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NIGHT VISION GOGGLE (NVG) HEADS-UP DISPLAY (HUD)

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SUMMARY

Standard night vision goggles were modified to accommodate a visual display similar to that employed in aircraft Heads-Up Displays (HUDs). Primary users of this device are Military Airlift Command (MAC) pilots flying low level special operations. During use, the pilot sees a thermal image of the ground, with critical flight path and attitude information symbolically displayed on the scene. This modification allows the pilot to fly at very low levels at night without having to look inside in the cockpit. This paper relates the process of design and fabrication of the HUD optics and the selection of the heads-up symbols (e.g., airspeed, altitude, heading) for transports and helicopters. It also reports the first successful trials on a C-141B jet transport.

INTRODUCTION AND BACKGROUND

This report documents the development and first application of NVGs modified with HUD symbols for flying night, visual flight rule (VFR), low level operations. The NVG/HUD combines monocularly presented flight symbology with a binocular view of the outside scene. Development and construction of the devices associated with the NVG/HUD were performed at the Air Force Aerospace Medical Research Laboratory (AFAMRL).

The NVG/HUD is presently used by pilots flying jet and turbo-powered cargo aircraft, as well as pilots of conventional helicopters. Flight testing was performed during night sorties in South Carolina and Florida. Structured questionnaries and interviews are used to guide design changes, suggest training requirements, and assess pilot acceptance.

Characteristics and use of NVGs

Godfrey (1982) described the development and use of NVGs in military crewstations.

> "NVGs have now attained a level of sophistication such that aircraft can be safely and comfortably flown using these devices. NVGs operate by amplifying reflected low intensity visible and near infrared (invisible) light. The goggles most commonly referred to are AN/PVS-5 (Generation II) and ANVIS (Generation III) (Aviators Night Vision Imaging System). Generation II goggles can be helmet-mounted

but are rather heavy and awkward. The user must see everything through them including cockpit instrumentation. The Generation II produces a bright target image at light levels as low as quarter moon illumination. The latest NVGs (Generation III) are helmet-mounted, lightweight, and well balanced so that the person wearing them can operate unhindered. The design permits use of the goggles to produce a clear green picture of the world around, while at the same time permitting use of the naked eye to look under the goggles and read instrumentation or other information. Generation III NVGs produce a bright target image at light levels as low as starlight illumination."

As with any new technology introduced into areas as complex as an aircraft crewstation, there are a number of problems which must be resolved. The most significant problem is the light which is enhanced to produce a picture of the outside world. The wavelength of this light is between 600 to 900 nm. This means that incandescent lamps or any other light whose wavelength is longer than approximately 525 nm (green light output) will also be amplified and interfere with the image of the outside scene. Yellows, reds, and infrared either "blind" the goggles or cause them to protectively shut down much as the unaided eye adapts to very bright light. The response of these goggles is shown in Fig. 1.

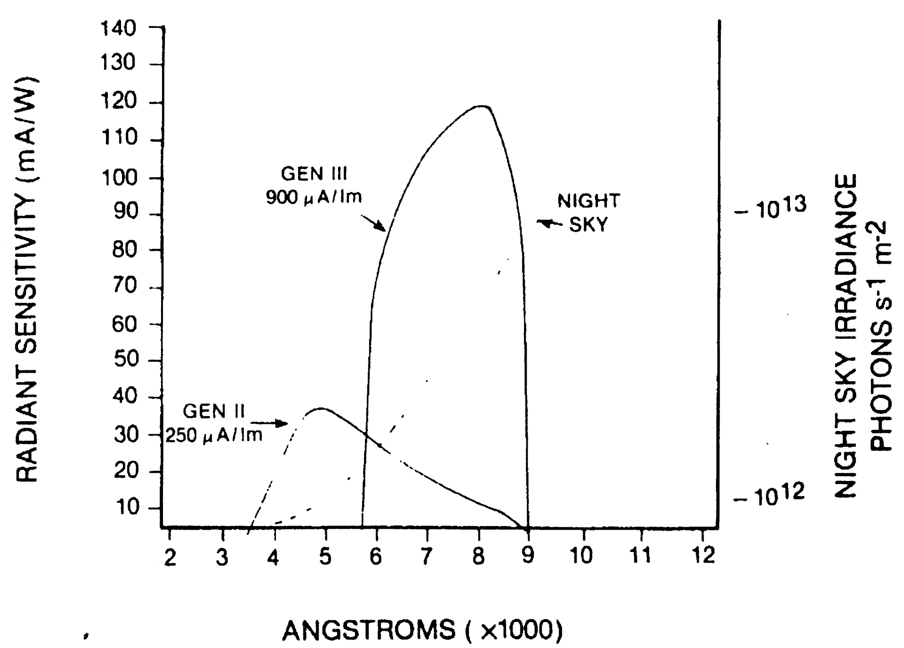


Figure 1. Response of night vision goggles.

Characteristics of the NVG/HUD

AFAMRL solved the problem of flying very low levels, at night, by providing HUD symbols on a combining glass over one of the goggle eyepieces. The concept was to provide sufficient position and attitude information to the pilot during enroute, air drop, and landing operations to allow an "eyes-out" orientation during the complete operation.

Several modes of information display are available. Fig. 2 shows the HUD symbols selected for one mode (normal) of the transport and helicopter mission. Generally, for other models such as SEARCH and LANDING, the number of symbols was reduced to avoid cluttering the center of the IR image when the pilot is concentrating on ground patterns and landmarks.

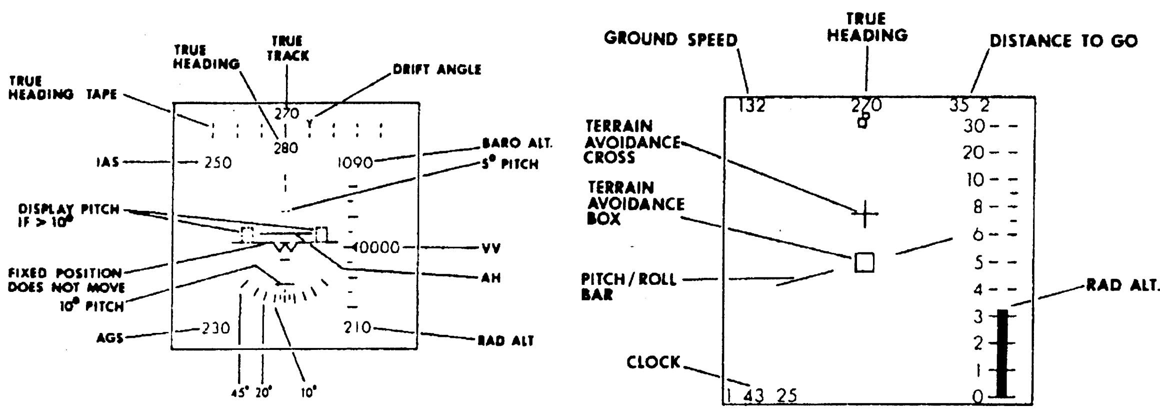


Figure 2. HUD symbols for transport and helicopters. Several special features of the symbology are indicated in Table 1.

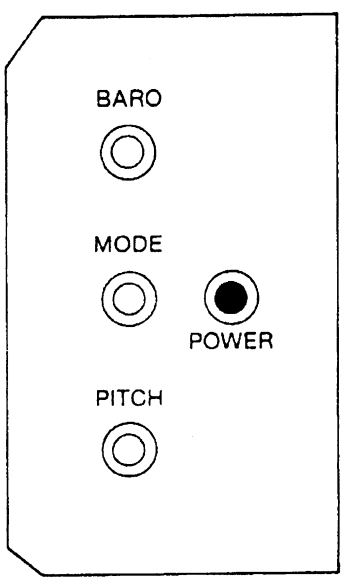
TABLE 1. Special control/display features.

Altitude	Displays barometric or radar altitude, radar changes in 1Ø-foot increments below 1ØØØ feet, 1ØØ-foot increments above 1ØØØ feet.
Fixed Digit	The last zero for altitude and vertical velocity is an unchanging zero (Ø) to reduce distraction of a fast changing digit.
Pitch	Over 1Ø degrees pitch, a 1Ø's digit is displayed to the left of the aircraft and 1's unit to the right.

The flight instrument raw signal information is collected by the aircraft's signal processing computer and converted into Arinc 429 formatted data. The data are transmitted to the AFAMRL display unit across the Arinc 429 bus.

The data unit converts the data to a symbolic display on a cathode-ray tube format. The symbology display is reflected from a front surface mirror to a relay lens which focuses onto a flexible fiber optic bundle. The bundle brings the image up to the NVG where a collimating lens moves the image or the symbology to optical infinity. This image is then reflected from a beam splitter into the NVGs. The observer sees the image of the HUD symbols superimposed over the outside view.

The controls for the HUD portion of the system are shown in Figure 3. The control panels are positioned at various locations, depending on the type of aircraft. The design goal was to include only critical pilot control functions and automate other functions (focus, brightness, contrast).



4 PUSHBUTTONS

BARO - Changes readout to match aircraft altimeter

MODE - Selects symbol set for mission segment

POWER - Turns HUD equipment ON

PITCH - Trims the aircraft symbol to horizon bar for aircraft attitude

Figure 3. Pilot's controls for transport and helicopters (tentative).

Evaluation of the NVG/HUD

Evaluation and modification of the device was iterative. The approach was to use actual flight experience to modify user HUD symbol requirements, obtain acceptance ratings for the device, and identify problems. For each aircraft, pretest discussions were held with MAC personnel to derive a symbol set that appeared to satisfy the aircraft mission requirements. Throughout the aircraft test series, the design goal was to minimize the number of symbols, modes, and controls without compromising crew safety or adding to crew workload.

HQ MAC authorized a series of evaluations based on successful trials in preliminary C-141 flights. Over a 1-year period, MAC directed that other aircraft be evaluated for NVG/HUD use:

Aircraft Evaluated for NVG/HUD Use

C-141B	C-13ØE (AWARDS)	H-53E
	MC-13ØE	HH-53B/C
	AC-13ØH	HH-53H
	HC-13Ø	UH-6ØA

Several C-141 and C-13Ø crews have flown and endorsed the NVG/HUD for low level operations. Testing and evaluation on other aircraft is ongoing.

RESULTS

The four-engine heavy jet transport, C-141B, flies a low level mission that currently relies on the pilot looking outside and maintaining terrain clearance while the co-pilot looks inside and ensures the integrity of aircraft velocity and attitude. The missions include a blacked-out approach, landing, and takeoff from a remote field. The current concept (pre-NVG/HUD) is for the co-pilot and two navigators to verbally provide critical information to the pilot throughout the operation. Six C-141B pilots flew night approached and full-stop landings with the NVG/HUD. A structured questionnaire was used to obtain the pilot ratings shown in Table 2.

Using a five point scale (Ø=unacceptable, 3=acceptable, and 5=excellent), all HUD symbols were rated between "more acceptable" and "excellent" except for the drift angle symbol. The three system controls (to adjust intensity and focus and to reset the barometric altimeter) were rated as more than acceptable. The location of the control panel was rated acceptable; however, its relocation was recommended. Visual fatigue was rated as below average to none and display contrast as being adequate for most night sky conditions under various levels of illumination. In terms of the systems contribution to mission success, the pilots generally agreed that the NVG enhances control of the aircraft, reduces interphone communication and increases flight safety (terrain clearance).