 8 – Green Perimeter Lights, ELP 'H' and Yellow LED Strips

The aircraft made an approach from 2NM and a height of 500ft; the green perimeter lights could instantly be seen. The pilots stated it was "a good helideck". At 1.27NM, the helideck produced a flat aspect which started to open as the approach progressed. By 0.9NM and a height of 500ft, the shape of the helideck was emerging from the flat lines.

By 0.66NM and a height of 480ft, the LED strips could be identified around the landing circle. The ELP 'H' came into view at 0.43NM at a height of 400ft. The pilots commented that the 'H' was not as obvious as the LED strip circle if used separately but, when used together, they were very effective.

The pilots commented that the combination of the green perimeter lights, yellow LED strips and green ELP 'H' provided a definite image that could only be the helideck. Again, this increased their confidence in the approach due to the improved closure rate and perspective information presented to them. Both pilots agreed that this configuration was the most useful they had seen so far. Both pilots preferred having the ELP 'H' and LED strips to the floodlighting. From 0.22NM and a height of 300ft onwards, the ELP 'H' provided useful information about the aircraft's descent rate and position over the helideck.

Again, the 'H' was lost from view as the aircraft moved over the helideck into the hover position, but the pilots still felt that they had a good cueing environment to work in. During the latter stages of the approach, the pilot relied heavily on the ELP 'H' and LED strips. The pilot used the aircraft landing light as the aircraft was actually landing on the helideck. This fills in any 'holes' in the helideck cues and accentuates details of the helideck surface.

The **presentation** for the **acquisition** phase was rated **8** while the **workload** rated **3**. The **final approach presentation** was a **7** and the **workload** a **3**. The **presentation** for both the **hover** and **landing** phases was **8** whilst the **workload** for both was **3**.

Run 9 – Floodlights with Hoods and Yellow Perimeter Lights

At 2.44NM and a height of 600ft, as the aircraft turned onto the final approach the helideck could not be distinguished from the platform lighting. At 1.7NM, the helideck was starting to appear as a separate entity. The aircraft was flying an approach at a glide path angle of about 5 degrees. Due to the lensing of the floodlights, stray light was escaping from under the hoods, which made little difference to the image of the helideck. By 1NM and a height of 460ft, the pilots saw what they thought was the helideck. By 0.77NM and a height of 450ft, the helideck had been positively identified. The hoods did not make a lot of difference to the cueing as the floodlights still obscured the perimeter lights.

The score for **presentation** for the **acquisition** phase was worse than the baseline and rated **1** with the **workload** rated as **6**. The **presentation** and **workload** for the other **3** phases were all rated at **5**.

Run 10 – Floodlights with Hoods and Green Perimeter Lights

The helideck was acquired as soon as the aircraft turned onto the approach at 2NM. The floodlights did not seem as bright and glaring as they were for Run 9. There was a noticeable difference between the runs although light was still escaping from the hoods. At 0.5NM and 400ft, the floodlights were still obvious although the approach was quite steep.

The pilots commented that, at long ranges, the floodlights possibly enhanced the view of the helideck as they drew the pilots eyes towards it but, at shorter ranges, the helideck looked better and gave more useful cueing information without them.

The score for **presentation** for the **acquisition** phase was worse than the baseline and rated **1** with the **workload** rated as **6**. The **presentation** and **workload** of the other 3 phases were all rated at **5**.

Run 11 - Green Perimeter Lights, Yellow LED Strips and No Aircraft Landing Light

This run was a repeat of Run 7 except that this time the aircraft landing light was switched off to allow an assessment of how effective the configuration would be if the aircraft landing light failed during a landing. As the floodlights were not used in this configuration, there were no highly lit areas on the helideck.

This approach was made from 1NM as acquisition would not be affected by a landing light failure. The pilots commented that it was obviously more difficult without the landing light on. The green perimeter lights were acquired as soon as the approach started and the yellow LED circle came into view at 0.6NM and a height of 500ft. At 0.35NM and a height of 350ft, the LED circle gave a very good perspective of the helideck.

The pilots were also acquiring closure rate information from the sea as well as the platform. The pilots could see a green ring surrounding a yellow circle. This was obviously a helideck. Although the helideck was much darker in the middle, the pilot received limited information from the green light thrown onto the helideck by the perimeter lights. This landing was obviously more difficult as there was no landing light but the test showed that enough information could be gained from the equipment to land the aircraft confidently.

4.3 Summary of lighting configurations and ratings

The lighting configurations evaluated during the 3rd flight trial are summarised in Table B5, and the corresponding presentation and workload ratings in Table B6.

A baseline of 5 was allocated to Run 1. The higher the rating of the presentation, the more effective the configuration. This is inverted for the workload ratings, with a higher score representing an increased workload for the pilot.

Table B5 Equipment Configurations for Trial 3

Run	Config.	Flood lights	Floodlights with hoods	Yellow Perimeter Lights	Green Perimeter Lights	ELP H	Yellow LED strips
1	(a)	✓		✓			
2	(b)	✓			✓		
3	(j)	✓			✓	✓	
4	(p)	✓			✓		✓
5	(q)	✓			✓	✓	✓
6	(d)				✓	✓	
7	(r)				✓		✓
8	(s)				✓	✓	✓
9	(t)		✓	✓			
10	(u)		✓		✓		
11	(r)				✓		✓

Table B6 Trial 3 Ratings

Run	Config.	Helideck Acquisition		Final Approach		Hover		Landing	
		Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work load	Presen-tation	Work load
1	(a)	5	5	5	5	5	5	5	5
2	(b)	8	4	6	4	5	5	5	5
3	(j)	8	4	7	3	5	5	5	5
4	(p)	8	4	8	3	9	3	8	3
5	(q)	8	4	8	3	9	3	8	3
6	(d)	8	4	6	4	5	5	5	5
7	(r)	8	4	8	3	8	3	8	3
8	(s)	8	3	7	3	8	3	8	3
9	(t)	1	6	5	5	5	5	5	5
10	(u)	1	6	5	5	5	5	5	5
11	(r)	-	-	-	-	-	-	-	-

Appendix C K14C/ P In-Service Trial

1 General

The K14C/ P complex is the 'mother' platform associated with the K14B satellite platform where the dedicated trials were performed. The platform has two helidecks, K14C and K14P, which make it an ideal location to conduct a trial requiring the comparison of two helideck lighting configurations. The purpose of the trial was to evaluate the green helideck perimeter lighting installed on K14P, and to compare it with the standard yellow lighting on K14C.

K14C is the larger of the two decks on the complex. It was fitted with standard 20 w fluorescent, yellow perimeter lighting units and helideck level 50 w halogen floodlights. The helideck also had a net until half way through the trial. The helideck has no superstructure above deck level to provide visual cueing to pilots (see Figure 2).

K14P was fitted with 20 w fluorescent, green perimeter lighting units. The helideck has 4 double 50 w halogen floodlight units (8 floodlights) with a lit panel on top of the unit which forms part of the perimeter lighting pattern. This contains 2 x 18 w fluorescent tubes. The helideck has some superstructure above deck level, which provides a source of visual cues (see Figure 3).

2 Methodology

As stated, the K14C/ P complex has two helidecks, which can be simultaneously viewed in the same ambient lighting and meteorological conditions from approaching helicopters, allowing pilots to directly compare the two types of perimeter lighting under evaluation.

An 'in-service' trial was conducted in order to allow a range of pilots to evaluate the two lighting configurations side-by-side in a range of ambient lighting and meteorological conditions. The results were obtained by having pilots complete a questionnaire after landing on the platform.

Questionnaires were available at Den Helder heliport in The Netherlands; the questionnaire is shown in Section 7 of this appendix. Ten completed questionnaires were returned. These were completed between December 1998 and March 2000. The conditions encountered during the trial are detailed in Table C1.

Table C1 K14C /P In-service Flight Trial Landing Conditions

Pilot	Time	Visibility (km)	Precipitation	Ambient light	Helideck
1	am	4	None	Twilight	C
2	pm	15	None	Night (no moon)	C
3	pm	10	None	Twilight	P
4	am	10	None	Twilight	C
5	pm	6	None	Night (no moon)	C / P
6	pm	6	Rain	Night (no moon)	Not stated
7	No details provided				
8	No details provided				
9	pm	10	None	Night (moon)	P
10	No details provided				

3 K14C/ P In-service Flight Trial Results

The following sections summarise the responses to the five questions presented to the pilots in the questionnaire (see Section 7 of this appendix).

3.1 Q1: Is it difficult to locate the helideck on the K14 at night with the standard yellow perimeter lighting?

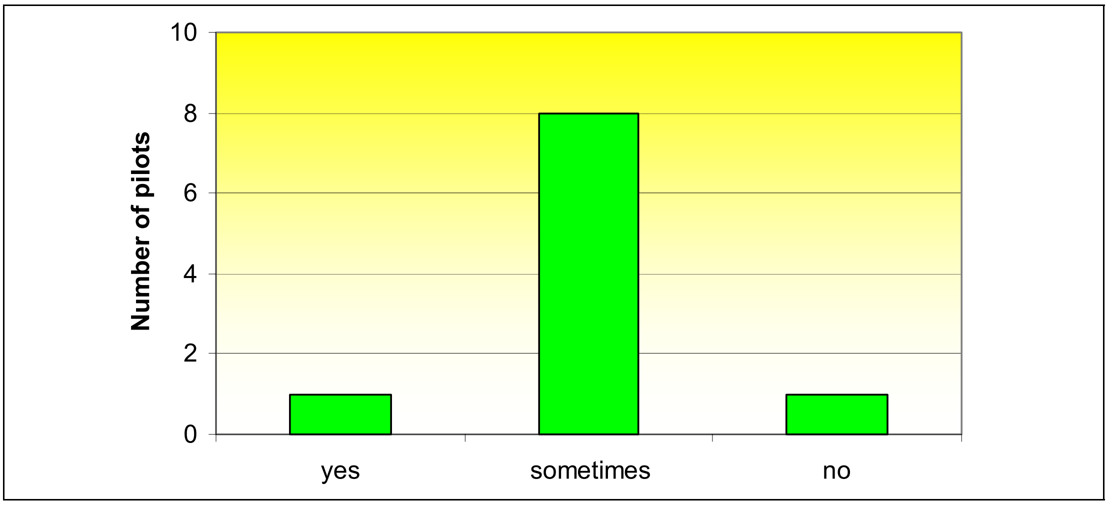

Figure C1 K14C/ P Question 1 Results

From the responses received, it can be seen that locating the helideck when approaching a platform with yellow helideck perimeter lighting (K14C) is an issue for experienced offshore pilots. This confirms that improved cueing is required, and supports the results from the dedicated flight trials on K14B.

The pilots' main problem when trying to acquire the helideck is to separate the helideck perimeter lighting from the extensive cultural lighting that covers the platform. This cultural lighting consists of yellow lights on walkways for personnel safety, and white lighting to illuminate working areas. These colours are the same as the visual aids used on the helideck (yellow perimeter lights and white floodlights).

Pilot 5 who answered 'yes' had landed on both helidecks. Pilot 6 answered 'no' but did not state which deck was used for the landing.

3.2 Q2: The helideck with green perimeter lighting (P) was easier to locate on the platform at night than the helideck with yellow perimeter lighting (C).

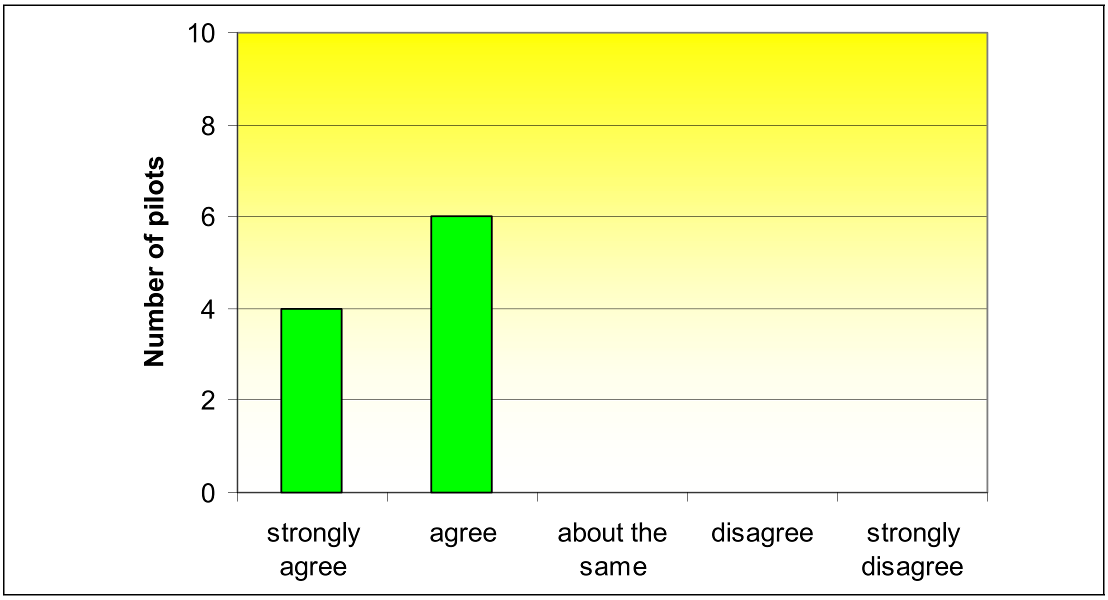

Figure C2 K14C/ P Question 2 Results

The responses to this question show that all the pilots who completed the questionnaires found the helideck with green perimeter lighting (K14P) easier to locate than the helideck with the existing yellow lighting (K14C), some more strongly than others. There is no other green lighting on the platform, so any lighting of this colour that is seen by the pilot can only be the helideck. Even if only a small section is seen, the pilot can be confident of the location of the helideck on the platform. This proves the basic concept that green perimeter lighting is an effective visual aid in an offshore environment.

Pilots 1, 2, 7 and 9 strongly agreed with the statement.

Pilot 5 commented that the green lighting was very distinctive, although early on in the approach they were masked by the floodlights.

3.3 Q3: The intensity of the green helideck perimeter lighting was?

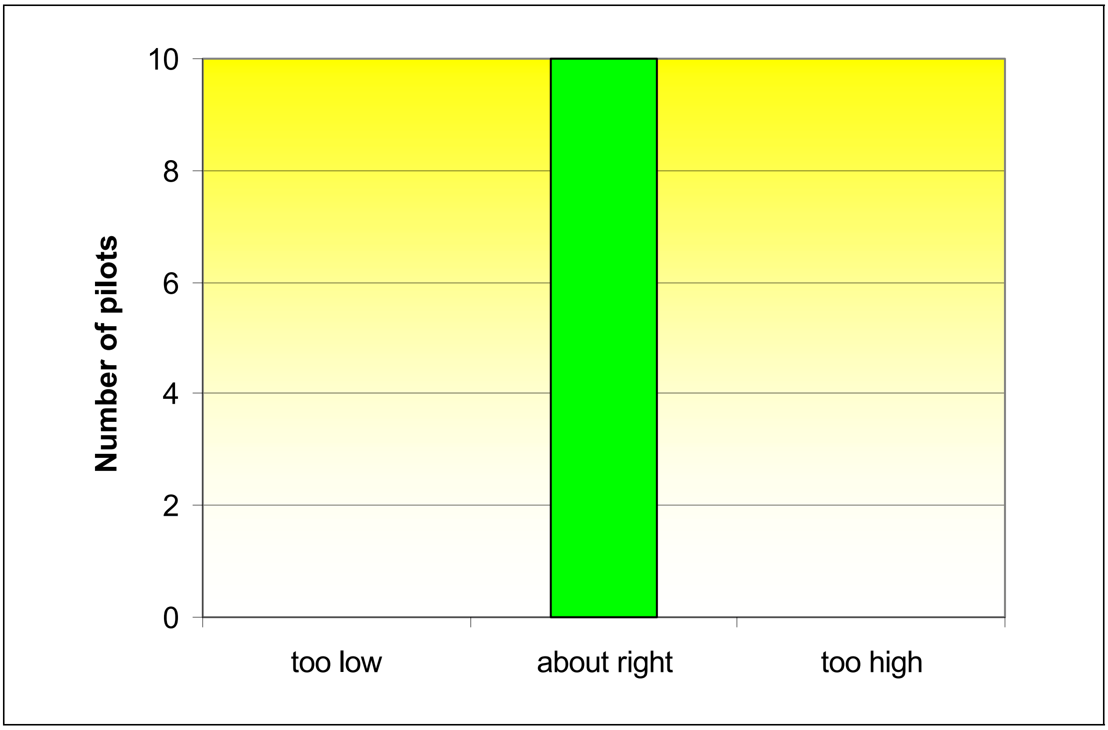

Figure C3 K14C/ P Question 3 Results

The green perimeter lamps installed on the K14P are the same as the units evaluated during the 3rd dedicated flight trial to the K14B.

The pilot comments show that, in the conditions experienced during the trials, the light units were conspicuous against the platform cultural lighting during the acquisition phase, but were not so bright as to dazzle the pilot once the aircraft had landed.

Pilot 5 landed on both helidecks and so was able to assess the intensity of both sets of lights nearby and from range.

3.4 Q4: The green perimeter lighting was easily distinguished from the platform cultural lighting.

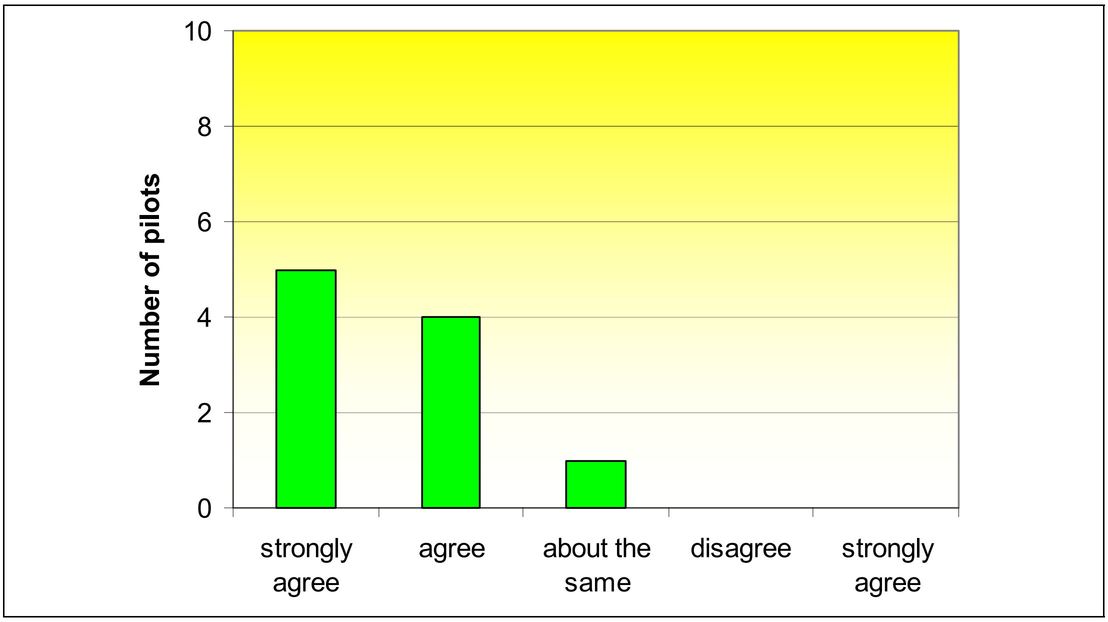

Figure C4 K14C/ P Question 4 Results

All but one of the pilots agreed with the statement, and he thought that the helideck lighting was no better and no worse than the yellow perimeter lighting. These responses show that the green perimeter lighting is more conspicuous to the pilot's eyes as it is more easily distinguishable from the yellow and white cultural lighting. This helps the pilot to locate the helideck on the platform, providing him with a target area to aim for.

Pilots 1, 3, 5, 7 and 9 strongly agreed with the statement.

Pilot 2 stated that the green perimeter lights were as distinguishable as the yellow perimeter lights.

3.5 Q5: Changing the colour of the helideck perimeter lighting from yellow to green would significantly reduce the problem of locating helidecks on offshore platforms at night.

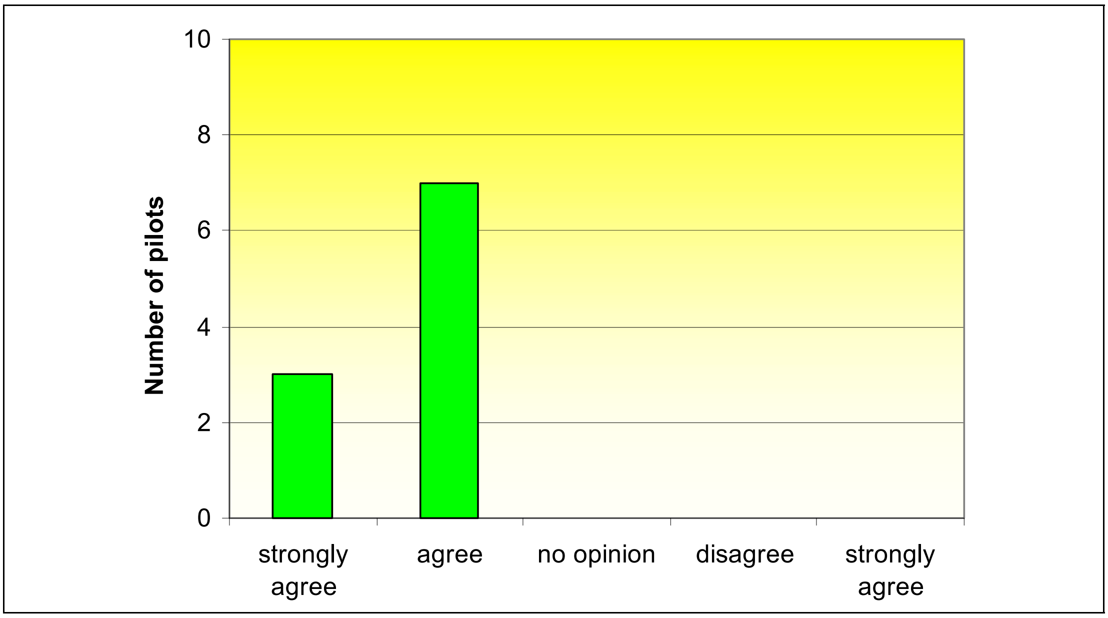

Figure C5 K14C/ P Question 5 Results

The responses indicate that changing the colour of the helideck perimeter lighting from yellow to green would be the preferred option of the pilots who completed the questionnaire. All the pilots agreed, (and some strongly) that green was the most conspicuous colour for the helideck perimeter lighting. They said that changing the colour of the perimeter lights would reduce their workload and increase their confidence when performing approaches at night. Pilots 2, 3 and 5 strongly agreed with the statement.

4 Discussion

It can be seen from the completed questionnaires that experienced offshore pilots have difficulty acquiring helidecks fitted with yellow perimeter lighting and white floodlights against the background of a platform highly illuminated with yellow and white lighting.

In the absence of suitable cueing pilots resort to using the 'black hole' in the visual scene, formed as a result of the ineffectiveness of the helideck floodlights in illuminating the centre of the helideck. The pilot presumes that a darkened area surrounded by yellow lighting is the helideck, and approaches the platform accordingly. The lack of positive identification, however, reduces the pilot's confidence during the approach until he is close enough to be certain of the location of the helideck on the platform.

The lack of a visible, well-defined helideck perimeter removes essential cues required by the pilot during the approach. The changing aspect of the perimeter shape, when clearly visible, helps to indicate the aircraft's angle of approach to the deck and provides height and closure rate information.

By increasing the both the conspicuity and definition of the helideck perimeter, green perimeter lighting addresses both of these issues. Green lighting was selected following earlier flight trials at the K14C, during which red / green 210 ° obstacle free sector lighting was evaluated. Although this aid was not effective, the pilots who took part in the trial stated that the green section of the light was very conspicuous. No other green lighting exists on offshore platforms, and it is known that green is one of the few signal colours that can be identified easily at long range.

All the pilots in the K14C/P trial stated in their responses that the experimental green lighting was easier to locate than the standard yellow lighting. The pilot responses show that this simple alteration has a dramatic effect on the pilots' ability to acquire the helideck against the background of the platform lighting. The change to green removes the pilots' concerns over incorrectly identifying the helideck location, enabling him to conduct the approach with confidence. All the pilots agreed that the change would reduce their problems in acquiring the helideck and that this, in turn, would reduce their workload during the approach.

The perimeter lighting is required to be bright enough to be conspicuous above the platform cultural lighting under the worst-case meteorological conditions, but it must not dazzle the pilots once the aircraft has landed on the helideck. The responses show that the lamps used in the trial are of a suitable intensity for the range of meteorological conditions experienced. However, given the relatively limited range and generally good visibilities encountered during the trial, further trails should be undertaken to confirm this finding.

5 Conclusions

The results of this in-service flight trial compliment the results of the dedicated flight trials conducted on the K14B. Both trials conclude that offshore helideck perimeter lighting should be changed from yellow to green.

6 Recommendations

CAP 437 and ICAO Annex 14 Volume 2 should be updated to reflect the proposed change in the colour of offshore helideck perimeter lighting. Further trials should be performed to confirm the required intensity of the green lights.

7 K14C/ P In-service Trial Questionnaire

CAA/ DERA K14 P HELIDECK LIGHTING TRIAL

Introduction:

Analysis of the responses and comments received under the offshore helicopter pilot questionnaire-base survey, conducted on behalf of CAA and reported in CAA Paper 97009, indicates that the location of helidecks on offshore platforms can be difficult at night. The problem is believed to be due to the lack of conspicuity of the yellow helideck perimeter lights, which has worsened with increased use of sodium flood lighting. The purpose of this trial is to establish the impact of changing the colour of the helideck perimeter lighting to green.

Evaluation of Green Perimeter Lighting:

As soon as it is safe to do so after completing the approach and landing on the K14, please answer the following questions by ticking the box which most accurately represents your opinion: -
NB: The K14 `P' (production module) helideck has been fitted with green perimeter lighting, the K14 `C' (compression module) helideck has standard yellow perimeter lighting allowing a direct comparison to be made.

1. Is it difficult to locate the helideck on the K14 at night with the standard yellow perimeter lighting?

☐ yes ☐ sometimes ☐ no

2. The helideck with **green** perimeter lighting (P) was easier to locate on the platform at night than the helideck with yellow perimeter lighting (C).

☐ strongly agree ☐ agree ☐ about the same ☐ disagree ☐ strongly disagree

3. The intensity of the **green** helideck perimeter lighting was:-

☐ too low ☐ about right ☐ too high

4. The **green** perimeter lighting was easily distinguished from the platform cultural lighting.

☐ strongly agree ☐ agree ☐ about the same ☐ disagree ☐ strongly disagree

5. Changing the colour of the helideck perimeter lighting from yellow to green would significantly reduce the problem of locating helidecks on offshore platforms at night.

☐ strongly agree ☐ agree ☐ no opinion ☐ disagree ☐ strongly disagree

NB: Please use area on reverse side for any written comments you may wish to add.

Operational Data:

After flight, please record the following information relating to the approach and landing on the K14 (please record information and tick boxes as appropriate): -

Date: .... Time (GMT):.................. Aircraft type:.......................................

Visibility (km): .... Precipitation: ☐ None ☐ Rain ☐ Snow

Ambient light: ☐ Twilight ☐ Night (moon) ☐ Night (no moon)

Helideck used for landing: ☐ P ☐ C

Comments:

Please use this area to record any comments that you wish to make:-

When completed, please return this questionnaire to DERA Bedford

THANK YOU FOR YOUR ASSISTANCE

Appendix D LED Photometric Tests

Following the K14B trials, an investigation of the intensity characteristics of the yellow LED landing circles was performed. To achieve this, LED strip recovered from the trial was cut into various lengths and the test samples mounted on metal plates (Figure D1). These were then characterised by the British Standards Institute (Report No. 247/4240365) over a complete range in elevation (0 to 180 degrees) and at 4 azimuth angles relative to the short axis of the LED strip (Figure D2). Of particular interest were; a single LED with the overlying extrusion removed, a single embedded LED in the centre of a strip of 7 and a strip of 4 embedded LEDs (0.03 metre pitch) comprising a so-called ‘lamp’.

The LEDs themselves were found to have a relatively narrow beam. Thus if mounted flat on the helideck, they would produce a negligible output at the low angles at which a pilot would view them on the approach to a platform (Figure D3). However, it was found that the plastic extrusion in which they are mounted greatly improves the intensity at low elevation angles for all azimuth angles (Figure D4). In general, it is seen that the intensity characteristics surpass those of an emitter, obeying a cosine law. Whilst it is recognised that a local peak in intensity occurs at some 30 to 40 degrees in elevation, the cause is not fully understood.

The intensities achieved by the LEDs were quite low, the peak intensity of the single embedded LED being 0.35 candela, while a ‘lamp of 4 LEDs (Figure D5) gave 0.75 candela, not the 1.4 candela that might have been expected. Subsequent tests of relative intensities (uncalibrated) revealed a wide range of peak intensities in the ‘lamp’ under test, such that the brightest LED in the ‘lamp’ under test was 1.8 times that of the dimmest. By comparison, the intensity of the single embedded LED was 1.7 times the brightest in the ‘lamp’.

A further investigation was made and the peak intensities of a strip of 16 embedded LEDs were measured. These gave a mean intensity only 5% lower than the single embedded LED, suggesting that the intensity achieved by the ‘lamp’ under test at BSI was not representative. Relating this back to the BSI results suggests that more representative values would have been 0.33 candela for a single embedded LED and 1.31 for a ‘lamp’. Assuming that the intensities are normally distributed, the standard deviation obtained for individual embedded LEDs was 0.09 candela, or 28% of the mean. The range of intensities between the brightest and dimmest LEDs at the 2 standard deviations level being 3.5:1.

In practice, it has been seen that the LED landing circles are effective in the light environment of an offshore platform. The angular characteristics are, however, far from optimised for an approaching aircraft, most of the light flux being directed immediately upwards. From the measurements it is seen that the intensity for 4 degrees above the horizontal is at best (broadside on) 0.61 candela for a ‘lamp’, though at distance individual LEDs may augment each other to produce a higher effective intensity. To further improve the efficiency of a strip formed from a single row of LEDs, a means would be required for increasing the proportion of light directed at low angles in all directions. Where a strip was formed from multiple rows of LEDs the outer rows might be inclined outwards, although this would not have the same benefit when viewed obliquely, or end-on.

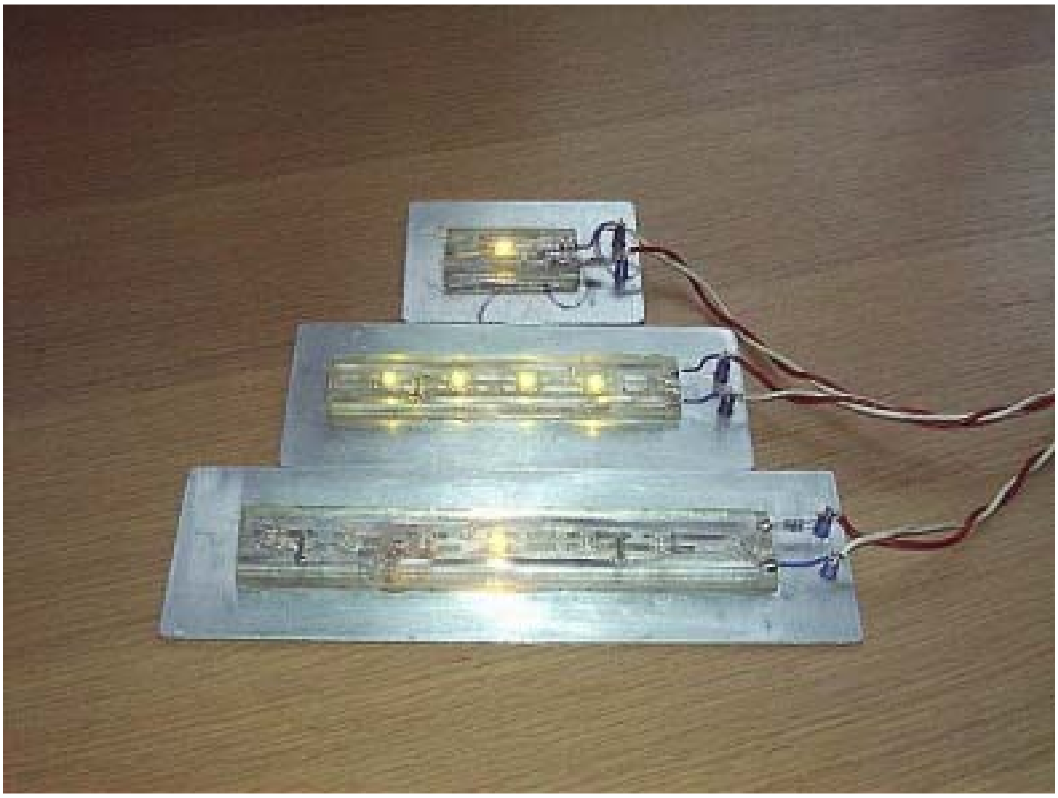

Figure D1 LED Test Samples

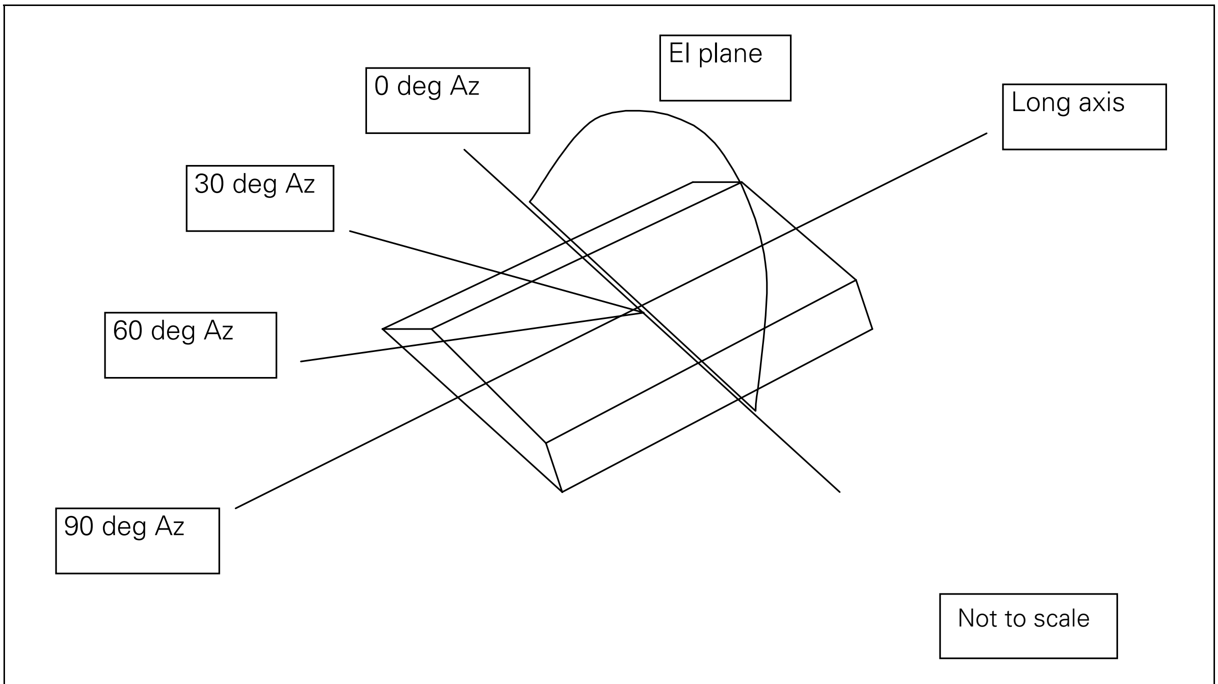

Figure D2 Test Geometry for LED strips

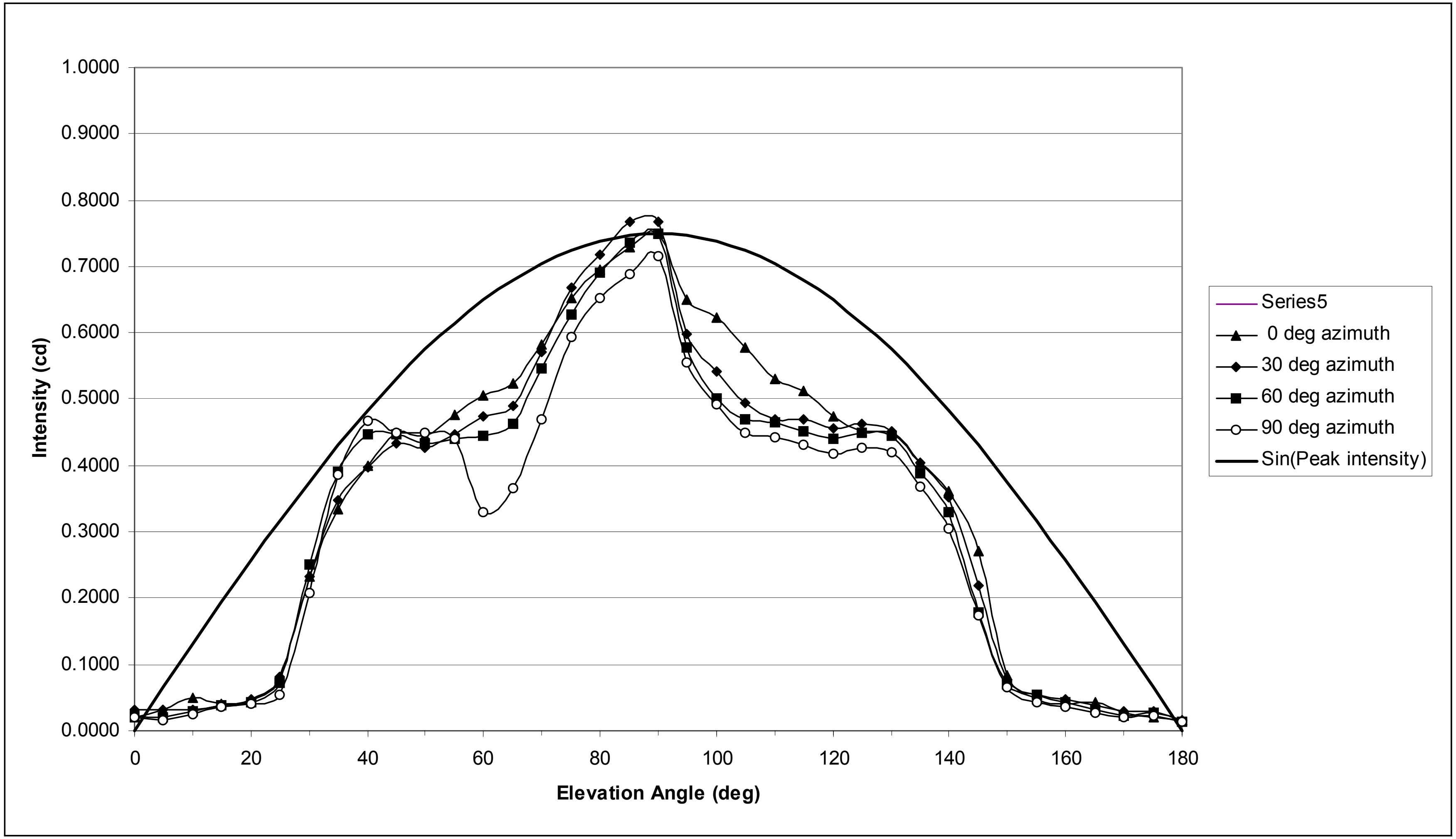

Figure D3 Single Exposed Yellow LED

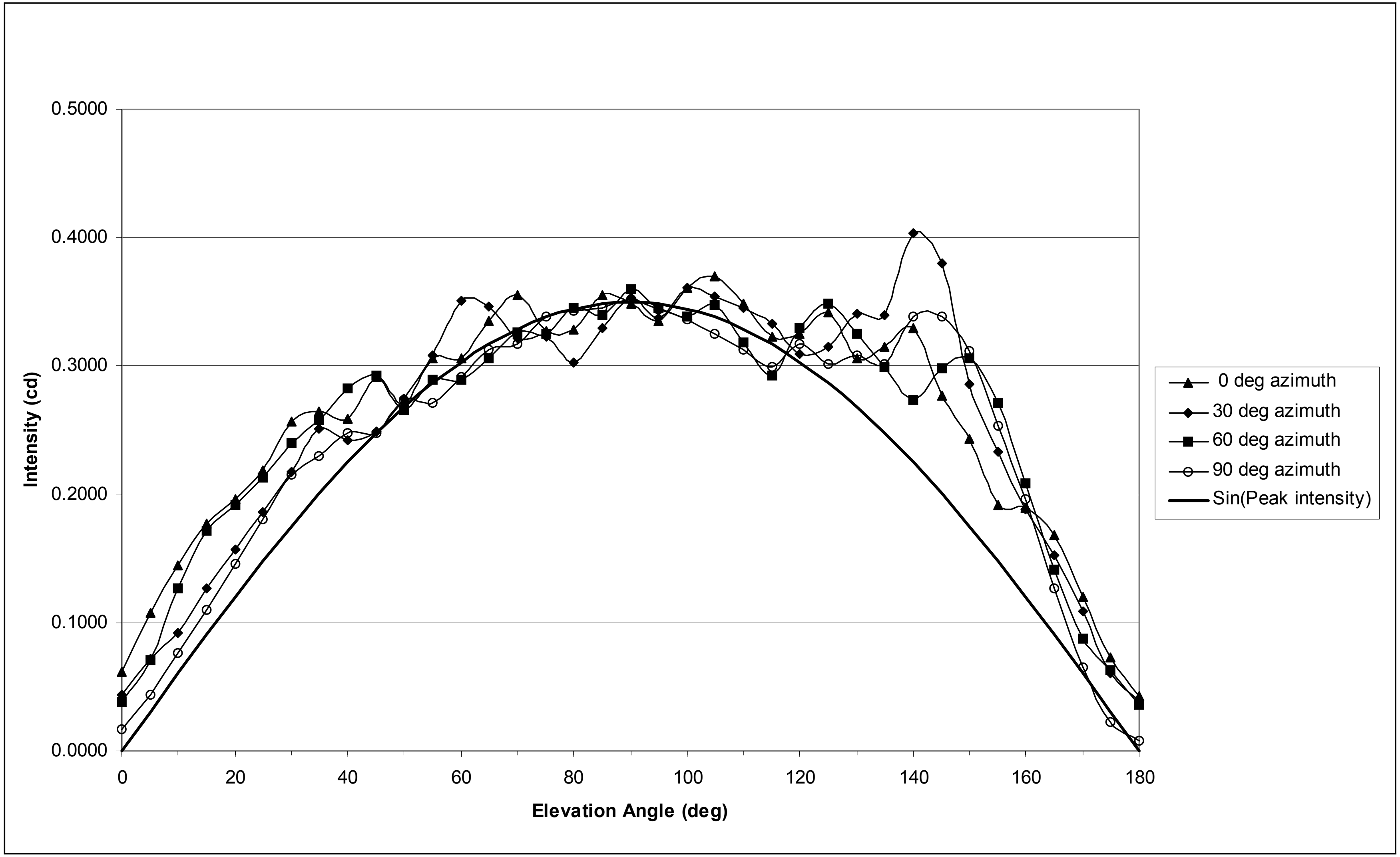

Figure D4 Single Embedded LED (1 of 7)

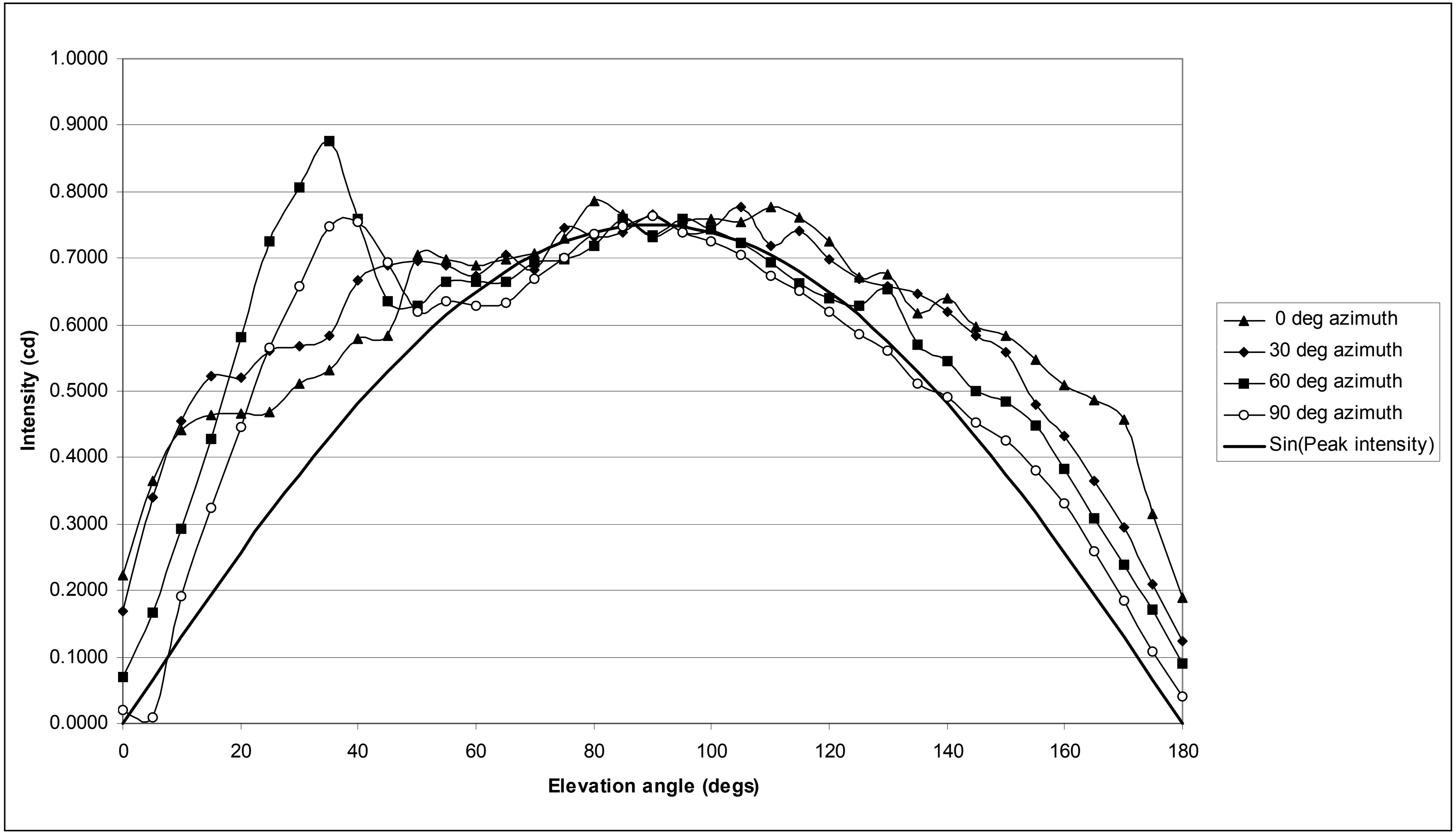

Figure D5 'Lamp' (4 embedded LEDs)

Appendix E Operational Pilot Opinion of Helideck Lighting

A Questionnaire Survey of Workload and Safety Hazards Associated With North Sea and Irish Sea Helicopter Operations - CAA Paper 97009.

A questionnaire-based survey of all offshore helicopter pilots was performed by the DERA Centre for Human Sciences on behalf of CAA in the mid-1990's in connection with a study of the workload associated with the completion of paperwork in flight. The analysis of the results was published as CAA Paper 97009 in August 1997. An unprecedented response rate of 73% was obtained, indicating that the conclusions drawn from the results could reliably be considered representative of the offshore pilot population.

In order to attempt to camouflage the true intent of the questionnaire, and thus avoid bias in the responses, the questionnaire addressed a broad range of offshore issues including helideck lighting and visual cueing. For this aspect, the six questions detailed below were included. Respondents were requested to indicate their responses on scales of 1 to 10 as shown.

Q.40 "Does the helideck lighting cause you a high workload or a safety hazard at night?"

	Mean	Standard Deviation
High workload	5.2	2.3
Safety hazard	4.7	2.3

[1 = never; 10 = always]

Q.41 "How easy or difficult is it generally to see the position of the helideck on the platform in daylight?"

Mean	Standard Deviation
3.9	2.0

[1 = easy; 10 = difficult]

Q. 42 "How easy or difficult is it generally to see the position of the helideck on the platform at night?"

Mean	Standard Deviation
6.6	2.3

[1 = easy; 10 = difficult]

Q. 43 "Are the visual cues (such as the lighting), that help you to position your aircraft during the approach to the helideck generally poor or good?"

	Mean	Standard Deviation
During daylight	6.5	2.2
At night	4.1	2.2

[1 = poor; 10 = good]

Q. 44 "Are the visual cues (such as the lighting), that help you to position your aircraft during the hover, and whilst landing on the helideck generally poor or good?"

	Mean	Standard Deviation
During daylight	7.3	1.8
At night	5.6	2.2

[1 = poor; 10 = good]

Q. 45 "Is the quality of flood lighting on the helidecks generally poor or good?"

Mean	Standard Deviation
5.3	2.3

[1 = poor; 10 = good]

Q. 46 "Do other lights on the platforms interfere with your ability to see the helideck at night?"

Mean	Standard Deviation
6.2	2.4

[1 = poor; 10 = good]

Respondents were also invited to submit 'freeform' comments on the questions regarding helideck lighting. Fifty one percent of respondents provided comments, and these are reproduced below:-

QUESTION 40

1) Not enough down lighting - too much yellow lighting at eye level.
2) Some of the surrounding lights can be blinding. MCP01 is a good example.
3) In poor met conditions. Helideck lights must make it easy to pick up sight picture, single colour is dangerous and can be lost in ambient and surrounding rig lights. Strong clear contrasting colour on dark deck ideal for me.
4) Deck always darkest part of rig/platform!
5) Sometimes difficult to identify landing area among other rig lighting. Exciting taking off into the black night from a well lit rig!

6) More so on take off or go-around. Going from bright light to pitch dark is potentially risky.

7) Some smaller rigs are still poorly lit and difficult to judge approaches to.

8) Bright lights poorly directed or situated destroy night vision and disrupt concentration, often at critical moments.

9) Sometimes dazzled by sodium lights.

10) A black hole with a circle of lights around it.

11) Bright lighting of deck but more often of installation very dazzling. This effect can block out any external horizon if present.

12) Some lighting - especially tube lights - do not give adequate sight picture. Also circular pads - because more common - do not allow you to get current perspective. Floodlights on helideck completely destroy night vision and should be banned.

13) High workload - if the lighting level is too low on the deck. Safety - above plus floods adjusted to shine in at eye level.

14) Occasionally the brightness of other lights on the installations ‘obscures’ the helideck markings until the aircraft is close to the installation.

15) The lighting on the decks used to be blue/yellow which in my opinion was easier to see especially on a large platform.

16) Ok.

17) Varies widely from rig to rig. Poorly positioned floodlights can often mask helideck lights until closer in.

18) This can apply where, due to wind direction and difficulty with orientation, it is sometimes hard to decide which pilot’s landing it is going to be.

19) The change from alternate blue/amber lights to all amber lights is in my view a retrograde step.

20) Flood lighting can be too bright.

21) No standardisation of deck lighting. Plenty of room for improvement. Most deck landings made a lot easier by use of searchlight. This shouldn’t be necessary. Some deck lighting causes too much glare.

22) Floodlighting the deck often works against you because the floods are poorly adjusted and dazzle you in the hover.

23) Deck edge lighting can be dazzling.

24) Not a problem.

25) Flood lighting of the helideck is not satisfactory. The floodlights can cause the pilot to be dazzled and they do not effectively floodlight the landing surface. There is evidence that the ICAO Annex 14 standard cannot be achieved in practice.

26) On dark nights with not much moonlight often rig lighting can be too bright which can cause difficulties looking in and out of the cockpit as often the cockpit/ instrument illumination is low.

27) Windsock is usually not lit.

28) Mostly inadequate at night to be able to do an external inspection of the aircraft properly.

29) Who on earth had the ridiculous idea to replace excellent blue/yellow lighting with appalling all-yellow?

30) It is a standing joke that you aim at the darkest area of the rig/platform until you can see the markings.

31) Some lights particularly good, others particularly poor. Alternating blue/yellow (now being replaced by all-yellow) are easier to distinguish from remainder of installation lights to identify where deck is.

32) Problems, first is severe dazzle, particularly on departure which is then into inky black. Second is deck lighting colour. In their wisdom CAA require deck edge lights to be orange. General platform/rig lighting tends to be sodium lights (orange) so flight deck often difficult to see.

33) Some decks have few or no lateral cues. Judging angles by approach can be difficult.

34) Lighting is often directed directly at the aircraft rather than being discrete.

35) All night deck landings are high workload.

36) I have experienced an occasion at night with a low cloud base where the reflected light from the land was so bright that judgement of rate of closure was impossible so a go-around was initiated.

37) Often difficult to see owing to rest of platform being over-illuminated.

38) Varies with location.

39) With the prevailing wind through the derrick can cause a bit of disorientation at night in rain when the helideck is “straddled” by lights. Especially an accommodation rig in front of a production platform or multiple rigs during construction.

40) Circle markings are most important. Flood lights are the most distracting.

41) Pre-landing preparation of deck site and careful choice of approach path is vital to minimise workload. Flares can be too bright and hazard night vision.

42) Deck lighting is good, but landing on a deck in darkness is difficult. Rate of closure, rate of decent are difficult to ascertain visually and require use of instruments/radar.

43) Too many bright floodlights are provided at helideck level on the helideck and destroy what little night vision you have achieved.

44) Some lights do blind on the approach, rigs are reluctant to relocate them.

45) Satellite decks floodlights cannot be moved or their light intensity varied. Sometimes shine right at you when on deck.

46) Not too bad.

47) On a few occasions certain lights can be too bright.

48) Some helidecks have bright lights that suddenly appear during the landing phase. Very distracting. Helideck lighting at night should be standardised.

49) All night flying imposes a higher workload than by day.

50) Decks are sometimes not very obvious with all the background lighting on a rig. The main problem is going from pitch dark to brilliant light and the other way round on departure. Many sodium lights not just associated with the helideck.

51) It is like trying to find a black circle in the middle of a Christmas tree.

52) Helideck lighting on manned platforms and rigs generally ok. Satellites are a different matter, they can be acceptable to very difficult.

53) Night landings are hard work anyway - especially when they occur so rarely.

54) Occasional dazzle from deck lights.

55) Fixed platforms are normally good, ‘semis’ can sometimes be difficult.

56) Bad lighting in rain combined with S76 window deformation can be a safety hazard.

57) Quite often difficult to find helideck in amongst a blaze of bright lights. Perimeter deck lighting sometimes alternate blue/amber which is poor. Goal Glamox type lights are dangerous. Deck floodlights are blinding .

58) It needs to be bright, to be identified from a distance. Unfortunately this becomes a problem in the latter stages of the approach and hover, as one is dazzled.

59) Sometimes difficult to see orientation of deck in relation to other lights on destination platform.

60) There are too many lights on at night to make helideck identification easy. It does, however, make rate of closure & depth perception easier.

61) Not brilliant but ok.

62) They vary, the nasty little unmanned ones can be bloody nasty.

63) Deck lighting rarely bright enough. It is almost SOP [standard operating procedure] to aim for the darkest part of a rig/platform.

64) The highest workload you can (and should) expect is the first time night flight offshore in the year. Night work is hard work.

65) Often high workload.

66) Some lights do glare in cockpit.

67) I don’t really find lighting a problem. What is a problem is the removal of deck nets. I realise now that deck nets provide me with perception of wheel height above deck. No net, no height perception.

68) Sometimes too bright, a variable system controlled by the HLO dimming slightly on short finals after a call from the heli crew would be better.

69) Hard to differentiate the deck against all other rig lights (Xmas tree).

70) Some rigs have flood lighting which can blind.

71) It varies from rig to rig.

72) At night a rig is just a mass of lights and is two dimensional. It is only when on very short finals to where you think the deck is that it all becomes 3-D.

73) Many variables/requirements -leg lighting a big step forward. (Amethyst B1D an interesting one at night).

74) Lighting often difficult to pick up at a distance, and setting yourself up for a decent approach at a reasonable distance isn’t easy. Platform/rig lighting usually too bright.

75) On some decks only.

76) Decks should be floodlit from above or logo should be floodlit to give depth perception, logo lights should be bright orange.

77) The helideck often appears as the worst lit part of the platform. Deck floodlighting poorly angled and can be blinding during touch down and take off.

78) The helideck is always the darkest part of a rig/platform.

79) Occasionally the lights are fitted incorrectly which glow in your face.

80) Again changes have been made to improve lighting. Main problem used to be floodlighting on deck blinding pilot for take off. I have not had many night landings this year but so far no problems.

81) On one occasion, making my approach to an unfamiliar rig at night in rain to what I thought was the circle, however, the combination of ineffectivity and the rig sodium lights shining on a wet deck had produced a false circle which was half on/off the net.

82) High workload and safety hazard always when they have the floodlights around the helipad on.

83) Deck illumination and background illumination are inadequate.

84) Varies quite a lot. Also dependent on weather.

85) Poor - very difficult to use effectively - visual cues gained are minimal and provide little warning of flight path error.

86) Bright misdirected lights are blinding.

87) Can't remember last time I landed in darkness.

88) Often you find sodium lights aimed at you which doesn't improve night vision much.

89) When they are not set right, i.e. blinding the pilot!

90) Again, it varies tremendously. On a no-mover right off a floating semi-sub the helideck lighting can be so poor.

91) Too many other lights make helideck hard to pick out. Intensity of lighting is too high.

92) Main problem caused at night by other bright lights on platforms 'masking' the helideck lighting.

93) It is more difficult to land at night because of reduced visibility, dazzle, poor lighting etc.

94) The decks vary considerably; standardisation is very difficult, so airmanship and crew co-op is almost always a central issue.

95) Often lighting at night is not good enough to give good approach azimuth and often much too bright on deck.

96) All orange helideck perimeter lights get lost among the general platform/rig lighting. The deck was easier to see when they were alternately blue/orange.

97) The floods are incorrectly set to shine in your eyes. Generally the helideck is the dark bit.

98) Lighting that showed the texture of the deck surface would help a lot (it's what you look at on a day approach). The present ring of lights leaves you flying at a black hole with little perception of depth or rate of closure.

99) The helideck always seems to be the dimmest part of the platform which makes it difficult to find on unfamiliar rigs. Legs are often poorly lit which is dangerous. Floodlighting which is controlled by HLO often shines straight into your eyes and blinds you.

100) Some helideck 'floods' are badly positioned.

101) Helideck light per se not a problem, but there is invariably much distracting light surrounding the deck from a variety of sources.

102) Poor differentiation with remainder of rig. Soft floodlighting of the deck is often surrounded by a lot of high intensity lights and a huge flare!

103) Some lights shine at poor angles, and into one's eyes.

104) Deck edge lighting is difficult to sort out from the general installation lighting and is often swamped by the brightness of other lights/flares. Deck lighting should form a continuous circlet or ring of light which cannot be confused with other lighting in the vicinity.

105) Needs a radical rethink.

106) Only a problem when lights are out or floods are wrongly adjusted.

107) Can be 'dazzling' flying from very dark to very bright.

108) The change from blue - orange - blue lighting around the helideck to just orange is a disaster. When approaching a rig for the first time at night it is now very difficult to make out the helideck amongst all the other orange lighting on the rig.

109) The lighting is fine. It's the other lights and layout that will often confuse the whereabouts of the deck.

110) Why do helidecks seem to be the darkest part of a platform?!

111) The lighting at night is poor and needs improving.

QUESTION 41

1) Varies from rig to rig and how familiar you are with the rig.

QUESTION 42

1) Semi-subs much worse.

QUESTION 43

1) At night, I always overfly the platform to orient myself.

2) Depends on visibility at night can be impossible until finals - always head for the darkest bit.

3) At night and in poor weather you frequently run a fine line between flying on instruments and flying visually. You frequently need to combine both until on late finals.

4) It is difficult to say what cues are used. However there are fewer at night.

5) As mentioned in earlier question. Also smaller decks have the lights set in a circle which doesn't help orientation at all.

6) It depends greatly on peripheral reference. On a stand-alone platform, at night, with no room this occupation is highly dangerous. In good ambient light with other platforms around it is of medium danger. The smaller the platform (and therefore deck) the greater the danger.

7) Sight picture judgement is required. None other known.

8) The lighting on the helideck is not often easily identified compared to the rest of the lights on the rig platform.

9) Often very difficult at night. Particularly considering the infrequent practice we have.

10) All yellow lighting blends with other background lighting in snow/rain at night.

11) There are no aids for helideck approach. It's all done by skill!

12) Generally it is known before arrival, a rig heading and therefore a deck position. If not, a good clue during daytime is the uncluttered side. This applies at night - time although the general profusion of lights and glare can obscure sea lighting.

13) Standards are getting worse. We are getting more and more helidecks mounted on a pedestal with no surrounding structure to give depth perception, very, very, difficult at night or in misty conditions - dangerous!

14) Helidecks are frequently illusive until within about 2 miles from the rig/platform, particularly during daylight when, unless they are sticking out to one side as you look at it, they tend to merge.

15) The whole platform is a blaze of light, so the helideck position is not apparent until very close. Maybe the lights nearest the helideck could be switched off a few minutes prior to the aircraft arrival.

16) On some semi-submersible drilling rigs, some flare structures (when not burning) are poorly lit and only visible when very close to the structure.

17) As 40 - the lighting on the decks used to be blue/yellow which in my opinion was easier to see, especially on a large platform.

18) Daylight approaches are no problem generally but, during a night approach, it is very difficult to determine the distance to run and relative speed to the rig.

19) Preplanning is essential - knowing where the deck is.

20) Helideck lighting indistinguishable from other lights.

21) A lot of background lighting around platform.

22) Poor lighting mainly. Some drilling rigs are difficult to approach in some wind conditions because the helideck is positioned awkwardly between two legs instead of out board of one of them.

23) From the 500'/80 kt 'gate', the deck lighting is normally difficult to use for sight picture approach. The multitude of other lights, including flood lights, are used. Only once close in do the deck lights give visual cues.

24) The visual perspective of deck lighting changes when the deck is pitching/rolling. This causes apparent fluctuation in the approach angle.

25) Difficult to see until the last 1/4 to 1/2 mile or so for reasons given in Q 46.

26) It is often impossible to see the turbine exhausts during the approach. The possibility of flying through the exhaust gasses cannot be avoided.

27) The visual cues are practically non-existent. The approach technique which is most satisfactory involves a final approach in level flight at 50 ft to 100 ft above helideck elevation on a track to one side of the helideck. When very close to the deck it is easy to slow up and move sideways on to the deck. If no satisfactory visual cues materialise then overshoot straight ahead.

28) The problem at night is the amount of ambient lighting from the rest of the rig which obscures the helideck lighting until quite close when the shape, and hence the position of the helideck, can be determined.

29) Adequate, but not very important. More importantly IS IT THE RIGHT RIG? which is not usually so easily determined. See remarks on deck/rig identification.

30) Why no use of slope indicators?

31) During the day the yellow circle can be obscured by rope netting when seen from an oblique angle.

32) At night, particularly in bad weather, it can be difficult to know precisely which is the best approach, but by knowing where the deck is, whether by experience and/or a chart showing you its position, it is not a problem.

33) The main problem is the aspect - if the deck is on the opposite side from the approach direction, particularly with an unfamiliar semi-sub in poor weather, it is often very difficult to find the deck.

34) Circular or octagonal decks with a yellow circle are always difficult at night. Poor lighting, approaching into a black overshoot, poor visual cues, do not make the approach easier. The smaller the deck the more difficult it is to land at night under a given set of conditions.

35) In daylight suggest 1) value size of helideck painted (say) grey/black, any additional deck area painted lightish green thus landing visual cues are always the same whatever the deck shape (total deck).

36) At night, pick out the edge of the D value circle in brightish BLUE lights and floodlight the area in a 'carrier' type of illumination NOT bright white in my eyes.

37) Daylight is normal slight picture.

38) The Company provide 'deck information' sheets (frequency, pressure, range and bearing etc) and these have a diagram showing the location of the deck. Sometimes these are not quite adequate as obstructions may suggest a landing from a slightly different direction.

39) Platform lighting is usually very bright (dazzle) or too dark (lack of reference). Very difficult one this. I doubt things can be improved much except to have all bright lights facing away from all approaches.

40) Adjust your flight path to give the maximum information available. Never been there before or new right position, overfly. Set yourself up for a 3° glide slope or thereabouts dependant on wind.

41) There is a vast difference between semi-subs and platforms. Semi-subs generally have poor lighting but clear deck. Platforms have masses of lights but it is more difficult to find the deck.

42) At night if there are other platform/rigs in vicinity.

43) If isolated.

44) At night a flare makes a big difference. Sometimes all the platform's lights mask the actual deck ones.

45) Deck lighting is good, but landing on a deck in darkness is difficult. Rate of closure, rate of decent are difficult to ascertain visually and require use of instruments/radar.

46) At night the helideck is just another set of lights amongst a myriad of other rig/platform lights.

47) The decks that cause the problems are those that arrive and depart at short notice. Established decks on platforms/rigs not over difficult if in practice at night landings and in the general use.

48) Helideck lighting often merges into the background of the general platform lighting.

49) I am not sure how to improve this.

50) Ideally an approach aid, giving the correct angle of decent, into wind and clear of obstacles whilst being easily set up by an HLO would be a great help. But I am a realist.

51) If it is a rig or platform you are familiar with then you know in your mind where the deck is. Only at night in may be poor conditions to an unfamiliar rig is it a problem.

52) Daylight is no problem. Night time/darkness, lack of horizon and distance perception along with no speed perception is not helped by a poorly lit or too brightly lit helideck.

53) Deck edge lighting blends in with all other lights. Flood lights generally dazzle. I have seen flood lights at very high level on a derrick or rig, pointing downwards, give a good overall illumination without dazzle. Can't remember which rig, but not in UK.

54) In general the bigger the platform, the easier life is. Depth perception and rate of closure to small satellites at night can be very difficult.

55) Prior planning.....!!!

56) We operate to the same decks with frequent visits. They are familiar.

57) Again semis are more of a problem.

58) Some lights do blind you when on short finals.

59) Vary considerably. The new very small unmanned platforms are especially difficult.

60) When positioning at an airfield, one has direction, glide angle, cues all defined way back. When approaching a rig, at night, one needs to set up the aircraft on instruments, well back from the approach, for a safe approach. But you cannot, for you don't know where the helideck is or the obstructions until you are close. So the final stages are over-manoeuvred. Oh! have you read the rig name?

61) There are too many lights on at night to make helideck identification easy. It does, however, make rate of closure & depth perception easier.

62) They vary ,the nasty little unmanned ones can be bloody nasty.

63) By day - lighting almost irrelevant. Deck circle, rig structure & horizon being used.

64) By night - once the deck has been located, general rig lighting/flare is most useful in positioning.

65) Both - some obstructions, particularly crane booms pointing directly at you, are hard to spot & therefore avoid.

66) Peri lights not as good as could be.

67) Night landings offshore are a time when crews earn their pay.

68) Visual cues are not given by any lighting during the day. At night - apart from a circle of lights on the helideck - visual cues are taken from the surrounding lights positions of other rig or boats.

69) A standard size circle would help.

70) Questions 41 and 42 - local knowledge - i.e. your expectation - help more than the question suggests.

71) To few or even too many lights can affect orientation.

72) It is sometimes very hard to locate the helideck on jack up drilling rigs at night.

73) Before you even take off for a rig you must know where to look for the helideck to help in your orientation on arrival.

74) As for Q 42 it is often difficult to see the position of the helideck at night until quite close.

75) Can be very confusing/scary even. French pilots think we're crazy to fly offshore at night and sometimes we agree.

76) On some decks.

77) Non-existent!

78) Deck shape is inevitably used at night for angle of approach good lighting helps with depth perception and closing speed.

79) Once the deck has been identified by night, cues for the approach are usually quite good.

80) Again varies, can be quite difficult amongst other lights on rig.

81) Cues in general are few and far between, particularly at night or in poor visibility.

82) Helidck lighting sometimes merges with background initially.

83) Distance and glide path information is difficult at night.

84) Lights only really become an issue at night.

85) Lone platforms with very little lighting other than helideck, give poor depth perception and closing speed info.

86) Too many lights around the helipad.

87) Every rig/platform is different. The only visual cue is the yellow circle.

88) At night the helideck is just a black hole. There are often other black holes on the rig.

89) 'Semi-submersibles' and 'barges' are bad.

90) Depends on approach direction, wx conditions etc. Helideck deck lights only usable for angle of approach in the last ½ mile or so.

91) Decks are lost in the background structure, particularly at night. This, in my view, is a real safety problem which leaves no room for error.

92) A moving rig or ship at night with little external illumination is very difficult.

93) Lighting is of no relevance during daylight.

94) By day approaches difficult into sun when rig becomes a silhouette with no texture. By night you are approaching a point source almost in total darkness sometimes.

95) There is no proper guidance for night approaches but, if you accept that, it's ok.

96) Daylight is only problem under poor weather conditions and limited view through the windshield (misting, rain etc).

97) Sometimes you can't see the helideck until you're <u>very</u> close.

98) Some approaches at night are to the 'back' of the rig. The helideck isn't seen until the last few hundred metres.

99) An approach path indicator would help.

100) The above need not be a problem but means the rig needs to be overflown before landing. This of course requires the weather to be suitable.

101) It is helpful to know the position of the helideck prior to arrival, therefore starting final approach from correct side (especially at night). Info available at base and in flight.

102) The nature of the work of the installation requires a high level of general lighting and this can disguise helideck location until quite close.

103) The surrounding lights are brighter.

104) Day - no visual cues needed. Night - on a large well lit installation it's always like day. The problems come on a small, flat-topped satellite.

105) The area of the rig/platform under the helideck could be painted a different/eye catching colour to the rest of the rig/platform.

106) Could a lighting system be devised to indicate wind over the deck at night (in the case of radio info not being available?)

107) From the range at which a visual approach is commenced (max ¾ mm on rig radar) it is difficult to a) identify the deck area b) glean useful trend information on rate of closure and approach profile (height). The problem is twofold 1) a visual approach path indicator (stabilised) is needed 2) a good means of deck identification is required. For 1) a simple Glide Path Indicator as used on military ships would work. For 2) discrete lower power strobes, perhaps.

108) Night deck approaches on this fleet have become a rarity therefore individual skills rusty. Techniques are re-learnt as the need arises.

109) Windsocks are generally very difficult to identify on final approach.

110) VASIs have been used at airfield for decades. Why no omni-directional version for use on helidecks?

111) At night there are no cues, if the deck is on the far side you do not know which pilot will do the landing until very close in, possibly necessitating a go around and second approach to re-position (with the passengers wondering what is going on).

112) Decks are more obvious at night because of the perimeter lights.

113) Visual cues other than finding the helideck are generally irrelevant during the day.

114) At night the helideck is the darkest place on the whole rig. It's dark with the rest of platform brightly lit up.

115) At night this varies enormously and is not only dependant on actual deck lighting but proximity and lighting of whole installation and position of deck relative to it. There are decks which are a pleasure to fly to, others are poor.

QUESTION 44

1) At night - lights from the rig can dazzle.
2) ‘H’ and large O or day/night. Occasional night fliers seem to want Blackpool illuminations which wreck night vision.
3) Often lights are dazzling with no other references.
4) An increasing number of small (17m) decks means that once in the hover there is little visual cue except the deck netting. In daylight this is ok., at night very hazardous.
5) On many modern satellites the only thing in sight is the deck edge. This calls for great care and a cool head.
6) At night moving decks a handful.
7) Difficult to see low lighting could be improved.
8) Illumination of landing circle usually depends on ambient lighting of a/c lights.
9) Lateral cues are poor day or night on any rigs, platforms, boats. Deck markings have greatly improved although there are still a few decks not conforming to CAP 437.
10) Pin point lights by far the best. Tube lights are dangerous. Floodlights are a disaster.
11) Some of the lights (sodium lights) can be very bright.
12) At night - sometimes the lighting level could be better.
13) Extraneous floodlights etc can cause problems.
14) Some ok. Some bad.
15) Assuming it is not snowing or sleeting, the landing lights give the best visual cues, especially when operating to normally unattended installations with little background lighting.
16) The UK CAA has standardised on a touch down circle which is offset from the centre of the deck. At night the a/c nose may be on the edge of the deck with blackness in front of the pilot.
17) Adequate - not normally a problem.
18) With only one circle which you aim to have beneath your seat there is not much guidance. You can be +/- 1m out and not know it.
19) All too often deck floodlighting can be dazzling - that apart, generally satisfactory.
20) Once you’ve found it, landing is not often a problem.
21) The lights give little visual cues - the lights enable horizontal or vertical sections of the rig to be seen for the cue. An S76 in the hover sits 5 degrees to 10 degrees nose up.

22) Most decks I use are now per ICAO Annex 14 Vol 2 marked.

23) At night I use the landing lights.

24) Can be too complex at a critical phase.

25) Plenty of available references for hover/landing.

26) Constant problem with lights being U/S causing orientation difficulties.

27) Varies with platform.

28) Not many visual cues when the rig's behind you! The 'bum line' is essential.

29) Flood lights are the main nuisance during hover etc.

30) Occasionally floodlights are badly placed affecting `night vision'.

31) Better than the approach phase. With some wind directions, the tail of the aircraft is towards the centre of the installation, which leaves you a lot less to look at.

32) Night landings and lighting need to be further developed.

33) Always use aircraft landing light at night to illuminate deck.

34) Not keen on decks without nets at night; good visual cues are definitely lost if net is removed.

35) Sometimes the helideck lights are so bright that on rotation at night one's night vision is non existent for several minutes after take off.

36) The larger the platform/rig the easier it is. Satellites at night can be a problem, particularly for inexperienced pilots.

37) Vary considerably. The new very small unmanned platforms are especially difficult.

38) Lighting at night dazzles very badly.

39) Orders on deck are sometimes inconsistent.

40) Some helidecks have non-standard avoid segments.

41) They vary, the nasty little unmanned ones can be bloody nasty.

42) Deck circle is dominant aid for exact touch down position

43) The decks on **new platforms** seem to have been designed to meet the minimum theoretical minima. They do not project over the side and often one's nose is almost over the edge of the deck when on the 'bum line' making landing at night potentially hazardous.

44) Compared with the Brent decks, the newer ones are more like the forties decks before they were modified, close in to the centre of the platform and nearer obstructions.

45) A retro grade step. (After 17 years, maybe I'm cynical, but could it have something to do with money).

46) Again, more use of external cues away from the helideck is employed. However daylight marking on decks are usually good except when operating to NNMIs where the decks are often covered in guano, obscuring any markings.

47) Often too bright at night (deck lighting).

48) Removal of deck net is a problem, lighting on a shiny deck surface such as North Cormorant, with no texture makes it difficult to maintain accurate hover, difficult to judge wheel height.

49) Once that close to the helideck it doesn’t really matter if its day or night.

50) Once you are over the deck you are then very well lit. The transition from inky black night to white light helideck happens quickly.

51) French crews in awe of night satellite ops, but they’ve all left the company.

52) On smaller decks.

53) Floodlighting the eye line would be preferred.

54) No real problems once in the hover.

55) Just a yellow line underneath you. Very difficult at night particularly during take off.

56) Decks are now doing away with deck nets - these gave good hover ref - at night the aircraft floods are used to hover/land with.

57) Often deck edge is fairly well lit but the middle can be quite dark.

58) Incoming cues are limited - the markings are vague and at night difficult to see easily.

59) Once in the hover - the a/c lights do the rest - usually.

60) At night on a moving deck the lights are 'your world', so when they're moving it's difficult to find some other reference to avoid PIO.

61) Again ambient light levels are variable, and sometimes visual cues from LDP onwards are scarce due to w/v/rig heading combination.

62) The wind direction plus the need to position the aircraft port door on, are key factors.

63) Lights shine in your eyes. The onboard systems are usually better.

64) Even at limiting 'D' value, the deck is so big it doesn't matter.

65) The new layout of aiming circles is not often the best place to land! Pilots tend to land on the ‘H’ in the centre of the circle.

66) Cues are obviously restricted, but no great problem on the S61 as visibility through the chin windows is good.

67) Again, on military ships, discreet lighting is used in the form of 'coned' lights. They provide good, strong light on to the deck itself without 'blinding' the aircrew.

68) Deck lighting is of little value at this stage. The aiming circle is the only useful visual cue by day or night.

69) At night, once in the hover, you don't notice the edge lighting it is the general illumination which is an aid to hovering.

70) The removal of deck nets has made this aspect a little worse.

71) Depending on orientation, but often poor.

QUESTION 45

1) Varies greatly but generally good.
2) Too often kills any semblance of night vision.
3) Lousy why is it there, a hazard to aviation. If for deck movement of passengers, don't point it at the aircraft!!!
4) Generally sufficient lights but far too bright or poorly positioned.
5) Varies between decks and deck landing headings.
6) Often badly positioned and directed.
7) Varies. May shine into your eyes.
8) More lights could make location of deck obvious at night. Also yellow lights around perimeter just blend into the rest of the installation's lighting. The ability for the HLO to **instantly** control flood/deck lighting brilliance is not something I have seen or heard practised but would be a help.
9) Just coming to the hover and then you get blinded by a floodlight!
10) Take-off - lift-off deck - transition into pitch black - no night vision left - highly dangerous.
11) See previous comment. Structures surrounding the helideck should be floodlit - not the deck itself - highly dangerous.
12) Generally good but occasionally poor to moderate.
13) Some decks with floodlighting too low can dazzle just on touchdown.
14) Varies a lot.
15) It is generally non-standardised.
16) Not sufficiently hooded to prevent light shining up.
17) Usually only just adequate if there is any, and sometimes it creates too much glare.
18) The priority should be to flood the structure and legs not the helideck.
19) Some lights, if incorrectly adjusted can dazzle crews during the last stages of take-off and landing.
20) Floodlighting does not work!
21) Often too bright especially in wet weather.
22) Too bright.
23) Poorish to adequate-ish.
24) Nearly all floodlighting causes some degree of `blinding'.
25) The lights are generally not bright enough and pointing in the right direction.
26) Lots of light for the HLO but most of it is on the edge of the deck, bright and pointing inward i.e. directly toward me.
27) Can quite often dazzle when on deck.
28) Must shine them down so as not to dazzle pilots at night.
29) Varies with platform.
30) Never had a problem with too little light.

31) There is a wide variety of lighting arrangements. The fluorescent lights with diffuser are the worst.

32) Inconsistent.

33) Flare helps - floodlights can be dazzling.

34) Too many bright floodlights are provided at helideck level on the helideck and destroy what little night vision you have achieved.

35) Different lights - different decks - different operators. All types seem to be acceptable including the bright lights at deck level.

36) This varies considerably.

37) The floodlights often fail to illuminate the spot, purely the deck edges. Also the lights are not discrete so on deck shine at you.

38) Becoming poorer.

39) Suggestion - variable intensity helideck lights.

40) Overall standard is reasonable, companies know we will grumble if they let the standards fall too much.

41) Sometimes hidden as floodlights shine in pilots eyes.

42) Generally good except on mobile rigs usually that have not had their helidecks cleaned after what seems to be an explosion of mud + general mess which happens from time to time.

43) Flood lighting not always properly adjusted.

44) Dazzling.

45) The deck is bright, but dazzling in the final approach. Also, after sitting on deck for 15 mins, you then lift off and transition into the blackness. It is very disorientating ,and eerily unreal, to be on instruments then. The poor artificial horizon is then a problem. Nose down pitch is crucial, to ensure a compromise between clearing obstructions, accelerating, and climbing - people frequently get it wrong.

46) Semi-subs are usually worse. Still necessary to use torch on deck.

47) White floodlighting destroys night vision and quite often dazzles. Some decks have super structure lit in such a way as to not give enough cues to avoid unless one knows orientation of deck/derrick/obstruction.

48) It does vary rig to rig.

49) Varies from dangerously blinding to excellent to non existent.

50) Very variable - generally floods mounted high on surrounding structure, shining down are most useful, give least glare & fewer shadows.

51) Just an odd deck has poor flood lighting and also matt black tiled surface which does make judgement of wheel height difficult.

52) Can still cause problems due to shining into the cockpit.

53) It varies.

54) Varies from one installation to the next, some good, some not so good. There is no way of telling until you are at the installation.

55) I have never been asked to comment on offshore helideck lighting before - that should say enough.

56) Always too much extra light; difficult to see the wood for the trees!

57) There should not be any.

58) Big platforms are better due to their own area lighting; specific helideck floodlights are often dazzling and must be turned off for take off.

59) Can/seems to vary from rig to rig/ship.

60) Occasionally at an intrusive angle.

61) Can be far too bright - much contrast between dark and light over a short time span on both approach and take-off.

62) But then they may be in your eyes if they were present.

63) Too bright.

64) Aircraft landing lights assist.

65) Depending on the oil/gas installation the lighting ranges from poor to good.

66) Lot of room for improvement here. Pilots need to take care where they look so they do not get dazzled.

67) When lights are positioned correctly - has been a tendency to point lights up - blinding the pilot - not illuminating the landing area.

68) Too bright at night! Invariably we take off with full instrument lighting in order to be able to read the panel fully, which in turn means zero night vision outside the cockpit until 30 mins or so later.

69) Lighting on rigs is normally good, the main problem being too many lights on the rig which obscure the deck lights until you are close. Ship deck lights are not as good in my experience.

70) Flashing helideck lights, pilot activated/de-activated would possibly work better.

71) These lights should be shielded to illuminate the deck only to waist height or lower. Floodlighting is generally too bright and shines directly into the cockpit.

72) Sometimes too good.

73) Adequate without being dazzling during landing, but can cause large shadow areas for working in whilst on deck.

74) Acceptable.

75) Especially the 'old' style blue/yellow dome lights. The modern strip light is an improvement, but still poor.

76) Once on deck generally ok.

77) Never enough light at night. I always try to leave landing/search light on.

QUESTION 46

1) Not normally a problem.

2) If you put white/yellow deck lights on a platform which is festooned in white lights you probably will have an interference factor. I repeat deck lights **must** contrast - ideally not red (almost as many red lights as white) or white. If you fly (NVMC) to Tern/Eider visually, the light positions give a false impression of aircraft attitude.

3) Can be very bright outside the deck area and dazzles/disorientates you.

4) Some extraneous rig lights can cause dazzle.

5) Sometimes. Jack up rigs often have a lack of lighting. Depending on weather conditions at night (haze, mist) and ambient light conditions, this can be a help or a hindrance.

6) From a distance with low angle subtended from the horizon the deck can merge with other lights or not be apparent that it is on other side of rig.

7) Variable by rig and direction of approach. When the wind direction requires an approach from behind the rig the deck cannot of course be seen until nearly alongside.

8) More lights could make location of deck more obvious at night. Also yellow lights around perimeter just blend into the rest of the installation's lighting. The ability for the HLO to **instantly** control flood/deck lighting brilliance is not something I have seen or heard practised but would be a help.

9) Look for the black patch from a distance. Closer to the rig, more lighting of rig usually helps.

10) A very bright flare sometimes causes the helideck to appear very dark.

11) The flare - but there's not a lot you can do about that.

12) The whole platform is a blaze of light, so the helideck position is not apparent until very close, maybe the lights nearest to the helideck could be switched off for a few minutes prior to the aircraft on arrival.

13) Poorly positioned dazzling flood lights.

14) High workload - if the lighting level is too low on the deck. Safety - above plus floods adjusted to shine in at eye level.

15) The **flare**! Night vision is lost approaching a rig and more important, on departure the sudden transition to total darkness can be more exciting than a ride on Disney World's Space Mountain.

16) Occasionally the brightness of other lights on the installations 'obscures' the helideck markings until the aircraft is close to the installation.

17) Sometimes there is the odd light that shines towards the deck but usually this can be altered.

18) Not usually.

19) If going to a platform that has lots of other lights showing, for external maintenance crews etc, it can sometimes be difficult to pick out helideck, especially when going to an unfamiliar location.

20) Extraneous floodlights etc. can cause problems.

21) Other lights on platforms or rigs are a help rather than a hindrance because they can greatly aid your visual references on approaching the deck. Deck landings at night are a combination of instrument flying and visual flying. The nearer you get to the deck the more visual reference you have got until the landing itself which is fully visual. Anything that gives you a better visual reference is a bonus.

22) Not much can be done, especially when you consider we are landing on top of a 24 hour per day 'factory'.

23) The mass of white/coloured lights on rigs makes confirmation of the expected deck position very difficult until the last 1/2 to 1/4 mile on the final approach.

24) Note: In common with most shore-based pilots, I do not carry out many night deck landings. Over the last 6 years (as handling pilot) I have carried out some 800 day deck landings, but only 75 night deck landings, i.e. an average of only 12 night landings per year.

25) Especially an intense flare.

26) Sometimes.

27) Especially since the introduction of all yellow perimeter lighting.

28) The other lights are generally floodlights that often shine directly in your eyes.

29) Not strictly speaking lighting, but the flare (from the flare boom) at night can be quite overwhelming in its intensity. I would not think that anything to reduce this intensity would be possible.

30) The plethora of bright lights does make it particularly difficult to identify the deck more particularly when sodium seems to be the common colour. Only a full overflight can eliminate doubts.

31) During initial approach, a well lit up rig (as they invariably are), together with glare from the flare, tend to obscure the deck lights. However, once reasonably close in and with good visual contact with the deck, it is no longer a problem.

32) All same colour.

33) From a distance most platforms are ablaze with light - the deck somewhere in the shadows.

34) On main platforms until fairly close in one is aiming for the black bit of the platform.

35) Some of the obstruction lighting is too dim. Crane jibs for instance.

36) The other lights are essential to help judge closure rates/distance to run.

37) Lights too bright making it difficult to see helideck.

38) Yes in most cases - platform lighting is usually very bright (dazzle) or too dark (lack of reference); very difficult one this. I doubt things can be improved much except to have all bright light facing away from all approaches. In nearly all cases a windsock is not visible. These can only be seen if clean and the lighting is on the inside of wind sock.

39) Depends on the direction of approach and weather conditions - do not think you can fix this one. Sometimes the lack of lights on what you know is there can cause distraction. (Flare booms are the prime example) and cause the flight path to be adjusted to give a bigger safety margin than needed at the cost of performance.

40) They give depth perception.

41) At night the helideck is just another set of lights amongst a myriad of other rig/ platform lights.

42) Sometimes the helideck can only be seen when very close in. Platforms seem to be the worse for this.

43) Flares can be a big problem.

44) The first few times to a “new” deck this is usually a problem. Then repetition makes life easier. You simply get used to it.

45) Sometimes, however, some extraneous lighting is desirable for spatial orientation. i.e. the most helpful lights are those which illuminate the legs of the platform.

46) Large flares close to helideck are worst offenders.

47) Some are sometimes too bright.

48) On some rigs but not all.

49) Some lights can irritate particularly if they are shinning directly at you.

50) There is generally always a problem with big (strange) lighting on or around the platform which can and often does cause a problem.

51) Sometimes helps to give depth perception.

52) Production platforms are very brightly lit and this can be distracting. Mobile ‘jack-up’ rigs usually have completely unlit legs adjacent to helideck which is unsafe.

53) Some floodlights are high, of course, these cannot be mounted “behind” the pilots, as wind and helideck orientation changes cause the approach direction to change.

54) Sometimes floodlights detract from helideck picture.

55) There are too many lights on at night to make helideck identification easy. It does, however, make rate of closure & depth perception easier.

56) Often other lights are a great help as they provide more visual cues as to up/down etc. The bigger the installation the easier.

57) Very often - but don’t suppress them as they are used for general attitude guidance. Make the deck lighting brighter.

58) Misdirected sodium lights occasionally glare out the deck.

59) This depends on the position of the helideck in relation overall to the rest of the rig/platform; sometimes structures offshore can be quite complex.

60) On approach the deck can be camouflaged in the background lighting but once close in and over deck not a problem.

61) Sometimes.

62) Particular problem in poor viz.(goldfish bowl) gas flare can turn the whole environment orange. Most disorienting, particularly on night departure. Leave rig that is a mass of lights and shadow straight into total blackness.(YUK!!).

63) All rigs are lit up like Christmas trees and it is often hard to discern easily the location of the helideck.

64) You have to know where to look, or do an orbit of the installation (if it is a deck new to you) once you’ve found the deck you have to figure the best approach given the wind direction.

65) Often hard to see helideck from a suitable distance out on the approach.

66) Until quite close at night, helideck identification is always difficult.

67) Can be a major hazard - again conflicting interests offshore - helicopters are a small but vital part of operations. Never seen through the pilots eyes.

68) The more structures that are lit the better.

69) Occasionally the flare can make it more difficult but it is not usually a problem.

70) Lights near helideck should be masked from above if brighter than deck lighting.

71) Yes, during initial identification, but generally provide a helpful reference.

72) Again particularly in rain.

73) The helideck lights tend to be fairly dim and the centre of the deck dark. Dayglow paint would improve matters, as the DECR nets tend to mark the yellow DECR markings.

74) Perhaps a change of colour of the deck lights would enable easier identification of the helideck. Most of the lights are of a similar colour i.e. white/sodium, causing difficulty in identification.

75) Generally they assist by offering background lighting.

76) This varies from rig to rig etc.

77) Very confusing, time consuming and distracting in trying to identify and use what is available.

78) Misdirected or aligned lights.

79) Strobes aid; occasionally the intensity of the flare.

80) Sometimes floodlights are set too high. Usually OK though.

81) Often.

82) Only strobes, but rigs switch them off before helicopter operations.

83) Dependent upon approach direction.

84) Sometimes a problem until close to the rig which makes the manoeuvre more tense.

85) Flare can blind you if not careful (night vision).

86) When rigs are flaring - this can affect night vision considerably.

87) Sometimes.

88) Walkway lighting below helideck - particularly flotels - at a distance can be misinterpreted as deck lights - colour does not make a difference.

89) Helideck lighting though `approved' intensity, tends to be much less bright than the vast number of lights covering working areas of the platform. The helideck thus becomes the 'dark' patch in the jumble of bright light points.

90) Helideck lighting is usually obscured by platform lighting until the latter stages of an approach, particularly so if the rig is an unfamiliar one.

91) Particularly flares on large platforms.

92) Frequent misunderstanding and misidentification from other lights.

93) Problems tend to come from sudden brightening or dimming of gas flares, not so much from other 'lights'.

94) However lots of rig lighting illuminate the sea surface thus helping the approach considerably.

95) The customer's priority is to work the rig. He is not going to cut the derrick lights to make my job easier!

96) But only at a distance.

97) Even with the helideck on the approach side it can be difficult to pick out until close in.

98) Rigs at night are a mass of lights which makes distinguishing helideck lights at a distance virtually impossible.

99) Like I said before the bright platforms. More white light needed on decks.

Appendix F Analysis of Trials Ratings Data

Table F1 Helideck Acquisition

Group	Configs	Trial(s)	Runs	Comparison	Presentation Ratings	Workload Ratings	Conclusion
1	(a) & (b)	T1, T2, T3	1 & 2, 2 & 1, 1 & 2	Yellow vs green perimeter lights	5 & 7, 5 & 5, 5 & 8	5 & 4, 5 & 5, 5 & 4	Consistent improvement in presentation ratings with change from yellow to green perimeter lights; minor improvement in workload ratings.
	(c) & (d)	T1	3 & 4		7 & 9	4 & 4	
	(t) & (u)	T3	9 & 10		1 & 1	6 & 6	
2	(b) & (j)	T2 & T3	1 & 3, 2 & 3	ELP 'H' (no/yes)	5 & 3, 8 & 8	5 & 6, 4 & 4	No overall improvement from adding ELP 'H'.
	(l) & (h)	T2	7 & 5		-	-	
	(k) & (d)	T2	6 & 4		-	-	
	(g) & (n)	T1	7 & 9		7& 8	4 & 4	
3	(c) & (a)	T1	3 & 1	ELP 'H' vs floodlights	7 & 5	4 & 5	Fair improvement overall in presentation ratings with ELP 'H' instead of floodlights; workload ratings virtually unchanged.
	(d) & (b)	T1, T2, T3	4 & 2, 4 & 1, 6 & 2		9 & 7, 4 & 5, 8 & 8	4 & 4, 6 & 5, 4 & 4	
	(h) & (g)	T1	8 & 7		9 & 7	4 & 4	
4	(r) & (s)	T3	7 & 8	ELP 'H' (with yellow LED circles) (no/yes)	8 & 8	4 & 3	Virtually no change in ratings from adding ELP 'H' in presence of yellow LED circles.
	(p) & (q)	T3	4 & 5		8 & 8	4 & 4	
5	(b) & (p)	T3	2 & 4	Yellow LED circles	8 & 8	4 & 4	No change.
	(b) & (q)	T3	2 & 5	Yellow LED circles & ELP 'H'	8 & 8	4 & 4	No change.
	(b) & (r)	T3	2 & 7	Yellow LED circles vs floodlights	8 & 8	4 & 4	No difference.

Table F1 Helideck Acquisition

Group	Configs	Trial(s)	Runs	Comparison	Presentation Ratings	Workload Ratings	Conclusion
6	(d) & (h)	T1	4 & 8	Green ELP perimeter markers	9 & 9	4 & 4	No change.
	(k) & (l)	T2	6 & 7		-	-	
7	(e) & (f)	T1	5 & 6	Floodlights (no/yes)	1 & 1	6 & 7	Slight degradation in presentation ratings with addition of floodlights; very minor degradation in workload ratings.
	(d) & (j)	T2 & T3	4 & 3, 6 & 3		4 & 3, 8 & 8	6 & 6, 4 & 4	
	(k) & (b)	T2	6 & 1		-	-	
	(h) & (n)	T1	8 & 9		9 & 8	4 & 4	
	(r) & (p)	T3	7 & 4		8 & 8	4 & 4	
8	(a) & (t)	T3	1 & 9	Floodlight hoods (no/yes)	5 & 1	5 & 6	Significant degradation with introduction of hoods.
	(b) & (u)	T3	2 & 10		8 & 1	4 & 6	

Table F2 Final Approach

Group	Configs	Trial(s)	Runs	Comparison	Presentation Ratings	Workload Ratings	Conclusion
1	(a) & (b)	T1, T2, T3	1 & 2, 2 & 1, 1 & 2	Yellow vs green perimeter lights	5 & 6, 5 & 4, 5 & 6	5 & 5, 5 & 5, 5 & 4	Slight improvement in ratings with change from yellow to green perimeter lights.
	(c) & (d)	T1	3 & 4		8 & 8	4 & 3	
	(t) & (u)	T3	9 & 10		5 & 5	5 & 5	
2	(b) & (j)	T2 & T3	1 & 3, 2 & 3	ELP 'H'	4 & 6, 6 & 7	5 & 4, 4 & 3	Consistent and significant improvement with addition of ELP 'H'.
	(l) & (h)	T2	7 & 5		2 & 4	8 & 5	
	(k) & (d)	T2	6 & 4		4 & 7	6 & 4	
	(g) & (n)	T1	7 & 9		6 & 9	4 & 3	
3	(c) & (a)	T1	3 & 1	ELP 'H' vs floodlights	8 & 5	4 & 5	ELP 'H' consistently rated better than floodlights.
	(d) & (b)	T1, T2, T3	4 & 2, 4 & 1, 6 & 2		8 & 6, 7 & 4, 6 & 6	3 & 5, 4 & 5, 4 & 4	
	(h) & (g)	T1	8 & 7		9 & 6	3 & 4	
4	(r) & (s)	T3	7 & 8	ELP 'H' (with yellow LED circles)	8 & 7	3 & 3	Impact of ELP 'H' insignificant in presence of yellow LED circles.
	(p) & (q)	T3	4 & 5		8 & 8	3 & 3	
5	(b) & (p)	T3	2 & 4	Yellow LED circles	6 & 8	4 & 3	Significant improvement.
	(b) & (q)	T3	2 & 5	Yellow LED circles & ELP 'H'	6 & 8	4 & 3	Significant improvement.
	(r) & (b)	T3	2 & 7	Yellow LED circles vs floodlights	8 & 6	3 & 4	Yellow LED circles better than floods.
6	(d) & (h)	T1	4 & 8	Green ELP perimeter markers	8 & 9	3 & 3	Slight improvement with ELP perimeter markers.
	(k) & (l)	T2	6 & 7		4 & 2	6 & 8	
7	(e) & (f)	T1	5 & 6	Floodlights	2 & 2	7 & 7	Virtually no benefit from adding floodlights.
	(d) & (j)	T2 & T3	4 & 3, 6 & 3		7 & 6, 6 & 7	4 & 4, 4 & 3	
	(k) & (b)	T2	6 & 1		4 & 4	6 & 5	
	(h) & (n)	T1	8 & 9		9 & 9	3 & 3	
	(r) & (p)	T3	7 & 4		8 & 8	3 & 3	
8	(a) & (t)	T3	1 & 9	Floodlight hoods (no/yes)	5 & 5	5 & 5	No effect from adding hoods.
	(b) & (u)	T3	2 & 10		6 & 5	5 & 5	

Table F3 Hover

Group	Configs	Trial(s)	Runs	Comparison	Presentation Ratings	Workload Ratings	Conclusion
1	(a) & (b)	T1, T2, T3	1 & 2, 2 & 1, 1 & 2	Yellow vs green perimeter lights	5 & 6, 5 & 5, 5 & 5	5 & 5, 5 & 5, 5 & 5	Modest improvement in presentation ratings with change from yellow to green perimeter lights; no effect on workload ratings.
	(c) & (d)	T1	3 & 4		6 & 8	4 & 4	
	(t) & (u)	T3	9 & 10		5 & 5	5 & 5	
2	(b) & (j)	T2 & T3	1 & 3, 2 & 3	ELP ‘H’	5 & 5, 5 & 5	5 & 5, 5 & 5	No significant change overall from adding ELP ‘H’.
	(l) & (h)	T2	7 & 5		5 & 4	5 & 5	
	(k) & (d)	T2	6 & 4		5 & 5	5 & 4	
	(g) & (n)	T1	7 & 9		8 & 9	3 & 3	
3	(c) & (a)	T1	3 & 1	ELP ‘H’ vs floodlights	6 & 5	4 & 5	Modest degradation in presentation and workload ratings in changing from ELP ‘H’ to floodlights.
	(d) & (b)	T1, T2, T3	4 & 2, 4 & 1, 6 & 2		8 & 6, 5 & 5, 5 & 5	4 & 5, 4 & 5, 5 & 5	
	(h) & (g)	T1	8 & 7		9 & 8	3 & 3	
4	(r) & (s)	T3	7 & 8	ELP ‘H’ (with yellow LED circles)	8 & 8	3 & 3	No change.
	(p) & (q)	T3	4 & 5		9 & 9	3 & 3	
5	(b) & (p)	T3	2 & 4	Yellow LED circles	5 & 9	5 & 3	Significant improvement.
	(b) & (q)	T3	2 & 5	Yellow LED circles & ELP ‘H’	5 & 9	5 & 3	Significant improvement.
	(r) & (b)	T3	2 & 7	Yellow LED circles vs floodlights	8 & 5	3 & 5	Yellow LED circles significantly better than floods.
6	(d) & (h)	T1	4 & 8	Green ELP perimeter markers	8 & 9	4 & 3	Slight improvement with ELP perimeter markers.
	(k) & (l)	T2	6 & 7		5 & 5	5 & 5	
7	(e) & (f)	T1	5 & 6	Floodlights	6 & 4	5 & 6	No overall benefit from adding floodlights.
	(d) & (j)	T2 & T3	4 & 3, 6 & 3		5 & 5, 5 & 5	4 & 5, 5 & 5	
	(k) & (b)	T2	6 & 1		5 & 5	5 & 5	
	(h) & (n)	T1	8 & 9		9 & 9	3 & 3	
	(r) & (p)	T3	7 & 4		8 & 9	3 & 3	
8	(a) & (t)	T3	1 & 9	Floodlight hoods (no/yes)	5 & 5	5 & 5	No effect from adding hoods.
	(b) & (u)	T3	2 & 10		5 & 5	5 & 5	

Table F4 Landing

Group	Configs	Trial(s)	Runs	Comparison	Presentation Ratings	Workload Ratings	Conclusion
1	(a) & (b)	T1, T2, T3	1 & 2, 2 & 1, 1 & 2	Yellow vs green perimeter lights	5 & 6, 5 & 5, 5 & 5	5 & 5, 5 & 5, 5 & 5	Slight improvement in presentation ratings with change from yellow to green perimeter lights; no effect on workload ratings.
	(c) & (d)	T1	3 & 4		6 & 8	4 & 4	
	(t) & (u)	T3	9 & 10		5 & 5	5 & 5	
2	(b) & (j)	T2 & T3	1 & 3, 2 & 3	ELP 'H'	5 & 5, 5 & 5	5 & 5, 5 & 5	No significant change overall from adding ELP 'H'.
	(l) & (h)	T2	7 & 5		5 & 5	5 & 5	
	(k) & (d)	T2	6 & 4		5 & 3	5 & 5	
	(g) & (n)	T1	7 & 9		7 & 8	4 & 3	
3	(c) & (a)	T1	3 & 1	ELP 'H' vs floodlights	6 & 5	4 & 5	Overall degradation in presentation and workload ratings in changing from ELP 'H' to floodlights.
	(d) & (b)	T1, T2, T3	4 & 2, 4 & 1, 6 & 2		8 & 6, 3 & 5, 5 & 5	4 & 5, 5 & 5, 5 & 5	
	(h) & (g)	T1	8 & 7		8 & 7	3 & 4	
4	(r) & (s)	T3	7 & 8	ELP 'H' (with yellow LED circles)	8 & 8	3 & 3	No change.
	(p) & (q)	T3	4 & 5		8 & 8	3 & 3	
5	(b) & (p)	T3	2 & 4	Yellow LED circles	5 & 8	5 & 3	Significant improvement.
	(b) & (q)	T3	2 & 5	Yellow LED circles & ELP 'H'	5 & 8	5 & 3	Significant improvement.
	(r) & (b)	T3	2 & 7	Yellow LED circles vs floodlights	8 & 5	3 & 5	Yellow LED circles significantly better than floods.
6	(d) & (h)	T1	4 & 8	Green ELP perimeter markers	8 & 8	4 & 3	Virtually no improvement from adding ELP perimeter markers.
	(k) & (l)	T2	6 & 7		5 & 5	5 & 5	
7	(e) & (f)	T1	5 & 6	Floodlights	5 & 5	5 & 5	No overall benefit from adding floodlights.
	(d) & (j)	T2 & T3	4 & 3, 6 & 3		3 & 5, 5 & 5	5 & 5, 5 & 5	
	(k) & (b)	T2	6 & 1		5 & 5	5 & 5	
	(h) & (n)	T1	8 & 9		8 & 8	3 & 3	
	(r) & (p)	T3	7 & 4		8 & 8	3 & 3	
8	(a) & (t)	T3	1 & 9	Floodlight hoods (no/yes)	5 & 5	5 & 5	No effect from adding hoods.
	(b) & (u)	T3	2 & 10		5 & 5	5 & 5	