

# Enriched Visual System for Pilot by Using Head Mounted Display

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**ABSTRACT:** As the key source of information for pilots, the human visual system has necessarily driven much of the evolution in cockpit technology. In contrast to complicated, gauge-based systems of the past, the electronic flight displays of today's modern airliners are testament to advances in human factors engineering. The next step in flight instrumentation, although already used for 50 years in military, is just the beginning to emerge in civil transport aircraft. Head mounted displays (HMDs) allow pilots to see key flight instrumentation while viewing the outside world. The need to look down at the flight instruments is removed by the HUD, resulting in increased situational awareness and greater precision in aircraft control. While the head-up display is a welcome development, as with many instances use of human-technology.

**KEYWORDS:** CGI, 3D Format, IMC, infrared sensing, acoustic, thermographic sensor, HMIT

## I. INTRODUCTION

A helmet – mounted display (HMD) is a device used in aircraft to project information to the pilot's eyes. Its scope is similar to that of head-up displays (HUD) on an aircrew's visor or reticle. An HMD provides the pilot with situation awareness, an enhanced image of the scene, and in military applications cue weapons systems, to the directions their head is pointing. Application which allow cueing of weapon systems are referred to as helmet-mounted sight and display (HMSD) or helmet-mounted sights (HMD).

## II. HISTORY

In the first days of aviation the leather helmets used in motor-racing were adopted by pilots as head protection. The initial design of early leather flying helmets was adapted during the 1930s to become the type B helmet which enabled the external attachment of radio earphones oxygen masks and removable goggles to protect pilot's eyes from the elements. By World War II, an oxygen mask was added to the equipment as planes flew higher where thinner air required a breathable air supply to the pilots and crew. After World War II into the Korean War, the leather headpiece was gradually replaced with a hard helmet needed as head protection during bailing out (and later with high velocity ejection). Also, goggles were replaced by a visor that was incorporated to the helmet and tinted to protect against sun. Current head gear (appears after the Vietnam War) also includes communications equipment (head set and microphones) to let pilots communicate with ground operations and their crew. In 1962, Hughes Aircraft Company revealed the Electrocular, a compact CRT, head-mounted monocular display that reflected a TV signal onto a transparent eyepiece. The first aircraft with simple HMD devices appeared for experimental purpose in the mid-1970s to aid in targeting heat seeking missiles. These rudimentary devices were better described as Helmet-Mounted Sights. Mirage F1AZ of the SAAF (South African Air Force) used a locally developed helmet-mounted sight. This enables the pilot to make bore attacks, without having to maneuver to the optimum firing position. South Africa subsequently emerged as one of the pioneers and leaders in helmet-mounted sight technology. The SAAF was also the first air force to fly the helmet sight operationally. The US Navy's Visual Target Acquisition System (VTAS), made by Honeywell Corporation was a simple mechanical "ring and bead"-style sight fitted to the front of the pilot's

helmet that was flown in the 1974–78 ACEVAL/AIMVAL on U.S. F-14 and F-15 fighters. VTAS received praise for its effectiveness in targeting off-bore sight missiles, but the U.S. did not pursue fielding it except for integration into late-model Navy Phantoms equipped with the AIM-9 Sidewinder. MDs were also introduced in helicopters during this time were fielded by the Force. As a result, the MiG-29 was fielded in 1985 with an HMD and a high off-bore sight weapon (R-73), giving them an advantage in close in manoeuvrings engagements.

### III. TIMELINE OF HELMET



Fig 1 British leather flying helmet from 1918



Fig 2 B-6 winter flying helmet with A-9 oxygen mask, WW2 vintage



Fig 3 Soviet MiG-25 pilot helmet of the 1980s



Fig 4 Modern US Army Apache helmet



Fig 5 Gentex SPH-5 helicopter helmet

#### IV. OVERVIEW

HMD has one or two small displays, with lenses and semi-transparent mirrors embedded in eyeglasses (also termed *data glasses*), a visor, or a helmet. The display units are miniaturised and may include cathode ray tubes (CRT), liquid crystal displays (LCDs), liquid crystal on silicon (LCos), or organic light-emitting diodes (OLED). HMDs differ in whether they can display only computer-generated imagery (CGI), or only live imagery from the physical world, or combination. Most HMDs can display only a computer-generated image, sometimes referred to as virtual image. Some HMDs can allow a CGI to be superimposed on real-world view. This is sometimes referred to as augmented reality or mixed reality. Combining real-world view with CGI can be done by projecting the CGI through a partially reflective mirror and viewing the real world directly. This method is often called *optical see-through*. Combining real-world view with CGI can also be done electronically by accepting video from a camera and mixing it electronically with CGI. This method is often called *video see-through*.

#### OPTICAL HMD

An optical head-mounted display uses an optical mixer which is made of partly silvered mirrors. It can reflect artificial images, and let real images cross the lens, and let a user look through it.

Various methods have existed for see-through HMD's, most of which can be summarized into two main families based on *curved mirrors* or *waveguides*. Curved mirrors have been used by Laster Technologies, and by Vuzix in their Star 1200 product. Various waveguide methods have existed for years. These include diffraction optics, holographic optics, polarized optics, and reflective optics.

#### AVIATION AND TACTICAL, GROUND

In 1962, Hughes Aircraft Company revealed the Electrocular, a compact CRT (7" long), head-mounted monocular display that reflected a TV signal in to transparent eyepiece. Ruggedized HMDs are increasingly being integrated into the cockpits of modern helicopters and fighter aircraft. These are usually fully integrated with the pilot's flying helmet and may include protective visors, night vision devices, and displays of other symbology.

Military, police, and firefighters use HMDs to display tactical information such as maps or thermal imaging data while viewing a real scene. Recent applications have included the use of HMD for paratroopers. In 2005, the Liteye HMD was introduced for ground combat troops as a rugged, waterproof lightweight display that clips into a standard US PVS-14 military helmet mount. The self-contained color monocular organic light-emitting diode (OLED) display replaces the NVG tube and connects to a mobile computing device. The LE has see-through ability and can be used as a standard HMD or for augmented reality applications. The design is optimized to provide high definition data under all lighting conditions, in covered or see-through modes of operation. The LE has a low power consumption, operating on four AA batteries for 35 hours or receiving power via standard Universal Serial Bus (USB) connection.

Research universities often use HMDs to conduct studies related to vision, balance, cognition and neuroscience. According to BMW, "The HMD is part of an advanced telemetry system approved for installation by the Formula One racing committee... to communicate to the driver wirelessly from the heart of the race pit." Recon

Instruments released on 3 November 2011 two head mounted displays for ski goggles, MOD and MOD Live, the latter based on an Android operating system.

**Training and simulation**



Fig 6 Paratrooper training with an HMD

A key application for HMDs is training and simulation, allowing to virtually place a trainee in a situation that is either too expensive or too dangerous to replicate in real-life. Training with HMDs covers a wide range of applications from driving, welding and spray painting, flight and vehicle simulators, dismounted soldier training, medical procedure training, and more. However, a number of unwanted symptoms have been caused by prolonged use of certain types of head-mounted displays, and these issues must be resolved before optimal training and simulation is feasible.

**SUPPORT OF 3D FORMAT**

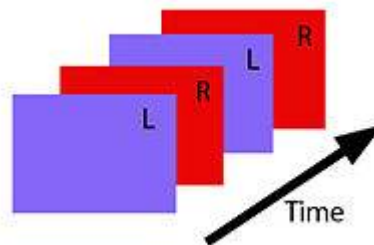


Fig 7 Frame sequential multiplexing

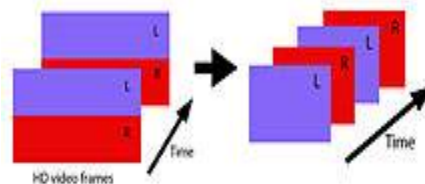


Fig 8 Side-by-side and top-bottom multiplexing

Depth perception inside an HMD requires different images for the left and right eyes. There are multiple ways to provide these separate images:

- Use dual video inputs, thereby providing a completely separate video signal to each eye
- Time-based multiplexing. Methods such as frame sequential combine two separate video signals into one signal by alternating the left and right images in successive frames.
- Side by side or top-bottom multiplexing. This method allocated half of the image to the left eye and the other half of the image to the right eye.

The advantage of dual video inputs is that it provides the maximum resolution for each image and the maximum frame rate for each eye. The disadvantage of dual video inputs is that it requires separate video outputs and cables from the device generating the content.

### **HEAD POSITION SENSING**

HMD designs must sense the elevation, azimuth and tilt of the pilot's head relative to the airframe with sufficient precision even under high "g" and during rapid head movement. Three basic methods are used in current HMD technology – optical, electromagnetic and sonic.

### **HYBRID INERTIAL OPTICAL TRACKING**

Hybrid inertial tracking systems employ a sensitive Inertial Measurement Unit (IMU) and an optical sensor to provide reference to the aircraft. The optical sensor also constrains IMU drift. Hybrid trackers feature low latency and high accuracy. The Thales Visionix Scorpion HMCS utilizes a tracker called the Hybrid Optical-based Inertial Tracker (HOBIT).

### **OPTICAL TRACKING**

Optical systems employ infrared emitters on the helmet (or flightdeck) infrared detectors in the flightdeck (or helmet), to measure the pilot's head position. The main limitations are restricted fields of regard and sensitivity to sunlight or other heat sources. The MiG-29/AA-11 Archer system uses this technology. The Cobra HMD as used on both the Eurofighter Typhoon and the JAS39 Gripen both employ the optical helmet tracker developed by Denel Optronics (now part of Zeiss Optronics).

### **ELECTROMAGNETIC TRACKING**

Electromagnetic sensing designs use coils (in the helmet) placed in an alternating field (generated in the flightdeck) to produce alternating electrical voltages based on the movement of the helmet in multiple axes. This technique requires precise magnetic mapping of the flightdeck to account for ferrous and conductive materials in the seat, flightdeck sills and canopy to reduce angular errors in the measurement

### **SONIC TRACKING**

Acoustic sensing designs use ultrasonic sensors to monitor the pilot's head position while being updated by computer software in multiple axes. Typical operating frequencies are in the 50 to 100 kHz range and can be made to carry audio sound information directly to the pilot's ears via subcarrier modulation of the sensing ultrasonic sensing signals.

### **OPTICS**

Older HMDs typically employ a compact CRT embedded in the helmet, and suitable optics to display symbology on to the pilot's visor or reticle, focused at infinity. Modern HMDs have dispensed with the CRT in favour of micro-displays such as liquid crystal on silicon (LCOS) or liquid crystal display (LCD) along with a LED illuminator to generate the displayed image. Advanced HMDs can also project FLIR or NVG imagery. A recent improvement is the capability to display colour symbols and video.

## INTEGRATED HELMET AND DISPLAY SIGHT SYSTEM (IHADSS)



Fig 9 IHADSS

In 1988 the U.S. Army fielded the AH-64 Apache and with it the Integrated Helmet and Display Sighting System (IHADSS), a new helmet concept in which the role of the helmet was expanded to provide a visually coupled interface between the aviator and the aircraft. The Honeywell M142 IHADSS is fitted with a 40° by 30° field of view, video-with-symbolology monocular display. IR emitters allow a slewable thermographic camera sensor, mounted on the nose of the aircraft, to be slaved to the aviator's head movements. The display also enables Nap-of-the-earth night navigation. IHADSS is also used on the Italian Agusta A129 Mangusta.

### ZSH-5 / SHCHEL-3UM

The Russian designed Shchel-3UM HMD design is fit to the ZSh-5 series helmet, and is used on the MiG-29 and Su-27 in conjunction with the R-73 (missile). The HMD/Archer combination gave the MiG-29 and Su-27 a significantly improved close combat capability and quickly became the most widely deployed HMD in the world.

### DISPLAY AND SIGHT HELMET (DASH)

The Elbit Systems DASH III was the first modern Western HMD to achieve operational service. Development of the DASH began during the mid-1980s, when the IAF issued a requirement for F-15 and F-16 aircraft. The first design entered production around 1986, and the current GEN III helmet entered production during the early to mid-1990s. The current production variant is deployed on IDF F-15, and F-16 aircraft. Additionally, it has been certified on the F/A-18 and F-5. The DASH III has been exported and integrated into various legacy aircraft, including the MiG-21. It also forms the baseline technology for the US JHMCS.

The DASH GEN III is a wholly embedded design, where the complete optical and position sensing coil package is built within the helmet (either USAF standard HGU-55/P or the Israeli standard HGU-22/P) using a spherical visor to provide a collimated image to the pilot. A quick-disconnect wire powers the display and carries video drive signals to the helmet's Cathode Ray Tube (CRT). DASH is closely integrated with the aircraft's weapon system, via a MIL-STD-1553B bus.

### JOINT HELMET-MOUNTED CUEING SYSTEM (JHMCS)

After the U.S. withdrawal from ASRAAM, the U.S. pursued and fielded JHMCS in conjunction with the Raytheon AIM-9X, in November 2003 with the 12th and 19th Fighter Squadrons at Elmendorf AFB, Alaska. The Navy conducted RDT&E on the F/A-18C as lead platform for JHMCS, but fielded it first on the F/A-18 Super Hornet E and F aircraft in 2003. The USAF is also integrating JHMCS into its F-15E, F-16, and F-22 aircraft.

JHMCS is a derivative of the DASH III and the Kaiser Agile Eye HMDs, and was developed by Vision Systems International (VSI), a joint venture company formed by Rockwell Collins and Elbit (Kaiser Electronics is now owned by Rockwell Collins). Boeing integrated the system into the F/A-18 and began low-rate initial production delivery in fiscal year 2002. JHMCS is employed in the F/A-18A++/C/D/E/F, F-15C/D/E, and F-16 Block 40/50 with a design that is 95% common to all platforms.



Fig 10 JHMCS

When combined with the AIM-9X, an advanced short-range dogfight weapon that employs a Focal Plane Array seeker and a thrust vectoring tail control package, JHMCS allows effective target designation up to 80 degrees either side of the aircraft's nose. In March 2009, a successfully 'Lock on After Launch' firing of an ASRAAM at a target located behind the wing-line of the 'shooter' aircraft, was demonstrated by a Royal Australian Air Force (RAAF) F/A-18 using JHMCS.

#### **SCORPION HELMET MOUNTED CUEING SYSTEM (HMCS)**

Thales Introduced the Scorpion Helmet-Mounted Cueing System to the military aviation market in 2008. Scorpion was the winner of the Helmet Mounted Integrated Targeting (HMIT) program in 2010. Scorpion has the distinction of being the first colour HMD introduced. It was developed for targeting pod, gimballed sensor or high off-boresight missile cueing mission scenarios. Unlike most HMDs, which require custom helmets, Scorpion was designed to be installed on standard issue HGU-55/P and HGU-68/P helmets and is fully compatible with standard issue U.S. Pilot Flight Equipment without special fitting. It is also fully compatible with standard unmodified AN/AVS-9 Night Vision Goggles (NVG) and Panoramic Night Vision Goggles (PNVG).

#### **ASELSAN AVCI**

Aselsan of Turkey is working to develop a similar system to the French TopOwl Helmet, called the AVCI Helmet Integrated Cueing System. The system will also be utilized into the T-129 Turkish Attack Helicopter.

#### **TOPOWL-F (TOPSIGHT/TOPNIGHT)**

The French thrust vectoring Matra MICA (missile) for its Dassault Rafale and late-model Mirage 2000 fighters was accompanied by the Topsight HMD by Sextant Avionique. TopSight provides a 20 degree FoV for the pilot's right eye, and cursive symbology generated from target and aircraft parameters. Electromagnetic position sensing is employed. The Topsight helmet uses an integral embedded design, and its contoured shape is designed to provide the pilot with a wholly unobstructed field of view.

#### **EUROFIGHTER HELMET-MOUNTED SYMBOLOGY SYSTEM**

The Eurofighter Typhoon utilizes the Helmet-Mounted Symbology System (HMSS) developed by BAE Systems and Pilkington Optronics. It is capable of displaying both raster imagery and cursive symbology, with

provisions for embedded NVGs. As with the DASH helmet, the system employs integrated position sensing to ensure that symbols representing outside-world entities move in line with the pilot's head movements.

## HELMET-MOUNTED DISPLAY SYSTEM



Fig 11 Helmet-Mounted Display System for the F-35 Lightning II Joint Strike Fighter

Vision Systems International (VSI; the Elbit Systems/Rockwell Collins joint venture) along with Helmet Integrated Systems, Ltd. developed the Helmet-Mounted Display System (HMDS) for the F-35 Joint Strike Fighter aircraft. In addition to standard HMD capabilities offered by other systems, HMDS fully utilizes the advanced avionics architecture of the F-35 and provides the pilot video with imagery in day or night conditions. Consequently, the F-35 is the first tactical fighter jet in 50 years to fly without a HUD. A BAE Systems helmet was considered when HMDS development was experiencing significant problems, but these issues were eventually worked out. The Helmet-Mounted Display System was fully operational and ready for delivery in July 2014.

## JED EYES TM

Jed Eyes TM is a new system recently introduced by Elbit Systems especially to meet Apache and other rotary wing platform requirements. The system is designed for day, night and brownout flight environments. Jed Eyes TM has a 70 x 40 degree FOV and 2250x1200 pixels resolution.

## V. FUTURE TECHNOLOGY

It is developing a standard view Night Vision Cueing & Display (NVCD) for the U.S. navy.

Eye tracking – Eye trackers measure the point of gaze relative to the direction of the head, allowing a computer to sense where the user is looking. These systems are not currently used in aircraft.

Direct retinal projection – Systems that project information directly onto the wearer's retina with a low-powered laser (virtual retinal display) are also in experimentation.

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