Helmet-mounted display technologies in naval aviation

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Future designs require high-resolution sensors and brighter displays to allow for the integration of night vision.

A pilot flying a combat mission requires a high level of situational awareness (SA) to maintain safe altitude and airspeed, avoid obstructions, evade enemy weapons and, at the same time, execute the mission. Whenever the pilot has a reasonable external scene—as during day operations with good weather—the more time can be spent looking outside of the aircraft, the less time looking at flight-critical instruments, and the better chance there is of avoiding a loss of SA. For several decades the US military has worked to keep the pilot’s attention outside the cockpit by utilizing helmet-mounted display (HMD) technologies.

In its simplest form, a HMD provides information (e.g., airspeed) that increases SA because the pilot does not need to break attention from the outside scene to look at instruments in the cockpit. Although this same capability exists in a head-up display (HUD), the fixed nature of this instrument requires the pilot to look forward to see the symbology.

Naval aviation has two fielded HMDs and several programs designed to put these displays into existing and new aircraft. However, HMDs present many problems for designers and require high-performance displays and optics on a helmet that also has to perform its standard functions such as impact protection, hearing and face protection, and provide communication.

The first widely used Naval HMD was the aviators’ night vision imaging system HUD (ANVIS-HUD), which performs functions only for night missions where night-vision goggles (NVGs) are in use. The ANVIS-HUD attaches to the objective lens of the goggles and injects symbology into the NVG image seen by the pilot. Hence, it provides improved situational awareness due to minimized heads-down time in the cockpit. On the downside, though the ANVIS-HUD provides some symbology, it is not used to slew weapons/sensors or present space-stabilized symbology because the display has no head tracker. However, upgrades are being investigated.

In the late 1990s the US Navy and US Air Force created a joint program to develop the joint helmet-mounted cueing system (JHMCS) for use on F/A-18, F-15, and F-16 aircraft. This provides ‘first look, first shot’ capability when employed with high off-boresight weapons and under high-G conditions. This system reached initial operational capability in 2003 and provides aircrew with head-tracked HMD performance including weapons and sensor slewing and cueing via head direction (see Figure 1). This significantly decreases pilot workload.

Since initial fielding, the JHMCS capability has grown with integration into the F/A-18D, F, & G aircraft and a new night vision cueing and display (NVCD) capability has entered production which provides a NVG with integrated display of the JHMCS symbology.

Although existing HMDs provide an important tool for the warfighter, these systems do not fully integrate day and night capability in a single configuration. To simplify the integration with the pilot, the NVG has to be replaced by binocular integrated cameras and displays. Although current displays are capable of providing the necessary resolution for symbology, to replace a NVG both sensor and display must increase in resolution. A typical NVG has resolution specified at 1.3 cycles per degree.

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milliradian over a 40° field-of-view. A simplistic calculation would require a display with a minimum of 900 line-pairs or 1800 pixels in each row. However, the pilot does not look directly at the display but instead sees it through optics with modulation transfer function (MTF) loss. Many HMD optics include a final element—either the visor or a combiner lens—that distorts the image and so requires it to be de-warped: this is normally done on the display. Furthermore, the display has to be viewed while looking at the scene outside the cockpit through a canopy that often has complicated distortion properties requiring angularly dependent correction unique to each eye of the binocular system. When combined, these MTF losses and distortion effects result in a need for very small displays with considerably more than 1800 pixels per row.

In addition to breakthroughs in size and resolution, future HMDs require brighter displays for daylight viewing of video, higher contrast for day and night (background has to be extremely low to display multiple shades of grey) and faster switching (60 Hz or faster refresh) than we have today.

Naval aviators have benefited from the use of HMDs and will benefit from future capabilities as developing sensors and displays are integrated into the next generation. Currently, we are working towards accelerating component development, including high-resolution small-size displays for the HMDs of tomorrow. In the future, we hope to team up with industry to advance HMD technology to satisfy the needs of naval aviation.

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References