Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2006/03

Enhancing Offshore Helideck Lighting – Onshore Trials at Norwich Airport

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November 2006

ISBN 0 11790 618 2

Published November 2006

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

Published by TSO (The Stationery Office) on behalf of the UK Civil Aviation Authority.

Printed copy available from:
TSO, PO Box 29, Norwich NR3 1GN
Telephone orders/General enquiries: 0870 600 5522
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List of Effective Pages

Part	Page	Date
	iii	November 2006
	iv	November 2006
Report	1	November 2006
Report	2	November 2006
Report	3	November 2006
Report	4	November 2006
Report	5	November 2006
Report	6	November 2006
Report	7	November 2006
Report	8	November 2006
Report	9	November 2006
Report	10	November 2006
Report	11	November 2006
Report	12	November 2006
Report	13	November 2006
Report	14	November 2006
Report	15	November 2006
Report	16	November 2006
Report	17	November 2006
Report	18	November 2006
Report	19	November 2006
Report	20	November 2006
Report	21	November 2006
Report	22	November 2006
Report	23	November 2006
Report	24	November 2006
Report	25	November 2006
Report	26	November 2006
Report	27	November 2006
Report	28	November 2006
Report	29	November 2006
Report	30	November 2006
Report	31	November 2006
Report	32	November 2006
Report	33	November 2006
Report	34	November 2006
Report	35	November 2006
Report	36	November 2006
Report	37	November 2006
Report	38	November 2006
Report	39	November 2006
Report	40	November 2006
Report	41	November 2006
Report	42	November 2006
Report	43	November 2006
Report	44	November 2006
Report	45	November 2006
Report	46	November 2006
Report	47	November 2006
Report	48	November 2006
Report	49	November 2006
Appendix A	50	November 2006
Appendix A	51	November 2006
Appendix A	52	November 2006
Appendix B	53	November 2006
Appendix B	54	November 2006
Appendix B	55	November 2006

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Contents

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Report Enhancing Offshore Helideck Lighting – Onshore Trials at Norwich Airport

Foreword

The research reported in this paper was funded by the Safety Regulation Group (SRG) of the UK Civil Aviation Authority, and was performed with the assistance of QinetiQ Ltd. The work follows on from the earlier trials at the NAM K14 platform in the Dutch sector of the southern North Sea (reported in CAA Paper 2004/01), and at Longside Airfield near Aberdeen (reported in CAA Paper 2005/01). The aim of the trials was to improve, refine and characterise the helideck lighting systems developed during the earlier trials and to assess some new ideas and technologies. This paper is based on the contractor's final report ref. QinetiQ/D&TS/C&IS/CR052930, which has been enhanced by SRG's Research and Strategic Analysis section. All significant changes to the original report have been reviewed by and agreed with the contractor.

As a result of this work, guidance material on an interim (Stage 1) improved lighting system was issued to the Industry by letter in July 2004, and revised by a subsequent letter in March 2006. The two Stage 1 configurations have been installed on the ExxonMobil Galahad and Lancelot platforms in the southern North Sea for in-service evaluation. In addition, a provisional specification for the final (Stage 2) lighting configuration has been produced and used to tender for the production of two prototype systems. Contracts have been let to two different contractors, and the resulting two systems will be installed on operational offshore platforms for in-service trials aimed at validating the specification.

The overall programme of research on helideck lighting 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.

Safety Regulation Group

01 November 2006

Executive Summary

With support from QinetiQ Ltd., the Safety Regulatory Group of the Civil Aviation Authority (CAA) has been conducting a series of flight trials to address the need for improved offshore helideck lighting.

Current operational experience at night, as evidenced in the results of the survey of offshore pilot views on flight crew workload and safety hazards reported in *CAA Paper 97009*, provided strong support for a review of the existing provisions. In addition, considerations related to the possible future reduction of operating minima resulting from the ongoing development of the use of satellite navigation systems (e.g. the Global Positioning System (GPS)) as an offshore approach aid, also motivated the research to enhance existing visual aids.

Earlier flight trials had been performed to assess the benefits of changing the colour of the perimeter lighting from yellow to green, and of using new lighting technologies to improve the conspicuity of the deck markings at night. The first of these comprised dedicated offshore trials carried out on the NAM K14B platform in the Dutch sector of the southern North Sea during 1998/9 and is reported in *CAA Paper 2004/01*. These trials were followed by onshore trials at Longside Airfield, Aberdeenshire in 2002 which are reported in *CAA Paper 2005/01*.

This report presents the combined results of a series of trials conducted at a test site at Norwich Airport during 2003/4. The aim of this series of trials was to improve, refine and characterise the helideck lighting systems developed during the earlier trials and assess new technologies. In particular, the trials evaluated:

- the acceptability of the *CAP 437* upper limit on perimeter light intensity of 60 cd;
- the effectiveness of different floodlighting configurations and technologies in both an elevated position in the Limited Obstacle Sector (LOS), and at deck level around the helideck perimeter;
- the effect of changing the Touchdown Marking circle coverage (length of segments compared to the length of the gaps), the number of light emitting diodes (LEDs) per metre in the segments and the intensity of the individual LEDs;
- the effectiveness of green laser/optical fibre deployed to form an outline Heliport Identification Marking (‘H’) as an alternative to a green electro-luminescent panel (ELP) ‘H’;
- the effectiveness of a yellow LED segment chevron marking, indicating the general location of the obstacle-free sector (OFS) origin, in providing heading/alignment cues as a possible alternative to a lit ‘H’;
- the potential of some newly available lighting products to provide visual cueing for night approaches and landings;
- the effects of a landing net on each of the visual aids.

The trials were conducted at night on six separate occasions with approaches flown against various lighting configurations both with and without a landing net. Pilot ratings for each configuration were given following each approach. The results showed that all configurations provided positional and translational rate cueing information of varying benefit.

A dedicated test flight to two offshore platforms in the southern North Sea to evaluate the two most promising modified floodlighting configurations was also conducted.

The main conclusions derived from the results of the trials are:

- The upper limit on perimeter light intensity of 60 cd cited in *CAP 437* is acceptable.

- A floodlighting system comprising four deck-level floodlights has the potential to provide enhanced floodlighting for many offshore helidecks as an interim (Stage 1) solution prior to the implementation of the Touchdown Marking circle and 'H'.
- A floodlighting system comprising floodlights fitted with louvres and located at high level in the LOS together with floodlights mounted at deck level opposite the LOS may be suitable for providing enhanced floodlighting on offshore helidecks with significant obstacles in the LOS, pending implementation of the Touchdown Marking circle and Heliport Identification Marking lighting.
- The minimum Touchdown Marking circle coverage of 50% proposed in the ICAO standards is acceptable.
- The specification of the Touchdown Marking circle segments used for the Longside Airfield trials in respect of intensity and the number of LEDs per metre represents the minimum acceptable standard.
- A Touchdown Marking circle composed of discrete sources, as evaluated, is unacceptable as a minimum standard.
- The laser/optical fibre 'H' performed significantly better than the electro-luminescent panel (ELP) 'H' with no helideck net fitted, and as well as the ELP 'H' with a net fitted.
- The LED chevron cannot be considered an effective alternative to the 'H', but could be used to provide additional cueing where desired.
- The presence of a helideck net diminished the performance of the Touchdown Marking circle and the 'H'. Increasing the width (and hence intensity) of the Touchdown Marking circle was found to restore its performance. Increasing the width of the laser/optical fibre 'H' is expected to have the same effect.

The following recommendations are made:

- An in-service trial should be conducted to evaluate the two floodlighting configurations identified for use in the Stage 1 improved helideck lighting in a range of meteorological conditions, and to expose them to a broad range of pilots.
- Pending the outcome of the in-service trial recommended above, a floodlighting configuration of four deck-level floodlights, similar in performance to Tranberg TEF 9964 floodlights, should be recommended as the preferred interim minimum standard to improve the visual cueing environment on offshore helidecks.
- An equipment requirements specification should be drawn up for the Touchdown Marking circle and 'H'. It should be designed to produce a system of visual aids having the required range and visual cueing performance over the normal range of helicopter vertical approach paths, for the worst case metereological operating conditions, either with or without a helideck net fitted.
- Prototype equipment should be manufactured and installed on a representative offshore platform for extended in-service trials with the primary objective of validating the equipment requirements specification prior to inclusion in *CAP 437*. To this end, the trial should expose the system to a wide sample of offshore pilots, in an offshore environment and in a broad range of meteorological conditions.

1 Introduction

1.1 Background

With support from QinetiQ Ltd., the Safety Regulatory Group of the Civil Aviation Authority (CAA) has been conducting a series of flight trials to address the need for improved offshore helideck lighting.

The final approach and landing phases of all offshore helicopter operations are carried out by reference to visual cues that are derived from the destination platform. Visual aids are provided in the form of both marking and lighting. These aids are generally in accordance with the Standards and Recommended Practices described in the *International Civil Aviation Organisation (ICAO) Annex 14 Volume 2* [Ref. 1], and *CAP 437* [Ref. 2]. However, current operational experience at night, as evidenced in the results of the survey of offshore pilot views on flight crew workload and safety hazards reported in *CAA Paper 97009* [Ref. 3], provided strong support for a review of the existing provisions. In addition, considerations related to the possible future reduction of operating minima resulting from the ongoing development of the use of satellite navigation systems (e.g. the Global Positioning System (GPS)) as an offshore approach aid, also motivated the research to enhance existing visual aids.

In the light of the above, flight trials were commissioned to assess the benefits of changing the colour of the perimeter lighting from yellow to green, and of using new lighting technologies to improve the conspicuity of the deck markings at night. The first of these comprised dedicated offshore trials carried out on the NAM K14B platform in the Dutch sector of the southern North Sea during 1998/9 [Ref. 4]. These trials were followed by onshore trials at Longside Airfield, Aberdeenshire in 2002 [Ref. 5].

This report presents the combined results of a series of six trials conducted at a test site at Norwich Airport during 2003/4, and individually reported in interim reports [Refs. 6 to 9]. The aim of this series of trials was to improve and refine the helideck lighting system developed during the earlier trials. The suitability of a number of newly available lighting products for providing visual cueing for night approaches was also evaluated. In addition, the two most promising modified floodlighting configurations identified during the trials at Norwich Airport were installed on the ExxonMobil Lancelot and Galahad platforms in the southern North Sea and evaluated by means of a dedicated test flight in February 2006.

1.2 Trial Objectives

The focus of the series of trials at Norwich was to evaluate the effectiveness of each helideck lighting feature when presented in different formats and, in some cases, using different technologies. Trials were also conducted to evaluate key lighting configurations with a helideck net fitted. The specific objectives of the evaluation of each lighting feature are detailed below.

1.2.1 Perimeter Lights

A green perimeter light, designed to meet the new ICAO standard, had become available. In addition to the change of colour, the new standard introduces a revised vertical intensity distribution which contains a higher 'main-beam' peak intensity than the present standard (30 cd compared to 25 cd). In interpreting the new standard for *CAP 437* [Ref. 2], CAA has placed a precautionary upper limit on perimeter light intensity of 60 cd as a result of concerns over glare. The peak intensity of the new perimeter light was on this limit, and it was considered desirable to confirm the acceptability of the 60 cd limit by evaluating the new light. A specific objective within the trials was therefore to evaluate the new perimeter lights designed to meet the new ICAO standard.

1.2.2 Floodlighting

Different floodlights were located both elevated within the Limited Obstacle Sector (LOS), and around the helideck perimeter at deck level. The specific trial objectives were to:

- evaluate the performance of four Orga halogen floodlights, configured as high-level LOS floodlights, in providing visual cues during the latter stages of the final approach and the hover;
- evaluate the performance of two Tranberg xenon floodlights, configured as high-level LOS floodlights, in providing visual cues during the latter stages of the final approach and the hover;
- evaluate the performance of two Orga halogen floodlights, configured as high-level LOS floodlights, together with two or three Tranberg deck-level floodlights positioned opposite the LOS in providing visual cues during the latter stages of the final approach and the hover;
- compare the performance of the above with each other and relative to the LOS floodlight configuration evaluated during the Longside trials (two Orga halogen floodlights configured as high-level LOS floodlights);
- evaluate a deck-level floodlighting system comprised of eight Tranberg xenon floodlights;
- evaluate a deck-level floodlighting system comprised of four Tranberg xenon floodlights.

1.2.3 Touchdown Marking Circle

The earlier trials on the K14B and at Longside had evaluated the concept of an illuminated landing circle and had established that one circle was sufficient. The effect of a helideck net on its performance had also been investigated. Although the circle configuration used for the earlier trials was acceptable, it was considered necessary to establish the boundaries for the main design parameters of the circle in order to produce appropriate guidance material to support its implementation. The main parameters identified were: circle coverage (length of segments compared to the length of the gaps); the number of LEDs per metre in the segments; the intensity of the individual LEDs. The specific objectives were therefore to:

- evaluate the adequacy of the minimum circle coverage of 50% adopted in the ICAO standards [Ref. 1, Ch 5] as compared to the 74% coverage used during earlier trials;
- evaluate the effect of halving the number of LEDs from 32 per metre used in earlier trials to 16 per metre;
- evaluate the effect of reducing the intensity of the LEDs by reducing the supply voltage from 12 volts used in earlier trials to 9 volts;
- evaluate the effectiveness of a landing circle comprising a series of 16 equally spaced discrete sources as opposed to segments and gaps;
- evaluate the effectiveness of a landing circle comprising a series of 32 equally spaced discrete sources as opposed to segments and gaps;
- evaluate the effect of doubling the intensity of the yellow LED segments around the landing circle by deploying two adjacent LED landing circles;

- evaluate the effect of vertical approach path angle on the usable range of the landing circle.

1.2.4 Heliport Identification Marking ('H')

Previous trials had employed an Electro-Luminescent Panel (ELP) 'H' located in the centre of the helideck. An optical fibre 'string' was proposed by Intenslite as having potential application to helideck marking and lighting. In view of the characteristics of the product, it was decided to use it to form an outline 'H'. A specific objective of the trials was therefore to evaluate the effectiveness of green Intenslite laser/optical fibre deployed in the form of an outline 'H' as an alternative to the green ELP 'H'.

1.2.5 Chevron

An evaluation of the effectiveness of lighting the chevron indicating the position of the obstacle free sector (OFS) origin was proposed in order to determine its acceptability as an alternative source of heading/alignment cues to the lit 'H'.

1.2.6 Other Aids and Equipment

The opportunity presented by the trials was taken to assess some newly available lighting products to provide visual cueing for night approaches and landings. Objectives were therefore included within the trials to:

- evaluate the effectiveness of green Intenslite laser/optical fibre deployed to illuminate the helideck net, and thereby establish its acceptability as an alternative to floodlighting on decks fitted with landing nets;
- evaluate prototype Intenslite optical fibre panels, illuminated by green LEDs, to establish their suitability as lighting elements for the Touchdown Marking circle and/or the 'H';
- evaluate the Tri-O-Light green LED strip to establish its suitability as the lighting element for the Touchdown Marking circle and/or the 'H' applied to form a 2 m cross;
- evaluate prototype high-intensity green LEDline LED strips, deployed in the form of a chevron, to check for absence of glare or other undesirable properties.

1.3 Scope of Report

This report presents the combined results and analysis of the complete series of trials conducted at Norwich Airport.

The structure of the report is as follows:

- This section provides an introduction to the flight trials and outlines the trial objectives.
- Section 2 provides details of the conduct of the flight trial, the lighting configurations evaluated and the trials procedure.
- Section 3 contains the data acquired during the flight trials.
- Section 4 covers the dedicated offshore flight trial of two modified floodlighting configurations.
- Section 5 presents the conclusions.
- Section 6 presents the recommendations.
- Section 7 contains the acknowledgements.
- Section 8 contains the references.

2 Conduct of Trials

2.1 Trials Site

Figure 1 below shows the position of all the lighting elements on the trial 'helideck'. The location of the trials site at Norwich Airport is shown in Figure 2.

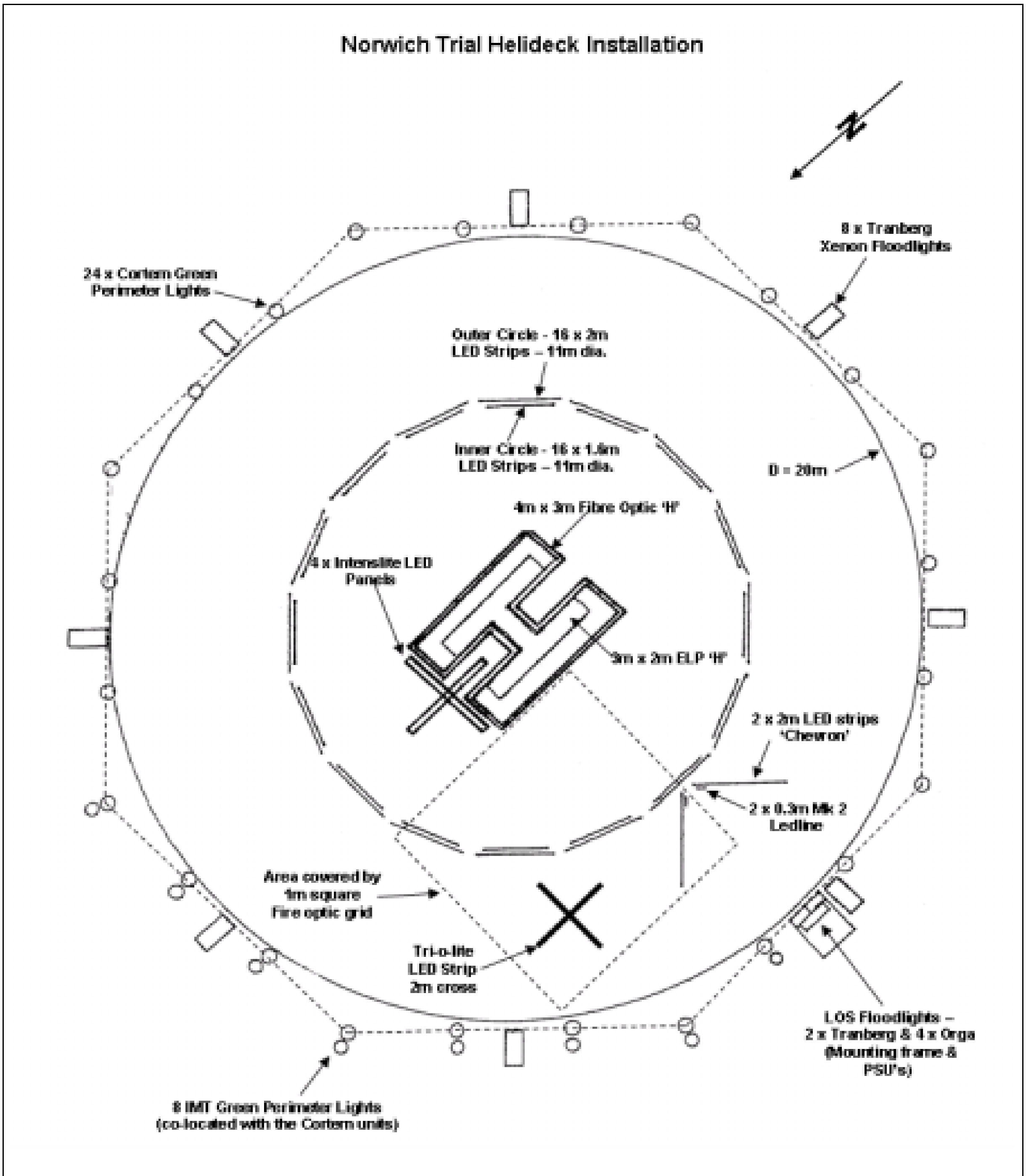

Figure 1 Diagram of Position of 'Helideck' Visual Aids

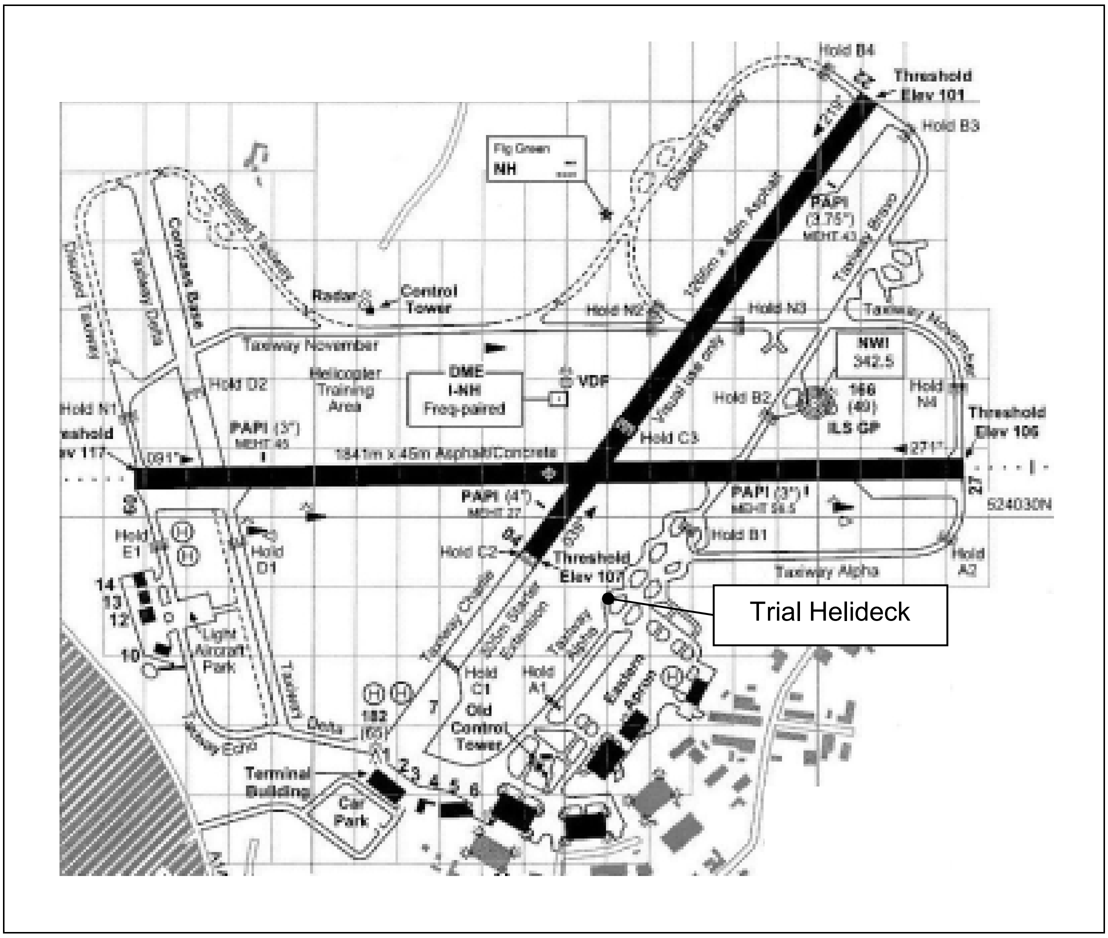

Figure 2 Norwich Airport Trial Site Location

2.2 Lighting Equipment

The lighting units used in earlier onshore trials at Longside Airfield, consisting of green perimeter lights, a filled green ELP 'H' and two yellow LED landing circles, were deployed at the trials site at Norwich Airport. The variations and additions to this equipment for this series of trials are detailed in the following sections.

2.2.1 Perimeter Lights

The Orga EVX2080/3060 units used for the Longside trials were positioned at 3 m intervals around the helideck perimeter, and were connected and secured in a similar manner to the earlier trial. In addition, eight IMT IQL55 units were installed around one quarter of the perimeter adjacent to the Orga perimeter lights. These lights had been designed to meet the new ICAO standard as interpreted in *CAP 437* [Ref. 2].

2.2.2 Floodlights

2.2.2.1 A framework, manufactured from Unistrut, was positioned on the western edge of the perimeter at the apex of, and within, the LOS. Four Orga SHLF18 halogen floodlights, wired in pairs, and two Tranberg TEF 9964 xenon floods were mounted on this framework as shown in Figure 3. The aperture centre of these six units was approximately 900 mm above deck level. The overall height of the structure was less than 1 m (0.05D), as allowed by Chapter 3 paragraph 6.4 of *CAP 437* [Ref. 2]. The centre of the beams from all elevated floodlights was set to 5° below the horizontal. The four Orga units were fitted with Louvers designed and manufactured by QinetiQ in accordance with the guidance contained in Appendix C of *CAA Paper 2005/01* [Ref. 5].

Figure 3 LOS Floodlights

2.2.2.2 In addition, eight Tranberg TEF 9964 xenon floodlights were mounted, equi-spaced around the edge of the deck (in the middle of each side of the octagon forming the perimeter). The centre of the aperture of each light was approximately 165 mm above deck level. These units were adjusted to project the centre of the beam 1° below the horizontal.

2.2.3 Touchdown Marking Circle

The yellow LED Touchdown Marking circle comprised two circles formed from LED segments. The LED circles were set up and, except for one approach (see subsection 2.2.3.7), used one at a time to allow rapid configuration changes during each trial.

2.2.3.1 Yellow LED circle no.1 was one of two circles (the inner circle) from the Longside trials, comprising 16 x 1.5 m segments separated by (approx.) 0.5 m gaps giving a coverage of 74%. With the slightly smaller deck size of the Norwich installation compared to the Longside installation (D value of 20 m v. 22.5 m), the radius of the circle was halfway between the inner and outer edges of a painted yellow circle appropriate for a helideck with a D value of 20 m.

2.2.3.2 Yellow LED circle no.2 was the second of two circles (the outer circle) from the Longside trials, comprising 16 x 2 m segments arranged to form a continuous circle (with nominal gaps to accommodate the end connectors) adjacent to circle no.1 (nominally the same diameter).

2.2.3.3 Reductions in the coverage of the circles were achieved by applying adhesive tape to the unwanted sections of the segments, e.g. for circle no.1, the 50% coverage was achieved by covering approx. 0.5 m of each segment with tape.

2.2.3.4 Halving the number of LEDs per metre was adopted as being the most practical means available to effect a reduction. An evenly lit result was achieved by covering every other LED with adhesive tape. Although somewhat arbitrary, the method employed produced a significant reduction in the number of LEDs per metre without requiring the provision of additional, non-standard LED segments.

2.2.3.5 To simulate a circle composed of 16 discrete sources rather than segments, each segment in circle no.1 was completely covered in tape apart from the last four lamps at one end, and each segment in circle no.2 was completely covered in tape apart from the 4 lamps adjacent to those in circle no.1. To simulate 32 discrete sources, the four lamps in the centre of each segment of circle no.1 were also left uncovered together with the adjacent lamps in circle no.2.

2.2.3.6 The reduction in intensity was achieved by lowering the LED supply voltage. The reduced supply voltage setting was determined by observation. The objective was to achieve a noticeable reduction in intensity without making the circle so dim as to be unusable. The intensity produced by a supply voltage of 9 volts, compared to the normal value of 12 volts, was considered to be appropriate by the CAA test pilot.

2.2.3.7 In order to evaluate the effect of increasing the intensity of the LED Touchdown Marking circle, expected to be beneficial with a helideck net fitted, both LED circles were illuminated together.

2.2.4 Heliport Identification Marking (‘H’)

2.2.4.1 The ELP ‘H’, manufactured by Pacel was deployed in the centre of the deck in the same manner as at Longside (see Figure 4). This ‘H’ is, in fact, somewhat smaller than the painted ‘H’ on a helideck, being 3 m x 2 m x 0.3 m as opposed to the normal (UK) dimensions for an offshore marking of 4 m x 3 m x 0.75 m.

Figure 4 ELP ‘H’

2.2.4.2 An alternative to the filled ELP ‘H’ in the form of an outline laser/optical fibre ‘H’ was also deployed during the series of trials. The optical fibre ‘H’ was manufactured from Intenslite ‘leaky’ optical fibre in a 4 m x 3 m wide outline ‘H’ as shown in Figure 5. Approximately 100 m of optical fibre was fed from the laser sources (situated behind the LOS framework) out to the centre of the deck and around the outline four times. The optical fibre was clamped to white-painted plywood boards at regular intervals at a spacing between each length of approximately 22 mm, giving an overall line width of 70 mm. The stroke width of the ‘H’ uprights was 0.9 m (as opposed to the required 0.75 m) due to the constraints imposed by the existing ELP ‘H’.

The optical fibre was driven by a laser at each end to reduce the effect of dimming at the undriven end. Subsequent lab tests indicated that a luminance of up to 118 cd/m^2 was achieved at the driven end of 100 m with as little as 7.4 cd/m^2 at the remote end.

It should be noted, however, that with narrow band light (as in a laser) the chromaticity meter might not give accurate results. The lasers used were 532 nm diode-pumped solid-state lasers with 300 mW of optical power.

Figure 5 Laser/Fibre Optic 'H'

2.2.5 Chevron

To give an approximate indication of the position of the origin of the obstacle-free sector (OFS), a yellow LED chevron was deployed as a potential alternative to the ELP 'H'. The chevron was assembled using two, 2 m yellow LED segments (as used in LED circle no.2), mounted on Unistrut channel. The included angle formed by the two strips was 90°, with the apex located adjacent to the Touchdown Marking circle at a point in line with the bisector of the LOS as shown in Figure 6.

Figure 6 LED Chevron

2.2.6 Other Aids and Equipment

2.2.6.1 Illumination of the helideck net was evaluated by 'weaving' green laser/optical fibre into the net to form a 7 m x 7 m grid of mesh size approximately 1 m in from the top right-hand corner of the helideck net (facing the OFS origin). It was formed using approximately 100 m of 'leaky' optical fibre similar to that used in the optical fibre 'H'. Both ends were driven, using the same lasers as for the 'H'. It was speculated that this might provide better visual cueing than that generated by floodlighting and might even represent a low-cost option to the Touchdown Marking circle and Heliport Identification Marking lighting for helidecks fitted with nets.

2.2.6.2 Four Intenslite LED panels, measuring approximately 1 m long x 100 mm wide, were arranged to form a 2 m cross, positioned to the right of the ELP 'H' (facing the OFS origin) under the net. The panels were secured to the net. These panels were end-driven by four LEDs and radiated light from the top surface in a similar way to 'leaky' optical fibres. It was thought that these panels might provide the same cueing as ELPs but without the disadvantages of marginal intensity, high cost and short service life.

2.2.6.3 Tri-O-Light green LED strips were mounted on a wooden frame in the shape of a 2 m cross such that strips were attached to both sides and the top of each leg. The relatively narrow width of the strips allowed them to be mounted on the sides of the cross so that the main beam of the LEDs was horizontal rather than vertical, providing a vertical intensity distribution closer to the theoretical ideal. The cross was located in the top right-hand corner of the helideck (facing the OFS origin) under the net, and was secured to the net.

2.2.6.4 Two high-intensity green LEDline LED strips were mounted on the arms of the LED chevron adjacent to its apex. These strips were a development of the LED strips used to form the two Touchdown Marking circles and were to be evaluated for glare. Their configuration as a chevron was judged to be the most representative deployment possible with the limited quantity available.

2.3 Lighting Configurations

Each of the trials commenced with the baseline lighting configuration which consisted of green perimeter lights, a filled green ELP 'H' and a single yellow LED Touchdown Marking circle (74% coverage, 32 lamps/m, 12 volts supply). This configuration had been adopted as the baseline during earlier onshore trials at Longside Airfield. The results of the first trial at Norwich indicated that the reduced coverage of the yellow LED circle of 50% (from 74%) was adequate in terms of the range at which it provided usable cueing information. This configuration was therefore adopted as the new baseline standard for all subsequent trials. The following tables give the matrix of configurations assessed during the six trials performed. Note that no helideck net was installed until Trial 4.

Table 1 Trial 1 Matrix of Configurations

	Green perimeter lights	Yellow LED circle No.1			Yellow LED circle No.2			Comments
		Coverage	Intensity	Lamps/ metre	Coverage	Intensity	Lamps/ metre	
Run 1	Modified	74%	max	32				Evaluate high intensity perimeter lights.
Run 2	Std	74%	max	32				Baseline (Longside config. but with octagonal perimeter).
Run 3	Std				74%	max	16	Evaluate effect of halving lamps/metre.
Run 4	Std	74%	reduced	32				Evaluate effect of reducing intensity of lamps.
Run 5	Std				74%	reduced	16	Evaluate effect of halving lamps/metre and reducing intensity of lamps.
Run 6	Std	50%	max	32				Evaluate effect of reducing coverage.
Run 7	Std				50%	max	16	Evaluate effect of reducing coverage and halving lamps/metre.
Run 8	Std	50%	reduced	32				Evaluate effect of reducing coverage and reducing intensity.
Run 9	Std				50%	reduced	16	Evaluate effect of reducing coverage and intensity and halving lamps/metre.
Run 10[1]	Std	6.25%	max	32				Evaluate circle composed of 16 equally spaced individual lamps.

1. Run 10 was not completed due to lack of time.

Table 2 Trial 2 Matrix of Configurations

	LOS floodlights	Deck-level floodlights	Green ELP 'H'	Yellow LED chevron	Yellow LED circles		Comments
					No. 1	No. 2	
Run 1			ON		50%		Final lighting system (Stage 2) baseline.
Run 2	2 x Orga						Interim lighting system (Stage 1) baseline.
Run 3	4 x Orga						Evaluate effect of doubling the number of halogen LOS floodlights.
Run 4	2 x Tranberg						Evaluate effect of replacing halogen LOS floodlights with xenon units.
Run 5		8 x Tranberg					Evaluate xenon deck-level floodlighting system.
Run 6			ON		50%		Final lighting system (Stage 2) baseline.
Run 7				ON	50%		Evaluate yellow LED chevron as an alternative to the ELP 'H'.
Run 8			ON		50%	50%	Evaluate effect of doubling intensity of yellow LED strips.
Run 9			ON		6.25%	6.25%	Evaluate circle composed of 16 equally spaced individual lamps.

Table 3 Trial 3 Matrix of Configurations

	LOS floodlights	Deck-level floodlights	Green ELP 'H'	Green laser 'H'	Yellow LED circles		Comments
					No. 1	No. 2	
Run 1			ON		50%		Final lighting system (Stage 2) baseline steep (6 deg.) approach.
Run 2[1]	2 x Orga						Interim lighting solution (Stage 1) baseline.
Run 3[1]	4 x Orga						Evaluate the effect of doubling the number of halogen LOS floodlights.
Run 4[1]	2 x Orga	2/3[2] x Tranberg opposite LOS					Evaluate the effect of adding 2/3 low-level floodlights to the Stage 1 baseline configuration.
Run 5		ON					Evaluate xenon deck-level floodlighting system.
Run 6[3]			ON		50%		Final lighting system (Stage 2) baseline normal (3 deg.) approach.
Run 7[3]				ON	50%		Evaluate green laser outline 'H' as an alternative to the ELP 'H'.
Run 8[4]			ON		12.5%	12.5%	Evaluate circle composed of 32 equally spaced individual lamps.

1. Approach track to be at least 30 deg. off the bisector of the OFS to prevent glare due to reflections from the ELP 'H' top surface impeding the evaluation.
2. Run 4 to be initially be performed with two deck-level floodlights (symmetrically located either side of the OFS bisector), but repeated with three floodlights if deemed appropriate.
3. Precipitation during these runs allowed the effect of rain on the transparencies to be assessed.
4. Run 8 was not completed due to lack of time.

Table 4 Trial 4 Matrix of Configurations

	LOS floodlights	Deck-level floodlights	Green ELP 'H'	Green laser 'grid'	Yellow LED circles		Comments
					No. 1	No. 2	
Run 1			ON		50%		Final lighting solution (Stage 2) baseline steep (6 deg.) approach.[1]
Run 2	2 x Orga						Interim lighting solution (Stage 1) baseline.
Run 3	4 x Orga						Evaluate the effect of doubling the number of halogen LOS floodlights.
Run 4	2 x Orga[2]	2 x Tranberg opposite LOS[2]					Evaluate effect of adding 2 low-level floodlights to stage 1 baseline configuration.[3]
Run 5		8 x Tranberg					Evaluate xenon deck-level floodlighting system comprising 8 floodlights.
Run 6				ON			Evaluate laser/optical fibre illuminated net grid.

1. No range data obtained, so this run was repeated during Trial 6.
2. For run 2, two adjacent deck-level floodlights are to be used in combination with the two adjacent high-mounted floodlights which best preserve the symmetry of the layout.
3. Repeated on Trial 6 as Stage 1 final configuration.

Table 5 Trial 5 Matrix of Configurations

	Green laser 'H'	Green Intenslite panels	Green LEDline chevron	Green Tri-O-Light cross	Yellow LED circles		Comments
					No. 1	No. 2	
Run 1		ON					Evaluate prototype green LED panels arranged in the form of a cross.
Run 2				Sides ON			Evaluate green Tri-O-Light LED strips arranged in the form of a cross – sides only.
Run 3				Sides & top ON			Evaluate green Tri-O-Light LED strips arranged in the form of a cross – sides and top.
Run 4	ON						Evaluate green laser outline 'H' as an alternative to the ELP 'H'.
Run 5			ON		ON	ON	Evaluate high-intensity green LEDline LED strips in the form of a chevron.

Table 6 Trial 6 Matrix of Configurations

	LOS flood-lights	Deck-level floodlights	Green ELP 'H'	Green laser 'H'	Green Intenslite panels	Green Tri-O-Light cross	Yellow LED circles		Comments
							No.1	No.2	
Run 1			ON				50%		Final lighting solution (Stage 2) baseline steep (6 deg.) approach.
Run 2	2 x Orga[1]	2 x Tranberg opposite LOS[1]							Interim lighting solution (Stage 1) final configuration.
Run 3	4 x Orga	2 x Tranberg opposite LOS							Enhanced Stage 1 configuration.
Run 4		4 x Tranberg [1]							Evaluate xenon deck-level floodlighting system comprising only 4 floodlights.
Run 5			ON				50%		Stage 2 baseline normal (3 deg.) approach.
Run 6				ON			50%		Evaluate green laser outline 'H' as an alternative to the ELP 'H'.
Run 7			ON				50%	50%	Evaluate effect of doubling intensity of yellow LED strips.
Run 8					ON		ON	ON	Evaluate prototype green LED panels arranged in the form of a cross.
Run 9						ON	ON	ON	Evaluate green Tri-O-Light LED strips arranged in the form of a cross – sides and top.

1. The four deck-level floodlights used will be equally spaced around the perimeter, and will comprise the set for which the beam centrelines cut the OFS bisector at 45°.

2.4 Trials Procedure

The aircraft used was a Eurocopter AS355 'Twin Squirrel' helicopter operated by two CAA pilots, the handling pilot being an experienced Rotary Wing Test Pilot, and the co-pilot a Senior Flight Operations Inspector. All test personnel on the aircraft were equipped with a headset with a microphone and all communications were recorded on a cassette tape recorder. Operational data were recorded prior to lift on the first run which, for all trials, remained valid for the entire sortie (an example of the trials proforma used is given in Appendix A). The minimum acceptable weather for the trial was 700 ft cloud base and 5 km meteorological visibility.

On receipt of ATC clearance the aircraft transited from the Bristow Helicopters apron to the trials 'helideck' and departed for each run from this location. Each run comprised a take-off, an outbound transit, and an into-wind approach to the 'helideck'.

For Trials 1 and 2 the approach started at a height of 800 ft and range of 1.5 NM (~2780 m). For Trials 3 to 6 inclusive, each run comprised a normal (3º) approach (except where otherwise indicated), starting at a height of 450 ft and range of 1.5 NM, descending to 300 ft at 1.0 NM and then to 150 ft at 0.5 NM. Where a steep (6º) approach was required, the start point was 900 ft at 1.5 NM, descending to 600 ft at 1.0 NM and then to 300 ft at 0.5 NM.

The vertical profile flown during each approach was intended to be representative of a normal offshore approach, and the maximum consistency possible between successive approaches was attempted. For Trials 3, 4 and 6, regular height and range calls were made by the non-handling pilot during the approach (nominally at every 0.1 NM) so that the vertical approach path could be plotted for each run. These plots are contained in Appendix B.

During each run, the handling pilot was required to report the range at which the various visual aids became visible and the range at which they became usable as a final approach cue. The range data was obtained by the pilot from the aircraft's Global Positioning System (GPS) and recorded by the QinetiQ trials officer.

Each approach concluded with a low hover over the 'helideck'. Although the majority of the installation was designed to withstand the weight of the wheeled S76 helicopter used for the earlier trials, the lighting equipment was not stressed for the higher point loading generated by the skids of the AS355 aircraft used for the Norwich trials, so no landings were performed on the 'helideck'. Use of the aircraft landing light, as per normal offshore procedures, was permitted for all runs.

On conclusion of each run the aircraft transited to the Bristow Helicopters apron and landed. After landing, the cueing performance of the configuration for the final approach phase and hover over the 'helideck' was evaluated by the handling pilot. The handling pilot was prompted for his responses to the 'post run' rating questionnaire by the QinetiQ trials officer, which were recorded on the trial proforma (see Appendix A). The pilot was asked to provide a rating from 1 to 5 (where 1 is 'poor' and 5 is 'excellent') for the different aspects of visual cueing information, based on his experience of cueing during offshore operations.

The lighting configuration required for the next run was then set up and confirmed prior to lift from the Bristow Helicopters apron for commencement of the next run from the 'helideck'. The aircraft held on the ground until ATC confirmed the availability of a suitable slot to position for, and then conduct, each approach.

At the end of Trial 3 the helicopter was to land adjacent to the 'helideck' and shut down. The aircraft's transparencies were then to be wetted using a spray pack and observations of the key lighting configurations made. This procedure was not required, however, as significant rainfall occurred during the trial, allowing the effect of rain on the transparencies to be evaluated in flight.

On Trial 5, the weather was below the acceptable minimum, and therefore the trial could not be conducted as planned. However, some short low-level circuits (0.5 NM, 300 ft) were flown within the airfield boundary and an evaluation of the close-in visual aids was conducted.

3 Trial Results

3.1 Introduction

A summary of the operational data associated with each trial is given in Table 7 below.

Table 7 Summary of Operational Data

Trial	No.1	No.2	No.3	No.4	No.5	No.6
Date	03/11/03	06/01/04	03/03/04	06/05/04	04/08/04	23/09/04
Approach Heading	Not recorded*	245^0	Not recorded*	220^0	Not recorded*	310^0
Cloudbase	No cloud	No cloud	3000 ft, 6 octas	3500 ft	300 – 350 ft	3500 ft
Visibility	>10 km	>10 km	5 km	>10 km	7–8 km	>10 km
Wind (Direction & Speed)	250^0 12–17 kts	240^0–250^0 5 kts	180^0 12 kts	No wind	90^0 5 kts	340^0 12 kts
Ambient Light	2/3 moon	Full moon	No moon	Twilight - night	Twilight - night	Night + moon
Precipitation	None	None	Rain commen-ced during Run 6	None	None	None
Number of runs	9	10	7	6	5	9
Helideck Net fitted	No	No	No	Yes	Yes	Yes
Features evaluated	• Modified perimeter lights • Variation of Touchdown Marking circle design parameters	• Floodlights (LOS and deck level) • LED chevron • Touchdown Marking circle (2x intensity, 16 lamps)	• Floodlights (LOS and deck level) • Fibre optic 'H' • Touchdown Marking circle (32 lamps)	• Floodlights (LOS and deck level) • Fibre optic grid	• LED panels • Tri-o-Light LED strips • Laser outline 'H' • High-intensity LEDLine	• As Trial 5 • Floodlights (LOS and deck level) • Touchdown Marking circle (2x intensity)

NOTE: Although the approach heading was not recorded on Trials 1, 3 and 5, it can reasonably be assumed that the heading was substantially into wind.

During each run the handling pilot provided data regarding the range at which usable cueing information was provided by the visual aid under evaluation. During some runs the handling pilot was also asked to provide data regarding the range at which various aids became visible. Comments made throughout the sortie were recorded. After specified runs, ratings of the provision of visual cueing information during the final approach phase and the hover over the 'helideck' were taken from the handling pilot.

The range data recorded was derived by the pilot from the aircraft's GPS at the point at which he assessed that the visual aid had become visible/useable. In interpreting these data it should be noted that the ranges are not precise figures. There is likely to have been some small delay between the visual cue becoming visible/useable and the pilot becoming aware and calling the range, caused by the pilot completing routine tasks such as instrument scans and lookout for other traffic as well as looking out at the 'helideck' for approach cues. Despite these possible variations however, the data provided give a good indication of the range of the various aids.

3.2 Assessment of Modified Perimeter Lights

An assessment of the green perimeter lights designed to meet the new ICAO standard was made during the first run of Trial 1. Pilot comments formed the basis of this evaluation.

During the approach the pilot could see the higher intensity green lights on the right-hand side of the 'helideck'. The pilot commented that the lights were definitely brighter and that they stood out well. No negative effects from the change in intensity were observed; the pilot did not experience any glare, and there was also no impact on the effectiveness of the other lighting aids.

Comment was also elicited on the colour of the lights since there was concern prior to the trial that the modified lights might be too white-green in colour. It was considered that, although the new lights were a different shade of green to the rest of the perimeter lights, they were still very definitely green in colour. Post trial analysis supports this subjective assessment, with the colour co-ordinates (x = 0.25, y = 0.475) being within the range for 'green' as defined in *ICAO Annex 14 Volume 1 Appendix 1 paragraph 2.1.1(c)*.

3.3 Assessment of the Floodlighting

The details of the various floodlighting evaluations performed are presented in Table 8.

Table 8 Floodlight Configurations Evaluated

Lighting Configuration		Helideck Net Fitted	Trial	Run
(a)	2 halogen LOS floodlights	No	2	2
			3	2
		Yes	4	2
(b)	4 halogen LOS floodlights	No	2	3
			3	3
		Yes	4	3
(c)	2 halogen LOS floodlights plus 2 deck-level xenon floodlights	No	3	4
		Yes	4	4
			6	2

Table 8 Floodlight Configurations Evaluated (Continued)

(d)	4 halogen LOS floodlights plus 2 xenon floodlights at deck-level	Yes	6	3
(e)	8 deck-level xenon floodlights	No	2	5
			3	5
		Yes	4	5
(f)	4 deck-level xenon floodlights	Yes	6	4
(g)	2 xenon LOS floodlights	No	2	4

The purpose of the assessment was to evaluate the performance of the various configurations of Orga halogen and Tranberg xenon floodlights detailed in Section 1.2.2. It should be noted, however, that the selection of the lighting technologies and manufacturers is incidental. The floodlights used for the trials were selected on the basis of their beam characteristics and alternatives units having similar beam characteristics may be substituted. The Orga halogen units are typical of many existing installations and have a relatively wide, low peak intensity and uncontrolled beam. The Tranberg xenon units are relatively new to the application and have a relatively narrow, high peak intensity and well-controlled beam. The disposition of the floodlights for the trials was intended to ensure adequate illumination of the centre of the helideck without generating glare.

3.3.1 Range Data

During Trial 2 there was found to be little difference in the range at which the various floodlighting configurations (configurations (a), (b), (e) and (g)) provided useable cueing information, the range being between 0.11 NM and 0.13 NM in all cases. This was considered to be due to unrepresentative glare from the floodlights caused by reflections from the top surface of the ELP 'H'. For this reason the results of Trial 2 have not been included. The glare was avoided in subsequent trials by flying the approaches at least 30° off the bisector of the LOS. The range data obtained using the revised approach track revealed differences in the range at which useable 'in deck' cueing information was provided by the various configurations, as shown in Figure 7.

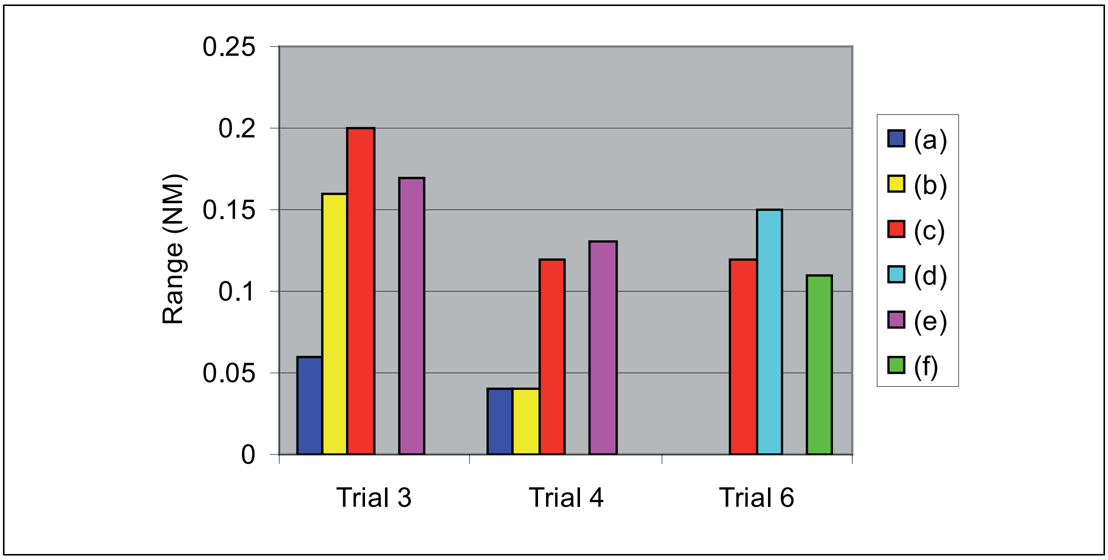

Figure 7 Range Data for Floodlighting Configurations Evaluated

3.3.1.1 Considering only the results from Trial 3, without the helideck net fitted the configuration of two halogen LOS floodlights combined with two xenon floodlights located at deck level (configuration (c)) provided useable cues at the greatest range of 0.2 NM. This was closely followed by the configuration of eight xenon floodlights at deck level (configuration (e)), and the configuration of four halogen LOS floodlights (configuration (b)), useable at 0.17 NM and 0.16 NM, respectively. The configuration comprising two halogen LOS floodlights did not provide useable information until 0.06 NM, very late in the approach; this was the initial LOS floodlight configuration evaluated at Longside Airfield [Ref. 5].

3.3.1.2 The evaluations of the floodlighting with a helideck net fitted were conducted during Trial 4 and Trial 6. Due to the possibility of inter-trial differences such as weather and approach angle, the ratings that were given are compared within each trial only.

Considering the Trial 4 results, the two configurations that included xenon deck-level floodlights provided usable cues at similar ranges. The best was the eight xenon deck-level floodlight arrangement (configuration (e)) at 0.13 NM, followed by the two halogen LOS floodlights with two xenon deck-level floodlights (configuration (c)) at 0.12 NM. Poorest in terms of the range at which usable information was available were the halogen LOS floodlights alone (either two or four units – configurations (a) and (b), respectively), which did not provide useable cues until very late in the approach.

Considering the Trial 6 results, all three configurations evaluated included xenon deck-level floodlights and provided usable cues at similar ranges. The best was the combination of four halogen LOS floodlights with two xenon deck-level floodlights (configuration (d)) at 0.15 NM, followed by the two halogen LOS floodlights with two xenon deck-level floodlights (configuration (c)) at 0.12 NM, and finally the four xenon deck-level floodlight arrangement (configuration (f)) at 0.11 NM.

Noting that the results are spread over two separate trials, the overall pattern of results is nevertheless similar to those of the trials without the helideck net, except that there was little difference in the range at which useable information was provided by two and four halogen LOS floodlights with the helideck net fitted.

3.3.2 Ratings of Visual Cueing Information

3.3.2.1 The ratings of visual cueing information that were given for the floodlighting configurations without a helideck net fitted (Trial 2 and Trial 3) for the final approach and hover phases are given in Table 9.

For Trial 2, as with the range information, no appreciable difference was found in the cueing information provided by each of the LOS floodlighting conditions (configurations (a) (b) and (g)), and identical ratings were awarded for all three. The deck-level configuration (e), useable at a similar range to the LOS floodlighting, provided less cueing information to the pilot. The degradation was most marked in attitude, azimuth alignment and closure rate during the final approach phase, and in heading in the hover phase.

The results for Trial 3 clearly indicate that the combination of two halogen LOS floodlights and two xenon deck-level floodlights (configuration (c)) provided the best cueing for both the final approach and hover phases. The final approach phase ratings for the configurations of two and four halogen LOS floodlights only (configurations (a) and (b)) were all half-a-point lower except for flight path angle which was degraded by one point. The approach phase ratings for the xenon deck-level system (configuration (e)) attracted quite poor ratings. The ratings for the hover phase for the two halogen LOS floodlights and two xenon deck-level floodlights combination were half-a-point higher than the other three floodlighting configurations (configurations (a), (b) and (e)), which were awarded the same ratings as each other.

Table 9 Ratings of visual cueing information for the floodlighting in the final approach and hover phases without a helideck net fitted. (1 = poor, 5 = excellent; Trial 2 results shaded)

Configuration (see Table 8)	Final Approach				Hover					
	Flight Path Angle	Attitude	Azimuth Alignment	Closure Rate	Position	Translational Rate	Height	Descent Rate	Heading	Yaw Rate
(a) (b) (g)	2.5	3	3	3	4	4	4	4	4	4
(e)	2	2	2	2	4	4	3.5	3.5	2.5	4
(a)	2	3	2	2	4	3.5	3.5	3.5	2.5	3.5
(b)	2	3	2	2	4	3.5	3.5	3.5	2.5	3.5
(c)	3	3.5	2.5	2.5	4.5	4	4	4	3	4
(e)	1	2	1	1	4	3.5	3.5	3.5	2.5	3.5

3.3.2.2 The ratings for the floodlighting configurations assessed with a helideck net fitted (Trials 4 and 6) are given in Table 10.

Table 10 Ratings of visual cueing information for the floodlighting in the final approach and hover phases with a helideck net fitted. (1 = poor, 5 = excellent; Trial 4 results shaded)

Configuration (see Table 8)	Final Approach				Hover					
	Flight Path Angle	Attitude	Azimuth Alignment	Closure Rate	Position	Translational Rate	Height	Descent Rate	Heading	Yaw Rate
(a)	2.5	2.5	2	2	2.5	3	3	2.5	2	2.5
(b)	2.5	2.5	2	2.5	2.5	3.5	3	2.5	2	3
(c)	3	2.75	3	3	3	3.5	3.5	3	3	3
(e)	1.5	1.5	1	1	3.5	4	4	3.5	3	3.5
(c)	1.5	2	2	2.5	3	3	3	3	3	3
(d)	1.5	2	2	2.5	3	3	3	3	3	3
(f)	2	2	1.5	2.5	3	3	3	3	3	3

Due to the possibility of inter-trial differences such as weather and approach angle, the ratings that were given are compared within each trial only.

For the first of the trials with the net fitted, Trial 4, the pattern of results obtained for the final approach phase was similar to those obtained without the net during Trial 3. For this phase, the combination of two halogen LOS floodlights and two xenon deck-level floodlights (configuration (c)) provided the best ratings for all cues, the most notable being azimuth alignment which was one point higher than the nearest rival. The results for the hover phase were slightly different to Trial 3, however, with the xenon deck-level system (configuration (e)) outperforming the two halogen LOS and xenon deck-level combination configuration by half-a-point for all cues except for heading, where equal ratings were awarded. It seems likely that the xenon deck-level system benefited more from the additional texture provided by the net than the halogen LOS and xenon deck-level combination. The ratings for the configurations of two and four halogen LOS floodlights (configurations (a) and (b)) for the hover phase were generally half-a-point lower than for the halogen LOS and xenon deck-level combination. The performance of the four halogen LOS floodlight configuration was only marginally better than that of the two-light version in both phases.

Helideck floodlighting was further assessed with a helideck net fitted during Trial 6. The configurations evaluated during this trial were two and four halogen LOS floodlights in combination with two xenon deck-level floodlights (configurations (c) and (d)), and a deck-level system comprising just four xenon floodlights (configuration (f)). The ratings for all three configurations were similar for the final approach phase and identical for the hover phase. For the final approach phase, the four xenon deck-level system was rated half-a-point higher for flight path angle and half-a-point lower on azimuth alignment than the two and four halogen LOS and two deck-level floodlight combinations. It appears that halving the number of floodlights in the xenon deck-level system (configuration (e) to configuration (f)) significantly improved the cueing provided during the final approach phase, relative to the halogen LOS and xenon deck-level combination (configuration (c)). This is considered likely to be due to the reduction in disruption to the cueing provided by the perimeter lighting and the reduction in glare.

3.3.3 Pilot Comments

For all configurations and all trials, the pilot observed that the floodlighting provided good textural detail when close in. The surface of the trial helideck was very rich in texture due to the tar joint lines in the concrete and the trials equipment mounted on the deck surface. It was noted that this level of textural cueing would generally not be present on most offshore helidecks.

3.3.3.1 The following comments were recorded for the trials performed with no helideck net fitted.

On Trial 2, where the final approach track for all of the runs with LOS floodlighting was directly towards the bisector of the LOS, a bright reflection from the surface of the unlit ELP 'H' was observed which was described as looking like a very brightly illuminated spot in the middle of the deck. With the configuration comprising the xenon lights (configuration (g)), it was commented that the floodlights degraded the conspicuity of the green circle formed by the perimeter lights.

The two halogen LOS floodlight configuration (configuration (a)) was judged to be unacceptable as a minimum standard for a floodlighting system, good textural information being provided too late to be useful for anything other than the very final stages of approach at 20 m from the deck. Although the level of visual cueing information provided by the four halogen LOS floodlight configuration (configuration (b)) was considered to be the same, the information was available earlier in the approach, providing a better build up of cues at 50 m from the deck. This reduced pilot workload and increased confidence in terms of making the approach, and led to the pilot feeling more comfortable.

The pilot commented that the xenon LOS floodlights (configuration (g)) did not provide quite such a good level of textural information when approaching the deck. These lights were considered to be harsher than the halogen lights and they also appeared to provide a less even coverage of the surface of the deck.

The combination of two halogen LOS floodlights and two xenon deck-level floodlights (configuration (c)) provided information at a slightly greater range than the four halogen LOS floodlights (configuration (b)), and was also rated slightly higher in terms of the visual cueing information provided. However, during the assessment it was commented that this enhancement was due to the specific texture on the trial 'helideck'. The LED circle and the ELP 'H', although not powered, were illuminated at low level by the floodlighting and provided an enhancement in the visual cueing information available to the pilot. Without these elements on the deck, this enhancement might not be seen.

With xenon deck-level floodlights only (configuration (e)), the information available was not as good as with the other configurations. During the early stages of the approach, the xenon deck-level floodlighting configuration was described as looking very similar to the LOS floodlighting. The high intensity of the xenon floodlights on the opposite side of the deck to the approach direction produced an effect similar to the bright reflections produced by the elevated xenon floodlights, which affected the conspicuity of the circle formed by the green perimeter lights. It was commented that the effectiveness of the green perimeter lights (in providing deck location cues) was degraded by the brightness of the floodlights and that the deck looked like a great mass of lights with one white one in the middle. It was also commented that the light unit that was directed towards the aircraft seemed more intrusive than the high-mounted lights (which were also directed towards the aircraft). When closer in, the lights produced a pattern of 'spokes' on the deck surface which, although providing good textual information, the pilot described as "surreal". The pilot commented that this lighting produced a slightly artificial, monochrome effect and this was cited as a reason for the lower rating awarded for height information compared to the LOS floodlighting configurations. The pilot considered that, on balance, the degradation of the green perimeter lights at the helideck acquisition stage outweighed the good visual cueing at close range.

3.3.3.2 With the helideck net fitted the pilot's comments were very similar to those without the net. The four halogen LOS floodlights system (configuration (b)) was judged to be better than the two-light version (configuration (a)) since textural information was provided slightly further out, and the coverage of the deck was also more extensive. For both configurations, however, the range at which useable cueing information was available was not until very late in the approach, at a point too late to be useful in anything other than the very final stage. The two halogen LOS and two xenon deck-level floodlight combination (configuration (c)) provided an enhancement in terms of the visual cueing information over the LOS floodlights alone. The greatest benefit of this configuration was the increased range at which usable information was provided. Enhancement of visual cueing through illumination of the LED circle and the ELP 'H' at low level by the floodlighting was not evident with the helideck net fitted, since this equipment was obscured by the net. The enhanced cueing with the net fitted is therefore attributed to the net itself rather than the specific texture of the trial deck. Indeed, the pilot commented that light was reflecting off the net itself and providing good cues.

The xenon deck-level system comprising four floodlights (configuration (f)) performed better than the eight-light system (configuration (e)). With four lights, the visual cueing information in the final approach was improved over that of the eight-light system. The main reason cited for the improvement was the reduction in the break-up of the pattern formed by the green perimeter lights.

3.3.4 Discussion

The configurations comprising two and four halogen floodlights located at high level in the LOS (configurations (a) and (b)) provided useable visual cueing information, but not until too late in the approach. Increasing the intensity by switching to two xenon LOS floodlights to raise the level of illumination (configuration (g)) risks unacceptable glare due to reflections from the surface of the helideck (especially when wet), as the angle of depression of the floodlights is similar to the vertical approach angle of the helicopter.

Although available at good range, the visual cueing information provided during the final approach phase by the deck-level floodlighting system comprising eight xenon units (configuration (e)) was quite poor due to the adverse effect on the cueing provided by the perimeter lighting and glare.

The configurations comprising two and four halogen floodlights located at high level in the LOS, combined with two xenon floodlights opposite the LOS at deck level (configurations (c) and (d) – see Figure 8), represented the best overall floodlighting systems of those evaluated. Useful visual cueing information was provided at good range with minimal glare. Four rather than two high-level floodlights should be considered for larger helidecks. A point to note with these systems, however, is the creation of an obstacle, albeit within the LOS and meeting the CAP 437 criteria. Another issue is the potential for glare caused by reflections from the surface of the deck when wet.

Figure 8 Combined High-Level and Deck-Level Configuration

The performance of the deck-level floodlighting system comprising four xenon units (configuration (f) – see Figure 9) was comparable to the high-level and deck-level combinations, and avoids the possibility of glare due to reflections from the deck surface without presenting the undesirable characteristics of the eight-unit system. In additional, this system would be particularly suitable for decks where the installation of floodlights at high level in the LOS would create an obstacle where there would otherwise be none.

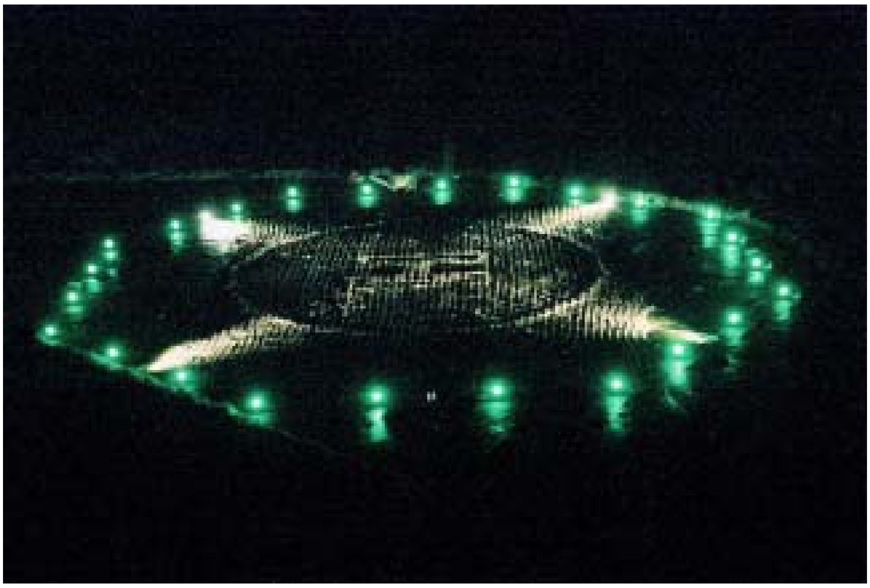

Figure 9 Deck-Level System Comprising Four Xenon Floodlights

3.4 Assessment of the LED Touchdown Marking Circle

The details of the various LED Touchdown Marking circle evaluations performed are presented in Table 11.

Table 11 Lighting Configurations of the LED Touchdown Marking Circle

Lighting Configuration		Helideck Net Fitted	Vertical Approach Angle	Trial	Run
(a)	Baseline1 (as per Longside trials)	No	-	1	2
(b)	Halved lamps per metre (Ref: 2.2.3.4)	No	-	1	3
(c)	Reduced intensity (Ref: 2.2.3.6)	No	-	1	4
(d)	Halved lamps per metre and reduced intensity	No	-	1	5
(e)	Reduced coverage (Ref: 2.2.3.3)	No	-	1	6
(f)	Reduced coverage and halved lamps per metre	No	-	1	7
(g)	Reduced coverage and reduced intensity	No	-	1	8
(h)	Reduced coverage, reduced intensity and halved lamps per metre	No	-	1	9
(i)	Baseline 2 (as (e) above)	No	‘3°’	2	1
		No	‘6°’	2	6
		No	6°	3	1
		No	3°	3	6
		Yes	6°	6	1
		Yes	3°	6	5
(j)	Double Circle (Ref: 2.2.3.7)	No	-	2	8
		Yes	3°	6	7
(k)	Circle of discrete sources (Ref: 2.2.3.5)	No	-	2	9

3.4.1 Range Data

Figures 10, 11 and 12 show the range at which the yellow LED Touchdown Marking circle became visible, and the range at which it became useable as a final approach cue.

3.4.1.1 With reference to Figure 10, the data from Trial 1 show that a reduction in the number of LED lamps per metre and/or LED intensity from the Baseline 1 configuration (configuration (a)) decreased the range at which the Touchdown Marking circle became visible and usable (configurations (b), (c), (d), (f), (g) and (h)).

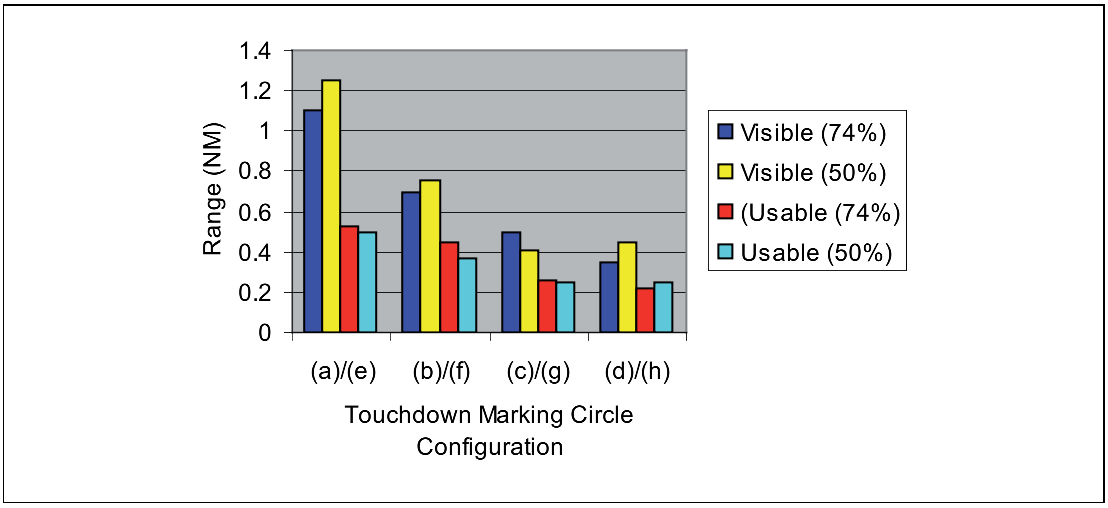

Figure 10 Range Data for Main LED Touchdown Marking Circle Configuration Evaluated (all results within Trial 1)

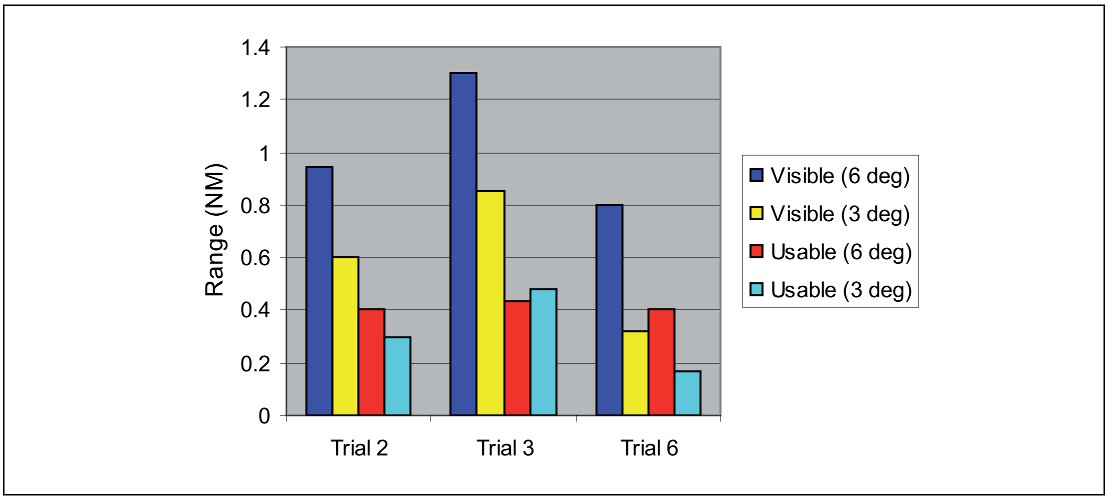

Figure 11 Range Data for Baseline 2 Touchdown Marking Circle (configuration (i)) as a Function of Vertical Approach Angle (nominally 6° and 3°)

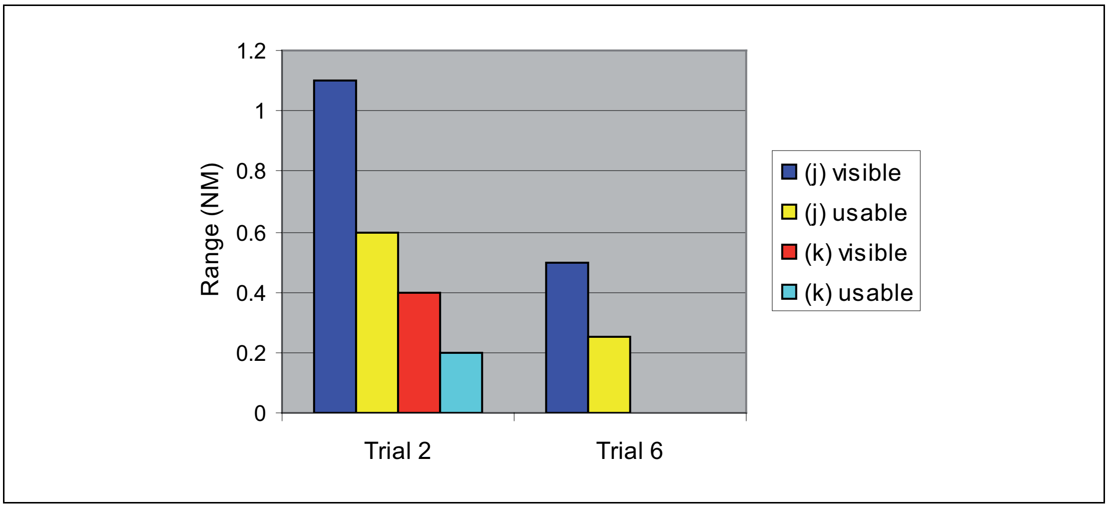

Figure 12 Range Data for Alternative LED Touchdown Marking Circle Configurations Evaluated

Reducing the intensity (configurations (c) and (g)) had a more pronounced effect than halving the number of lamps per metre (configurations (b) and (f)). The effects of reduced intensity and halving the number of lamps per metre were also found to compound (configurations (d) and (h)).

Figure 10 also demonstrates that a reduction in the coverage of the Touchdown Marking circle from 74% to 50%, either with or without a reduction in intensity and/or halving the number of lamps per metre (compare configurations (a) to (d) with (e) to (h), respectively), did not significantly affect the range at which the circle was visible or the range at which it was useable. The ranges recorded are close to and within the measurement tolerance of those for the baseline.

Based on Trial 1 data it was agreed to adopt configuration (e) as a new baseline (Baseline 2) for future trials (see Figure 13).

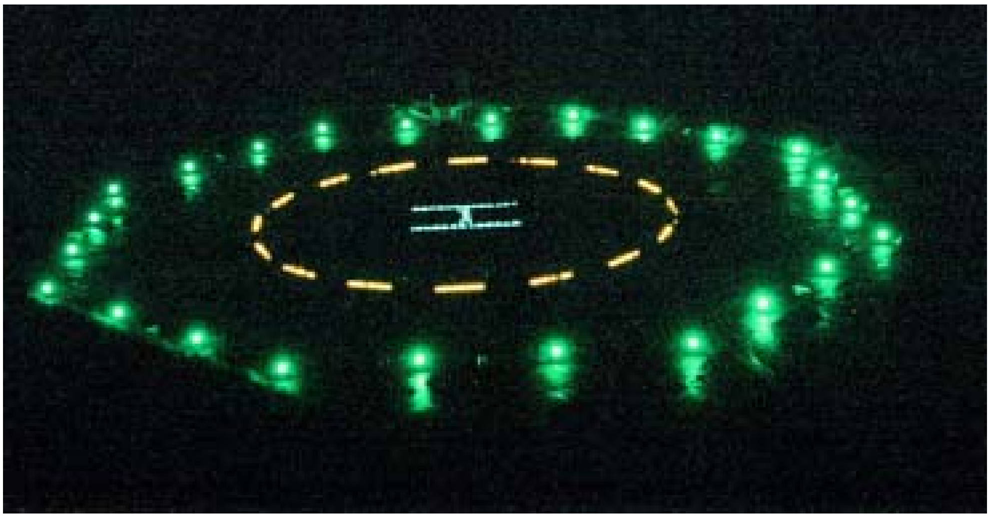

Figure 13 Revised Stage 2 Baseline Configuration

3.4.1.2 With reference to Figure 11, in Trial 2 the baseline run was repeated (configuration (i), Trial 2, Runs 1 and 6) as the first approach was considered to have been fairly flat and, as such, unrepresentative of an offshore approach. On the first run, the ranges at which the LED Touchdown Marking circle was visible and useable were 0.6 NM and 0.3 NM, respectively. When a slightly steeper approach (more typical of those conducted offshore) was flown, these ranges increased to 0.94 NM and 0.4 NM respectively. Details of the actual vertical approach path flown were not recorded, but the comparison was repeated without the net in Trial 3, and with a net in Trial 6 where this data was taken and is presented in Appendix B.

The data from Trial 3 (configuration (i), Trial 3, Runs 1 and 6) show that the LED Touchdown Marking circle was visible at a much greater range on a '6° approach' compared to a '3° approach' (1.3 NM v. 0.85 NM). However, the range at which useable cues were provided was similar on both approaches (0.43 NM and 0.48 NM). Height and range data recorded during the approaches (see Appendix B) indicate that the vertical approach angle in the latter stages of the '3° approach' was steeper than it should have been, being similar to that of the '6° approach'. On the '6° approach' the aircraft was at 200 ft at 0.2 NM, and on the '3° approach' the aircraft was at the same height, 200 ft, just 0.1 NM earlier at 0.3 NM. To be representative of a 3° approach the aircraft should be at 100 ft at 0.3 NM. The similarity in vertical approach angle in the latter stages of both approaches would account for the similarity in range at which the circle was considered to provide useable cues.

In Trial 6, the effect of the vertical approach angle on the range at which the LED Touchdown Marking circle was visible and the range at which it was useable as a visual cue was evaluated with a helideck net fitted (configuration (i), Trial 6, Runs 1 and 5). Height and range data recorded during the two approaches indicate that a representative vertical approach angle (6º and 3º) was achieved for each approach. The data given show that, as expected, the LED Touchdown Marking circle was visible and useable at a much greater range on the '6º approach' than on the '3º approach' (0.8 NM v. 0.32 NM, and 0.4 NM v. 0.17 NM). However, on both approaches the range at which the LED circle was visible and useable with the helideck net fitted was decreased from that recorded on previous trials without the helideck net fitted.

3.4.1.3 With reference to Figure 12, doubling the width and thereby increasing the intensity of the LED circle without a helideck net fitted during Trial 2 (configuration (j), Trial 2, Run 8) resulted in an increase in the visible and usable range (1.1 NM v. 0.6 NM visible, 0.6 NM v. 0.3 NM usable) compared to the baseline (configuration (i), Trial 2, Run 1).

The range at which the double circle was visible and useable for the 3º approach with the helideck net fitted was evaluated during Trial 6 (configuration (j), Trial 6, Run 7). The increase in both the width and the intensity of the LED circle significantly increased the range at which the circle was visible and useable (0.5 NM v. 0.32 NM visible, 0.25 NM v. 0.17 NM usable) compared to the baseline (configuration (i), Trial 6, Run 5).

3.4.1.4 In Trial 2, for the circle comprised of 16 discrete sources (configuration (k)), the visible and usable ranges (0.4 NM and 0.2 NM) were comparable to the worst obtained without the net fitted.

3.4.1.5 The range at which the LED strips and the individual LEDs became distinguishable was also recorded in Trials 2 and 6. These data are shown in Table 12. The angle subtended at the pilot's eye by the LED strips at the range at which they became distinguishable is also shown.

Table 12 Range at which LED Strips and LED Lamps became Distinguishable

Lighting Configuration	Helideck Net Fitted	Vertical Approach Angle	LED Strips Distinguishable			LED Lamps Distinguishable
			Range (NM)	Range (m)	Angle (º)	Range (m)
(i) Baseline 2	No	3°	0.18	333.4	0.86	20
	No	6°	0.32	592.6	0.48	50
	Yes	3°	0.17	314.9	-	-
	Yes	6°	0.20	370.4	-	-
(j) Double circle	No	-	0.50	926.0	0.31	15
	Yes	3°	0.50	926.0	-	-

Once close to the 'helideck' there was little difference, with or without the net, in the ranges at which the LED strips became distinguishable in the baseline configuration. A small increase in range was noted with steeper approaches. The most significant and consistent difference observed, however, was with a double circle which markedly increased the range at which the strips became distinguishable.

Individual LED lamps become distinguishable very close to the 'helideck'. Although only limited data was obtained, as for the LED strips, the ranges recorded appear to be proportional to the vertical approach angle – the steeper the angle of approach the greater the range.

Increasing the vertical approach angle and changing from a single to a double circle both result in an increase in the apparent intensity of the LED Touchdown Marking circle. It is therefore surmised that it is the changes in intensity that were responsible for the variation in the ranges observed during the trials.

3.4.2 Ratings of Visual Cueing Information

The ratings of visual cueing information awarded for each of the yellow LED Touchdown Marking circle configurations rated are presented in Table 13. All of these except for one (configuration (i)) relate to the same trial, Trial 1, and so may be compared with some confidence. The remaining configurations were not rated because the differences to previous runs were judged to be insignificant. No helideck net was fitted for any of the runs for which ratings were taken.

Table 13 Ratings of Cueing Information available for the LED Touchdown Marking Circle. (1 = poor, 5 = excellent)

Configuration (see Table 11)	Final Approach				Hover					
	Flight Path Angle	Attitude	Azimuth Alignment	Closure Rate	Position	Translational Rate	Height	Descent Rate	Heading	Yaw Rate
(a)	4	3	-	2.5	4	4	4	4	-	4
(b)	3.5	2.5	-	2	4	4	4	4	-	4
(c)	3	2	-	1.5	4	4	4	4	-	4
(d)	3	2	-	1.5	4	4	4	4	-	4
(e)	4	3	-	2.5	4	4	4	4	-	4
(f)	3.5	2.5	-	2	4	4	4	4	-	4
(g)	3	2	-	1.5	4	4	4	4	-	4
(h)	3	2	-	1.5	4	4	4	4	-	4
(i)	4	3	-	3	4.5	4.5	4	4	-	4

3.4.2.1 Halving the number of lamps per metre (configurations (b) and (f)) reduced all the final approach phase ratings by half-a-point compared to the baseline (configuration (a)). This effect ceased at the point at which the Touchdown Marking circle became a usable cue, after which the visual cueing provided was identical to the baseline configuration. The ratings awarded for the hover phase were consequently identical to those given for the baseline.

3.4.2.2 Reducing the intensity (configurations (c) and (g)) had a greater negative effect than reducing the number of lamps per metre, reducing all the final approach ratings by one point. This effect also ceased at the point at which the Touchdown Marking circle became a usable cue, the ratings for the hover phase being identical to the baseline.

3.4.2.3 When both the number of lamps per metre and the intensity were reduced (configurations (d) and (h)), there was no further negative effect on the cueing information available compared to that seen with the reduction in intensity alone.

3.4.2.4 Reducing the coverage of the Touchdown Marking circle from 74% to 50% (configurations (a) and (e)) did not have any effect on the visual cueing information available during either the final approach or the hover phases. Combining the reduction in coverage with reductions in the number of lamps per metre, reduced intensity, and halved lamps per metre and reduced intensity did not result in any further degradation of the ratings (compare configurations (b) and (f), (c) and (g), and (d) and (h)), confirming the benign effect of the reduction in coverage.

3.4.2.5 The new Stage 2 baseline (configuration (i)) used from Trial 2 onwards gave similar ratings to the equivalent configuration (configuration (e) in Trial 1. The half-a-point differences in closure rate cues during the final approach phase, and the position and translational rate cues during the hover phase, could easily be due to inter-trial differences such as ambient conditions.

3.4.3 Pilot's Comments

Comments from the handling pilot were recorded throughout the trials and during post-trial debriefs.

The pilot stated that the reduction in the coverage of the Touchdown Marking circle made little difference to the visual cueing. It was considered that this configuration was as good as the baseline in terms of the cueing information provided which is reflected in the ratings awarded. With the reduced coverage, the range at which the Touchdown Marking circle became useable was about 0.5 NM.

When the number of lamps per metre in the segments forming the circle was reduced, the pilot commented that the circle looked quite dull compared to the baseline, leading to a reduction in the range at which the circle became useable. When the intensity of the LEDs in the circle was reduced this range was reduced further, which the pilot judged to be too late in the approach. The pilot considered that the minimum range at which the circle should be usable was 0.5 NM.

It was also noted that once close to the 'helideck', reflections were apparent in the cockpit transparencies producing some 'double imaging' of the yellow LEDs in the lower part of the windscreen. The two images moved relative to each other as the aircraft's attitude changed. This effect was only seen in the curved part of the windscreen and, although noticeable, was not considered particularly disconcerting. A certain amount of the 'double imaging' was seen on all of the runs and, on some of the approaches, a small amount of double imaging of the green perimeter lights was also noted by the pilot.

It was commented that the double-LED Touchdown Marking circle was more distinct at an earlier stage and therefore provided useable cueing information at an increased range. However, some glare was experienced at close range and a very bright reflection in the windscreen was noted when moving across the deck. Although the glare was considered acceptable, concern was expressed regarding the possible effects of rain on the cockpit transparencies. It was therefore considered that this configuration represented a slight degradation from the baseline during the hover phase. With a helideck net fitted, however, the pilot's comment was that the double-LED Touchdown Marking circle represented an enhancement. Although the visual cueing information provided was the same as with the lower intensity circle, the information was available sooner in the approach and no problems with glare were experienced.

The LED Touchdown Marking circle made up of simulated discrete sources did not provide any useable information until too late in the final approach. An increase in the intensity of the LEDs to improve the range would likely result in unacceptable glare.

3.4.4 Discussion

Reducing the coverage from 74% to 50% had no effect in terms of the range at which the LED Touchdown Marking circle was visible, the range at which it was useable, or the visual cueing information provided.

Although having no effect on the visual cueing provided, reducing the number of LEDs per metre (from 32 to 16) and reducing the intensity of the LEDs (by reducing the supply voltage from 12 volts to 9 volts) had a negative effect on the range at which the LED Touchdown Marking circle was visible, and the range at which it was useable. The useable range that resulted in both cases was less than 0.5 NM, which was considered to be too late in the approach.

The usable range of the LED Touchdown Marking circle comprising a series of equally spaced discrete sources (as opposed to strips and gaps) was inadequate. Increasing the intensity to restore the range to the minimum 0.5 NM required would likely lead to glare at shorter ranges. Such a system would, in any event, be non-compliant with the ICAO minimum coverage requirement of 50% unless the spacing of the discrete sources was no greater than the width of the sources, leading to a large number of sources and the associated practical difficulties. In addition, a system comprising discrete sources would provide one less range cue compared to the segments formed from linear arrays of LEDs.

The general effect of the helideck net was to reduce the range at which the Touchdown Marking circle was visible and useable to below the 0.5 NM judged to be the minimum acceptable. Doubling the width of the LED Touchdown Marking circle restored the visible and useable range of the aid to 0.5 NM. No glare from LEDs was experienced, and the performance obtained was similar to that achieved with the single-width circle without the helideck net fitted.

As well as helping to counter the physical obscuration of the circle by the net, doubling the width of the circle would also be expected to result in an apparent increase in its intensity at ranges beyond which the human eye could resolve the two adjacent circles. It is not known to what extent it was the reduction in obscuration or the apparent increase in intensity that produced the desired result. In any event, increasing the width of the circle is likely to be preferable to simply increasing its intensity as the latter could lead to glare at shorter ranges.

The vertical approach angle had a significant effect on the range at which the LED Touchdown Marking circle was visible and useable during the approach. The range was greater for steeper approach angles. This undesirable property is considered to be related to the photometric performance of the LED segments employed. The vertical approach angle affects the lookdown angle which is the same as the angle of elevation from the helideck. The variation of intensity of the LEDs with elevation is approximately sinusoidal. Hence, at the small angles of elevation involved, a small change in elevation produces a relatively large change in intensity and hence viewing range.

The emergence of the gaps between the segments and between the individual LEDs during the approach were found to provide very useful range cues to the pilot. The ranges at which the segments and LEDs become distinguishable will obviously be influenced by the size of the gaps between them. In addition, however, the intensity of the LEDs and hence the strips was also found to have a significant effect. In order that the range cues are consistent from one helideck to the next, therefore, it would be desirable to apply a degree of standardisation to the gaps between the segments and between the individual LEDs and to the photometric properties of the strips. If segments comprising other than a linear array of discrete sources are to be used, consideration must be given to replicating the cueing provided by the gaps between the LEDs.

3.5 Assessment of the Laser/Optical Fibre Heliport Identification Marking

The details of the Heliport Identification Marking configurations evaluated are presented in Table 14.

Table 14 Heliport Identification Marking 'H' Configurations Evaluated

Lighting Configuration		Helideck Net fitted	Trial	Run
(a)	Stage 2 baseline 2 with ELP 'H'	No	3	6
(b)	Stage 2 baseline 2 with laser/optical fibre 'H'	No	3	7
(c)	Stage 2 baseline 2 with ELP 'H'	Yes	6	5
(d)	Stage 2 baseline 2 with laser/optical fibre 'H'	Yes	6	6

When assessing the results for the Heliport Identification Marking ('H'), it should be noted that the laser/optical fibre 'H' was significantly larger than the ELP 'H', the latter being undersized (see Section 2.2.4.1). In addition, the laser/optical fibre 'H' was in outline form whereas the ELP 'H' was filled. Previous trials at Longside Airfield [Ref. 5] had demonstrated that an outline 'H' performed better than a filled 'H' without a helideck net fitted and vice-versa.

3.5.1 Range Data

The purpose of the assessment was to evaluate the performance of a laser/optical fibre 'H' by comparison with the ELP 'H' used for previous trials. Figure 14 shows the range at which the two versions of the 'H' became visible, and the range at which they became useable as a final approach cue.

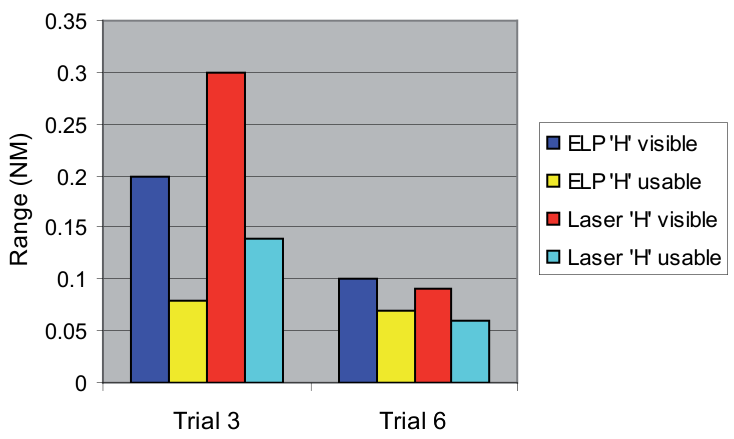

Figure 14 Range Data for the Heliport Identification Marking 'H' Configurations Evaluated

The data show that without a helideck net fitted, the laser/optical fibre 'H' was both visible and useable as a final approach cue at a significantly greater range than the ELP 'H'. With a helideck net fitted, however, there was little difference in the performance of the two aids; the laser/optical fibre 'H' appeared to have been affected more by the net than the ELP 'H'. Both aids were visible at shorter ranges with a net than without a net, but the effect on the range at which the aids became usable was much less.

3.5.2 Ratings of Visual Cueing Information

The ratings of visual cueing information that were awarded, for both forms of 'H' both with and without a net fitted, for the final approach and hover phases are presented in Table 15.

Table 15 Ratings of Visual Cueing Information for the Heliport Identification Marking 'H' in the Final Approach and Hover Phases (1 = poor, 5 = excellent)

Configuration (see table 14)	Final Approach				Hover					
	Flight Path Angle	Azimuth Alignment	Attitude	Closure Rate	Position	Translational Rate	Height	Heading	Descent Rate	Yaw Rate
(a)	4	3.5	2	3.5	4	4	4	4	2.5	4
(b)	4	3.5	2	3.5	4.5	4.5	4.5	4.5	3	4.5
(c)	1.5	3	2	3	2.5	3	3	3	3	3
(d)	1.5	3	2	3	2.5	3	3	3	3	3

The ratings show that both configurations of the 'H' were judged to have provided the same visual cueing information during the final approach phase both with and without a net fitted. The main effect of the net was on the rating for the flight path angle information which was reduced by two and a half points for both configurations.

In the hover phase without a net fitted the laser/optical fibre 'H' attracted ratings half-a-point higher than the ELP 'H' for all items of visual cueing information. With a net fitted all hover phase ratings were identical for both configurations of 'H' and the ratings were all significantly lower.

3.5.3 Pilot's Comments

The pilot considered that without a net fitted, the outline laser/optical fibre 'H' gave a good set of visual cues and stood out well. He commented that it gave a little more information than the filled ELP 'H' from the point at which it became a useable cue (which was at a greater range than the ELP 'H'), which he attributed to its distinctive shape and the micro-texture information provided.

During earlier trials at Longside Airfield [Ref. 5] a filled 'H' was preferred to an outline form with a helideck net fitted. Although there was no difference in the ratings awarded for each configuration of the 'H' during the present trials, the pilot once again considered that the filled form of the ELP 'H' was more tolerant of the helideck net than the outline form of the laser/optical fibre 'H'. It was noted that the width of the outline forming the laser/optical fibre 'H' was quite thin, and that this configuration might have benefited from a thicker outline. Overall, the pilot considered that both versions of the 'H' evaluated would be acceptable for use with a helideck net fitted.

3.5.4 Discussion

The better range performance of the laser/optical fibre 'H' without the net could be due to its larger size and/or its outline form. The intensity of the laser/optical fibre 'H' could also have been a little higher and may have helped, but this was not obviously a factor.

The slightly higher hover phase visual cue ratings for the laser/optical fibre 'H' without the net were most likely attributable to its larger size. This improved the visibility of the aid when the helicopter is overhead the aid and the smaller ELP 'H' is largely obscured from view.

With the net fitted, the outline form would have detracted from the performance of the laser/optical fibre 'H', and the benefit of any increased intensity would have been lower. The relatively small effect of the net on the range at which the aids became usable may be due to the rapidly increasing viewing angle at such short ranges; the effect of the net would be expected to reduce with an increase in viewing angle.

Photographs of the ELP 'H' and laser/optical fibre 'H' with the helideck net fitted are given in Figures 15 and 16.

Figure 15 ELP Heliport Identification Marking ('H')

Figure 16 Laser/Optical Fibre Heliport Identification Marking ('H')

3.6 Assessment of the LED Chevron

The assessment aimed to evaluate the effectiveness of a chevron, formed from yellow LED strips indicating the general position of the OFS origin, in providing heading/alignment cues.

3.6.1 Range Data

Table 16 shows the range at which the LED chevron became visible, and the range at which it became useable as a final approach cue. This is compared to the same data for the ELP 'H' which has been shown to provide useable heading information during previous trials.

Table 16 Range Data for LED Chevron and ELP 'H'

Lighting Aid	Trial	Run	Range (NM)	
			Visible	Usable
ELP 'H'	2	6	0.3	0.2
LED Chevron	2	7	0.15	0.15

It was considered that the point at which the chevron was visible and the point at which it became useable was the same. It can be seen that this point was at a later stage than the ELP 'H' both in terms of visibility and usability.

3.6.2 Ratings of Visual Cueing Information

The LED chevron was assessed relative to the ELP 'H' for assigning ratings of visual cueing information. The ratings that were awarded for the ELP 'H' and the LED chevron for the final approach and hover phases are presented in Table 17.

Table 17 Ratings of Visual Cueing Information for the ELP 'H' and the LED Chevron Marking in the Final Approach and Hover Phases (1 = poor, 5 = excellent)

Lighting Aid	Final Approach				Hover					
	Flight Path Angle	Azimuth Alignment	Attitude	Closure Rate	Position	Translational Rate	Height	Heading	Descent Rate	Yaw Rate
ELP 'H'	4	2	3	3	4.5	4.5	4	4	4	4
LED Chevron	3	1	2	2	4.5	4.5	3.5	4	3.5	4

With the LED chevron, the visual cueing information in the final approach phase was poorer than the ELP 'H', attracting ratings of one point lower. In the hover, height and descent rate information were both degraded by half-a-point from the ELP 'H'.

3.6.3 Pilot's Comments

Although the LED chevron attracted poorer ratings than the ELP 'H', it was considered that the LED chevron did provide some additional information. The chevron provided improved information regarding the direction of approach to the helideck and, in the hover, increased awareness of the obstacle sector and of absolute heading. The preference of the pilot, however, was for the ELP 'H' rather than the chevron. The 'H' provided continuity of information from the circle inwards to the centre of the deck.

3.6.4 Discussion

The range at which the LED chevron provided useable information was less than the ELP 'H', and the visual cueing information provided was also poorer. The LED chevron cannot therefore be considered an effective alternative to the Heliport Identification Marking ('H'). However, it could be used to enhance cueing and awareness of obstacles on helidecks with less benign obstacle environments. A photograph of the LED chevron without a helideck net is presented in Figure 17.

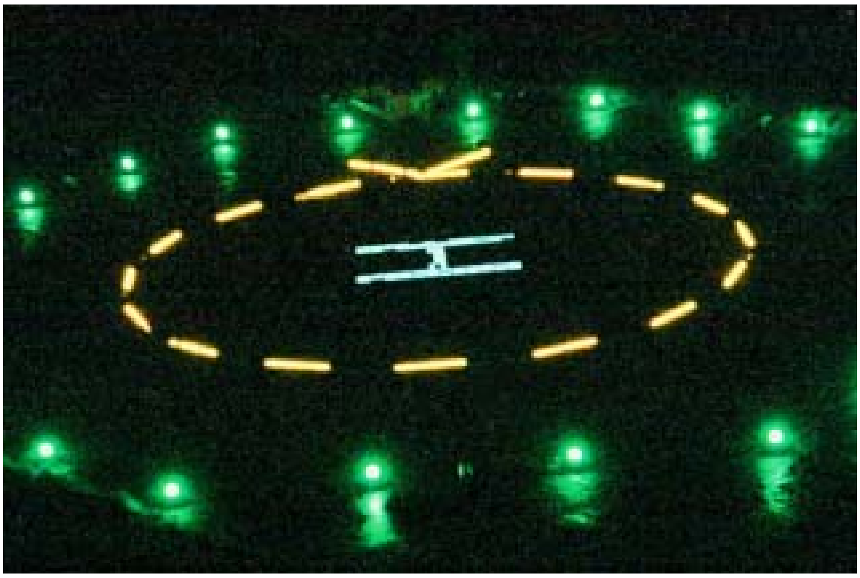

Figure 17 LED Chevron

3.7 Assessment of Alternative Technologies

The potential of several alternative technologies for use in providing visual cueing for operations to helidecks at night was evaluated. For practical reasons, part installations comprising samples of the lighting were deployed rather than full systems. Because the range and visual cueing provided by the incomplete systems would be unrepresentative, the evaluations comprised qualitative pilot assessment rather than the more formal rating system employed for the rest of the trials programme.

3.7.1 Laser/Optical Fibre Net Highlighting

The use of the laser/optical fibre 'woven' into the rope mesh to highlight the net was evaluated during Trial 4 as a potential alternative to floodlighting (see subsection 2.2.6.1). The visual cueing information provided was judged to be poor, and worse than that available with the floodlighting. No information was available in the final approach and, in the hover phase, the lighting was found to be very artificial and 'unreal' looking with no depth. The overall impression was that laser/optical fibre applied in this manner had no potential as a visual aid for operations to helidecks at night.

3.7.2 Green 'Intenslite' LED Panels

Four LED-driven fibre optic panels, arranged in the form of a 2 m cross, were assessed during Trial 5 (where due to poor weather, close-in, low-level circuits only were performed) and again on Trial 6 (see subsection 2.2.6.2). Compared to the

ELP 'H', the LED panels were brighter and consequently visible at a greater range. However, on both occasions it was noted that the panels were unevenly lit, being noticeably brighter at the driven end (the inner end at the centre of the cross). On the second evaluation during Trial 6 the bright area at the centre of the cross was noted as dominating and, from a distance, the cross initially appeared as an additional green perimeter light.

It was also commented that the intensity of the panels might be too bright to be used to form a lit Heliport Identification Marking. From the point of view of intensity, it was considered that they would likely be more suitable for the yellow Touchdown Marking circle. However, the lack of texture would need to be addressed (e.g. by masking) to replace the cueing provided by segments formed from linear arrays of point sources (LEDs).

3.7.3 Green 'Tri-O-Lite' LED Strips

The 'Tri-O-Lite' LED strips were mounted on a 2 m wooden cross such that both the sides and the top of the cross were covered with LED strips (see subsection 2.2.6.3). The cross could then be set up with the sides only lit, or both the sides and top illuminated. The cross was assessed during Trial 5 and again during Trial 6.

During Trial 5 several approaches were made with only the sides of the cross illuminated and it was found that the visibility of the cross was affected by the horizontal approach track. Visibility appeared to be reduced by the LEDs being masked by the rope of the net and seemed to be worst when the approach track was aligned with the mesh of the net. Performance was noticeably better and more consistent when both the sides and top of the cross were illuminated. In this configuration the visibility of the cross was not affected by the approach track, and the overall pilot impression was that it was brighter and better than with only the sides lit. Any advantage that might have been gained by mounting the LEDs horizontally appeared to be largely negated by the net, but this would likely not be the case if the horizontal LEDs were mounted higher relative to the net, or if no net was fitted.

It was considered that the strips could potentially be used for the lit 'H' or for the yellow Touchdown Marking circle. It was noted that the LEDs did not appear to be as bright as the yellow LEDs in the circle. However, this may have been due to the difference in colour, i.e. reduction in brightness with green. They did provide the same point-source, micro-texture when close in as provided by the yellow LED circle segments.

3.7.4 Green 'LEDline' High-Intensity LED Strips

The high-intensity LED strips, deployed as an OFS chevron (see subsection 2.2.6.4), were difficult to evaluate in detail since only a small sample was available for assessment. The strips were bright and clearly visible when close-in to the 'helideck'. From the brief evaluation conducted it was considered that the strips may have potential for use in providing a Touchdown Marking circle, but it was felt that they might be too bright for the lit 'H'.

3.8 Effect(s) of Water on the Aircraft Transparencies

In addition to the assessment of the performance of various lighting configurations in terms of range and visual cueing performance, the trial also aimed to evaluate the effect of water contamination on the aircraft's transparencies on key lighting configurations. Fortunately, heavy rain was experienced during runs 6 and 7 of Trial 3, allowing this assessment to be conducted under representative conditions. It was subjectively assessed that the rain on the transparencies did not cause any adverse effect in terms of glare, dazzle or 'bloom' from any of the lighting elements.

4 Offshore Trial of Modified Floodlighting

4.1 Introduction

It was decided by the CAA that the helideck lighting improvements identified would be introduced in two stages. Stage 1 comprises the new green perimeter lighting (adopted by ICAO in Annex 14 Vol. 2, mandatory with effect from 1st January 2009), and improved floodlighting arrangements. In Stage 2, the floodlighting is replaced with the lit Touchdown Marking circle and Heliport Identification Marking 'H' (adopted by ICAO in Annex 14 Vol. 2 as an option to floodlighting) once suitable hardware is available.

Based on the results of the trials reported in Section 3.3, two improved floodlighting configurations were identified as being potentially suitable for Stage 1:

a) two or four halogen floodlights located at high level in the LOS combined with two xenon floodlights opposite the LOS at deck level;

b) four xenon floodlights located at deck level around the perimeter of the helideck.

Recognising the need to evaluate the two Stage 1 configurations in a representative offshore environment (as opposed to the somewhat artificial environment of the trials site at Norwich Airport), the need to evaluate the lighting in a range of meteorological conditions, and to expose the lighting to a broader range of pilots, both lighting configurations were installed on offshore platforms for in-service trials. Configuration a) was installed on the ExxonMobil Galahad platform which has an obstacle (vent pipe) in the LOS, and configuration b) was installed on the ExxonMobil Lancelot platform which has no obstacles. It should be noted that the two deck-level floodlights of configuration a) were mounted closer together than at the Norwich Airport test site shown in Figure 8.

A dedicated check flight was carried out on 10 February 2006 to confirm that the lighting systems had been correctly set up prior to the start of the in-service trials, and to confirm that the lighting was of an acceptable standard for in-service use. The results of this trial are reported in this section; the in-service trial is to take place during the night flying season of 2006/7.

4.2 Conduct of Flight Trial

The flight trial was conducted using a Sikorsky S-76 chartered from and operated by Bristow Helicopters Ltd. (BHL). The meteorological conditions were: night no moon (sunset 16.57, darkness 17.27); no precipitation; visibility 30 km; cloud base 2500–3000 ft; wind speed <5 kts.

The aircraft departed Norwich Airport at 17.30 and routed to the Lancelot. A normal approach was carried out at the Lancelot, culminating in a landing. Since no adjustment was considered necessary, the aircraft took-off and performed an orbit of the Lancelot before routing to the Galahad. A normal approach and landing was performed at the Galahad where the trials engineer disembarked to adjust the deck-level floodlights. An orbit was performed while the lighting was optimised, after which the aircraft landed to collect the trials engineer. The aircraft then returned to shore, conducting a fly-past at the Lancelot, and landing at Norwich Airport shortly after 19.00. A short debrief was conducted to confirm the overall observations and conclusions.

4.3 Results and Observations

4.3.1 Lancelot

The green perimeter lights were visible from approximately 5.5 NM and were very well received by the pilots. The pilots commented that deck location was much improved which is especially beneficial when operating to 'unfamiliar' platforms.

The cross on the surface of the helideck formed by the four deck-level floodlights was found to provide good depth perception and lateral cueing. The identification of the centre of the helideck by the centre of the cross and the symmetry of the pattern were also considered helpful. The light levels once landed on deck were considered acceptable, i.e. no glare was evident.

4.3.2 Galahad

The green perimeter lights were visible from 6.5 NM (at 400 ft), stood out well and were considered a very worthwhile improvement. The apparent difference in the range of the perimeter lights on the Lancelot and the Galahad may have been due to the differences in the vertical profile flown (not recorded), differences in the cultural lighting environment on the two platforms (impractical to measure), or simply variability in the observers.

It was noted that the raised floodlights did not appear to be contributing much to the lighting of the deck and that this could have been due to the high-intensity of the vent pipe floodlighting. The raised floodlights were not fitted with louvers as had been expected but, curiously, this did not result in any glare. It is possible that the intensity of the raised floodlights was below specification for some unknown reason.

Unlike the Lancelot configuration, the floodlighting did not generate a definitive pattern on the surface of the helideck and was consequently judged to be inferior. At the time this was thought to be partly due to the ineffectiveness of the raised floodlights, partly due to the disposition of the deck-level floodlights (they were mounted closer together than they had been during the onshore trials), and partly due to the high level of ambient lighting. It was suggested that a better result might be obtained if the deck-level lights were mounted further apart.

Once landed on the helideck, the intensity of the deck-level floodlights was considered to be higher than desirable. Some difficulty was experienced in adjusting the lights to reduce the glare without unduly compromising the illumination of the helideck, but an acceptable compromise was eventually achieved.

4.4 Conclusions and Recommendations

4.4.1 The interim helideck lighting systems on both platforms were considered acceptable for revenue service.

4.4.2 The floodlighting configuration on the Lancelot comprising four deck-level xenon floodlights was judged to be significantly better than that on the Galahad.

4.4.3 An in-service trial should be conducted to evaluate the two floodlighting configurations in a range of meteorological conditions, and to expose them to a broader range of pilots.

5 Conclusions

From the results of the trials, the following conclusions are drawn:

5.1 Perimeter Lights

(See Section 3.2)

The upper limit on perimeter light intensity of 60 cd specified by CAA in *CAP 437* is acceptable.

5.2 Floodlighting

(See Section 3.3 and Section 4)

5.2.1 A floodlighting system comprising only floodlights located at high level in the LOS is unacceptable as a minimum floodlighting standard.

5.2.2 A floodlighting system comprising eight deck-level floodlights is unacceptable as a minimum floodlighting standard.

5.2.3 A floodlighting system comprising four deck-level xenon floodlights has the potential to provide enhanced floodlighting for many offshore helidecks as an interim (Stage 1) solution prior to the implementation of the Touchdown Marking circle and Heliport Identification Marking lighting.

5.2.4 A floodlighting system comprising floodlights fitted with louvers and located at high level in the LOS together with floodlights mounted at deck level opposite the LOS, may be suitable for providing enhanced floodlighting on offshore helidecks with significant obstacles in the LOS, pending implementation of the Touchdown Marking circle and Heliport Identification Marking lighting.

5.3 LED Touchdown Marking Circle

(See Section 3.4)

5.3.1 The minimum circle coverage of 50% proposed in the ICAO standards is acceptable.

5.3.2 The specification of the Touchdown Marking circle strips used for the Longside Airfield trials [Ref. 5] in respect of the number of LEDs per metre (i.e. 32 LEDs/m) represents the minimum acceptable standard.

5.3.3 The specification of the Touchdown Marking circle strips used for the Longside Airfield trials [Appendix B of Ref. 5] in respect of the intensity of the LEDs represents the minimum acceptable standard.

5.3.4 A Touchdown Marking circle composed of discrete sources, as trialled, is unacceptable as a minimum standard.

5.3.5 With a helideck net fitted, a double-width Touchdown Marking circle was required to restore the range of the aid to the minimum of 0.5 NM considered acceptable by the test pilot.

5.3.6 The photometric properties of the LED strips used for the trials led to the range of the Touchdown Marking circle being sensitive to the vertical approach angle flown.

5.3.7 The gaps between the strips and between the individual LEDs were found to provide very useful range cues to the pilot, but the associated ranges were found to be sensitive to the intensity of the LEDs and hence the strips, which varied with approach path angle.

5.4 **Heliport Identification Marking ('H')**

(See Section 3.5)

5.4.1 The lit 'H' should be full size, i.e. 4 m x 3 m x 0.75 m.

5.4.2 If used in outline form with a helideck net, consideration should be given to increasing the width of the outline of the 'H'.

5.4.3 Either form of 'H' as trialled would be acceptable for use on a deck, either with or without a helideck net fitted.

5.5 **LED Chevron**

(See Section 3.6)

5.5.1 The LED chevron cannot be considered an effective alternative to the Heliport Identification Marking ('H'), but could be used to provide additional cueing where desired.

5.6 **Alternative Technologies**

(See Section 3.7)

5.6.1 Laser/Optical Fibre Net Illumination

The laser/optical fibre deployed to highlight the net proved ineffective and has no potential as an alternative to floodlighting.

5.6.2 Green 'Intenslite' LED Panels

If the uneven illumination can be addressed and the textural information conveyed by the individual LEDs can be replicated, the Intenslite LED panels have potential for use for both the Heliport Identification Marking ('H') and the Touchdown Marking circle.

5.6.3 Green 'Tri-O-Lite' LED Strips

5.6.3.1 The 'Tri-O-Lite' LED strips evaluated are suitable for use for the lit 'H' and, if available in yellow, for the Touchdown Marking circle.

5.6.3.2 Increasing the intensity of the 'H' and/or Touchdown Marking circle at lower angles of elevation should not be accomplished at the expense of the intensity at higher elevations.

5.6.4 Green 'LEDline' High-Intensity LED Strips

It was considered that the LEDline high-intensity strips would be suitable for the Touchdown Marking circle application but may be too bright for the 'H'.

5.7 **Effect(s) of Water on the Aircraft Transparencies**

(See Section 3.8)

The presence of rain on the aircraft transparencies had no noticeable effect on any of the perimeter lights, Touchdown Marking circle or either 'H'.

6 Recommendations

From the results of the trials, the following recommendations are made:

6.1 Floodlighting

6.1.1 An in-service trial should be conducted to evaluate the two floodlighting configurations identified for use in the Stage 1 improved helideck lighting in a range of meteorological conditions, and to expose them to a broader range of pilots.

6.1.2 Pending the outcome of the in-service trial recommended in subsection 6.1.1 above, the deck-level floodlighting system comprising four lighting units, similar in performance to Tranberg TEF 9964 floodlights, should be recommended as the preferred Stage 1 minimum standard to improve the visual cueing environment on offshore helidecks.

6.2 Touchdown Marking Circle

An equipment requirements specification should be drawn up for the Touchdown Marking circle which should detail:

- the size and location of the circle;
- the coverage of the circle;
- the size of the gaps between the segments;
- the width of the segments;
- the intensity and intensity distribution of the segments;
- the spacing of the point sources within the segments.

The specification should be designed to produce a visual aid having the required range and visual cueing performance over the normal range of helicopter vertical approach paths, for the worst case meteorological operating conditions, either with or without a helideck net fitted.

6.3 Heliport Identification Marking (‘H’)

An equipment requirements specification should be drawn up for the ‘H’ which should detail:

- the size and location of the ‘H’;
- the size/number of segments;
- the size of the gaps between the segments;
- the width of the outline if in outline form;
- the intensity and intensity distribution of the segments.

The specification should be designed to produce a visual aid having the required range and visual cueing performance over the normal range of helicopter vertical approach paths, for the worst-case meteorological operating conditions, either with or without a helideck net fitted.

6.4 General

Prototype equipment for the Touchdown Marking circle (see subsection 6.2) and the Heliport Identification Marking (see subsection 6.3) should be manufactured and installed on a representative offshore platform for extended in-service trials, with the primary objective of validating the equipment requirements specification prior to inclusion in *CAP 437* [Ref. 2]. To this end, the trial should expose the system to a wide sample of offshore pilots, in an offshore environment and in a broad range of meteorological conditions.

7 Acknowledgements

CAA gratefully appreciates and acknowledges the following contributions to the research reported in this paper:

- Hugh Lawson, Bob Kent and Bob Moore of Norwich International Airport for allowing and assisting with the installation of the trials equipment;
- Bob Goff of Norwich Air Traffic Control for accommodating the trials, some of which were outside normal operating hours;
- Mick Blackman and Jimmy Whyte of ExxonMobil for hosting the trials of the Stage 1 lighting systems on their Lancelot and Galahad platforms;
- Torstein Rysstad of Tranberg AS for the donation of floodlights;
- Peter Heyse of STL International for the donation of perimeter lights;
- Roland Murray of Intenslite for the free loan of the lasers and optical fibre;
- Peter Gay of Bristow Helicopters Ltd. for the free use of their facilities at Norwich Airport.

8 References

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Appendix A: Trial Proforma

DATE ______________________________

APPROACH HEADING ______________________________

PRE RUN DATA (ALL TRIALS)

TIME (GMT) ____________________

CLOUD BASE ____________________ VISIBILITY (KM) ____________________

WIND SPEED (KNTS) ______________ WIND DIRECTION ____________________

AMBIENT LIGHT	TWILIGHT	NIGHT / MOON	NIGHT / NO MOON
PRECIPITATION	NONE	RAIN	SNOW

DURING RUN DATA (TRIAL 4)

Run 1 Range at which the **landing circle** became visible................................. [ ]
Range at which the **landing circle** became usable
as a final approach cue... [ ]

Run 2 Range at which usable 'in deck' cues became available......................... [ ]

Run 3 Range at which usable 'in deck' cues became available......................... [ ]

Run 4 Range at which usable 'in deck' cues became available......................... [ ]

Run 5 Range at which usable 'in deck' cues became available......................... [ ]

Run 6 Range at which usable 'in deck' cues became available......................... [ ]

DURING RUN DATA (TRIAL 6)

Run 1 Range at which the **landing circle** became visible................................. [ ]
Range at which the **landing circle** became usable
as a final approach cue... [ ]

Run 2 Range at which usable 'in deck' cues became available......................... [ ]

Run 3 Range at which usable 'in deck' cues became available......................... [ ]

Run 4 Range at which usable 'in deck' cues became available......................... [ ]

Run 5 Range at which the **landing circle** became visible................................. ☐
Range at which the **landing** circle became usable
as a final approach cue.. ☐

Range at which the **ELP 'H'** became visible .... ☐
Range at which the **ELP 'H'** became usable
as a final approach cue.. ☐

Run 6 Range at which the **laser/optical fibre 'H'** became visible..................... ☐
Range at which the **laser/optical fibre 'H'** became usable
as a final approach cue.. ☐

Run 7 Range at which the **landing circle** became visible................................. ☐
Range at which the **landing circle** became usable
as a final approach cue.. ☐

Run 8 Range at which the **green LED panel cross** became visible .... ☐
Range at which the **green LED panel cross** became usable
as a final approach cue.. ☐

Run 9 Range at which the **green LED strip cross** became visible .... ☐
Range at which the **green LED strip cross** became usable
as a final approach cue.. ☐

POST RUN DATA (ALL TRIALS)

Final Approach

Ratings from 1 – 5 (1 = poor, 5 = excellent)
Ratings should be based on experience of cueing during off-shore operations currently.

- Rating of aircraft **flight path angle** provided by the configuration........... ☐
- Rating of aircraft **altitude information** provided by the configuration...... ☐
- Rating of **azimuth alignment information** provided by the configuration ☐
- Rating of **closure rate information** provided by the configuration.......... ☐

Hover

Ratings from 1 – 5 (1 = poor, 5 = excellent)
Ratings should be based on experience of cueing during off-shore operations currently.

- Rating of information on **position** relative to the deck provided by the configuration .... ☐
- Rating of information on **translational rate** relative to the deck provided by the configuration .... ☐
- Rating of information on **height** relative to the deck provided by the configuration .... ☐
- Rating of information on **descent rate** relative to the deck provided by the configuration .... ☐
- Rating of information on **heading** relative to the deck provided by the configuration .... ☐
- Rating of information on **yaw rate** relative to the deck provided by the configuration .... ☐

Appendix B: Approach Path Data

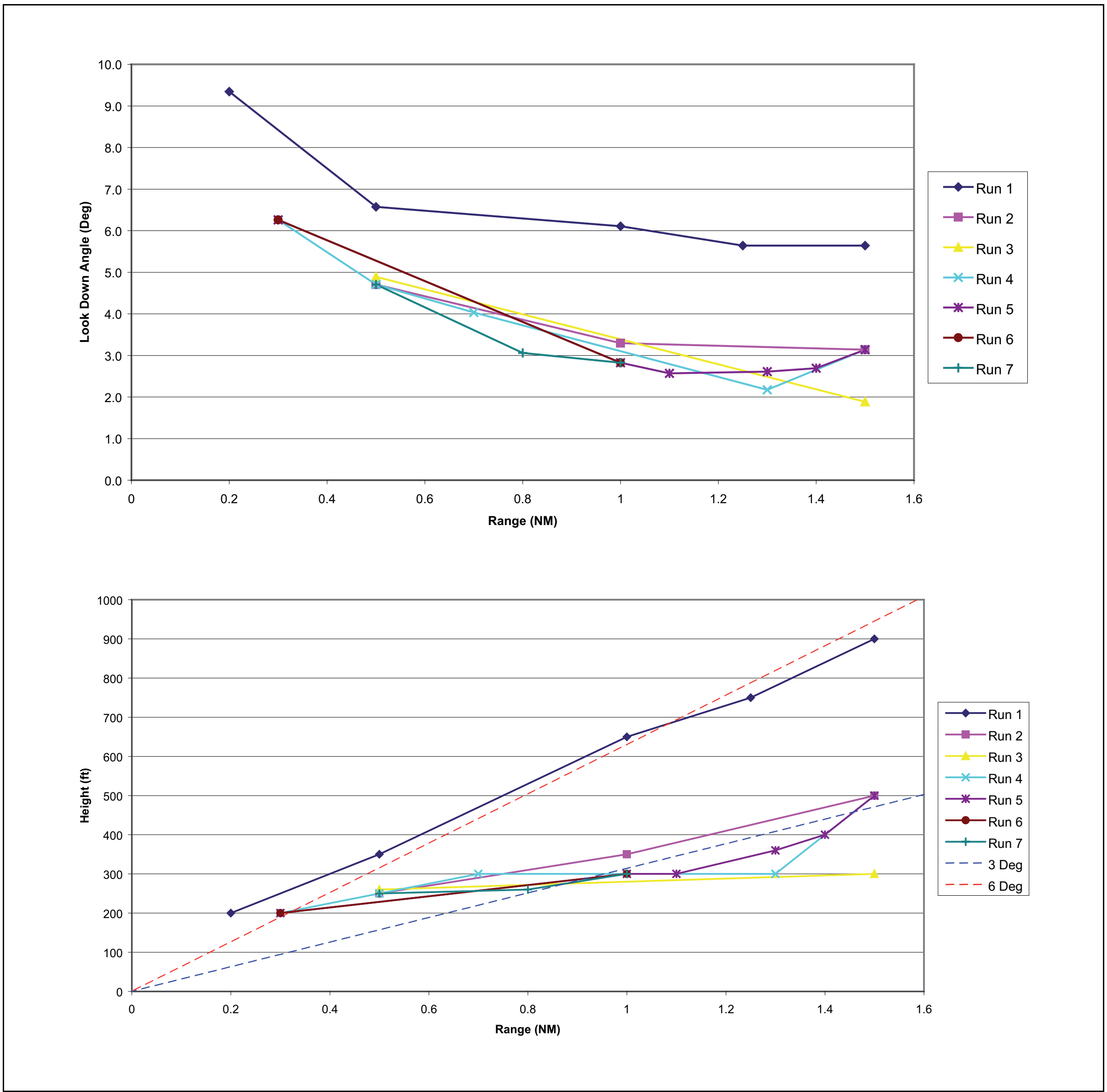

Figure B1 Trial 3 Approach Data

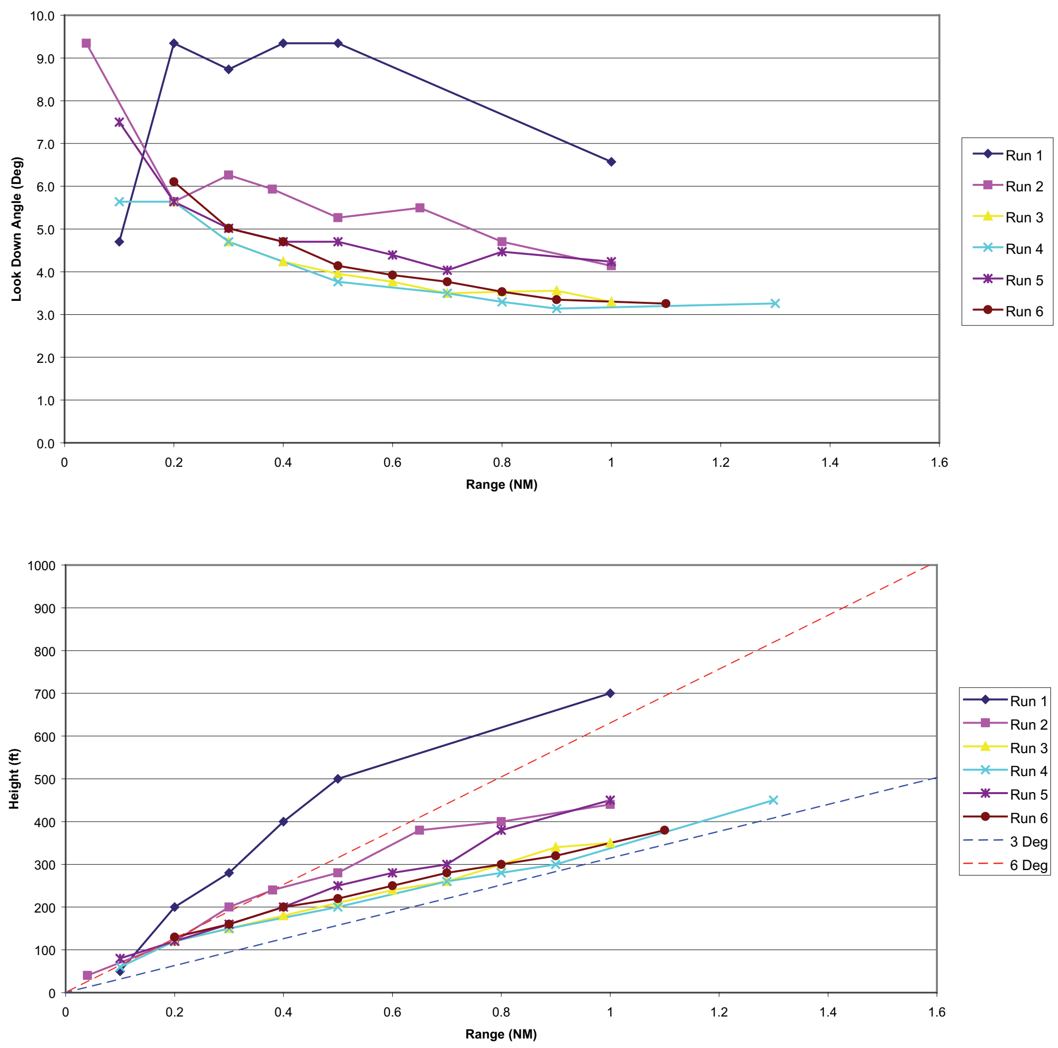

Figure B2 Trial 4 Approach Data

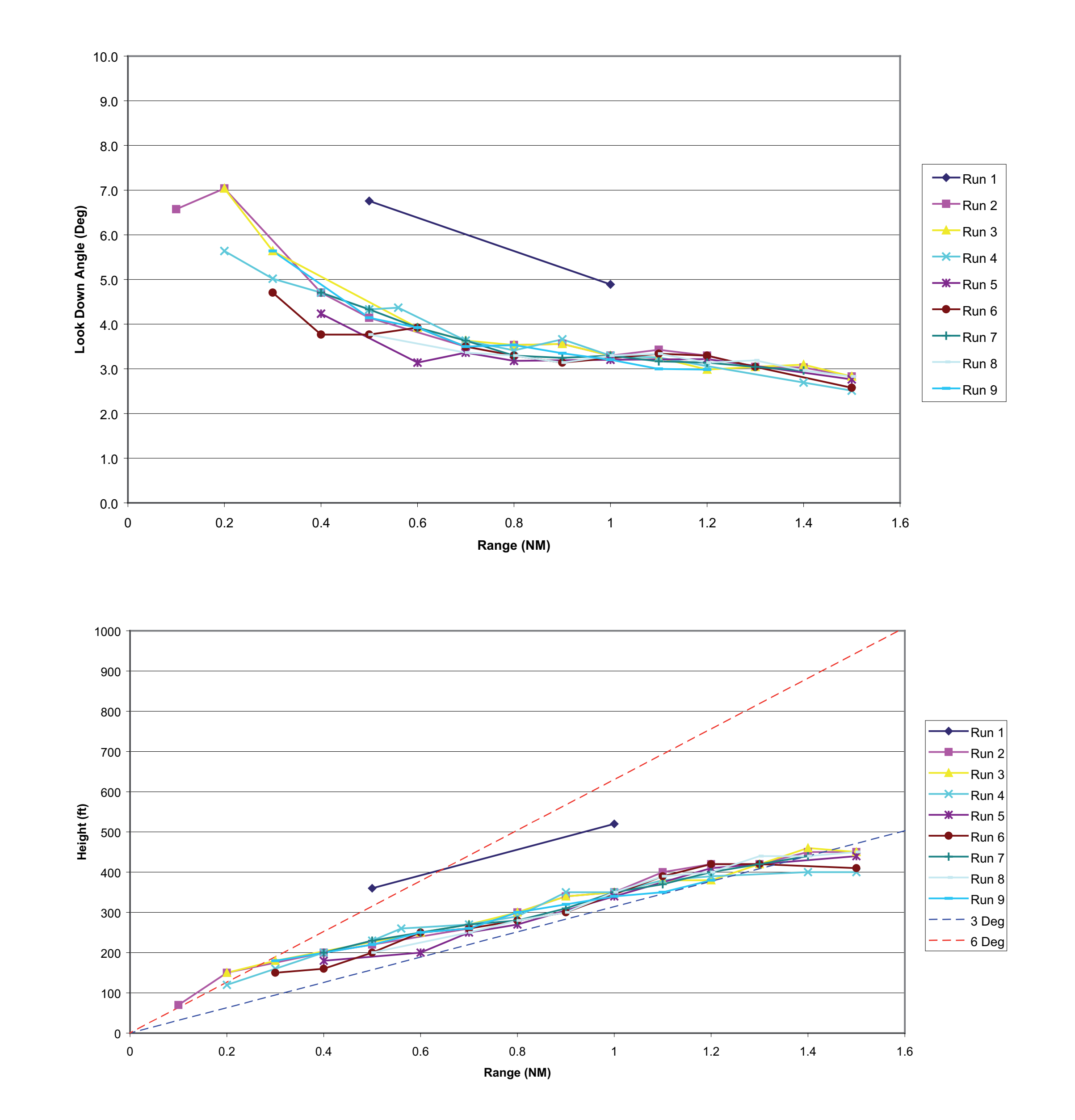

Figure B3 Trial 6 Approach Data

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