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## LIGHTWEIGHT HELMET-MOUNTED EYE MOVEMENT MEASUREMENT SYSTEM

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We first realized the need for a simple, easy to use, lightweight device to determine the aircrewman's fixation points and paths of eye movement between fixation points when we performed our initial eye movement measurement work. We used a Mackworth EMC-2 device, figure 1, to determine a helicopter pilot's visual work load during actual flight.

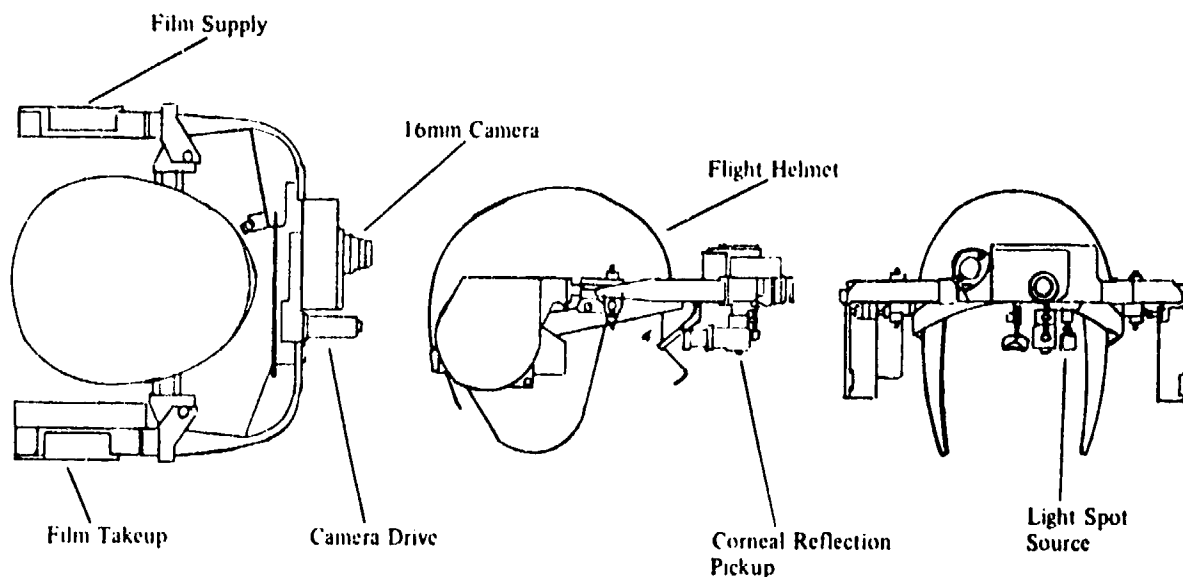


Figure 1. EMC-2 Eye-Movement Camera

The development of the present system has been a "spare-time" project since 1971. The components have been procured whenever funds were available or a particular project required their use. The interface components were constructed by our shop personnel during slack periods in their work schedules. There are no custom designed components in the present system; every item is, or is made up from commercially available components.

The helmet we used is the type that preceded the present US Army aviators' helmet. It has been modified slightly; a small amount of material has been removed from immediately above the brow to accommodate the camera case, the visor has been removed and the suspension system has been replaced with a removable, subject-fitted, molded plastic foam inner helmet similar to the one used in the USAF HCU-2 flight helmet. The fitted helmet

stabilizes the optical head and helps to keep the system in calibration during use. The helmet-mounted eye movement measuring system, figure 2, weighs 1,530 grams; the weight of the present aviators' helmet in standard form with the visor is 1,545 grams.



Front view of the system.



System in the stowed position.

Figure 2. Lightweight Helmet-Mounted Eye Movement Measurement System

The optical head is a standard NAC Eye-Mark. This optical head was mounted on a magnesium yoke which in turn was attached to a slide cam mounted on the flight helmet. The slide cam allows one to adjust the eye-to-optics system distance quite easily and to secure it so that the system will remain in calibration. The design of the yoke and slide cam is such that the subject can, in an emergency, move the optical head forward and upward to the stowed and locked position atop the helmet. This feature was necessary for flight safety.

The television camera that is used in the system is a solid state General Electric TN-2000 with a charged induced device (CID) imager used as the vidicon. This particular device has 45,000 cells which form the video picture. The charged coupled device (CCD) solid state imagers are also available but the CID imagers have an advantage in that they do not "bloom" as badly when they are struck by a bright light. Fairchild now offers a CCD imager which contains 185,440 cells and produces a more detailed video picture; this was not available when our system was assembled. The CID imager is mounted on the NAC optical head in place of the standard fiber optics. The camera electronic package which measures  $7\frac{1}{2} \times 2 \times 4$  inches and weighs less than two pounds is placed in the pocket of a vest worn by the subject. The imager and electronic package are connected by a very thin ribbon cable which is 42 inches long.

The output of the system can be sent to the video monitor and recorder by direct wire or by the use of video transmitter. It can be transmitted over a range of 3,000 feet. The video transmitter measures  $7\frac{1}{2} \times 3 \times 3\frac{1}{4}$  inches and weighs  $1\frac{1}{2}$  pounds; it can be placed in another pocket of the subject's vest.

All components of this system operate on 12 volts or less. The power can be supplied from a belt-type battery pack or can be taken from the vehicle electrical system; the total power requirement for the subject mounted equipment is less than three amperes.

A coupling lens is required to match the optical output from the NAC optical head to the CID imager. The design of the lens used determines the distance between the optical head and the CID imager.

For applications where the helmet is not necessary, the system's video components can be used with the standard EYE-MARK face mask mount. For our own laboratory use we have replaced the snap fasteners of the face mask mount with VELCRO for easier and faster adjustments.

This system is not without its difficulties; the video presentation is not as precise as a film rendition of the same scene but the instant feedback is worth the degradation of the presentation. For most purposes little or no information is lost by using the video recordings. When the system is used to investigate visual behavior where the fixation points will be at distances greater than 100 meters, there is an inherent problem in the EYE-MARK. The light marker that indicates the subject's fixation point is a fixed size, .5 mm, and as the scene lens presents an increased scene area this fixed mark increases in size relative to the rest of the presentation. We have had limited success in decreasing the size of the light marker by reducing the size of its aperture. This also decreases the marker's brightness and it will no longer be visible on the scene presentation. The minimum aperture size that we have been able to use is .11 inches (normal is .16), this reduces the light marker size by about one-third. One further problem that might bother some is that the video presentation is a mirror image of the real world, the fiber optics systems contains a mirror which is not used with this video system. We rectify this by placing a front surface mirror at some comfortable angle in front of the monitor and view the video picture from a position above and behind the monitor.

The Fiscal Year 1977 cost to the Government for the system components was:

NAC EYE-MARK Optical Head	\$ 3,420.00
GE TN-2000 CID Video Camera	2,925.00
Sony AV-3400 Video Recorder	888.75
Sony CVM-115 Monitor/Receiver	252.00
VM-2200 Video Transmitter 15 mw	1,584.00
Coupling Lens	400.00

The "off-of-the-shelf" cost of the complete system was \$9,469.75. This cost does not reflect the cost of interfacing these components into a system; this will vary with the user's support resources but should not exceed \$500.00.

We have field tested the system to check its performance with the performance specifications given by NAC for the optical head. The subject's

head was fixed in position so that all recorded movement was pure eye movement and the recorded errors were from eye movement only. The targets were set at a distance of 100 meters from the subject and extended in an arc of  $11^{\circ}$  either side of the center target. The NAC specifications indicated a maximum error of  $2^{\circ}$  of arc at  $10^{\circ}$  either side of the center position; this is 3.5 meters error at 100 meters range. We measured 3.6 meters at  $10^{\circ}$  on a smoothed curve of the 42 data points recorded. We have found in our work that a  $3^{\circ}$  eye movement will be tolerated before the head is moved, thus with this system for  $3^{\circ}$  of eye movement we have an error of 1 meter at 100 meters range, 10 cm at 10 meters range and 1 cm at 1 meter range.

The listing of trade name products in this article is not to be taken as an indorsement of these products. They were the products that were available at the time of procurement which met our requirement that all elements of the system operated on 12 volts DC. They were the least costly items that met that requirement and that were compatible with, or could easily be made compatible with, the other elements of the system.