NINTH EUROPEAN ROTOR CRAFT FORUM

Paper No.28

ROTATING IN THE DARK
(Electro-Optical Systems Development for Helicopter Night Operations)

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England

September 13-15, 1983

STRESA, ITALY

Assocuazone Industrie Aerospatiale

Associazione Italiana di Aeronautica ed Astronautica

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by

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ABSTRACT

This paper describes a series of flight trials undertaken at the Royal Aircraft Establishment, Farnborough, which have investigated various forms of passive night vision systems for low-level and nap-of-the-earth helicopter pilotage.

The programme has spanned a comprehensive range of sensors comprising image intensifiers, low light television and forward looking infra-red in a variety of systems from fixed external sensor arrangements to night vision goggles, to visually coupled helmet mounted displays. This paper concentrates on the results of trials to assess the performance of infra-red as a pilot aid system.

During the course of the trials, an infra-red system was evaluated in a wide range of meteorological conditions by day and night and throughout the seasons over a two year period. Meteorological and scene conditions were discovered, where the infra-red image can be totally misleading to a pilot, by producing scene contour detail which is in fact absent in the real world. In addition other predicted situations were discovered, where the scene detail becomes totally transparent as the emissivity of natural features is uniform over the whole scene. At the other end of the scale fog/mist conditions were discovered where the visual band sensor produced a totally unusable picture, but the infra-red image reproduced every scene detail very clearly. The paper demonstrates how visual and infra-red imagery can be combined using image processing techniques to produce a composite image, which can be more easily interpreted than the original individual sensor information.

1 INTRODUCTION

In the recent past there has been a growing emphasis on achieving a 24 hour totally passive operational capability for the helicopter. Since helicopters rely for their operational flexibility and capability on a direct view of the ground, this can only be achieved if the pilot has a system which will provide that external view. Potentially night vision aids can at least double the operational capability of the helicopter.

An essential and continuing part of the development of piloting aids for helicopter operations at night and in poor visibility being undertaken by the Royal Aircraft Establishment, Farnborough, is the assessment and selection of sensors, to determine which atmospheric window will provide the highest overall availability for operational use.

In the field of night vision research, two main forms of night vision device have been available to the researcher, those based on mainly visual band sensing, and those based on infra-red sensing. In the early development periods of low light television, which suffered badly from lack of sensitivity, bright light overload, and blooming, proponents of infra-red claimed that this technology would uniquely provide the answer to round-the-clock passive operation for both piloting, target acquisition and weapon aiming. Since infra-red systems need no reflected illumination to produce an image, infra-red images obtained in what appears to the unaided eye to be a totally black scene can be startling in their reproduction of fine scene detail.

This paper describes a series of trials which evaluated a wide field of view infra-red system mounted in a Sea King helicopter. The system was used to undertake low level flying at night over a period of two years, which encompassed the full range of meteorological conditions throughout the seasons.

Earlier flight trials of helicopter night vision systems established the basic system requirements in terms of sensor fields of view, resolution and overlay flight information. These earlier trials also investigated alternative methods of displaying the sensor and flight information to the pilot. The purpose of these current trials was to examine the infra-red sensor as an alternative to the previous low light television sensor within a similar system design.

The Forward Looking Infra-Red (FLIR) was mounted in the chin of the Sea King on a two-degrees-of-freedom platform which facilitated azimuth panning and elevation tilting. The output from the platform was presented primarily on a head down CRT display in the left hand instrument panel.

2 OBJECTIVES

The overall objective of the flight trials was to investigate the problems, define the limitations and establish operating procedures for using an indirect view of the terrain ahead to pilot and navigate at low level. In particular to establish what scene information is required for the pilot to undertake this task.

The trials also had the specific objectives to:

(a) Determine whether a wide field of view FLIR provides the scene detail on sufficient occasions to provide an operationally viable system.

(b) To determine the limitation of the FLIR under test in relation to an ideal sensor, and so establish in which areas further technical development was required.

(c) To determine the learning time required for a pilot to achieve good operational performance, bearing in mind that FLIR imagery, under some scene conditions can be totally different to daylight or low light television.

3 AIRCRAFT INSTALLATION

The RAE Sea King under test has been used for a number of years as a flying laboratory for testing electro-optical sensors. For these current trials the systems were updated, so that recordings could be made with real time change overs from each sensor, by the use of a video switching unit. Also a split screen system allowed two sensors to be displayed simultaneously.

The electro-optical systems fitted for these trials, comprised a daylight television camera mounted on the port side of the nose, and a low light television using an 80/40 demagnifying intensifier, coupled to a 40mm Isocon camera on the starboard side. The FLIR head in its pan and tilt platform was mounted on the front of the aircraft, by modifying the bow section to form a chin. This is illustrated in Fig 1.

3.1 FLIR camera

The FLIR camera was a parallel scan system using a 100 element Cadmium Mercury Telluride detector (CMT). The system scanned the scene via a five-sided drum, rotating at 20 Hz and a cam operating a 4 to 1 interlace. The scene image was relayed via an f/1 germanium lens, of 30 mm onto the detector set. The output from the detectors was fed via low noise amplifiers to the main electronics unit. This contained analogue to digital converters and associated timing functions along with the power supplies for the system. Primarily this unit provided channel amplification of the signals from the hundred detectors, together with balancing and bandwidth control of the signals. The 400 lines of scanned image information was converted to 625 line CCIR television standard via a digital scan converter. Analogue signals from the camera head were digitised to form a 6 bit binary word prior to storage, and given one of 64 levels of grey tone scale. Processing of this digitally stored information, allowed such facilities as a 3 to 1 zoom in eight discrete steps from 21 degrees to 30 degrees in elevation, and 30 degrees to 80 degrees in azimuth, video inversion white hot or black hot, and picture freeze.

The FLIR camera was mounted in a two-degrees-of-freedom platform giving panning coverage in azimuth ±100 degrees from ahead, and tilting in elevation from +30 degrees upwards to -100 degrees downwards. The two axes system was driven using dc motors, and contained a fail safe braking system, which held off electronically, whilst the unit was being moved, but otherwise stopped the system from creeping when set on a particular line of sight. The position of both pan and tilt axes were sensed by shaft encoders and this information serialised and transmitted to the system control unit where it was displayed on a three digit meter.

3.2 Low light television camera (LLTV)

The low light television camera was mounted rigidly to the external starboard side of the airframe below the cockpit. The camera was aligned in azimuth and depressed by 8 degrees in elevation relative to the aircraft longitudinal flight datum. At a cruising speed of 90 knots the aircraft normally held the nose down attitude of 2 degrees depressing the camera sight line 10 degrees from the horizontal. The camera comprised a 40mm Isocon camera fitted with a 80/40 demagnifying intensifier. The camera used a 111mm objective lens which effectively gave a f/1 performance with a fiew of view of approximately 40 degrees by 30 degrees on the head down TV display.

3.3 Daylight camera

The daylight TV camera was a 25 mm Vidicon. This was rigidly mounted to the port side of the airframe, aligned in azimuth and depressed by 10 degrees in elevation relative to the longitudinal flight datum. The camera was fitted with a zoom lens unit providing a range of outside world fields of view from 4 degrees to 40 degrees in azimuth.

3.4 Symbol generator

The overlay flight information format investigated during the trials comprised the following: Pitch and roll attitude presented by an artificial horizon referenced to an aircraft symbol with pitch and roll scales. Digital read-outs were presented for airspeed and height. Aircraft heading was presented as a linear tape and vertical speed as a thermometer read against a vertical scale.

The other symbol used during the trials was a "heading to steer" director positioned above the heading tape, and referenced to the heading lubber line. The linear displacement of this symbol from the lubber line represented the angular displacement between the helicopter heading and that required to intercept the next waypoint computed from the onboard navigational system.

The flight information was passed via the video distribution system to the pilot's monitor. The FLIR video line to the pilot's monitor utilised an experimental fibre optic video link.

3.5 Cockpit layout

The cockpit of the Sea King contained a 180 mm × 130 mm head down television monitor mounted in the port instrument panel. The pilot's eye to monitor distance in the cockpit was approximately 750 mm. At this distance the monitor subtended an angle of 14 degrees × 10 degrees.

In the after section of the helicopter near the port door, the remainder of the experimental system was fitted comprising the scan converter and electronics unit for the FLIR, the waveform generator, the video tape recorder, daylight camera control unit, the split screen video unit, sync pulse generator and video switching unit.

Remote control for all the systems was situated at the observer position. Here any one of the three sensors could be selected for recording or overlay flight symbology, and routed to observer monitors or pilot's monitors as required. In addition three video lines were run from the video switching unit to the pilot's position allowing all sensors to be routed to the pilot's monitor, and for the pilot to have the facility of selecting a different display if he desired by means of a three position switch, although only one line would normally have flight information superimposed.

If the pilot did not elect to fly using the FLIR, the system could be operated from the observer's position. The field of view from the FLIR could be matched and aligned to the TV using the zoom, and pan and tilt controls, such that the split screen system could present the same information from two sensors on one screen. Conversely, the two images from the sensors could be arranged to give a continuous picture, from left to right, showing the effect of differing sensors on cross-track features.

3.6 Navigation system

The Sea King was fitted with a Decca Doppler 71, a Sperry GM7 gyromagnetic compass and a Decca TANS (Tactical Air Navigation System) digital navigation computer. This had the facility for waypoint storage, and in addition provided the waypoint with a velocity vector, if for example recovery to a moving ship was required. Bearing and distance, or heading to steer, and time to go from the helicopter to the selected waypoint could be presented on an alphanumeric display. For the bulk of the flying, the TANS was coupled to a moving map display mounted above the centre coaming. Although the map unit could accommodate various map scaling, standard 1:50000 maps were used throughout the trial. By means of the rotating drum and sliding cursor, present position could be read very easily throughout the sortie.

4 EXPERIMENTAL DESIGN

To facilitate a slow progression in task difficulty, two experimental flying areas were selected. The first of these contained reasonably flat terrain, free from major obstacles and power cables. A route was formed which followed the boundaries of this area, some 35 km in length, and this was considered to be the basic training and familiarisation route for the trials. The main experimental flying area contained much more demanding terrain with hills up to 500 feet above adjoining valleys, and covered a much larger area than the familiarisation route. Within this advanced area, ten obvious ground features were selected to provide designated waypoints. A number of different routes could then be formed using these as turning points.

The trials flying was divided into four separate blocks. The first was a television familiarisation period. Here the daylight TV was used whilst the helicopter was flown along the training route at clearance heights of around 300 feet. These flights were all conducted in day Visual Meteorological Conditions (VMC). Sufficient flights were undertaken to bring the pilots up a learning curve on flying the helicopter using an un-collimated TV image of the terrain ahead, and to confirm the results of previous trials, regarding required fields of view and ground feature resolution for the piloting and navigation task.

In the second period of flying, the aircrew started using the FLIR to fly at safe clearance heights of around 300 feet agl along the training route. As confidence and experience increased, the clearance height was reduced. The airspeed flown was left to the discretion of the safety pilot, but was not greater than 90 knots. Once the evaluation pilots demonstrated a reasonable confidence and repeatability by day over the basic training route, the third block of flying was commenced and comprised night operations only, but ran concurrently with the latter half of the second period of daylight flying. At night the first exercise was to fly at 500 feet agl, using the FLIR system around the training route. This was done in a very wide range of meteorological conditions as discussed below. The main objective of this exercise was to see if the conclusions drawn from the daylight flying remained valid, and to investigate new problems created by the night environment. As experience and confidence increased, the clearance height was gradually reduced. This permitted longer flights to be undertaken with a wide choice of different routes.

5 METEOROLOGICAL CONDITIONS

During the early part of the trials, it became clear that in order to explain the achieved FLIR performance, it would be necessary to record significantly more meteorological data than had been required for previous LLTV work, where ambient light level and scene contrast had been adequate. The effects of the weather conditions prevailing during the preceding 12 hours, determined the results obtained during the flight. Temperature, relative humidity and cloud cover were also recorded on the actual flight, together with the meteorological history, which included sunshine hours and/or duration of rain periods.

Because of the very large dynamic range in a typical thermal scene (at least 60 dB) FLIR systems are ac coupled. The available scene temperature differences picked up by the sensor can be sampled electronically via a 'window aperture' and 'offset temperature' controls. By adjusting these, the temperature variations within the terrain detail can be used to set the shades of grey of the final TV picture. The hottest feature being set to peak white, and the coldest to black. The offset control enabled the 'window' datum to be shifted, to examine for example, temperature variations within a portion of the scene, which may be several degrees hotter than the remainder.

6 DISPLAY REQUIREMENTS FOR PILOTING

In order to provide a background against which to interpret the results sections of this paper, a brief resume of the pilot's display requirements is given below. This is set in the context of the interpretation of the terrain image from an electro-optic sensor, which has a limited field of view and a limited field of regard.

The pilot requires perspective in the scene in general, together with a flow of detail in the foreground, loosely termed texture, to enable the flying to be achieved from interpretation of the terrain image. In this situation the overlay flight instrument information is a secondary reference. There is no single unique feature which must always be present in the image to guarantee pilot interpretation. Hedges for example, are normally a strong cue for the pilot, but in their absence outcrops of rocks, groups of trees or dwellings may provide the cues necessary to allow safe low level flight to continue. Overall, what the pilot requires within the scene is sufficient change of angular information from familier objects, to allow him to work out relative positions, and therefore rates of change. When flying at very low level in forward flight, *eg* 100 feet agl, the resolution of texture in the foreground, and the obvious fanning out of the flow become essential for safe flight. Texture is also most important in hovering and hover manoeuvres to detect inadvertent drift. A very flat or featureless scene requires over-frequent reference to a radio altimeter, which in turn detracts from the scan of the scene. Although the radio altimeter reading is historical in relation to the viewed scene it enables the pilot to calibrate his judgement of height from the picture and to detect a trend. Ideally the FLIR should produce a good cosmetic picture comparable in quality with that from a high performance daylight TV under favourable light conditions. Any contrast improvement without loss of detail is an added advantage, and the desirability of seeing otherwise obscured targets or hostile emplacements due to their thermal signature is self-evident.

7 SYSTEM ASSESSMENT

The piloting techniques developed to use the infra-red system under test as a fixed sensor piloting aid were the same as those previously established in earlier low-light television (LLTV) trials. The evaluation largely concerned sensor qualities, but the use of the limited panning and tilting capability was investigated to determine the benefits of looking into turns, offsetting drift effects and the ability to maintain a landing site in view, when decelerating during an approach to land. Sorties were made with a target minimum route flying height, or higher depending on the terrain.

Although good images from both visual band daylight and low light cameras and infra-red systems looked at side by side, might produce a different sense of contrast and tone for particular features, the interpretation of the scene was on the whole similar. An important exception was that contour information giving the pilot a general impression of the terrain was not always clear from the FLIR and this is discussed in later sections. Where the presentations from the two types of sensor differed markedly was when the ambient conditions deteriorated from ideal. It was found to be much more difficult to predict good thermal conditions, because of the large number of meteorological factors needed to be taken into account, than for the corresponding situation for a visual band sensor such as low light television.

7.1 Contour information

The presentation of contour information by the infra-red system was not as easy to interpret as in a visual band sensor, and at times was misleading. This was most noticeable during poor thermal conditions when a very narrow thermal window had to be used, but some effects remained in good conditions. The main reason for this is that the thermal picture is derived from objects and features in the scene, which emit heat in differing amounts. The relative emissivity of two adjacent features, and hence their appearance on a thermal image can be totally different to the way they might reflect light and project shadows. As an example the variation of surface material on a hillside at times produced a thermal picture which rendered it difficult to determine the shape of the hill.

For visual band sensors, a television picture of the terrain under reflected ambient light gives shadows and shading indicating perspective, curvatures and vertical projections of the scene. Whilst the differences of surface material or texture produce tone changes, the consequences of the position of the light source are general to the whole scene, and the pilot is able to work out the hill shape with little effort. However, a thermal picture depicting areas of relative light and dark within a particular feature of the scene, gave an impression of rising and falling ground, of what in reality was a flat surface. This is demonstrated in Fig 2 where the front portion of a ploughed field looked like a vertical escarpment with a valley in front of it. Once close enough to resolve texture features the true layout of the field became clear, the front portion of the field having been ploughed had a lower emissivity than the remainder. The misleading information had the effect of making it more difficult to plan a track when contour flying and as misleading characteristics were discovered this reduced pilot confidence overall to fly as low as desired.

Conversely for low light television under very low light levels, the reduction in contrast, and increase in corresponding scene noise also made it difficult to appreciate contour information. However, this effect was readily predicted from the ambient conditions. Therefore, scene deterioration due to a drop in light level is obvious to the pilot, and does not cause him to react in the same way.

A second characteristic concerning contour information was that crests of hills or ridges sometimes blended into more distant landscape and only became evident when close, or when the crest was skylined, leaving less time than normal to initiate the change of flight path to pass over the crest. Although during the trials over moderate terrain, such hills or ridges were always detected in time to take the necessary action, the late appreciation had inherent dangers and led to a lack of confidence and a tendency to fly higher than planned.

7.2 Grey level clamping

Parallel scan infra-red systems exhibit cosmetic problems when the sensor is rotated relative to the natural horizon, as in a normal aircraft bank and turn. Without some form of dc restoration in the system, the effect of ac coupling on the sky/ground interface in a banked turn produces saturated white to black wedges. This totally obliterates the horizon detail, and also means that the pilot is unable to interpret the terrain into which he is turning. Under these circumstances the obstructions become impossible to see.

The difficulties associated with this phenomena were overcome in the particular system under test, by the introduction of a grey level clamping system. By artificially providing some dc restoration within the scene, the problem of black wedges was completely overcome. However, the introduction of the grey level clamp had the effect of setting a different optimum temperature offset from the top of the image to the bottom. Consequently when the FLIR was tuned to give the best resolution of detail and optimum contrast for the foreground area of a scene, the area towards the horizon tended to be lower in contrast, and appeared blurred. However, the temperature offset could then be adjusted to improve the horizon area significantly. The corresponding result of this adjustment was a poorer foreground picture. Thus it was not possible to obtain the best available performance of the sensor for all areas of the screen at once. A modification to the algorithm within the grey level clamping system to provide a variable bias for the offset temperature from the top to the bottom of the picture would overcome this difficulty.

8 EFFECTS OF AMBIENT METEOROLOGICAL CONDITIONS

In order to report on the effects of variations in ambient meteorological conditions, representative blocks of significant conditions were taken and the resultant changes in the FLIR presentation, and their effect on the flying task are described. The results have been collated from several flights for most sets of conditions examined, and although there were variations from sortie to sortie the general statements below held true. Reference is made in the results sections below to sunny weather, and while this is not directly relevant to the night flying task, the sunny day represented one of the extremes, and the results have significance when considering the role of the military helicopter in target detection.

8.1 Daylight-sunny-nil precipitation prior to flight - low humidity

In daytime sunny conditions, contrasts were usually excellent with significant detail apparent in the scene, giving a good cosmetic picture with ample information for piloting, and with vertical obstructions such as pylons showing up very well. Wires could not be reliably detected. Hills and ridges blended against the background only occasionally, normally hills were featureless crowns. Cosmetically the scanning lines from the detectors were very well matched at these higher temperature windows. Fig 3 shows a split screen summer scene by day, with the FLIR image presented 'white is hot' on the right, and the same scene on the daylight TV on the left.

When the FLIR was adjusted for a good piloting picture, areas of ground with unusually high thermal emissivity were regularly encountered, causing areas of the display to saturate. The signatures of objects such as vehicles in these areas were swamped by the output from the surrounding terrain, and were not visible in the image. Newly ploughed fields were the most common source of saturation.

8.2 The dry night after dry bright day - small cloud cover

Several sorties were flown to encompass sunset and the subsequent 2-3 hours in dry conditions, with little cloud cover, where surface cooling was expected after sunset. With the best cosmetic picture, scene contrast was slightly less than by day but remained good. Also the saturation effects found in sunlight were not apparent at night. Foreground detail was good and the piloting workload was generally similar to that with a good visual band daylight TV camera. Vertical man-made obstructions such as pylons were less obvious than on a sunny day, but usually showed up against a background of trees. Contour information was only occasionally misleading. The scene quality appeared to remain constant during the hours after sunset.

8.3 Day or night - overcast - high humidity - ground moist

After prolonged dull overcast conditions, particularly during or after precipitation, the contrast of perspective features was poor if the FLIR was adjusted to give a balanced overall scene. The foreground detail was poor, and for example, furrows in a field would not show up with the aircraft at 100-200 feet agl. Instead the field would show up as an apparently smooth area between hedge lines which was uniform in tone. If the FLIR was readjusted to provide better foreground detail, the rest of the scene was degraded and frequently caused large areas of the screen to saturate white or black. Horizontal banding due to detector mis-match became obstrusive, and in forward flight partially masked the flow of any foreground detail. In the worst cases, noise in the form of vertical lines looking rather like swathes of drizzle sweeping the scene, further detracted from the ability of the pilot to interpret the picture.

Trees tended to blend against the background landscape, and at times became almost invisible. The contrast of trees at times reversed (black to white/white to black) depending on background. Height changes were difficult to determine from the display until a significant change had occurred, and then only when really good perspective features were in the foreground. The poor quality of the imagery made it necessary to fly so that the pilot was sure he was well above the highest significant obstacles and terrain. This placed his reliance much more on the radio altimeter for height information. Flight at typical day-time height was not safe due to the risk of encountering effectively invisible obstructions and the difficulty of detecting rising ground, or an inadvertent descent in time to react. An example of trees merging into their background is given in Fig 4. The corresponding visual band signature is presented in Fig 5. The implications of these phenomena are discussed in section 10.

8.4 Snow

One flight was made in light continuous snow just after sunset, when snow had been falling for over 30 minutes, and approximately one inch of cover lay on the ground. This flight was made using the naked eye and was not a pre-planned trial sortie. The thermal image showed very little contrast or resolution of landscape features. The only features which showed up well were occupied buildings, vehicles, and other warm man-made structures, together with rivers. Fig 6 is a snow scene near Boscombe Down, and shows a view of an area of buildings, the lack of detail in the foreground and horizon is amply demonstrated. Naked eye visibility in the fading available light was at least double that of the FLIR in this situation, and the picture was considered unflyable.

8.5 Mist or haze - no significant cloud cover

Very little night flying was possible in misty or hazy conditions. However, the following results were significant. The FLIR gave significant visibility margins over the naked eye or visual band TV sensors. This was even more noticeable by day, when surface heating had taken place. In visibilities of less than one mile, the FLIR displayed navigation features 5 miles ahead. On one occasion in a time of rapidly reducing visibility ending in thick fog, the FLIR visibility remained well above the naked eye by a factor of at least 2 or 3 until the display was suddenly blotted out at a naked eye visibility of approximately 500 yards. Fig 7 shows a split screen image of an approach to RAE Farnborough where the left-hand side of the image is derived from the infra-red system, and the right-hand side is derived from the visual band sensor. These images were recorded in dusk condition after the runway lights were switched on, and the visibility was approximately 1 km. The picture adequately demonstrates the penetration capability of infra-red under these conditions.

9 PAN AND TILT PLATFORM

The FLIR sensor was steerable using a thumb-operated four-way trimmer on the collective lever. The electric motors accelerated the sensor very rapidly to a fixed angular rate of 30 degrees per second and when a selection was released, stopped immediately. The indicator showing sensor position was a two-needle ILS type gauge, and it was difficult to sense the true angular offset of the sensor from this indicator. In addition the position of the indicator on the glare shield was out of the normal scan of the pilot, and monitoring sensor position imposed an added workload. The system did not have an automatic centring facility, and two or more overshoots were common when attempting to centre the sensor. Despite the shortcomings of this particular installation the pan and tilt platform was an improvement over a purely fixed sensor. The sections below describe the applications investigated using the platform.

9.1 Looking into turns

When the FLIR was moving in azimuth, the characteristics of the scanning system caused a certain amount of picture break-up. Again this was purely a function of the parallel scan system where the picture elements associated with each detector were displaced to the left or right spacially depending on the direction of panning. This gave a stepped effect down the image. The stepping effect of picture break-up also occurred in the bottom corners of the scene, when the helicopter was flown fast, at very low level and when executing turns. It was most noticeable however when using the platform to look into a turn.

Generally when carrying out turns using a head-down display a high level of concentration on the scene was necessary. The picture break-up and the previously mentioned problem of interpreting the sensor line of sight reduced the pilot's orientation. Looking into turns with this system was not considered possible without an excessive workload and possible disorientation.

9.2 Offsetting drift

When flying straight tracks, the ability to offset drift effects by training the sensor down the track line proved useful in enabling the pilot to see the terrain actually to be flown over, rather than the offset area normally presented with a fixed sensor. The previously mentioned problem of initially training the sensor was not so important when offsetting drift unless a constantly changing track was required as part of the navigational task.

9.3 Approaches and landings

The facility to tilt the FLIR improved the pilot's ability to make approaches and landings when compared with a fixed sensor. The pilot was able to select a greater variety of approach angles, and was able to train the sensor at a landing area, and compensate the changes of attitude which was of particular benefit during transitions to the hover. The steppy nature of sensor movement detracted from the effectiveness of the system, and the need to operate the control on the collective contributed to an already high workload. Care was necessary to monitor the horizon bar on the display symbology to avoid being misled by the movement of the picture due to sensor movement. A means of stabilising the sensor to keep it pointing at the landing area during the approach would reduce the pilot workload, by removing the sensor steering task and allowing full concentration on the display.

10 DUAL WAVEBAND OPERATION

During the sorities undertaken in high humidity with wet ground and overcast conditions by day or night, situations were found where the emissivity of trees was almost identical to their background landscape. In these conditions the trees became almost invisible (see section 8.3 above). However, in the particular situation there were troops in the trees which could be easily seen on the thermal image. Conversely, the visual band signature showed the trees very well, but failed to register the troops within them.

Combining these images statically, via a signal processing facility produced a combined waveband image which retained all the significant features of each image, so providing a clear indication of the trees together with the troops. This is shown in Fig 8.

Provided that suitable signal processing algorithms could be developed to handle continuous real time changing scene data, and the two sensors could be accurately boresighted to guarantee registration, enhanced imagery could be presented to the pilot, which may provide a higher overall safe flight capability than could be achieved from any one sensor alone.

11 CONCLUSIONS

The particular FLIR under test demonstrated that under favourable conditions it gave an adequate image for piloting. However, contour information was at times misleading and this reduced the ability to fly low with confidence at high speed. There was a significant proportion of sorties when meteorological conditions resulted in the terrain having a fairly uniform emissivity and hence producing a poor thermal picture. During these low contrast conditions, in winter in particular, trees became difficult to detect when viewed against a landscape background and this presented a hazard to fast flight at low level.

The ability to steer the line of sight of the sensor had definite advantages over fixed sensors in offsetting drift effects and assisting during approaches and landings, but did not provide the flexibility and speed of response of head mounted systems such as night vision goggles.

The particular FLIR system under test exhibited masking effects in poor thermal conditions which contributed to the difficulty of interpreting the scene.

The trials demonstrated the feasibility of combining the outputs from sensors operating in disparate wavebands, to provide scene information which would not be present from one sensor. The sensors would need to be accurately boresighted, and considerable development work would be required on the signal processing algorithms, to achieve adequate additive effects under all weather conditions.

Fig 1 Sea King helicopter showing the FLIR in the nose together with the LLTV mounted on the starboard side

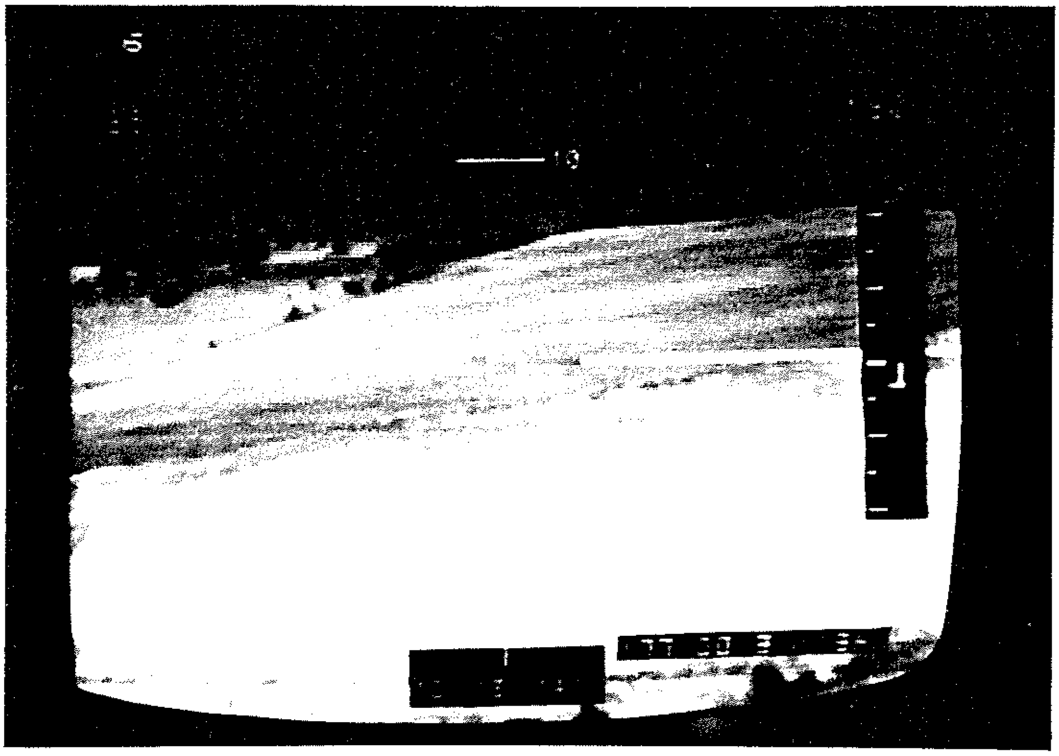

Fig 2 FLIR image of a ploughed field which appears as a vertical feature

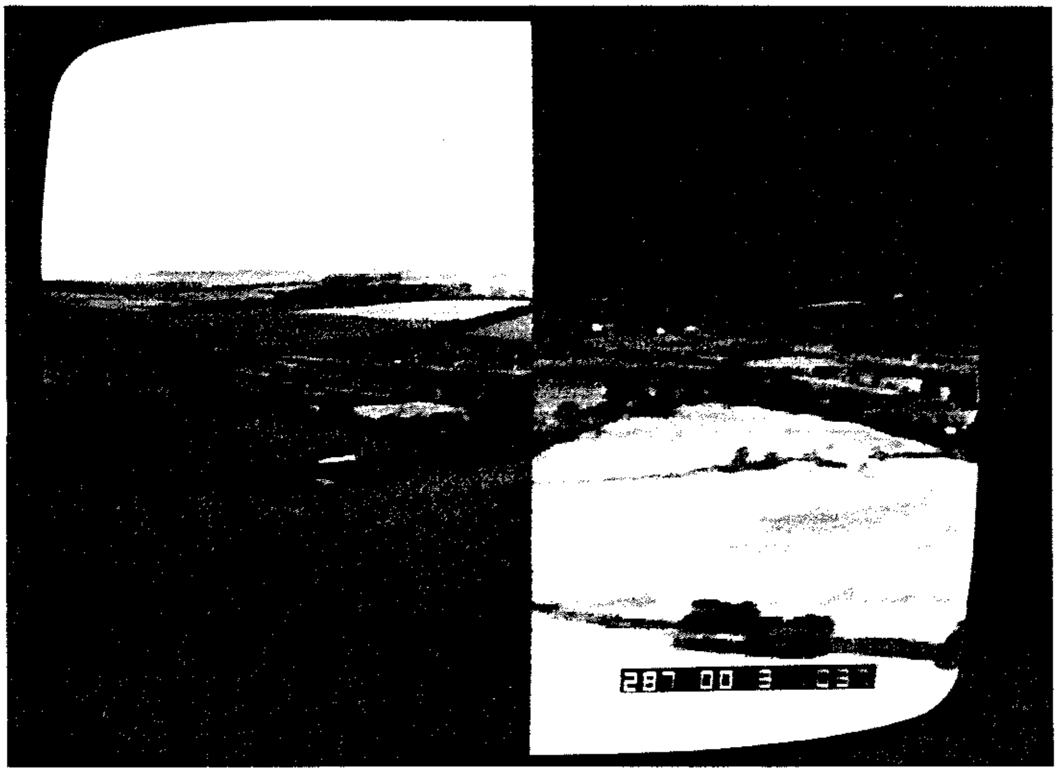

Fig 3 Split screen image showing the infrared image on the right, and the corresponding visual signature on the left of the same scene

Fig 4 Thermal signature of trees with an emissivity identical to their background merging into the landscape and becoming transparent

Fig 5 Corresponding visual signature of Fig 4 clearly showing the trees

Fig 6

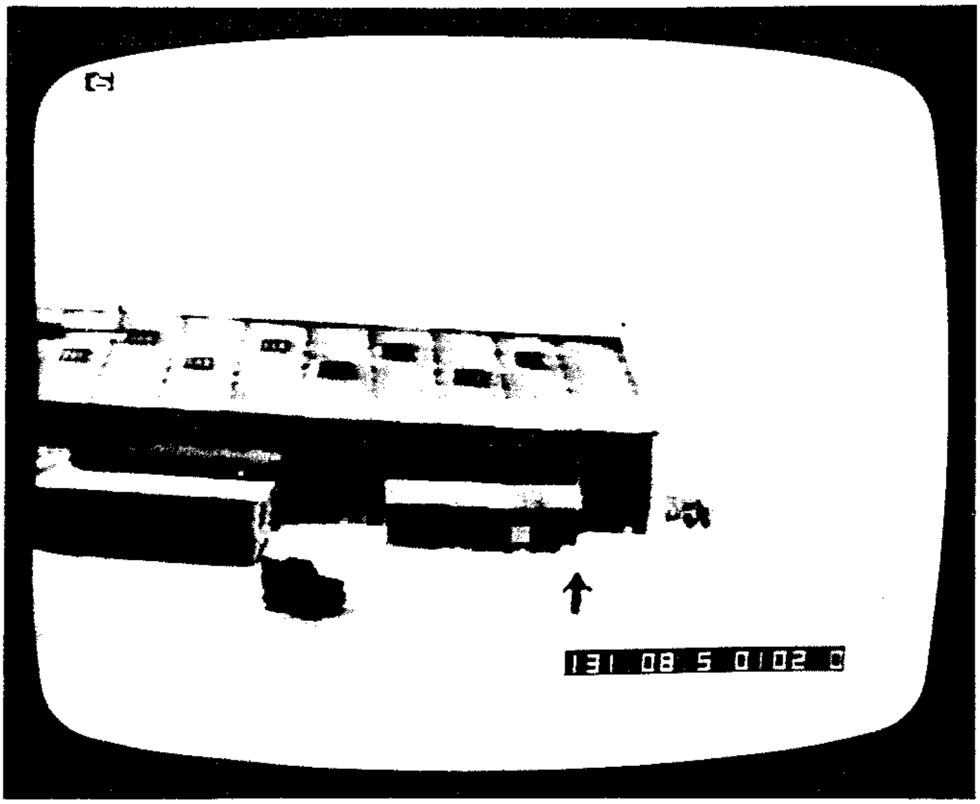

Fig 6 Approach in snow to Boscombe Down airfield, where man-made objects are well reproduced, but foreground detail and horizon disappear

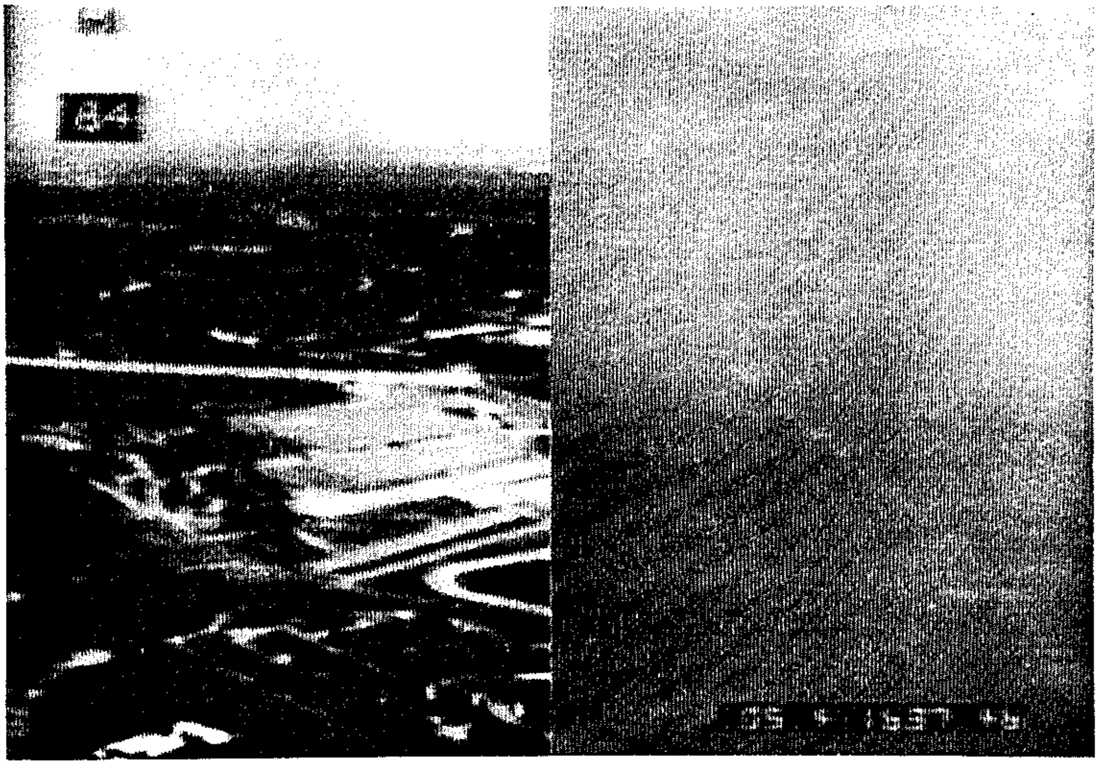

Fig 7 Approach under poor visibility to RAE Farnborough. The FLIR image is on the left. The continuation of the same scene in the visual band is on the right

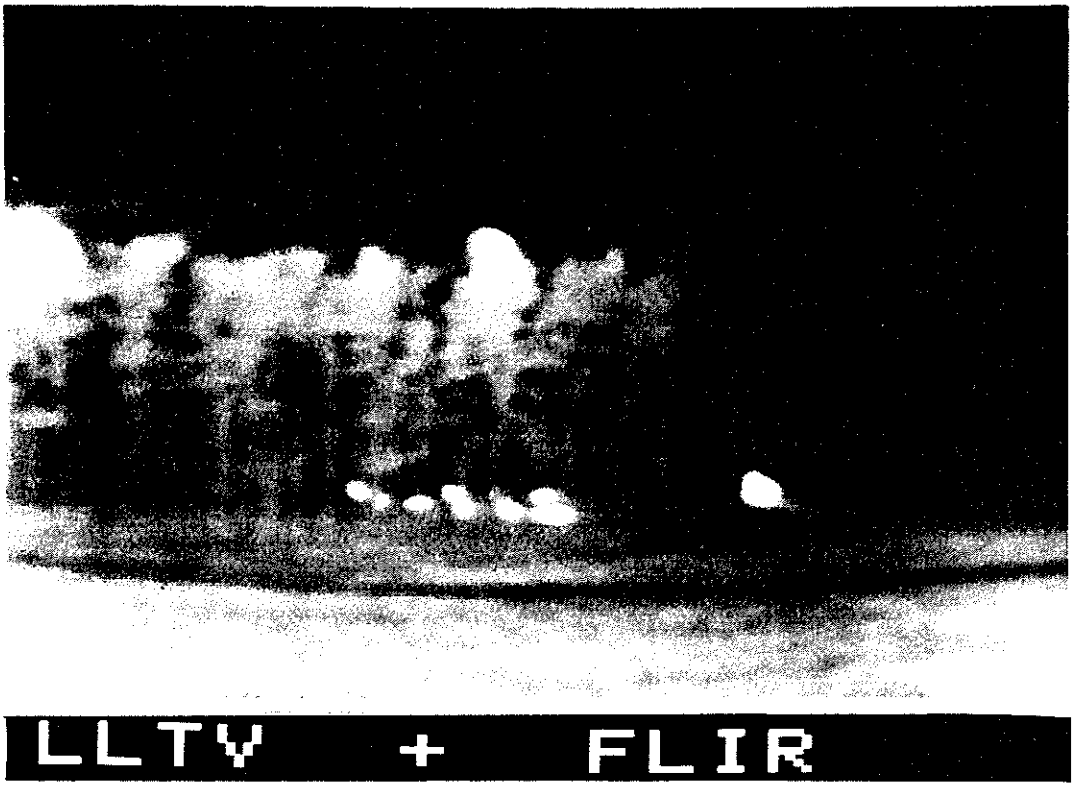

Fig 8 Computer generated combination of the same scene under visual and thermal conditions