Marconi-Elliott Avionic Systems Limited

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Solid State Helmet Mounted Display and Head Position Sensor System

Marconi-Elliott Avionic
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Introduction

The Marconi-Elliott Helmet System comprises a helmet mounted display (HMD) and helmet optical position sensor (HOPS). This system provides a powerful aid for extending the capability of the pilot by means of designating a ground target, slewing sensors such as FLIR, LLTV, laser and radar, or guiding a missile by simply looking in the required direction.

In this new form of HMD a moving display is generated on an array of light emitting diodes (LED) and, as with a conventional head-up display, is focussed at infinity so that information or instructions are over-laid on the outside scene. The display incorporates a novel form of optical design which requires only two components — a prism and a combiner.

The HMD can be used independently of the HOPS to provide displays of warnings and other information. However, in order to exploit its full potential in the weapon aiming role the addition of the HOPS is necessary.

The Helmet Mounted Display

The helmet mounted display is a logical extension of the successful range of aircraft mounted head-up displays where information is presented in graphical form to the pilot by superimposing a collimated display onto his real-world field of view. An aircraft mounted head-up display unit has to have a sufficiently large optical system to enable the pilot to move his head and scan his forward view whilst ensuring he never loses any of the vital information being presented to him. The field of view however is inevitably centred about the aircraft longitudinal axis and even with the most advanced optical design the field of view is most unlikely to include areas more than 30° from this axis.

By mounting the display on the helmet the field of view is extended to the full limits of the pilot's head movement and the optical system need only be large enough to cope with the relative motion between the pilot's head and his helmet which is typically less than 0.6 inches — even for high g manoeuvres.

Figure 1 shows how the display has been incorporated into an APH—6 helmet shell with minimal effect on the external appearance and protective capability of the helmet. The very compact arrangement of the helmet mounted display is made possible by the use of an advanced LED array and the novel optical design.

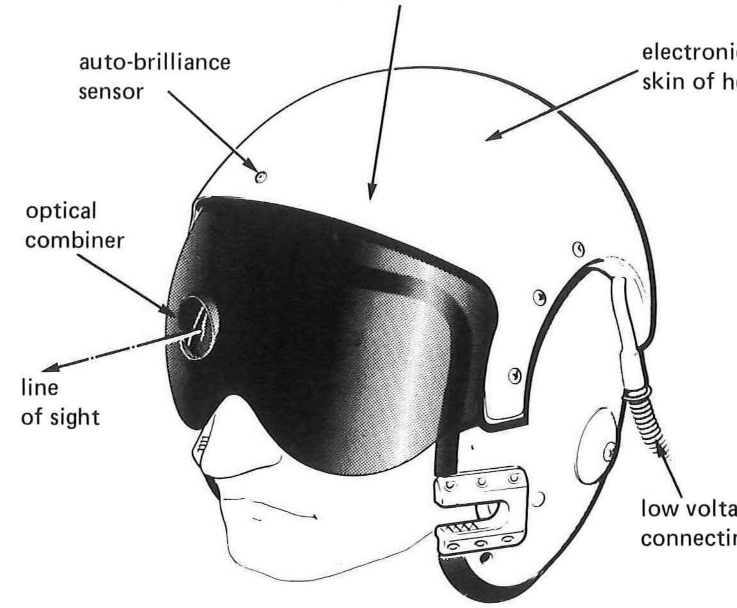

Figure 1
U S Navy APH-6 Helmet Incorporating The Helmet Mounted Display

The general layout of the components within the helmet is shown in Figure 2. The LED array and the prism are fitted to a simple but rigid aluminium mounting set into the only significant cutaway made into the original helmet shell.

The aluminium mounting maintains the structural rigidity of the original shell in this area and ensures the optical alignment of the system. The prism is pivoted so that it can be rotated to retract into the helmet shell to facilitate donning the helmet, although it has been found that this is not strictly necessary due to the very small size of the prism. The compactness of the prism also prevents intrusion into the pilot's field of view.

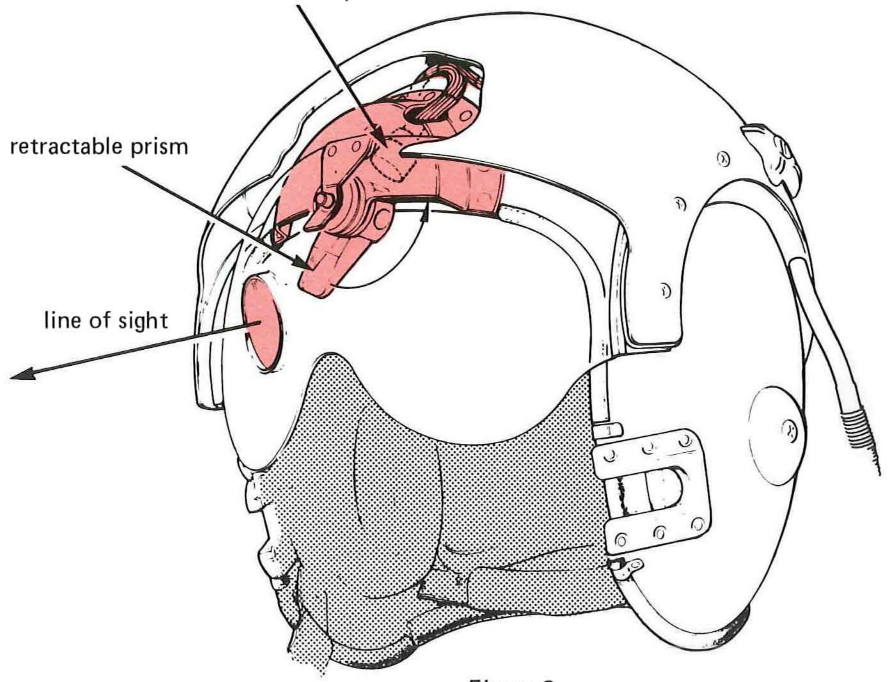

Figure 2
Helmet Mounted Display System

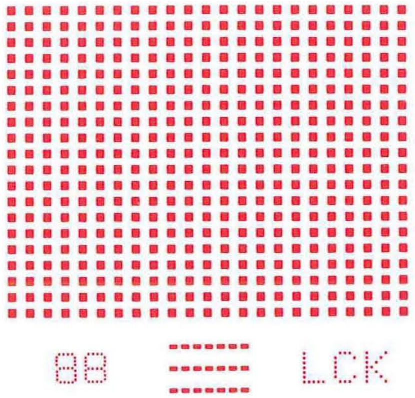

Figure 3
Helmet Mounted Display – LED Array

The LED Array

The LED array is shown in Figure 3 and is only 0.3 inch square. It is mounted on a header of 0.75 inch diameter and length. It comprises a matrix of LED on a 0.01 inch pitch and it is the compactness of this device which is the key to the design of the helmet mounted display. The display colour is red at a wavelength of 650 nm.

An early stage in the development of such arrays was the manufacture of arrays in which the format to be displayed was fixed at the design stage and the user had the facility of being able to select which parts of the display were to be illuminated. These arrays have been used in helmet mounted displays but the practical limit of their application is reached when the area required for connection to the drive circuits exceeds that of the display. A reasonable maximum for display content in this format is shown in Figure 4 in which each of the 72 separate elements is discretely addressable. To overcome the limit imposed by connections, it is necessary to adopt some form of matrix interconnection and the array used in the helmet mounted display described in this brochure is the first application of this technique. The specified array comprises 460 matrix points and 21 discretely addressable segments controlled by 65 connections.

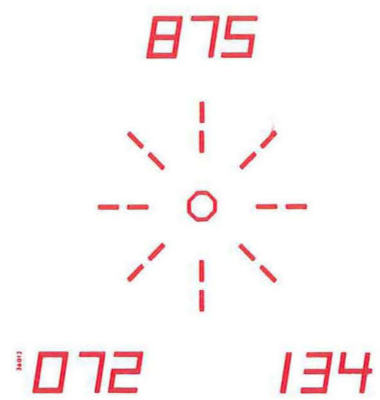

Figure 4
Typical Fixed Format LED Array

The individual LED in the matrix part of this array are 0.005 inch square on a pitch of 0.01 inch. In this particular display, up to 20 diodes may be used in a display format which is repeated at 180 frames/sec at a mean brightness of 1500 ft. Lamberts. The use of an array of this type permits a big step forward to be made in the design of helmet mounted displays as it eliminates the weight involved in a CRT solution with its EHT cable or a fibre optic bundle.

The current performance being achieved by these monolithic LED arrays is:

Brightness - 18,000 ft. Lamberts
Life - >10,000 hours at half brightness
Current Density - 136A/cm^2

Layout of the Helmet Mounted Display

The optical and mechanical layout is shown in Figure 5 which represents an approximately vertical section through the helmet. The LED array and the prism are mounted on the aluminium panel which maintains their relative position and provides a location onto which the visor clips when lowered. Thus the whole optical system is located together. The rays of light emerging from the LED array enter the prism at one face. The prism serves three purposes – it largely corrects the aberration introduced by the off-axis spherical combiner, it folds the optical path into the space available and its cylindrical surfaces correct astigmatism. The rays emerge from the prism and are reflected by the coating on the inside of the combiner. The curvature of this surface collimates the image and reflects it to the pilot's eye. The exit pupil of the optical system is a circle of 0.7 inch diameter which means that the entire display can be seen when the eye is at any point within the circle. This large exit pupil means that the fitting of the helmet to the pilot is relatively noncritical and accomodates helmet movement due to 'g'.

In the APH-6 helmet the combiner was required to be fitted to the neutral density visor, so the coating was chosen to provide a transmission equal to that of the visor and a relatively high reflectance to the LED image with the result that there is little difference in the outside view seen by each eye.

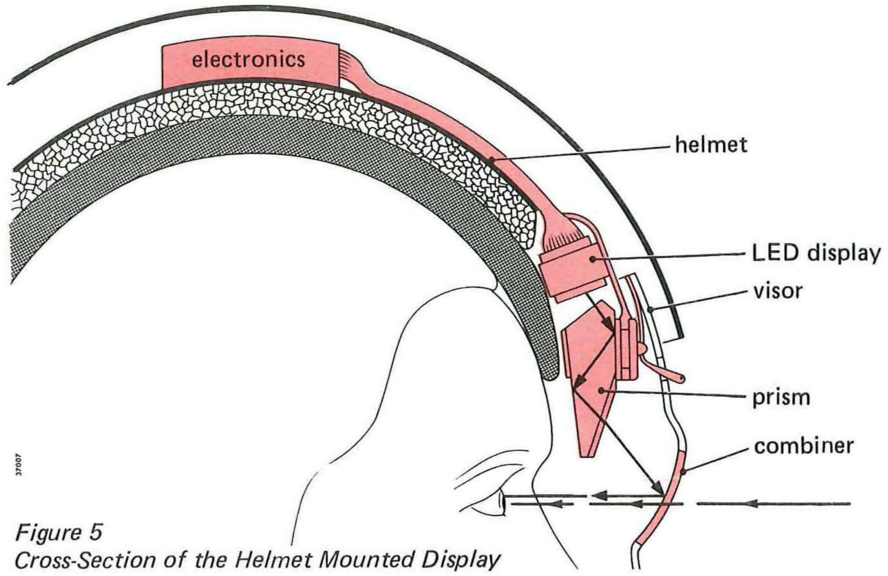

Figure 5
Cross-Section of the Helmet Mounted Display

The Helmet Optical Position Sensor System

While the HMD can provide the pilot with much useful information and guidance its full potential, in the weapon aiming role, cannot be achieved without the helmet optical position sensor system. (HOPS).

The design of the HOPS ensures that the system has the following features:

- Solid State
  - giving low complexity and high reliability
- High Accuracy
  - over wide angle coverage
- High Sampling Rate

The design is based around a simple V slit camera incorporating a high resolution linear charge coupled device (CCD) array. Helmet roll, pitch and yaw angles are sensed by this cockpit-mounted V slit camera viewing three LED on the side of the helmet. The lower two LED are arranged to be parallel to the pilot's line of sight through the helmet sight. Figure 6 shows the basic arrangement.

Three LED rays in space are determined by the camera referenced to its optical axis. The computer performs a 3-dimensional 'fit' of the LED triangle (of known size) into the frame contained by the three LED rays. By using the previously computed position a 'fit' is quickly and accurately obtained from this starting point. The LED positions in space are then computed, from which helmet roll, pitch and yaw angles are obtained. Increased helmet rotational coverage is achieved by using a further LED set mounted on the other side of the helmet and another camera on the other side of the cockpit.

A combination of LED sets and cameras enables 360° yaw coverage to be achieved by switching, within the computer, to the appropriate camera viewing a complete LED set.

The HOPS system comprises the following basic units

- V Slit Cameras (2 off)
- HOPS Electronic Unit

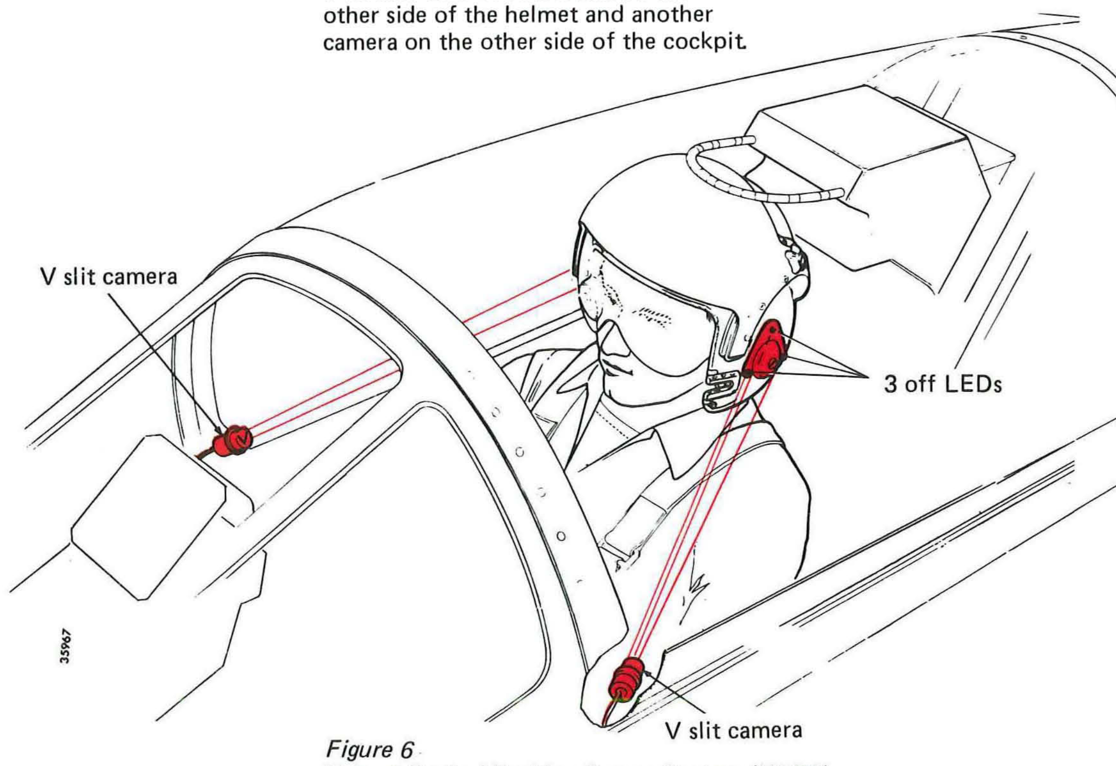

Figure 6
Helmet Optical Position Sensor System (HOPS)

The V Slit Camera

It is shown in Figure 7 that light from the helmet-mounted LED passes through the narrow 0.008 inch V slit and a V image is formed across the CCD. The CCD consists of 1728 photosensitive elements and the points at which the V image crosses the CCD is clearly defined in the CCD electrical output. Movement of the LED results in movement of the V image and hence changes the output waveforms of the CCD.

The camera actually determines the direction cosine of the LED with respect to its optical axis, and the accuracy achieved is limited only by the geometry of the V slit and the CCD. As these are produced by photolithographic methods and no refractive optics are involved, the basic accuracy is extremely high.

The V slit camera is unique in its ability to sense two degrees of freedom with a single CCD array and this results in a camera with low optical and electrical complexity giving the very desirable features of:-

- High Reliability
- High Accuracy
- Low Cost
- Compactness

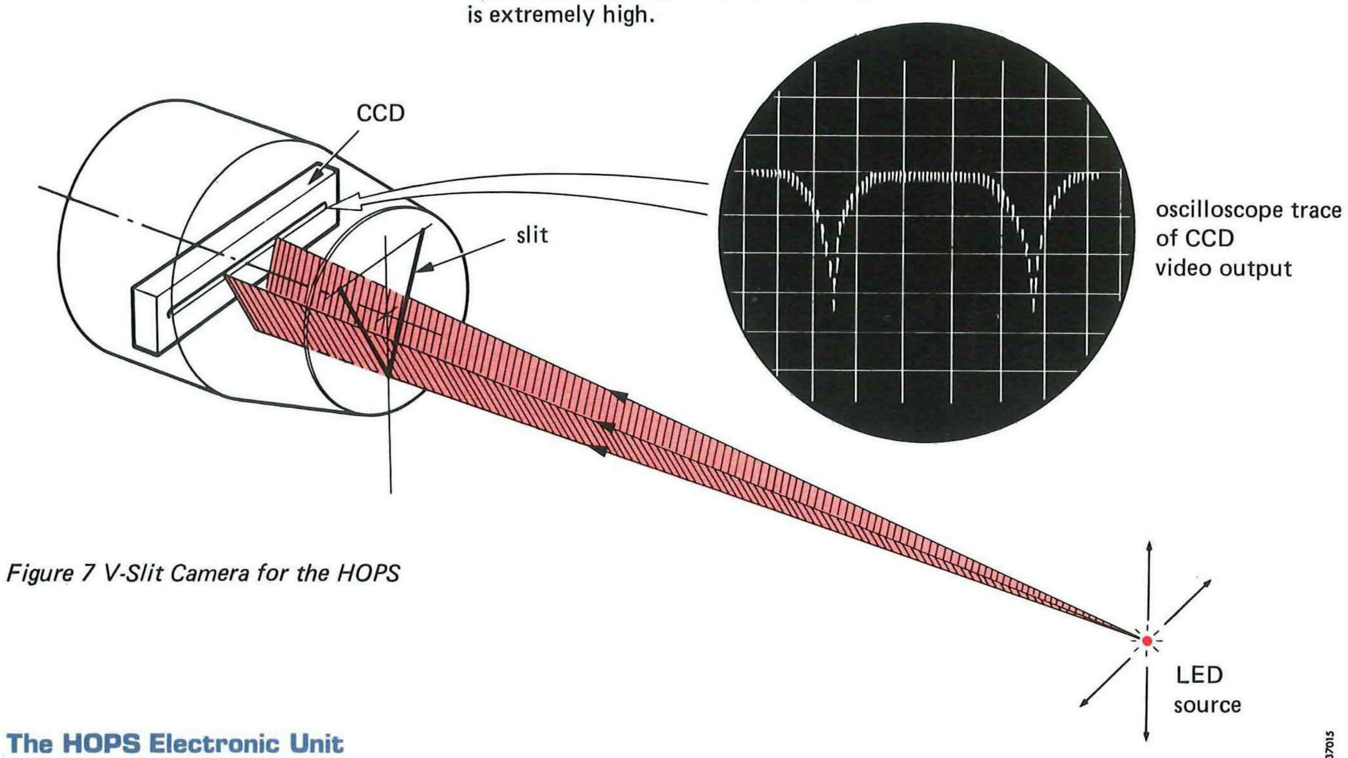

Figure 7 V-Slit Camera for the HOPS

The HOPS Electronic Unit

The helmet LED are switched cyclically in sequence from the HOPS electronic unit. The V slit camera first samples and stores the helmet background with the helmet LED switched off to establish the pattern of background illumination, which may include direct sun. This is used as the basis for recognising and extracting the wanted image from LED 1, 2 and 3. The V slit camera now samples the helmet with the LED emitting in turn, and the CCD output is subtracted from the background pattern to give clearly defined LED pulses.

The data is now in the form in which the peaks of the two LED images can be determined. This is done digitally using the LED pulses in the CCD output waveform to gate counters. These six binary numbers (two per LED) are output via the interface circuit in the HOPS electronics unit to the separate computer which carries out the line-of-sight (LOS) computation. The rate at which LOS data can be output to the aircraft weapon system is limited only by the clock rate of the CCD and the iteration rate of the associated digital computer. The designed CCD clock rate is 2.5 MHz which results in a signal sample time of 1.5 milliseconds. With a representative weapon aiming computer the LOS computation output data rate is 50/second. This means that even with any data rate reduction which results from special purpose digital filtering the performance of the system will be limited only by the physical tracking rate ability of the pilot. The system can be configured to interface with any other aircraft system with either digital or analogue interfaces.

Sizes and Weights

Each cockpit camera is only 2.25 inch diameter by 2.50 inch long weighing 14 ounces. The weight of the helmet LED set is 1 ounce and thus adds negligible weight to the helmet.

The HOPS electronic unit can be mounted in the aircraft equipment bay. The size is a ½ ATR short box weighing 15 pounds but it is anticipated that this willbe reduced when the design is changed to use custom hybrid/LSI components.

HOPS Errors

Tests conducted on a prototype HOPS have shown that the HOPS accuracy is 0.5° CEP dependent on the installation. This is more than adequate when considered relative to the other errors inherent in a complete helmet aiming system.

These errors arise from:

(a) pilot ability to track and mark a target to no better than 1° to 2° under the vibration experienced due to buffeting in high speed flight at low altitudes.

(b) optical distortion caused by the canopy, especially at acute angles. This error can be up to 2°.

Summary Specification

Helmet Mounted Display (HMD) Weight	6 oz
Power consumption	5W
Helmet Optical Position Sensor (HOPS) Range of head movement	lateral ± 4 inches longitudinal ± 6 inches
Angular range of head movement	Yaw ± 180° Pitch ± 70° Roll ± 20°
Accuracy	½° CEP (depending upon the installation)
Weights	Helmet installation 1 oz. Cockpit optical sensor installation 14 oz. HOPS electronic unit ½ ATR Short, 15 lb. Pilot's Controller 8 oz.
Power consumption	100W

Features

The Marconi-Elliott helmet display system offers a solid state display technology, with extensive development capability, which is able to fulfil all existing display requirements for fixed wing aircraft.

The cramped conditions of modern combat cockpits and the need for integrated displays places a premium on the use of a helmet display as a multi-mode display surface. The advanced LED matrix technology provides this capability without imposing any significant installation problem.

The ability to aim weapons off the aircraft axis provides the advantages of increased offensive capability of a combat aircraft.

The position sensor technique allows a compact installation on the helmet, a flexible installation of the cockpit mounted sensor, and the drift-free and EMC-proof properties inherent in the adoption of a solid state optical measurement system.

The sight line computing system is straightforward, needing no specialised characterisation for systematic errors, and is well within the capability of a modern microprocessor.

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