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Further Development of the Panoramic Night Vision Goggle

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ABSTRACT

A novel approach to significantly increasing the field of view (FOV) of night vision goggles (NVGs) has been developed. This approach uses four image intensifier tubes instead of the usual two to produce a 100 degree wide FOV. A conceptual demonstrator device was fabricated in November 1995 and limited flight evaluations were performed. Further development of this approach continues with eleven advanced technology demonstrators scheduled for delivery by the end of December 1998 that will feature five different design configurations. Some of the units will be earmarked for ejection seat equipped aircraft due to their low profile design allowing the goggle to be retained safely during and after ejection. Other deliverables will be more traditional in design approach and concentrate more on transport and helicopter aircraft as well as ground personnel. Planned testing to collect both subjective and quantitative data will begin in November 1998.

INTRODUCTION

Delivery of the conceptual demonstrator device (Figure 1), now referred to as the panoramic night vision goggle (PNVG), was quite impressive considering it was developed with very limited funding under a phase I small business innovative research (SBIR) program with Night Vision Corporation. The extremely positive feedback of this demonstrator from the warfighter community propelled the program into a phase II SBIR effort and also received the attention and supplemental funding support of the Air Force Research Laboratory's Helmet-Mounted Sensory Technologies program office. Phase II will further develop the PNVG by first addressing ejection seat aircraft with two configurations of a low profile design (designated PNVG I). This version with its better center of gravity should be less fatiguing during longer flights and will potentially allow for ejection by permitting retention of the system on the head throughout the ejection sequence. Retention of PNVG I may also permit quick evasion and rescue. Additionally, three configurations of a never-before-seen NVG for transports, helicopters, and ground personnel (designated PNVG II) are being developed. These models will look more like a traditional goggle. PNVG II, while weighing more than a PNVG I, should be more robust and will attach to any existing ANVIS mounting system. Both PNVG I and II, like the phase I conceptual demonstrator, will provide a 100 degree horizontal by 40 degree vertical (100° H X 40° V) intensified field of view (FOV) (Figure 2). This represents a 160% increase of the warfighter's intensified image FOV compared to currently fielded 40° circular FOV systems.

Figure 1. PNVG conceptual demonstrator (Patent Pending)

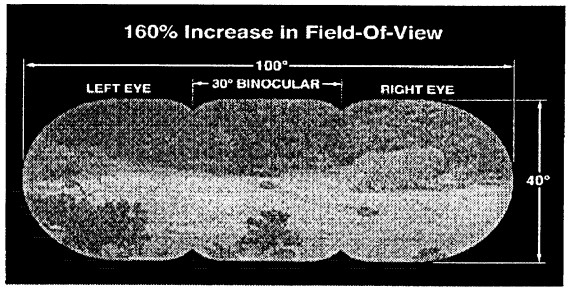

Figure 2. PNVG simulated FOV

BACKGROUND

NVGs with FOVs ranging from 30° (GEC-Marconi Avionics' early Cat's Eyes NVGs) to 45° (GEC-Marconi

Avionics' NITE-OP and NITE-Bird NVGs) have been used in military aviation for more than 20 years. The vast majority of NVGs (AN/AVS-6 and AN/AVS-9) provide a 40° FOV (Figure 3). Because each ocular uses only a single image intensifier tube, increased FOV for these NVGs can only be obtained at the expense of resolution (Donohue-Perry, Task, & Dixon, 1994 and Task, 1992). The image intensifier tube has a fixed number of pixels (picture elements). Therefore, if the pixels are spread over a larger FOV, the angular subtense per pixel increases proportionally. As a result, resolution is reduced.

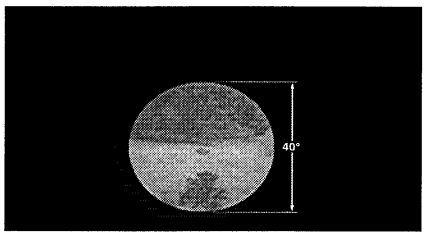

Figure 3. Simulated AN/AVS-6 and AN/AVS-9 FOV for comparison with the PNVG

An extensive survey of military (U.S. Air Force) NVG users conducted during 1992 and 1993 revealed that increased FOV was the number one enhancement most desired by aircrew members. Resolution followed closely (Hettinger, Donohue-Perry, Riegler, & Davis, 1993 and . Donohue-Perry, Hettinger, Riegler, & Davis, 1993). This was a major motivating factor for the development of an enhanced NVG capability.

PNVG I DESCRIPTION

PNVG I (figure 4) is similar in design approach to the conceptual demonstrator PNVG developed under the phase I SBIR program but has optimized the overall design and added several enhancements. PNVG I still features a partial overlap (100° H X approximately 40° V) intensified FOV. The central 30° H X 40° V FOV remains completely binocular while the right 35° is visible only to the right eye and the left 35° is visible only to the left eye.

Additionally, a thin demarcation line separates the binocular image from the monocular peripheral image. PNVG I features a newly developed 16mm image intensifier tube rather than the currently fielded 18mm format tube. Along with the goal of offering comparable performance to the recent Omni IV tubes, its weight will be reduced by more than 50%. Therefore, four 16mm PNVG tubes weigh less than two of the current 18mm tubes. The 16mm tubes have longer fiber optics on the

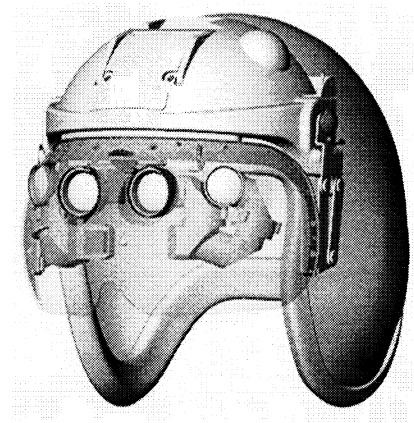

Figure 4. PNVG I (Patent Pending)

outside optical channel than the inner optical channel. The outer and inner channel fiber optics do not require image-inverting fiber optics. Dual fixed eyepieces (tilted and fused) and four objective lenses (the inner two adjustable and the outer two fixed) make up part of the folded optical approach. The inner optical channels include very fast F/1.17 objective lenses as compared with the F/1.25 objective lenses of the currently fielded AN/AVS-6 and AN/AVS-9 goggles. The outboard channels, due to size and weight constraints, incorporate F/1.30 objective lenses. All of the objective lenses will incorporate Class B, leaky green filters for compatibility with color cockpits and aircraft head-up displays. Eyepiece effective focal length is 24mm while the physical eye clearance has been designed for 22mm. A specially designed single left side and single right side power supply is remotely located but allows each side's inner and outer optical channels to be controlled independently. Multiple adjustments (i.e. tilt, independent inter-pupilary distance, up/down, and fore/aft) should permit an optimized optical fitting. Customized visors will also be incorporated for mechanical stability and escape protection. Individualized holes will be cut for the objective lenses to stick through. Also, a unique latching mechanism affords one-handed don/doff capability. A new linkage system enables the PNVG I to easily transition into a stow position (Figure 5).

During normal use, power is provided to the system by the aircraft. In the event of an ejection, two "AAA" alkaline batteries located in the remote electronics module (REM) provide power during the escape sequence, evasion, and rescue. Due to funding constraints, PNVG I is currently designed to attach to only the Air Force's HGU-55P helmet.

Two configurations of the PNVG I will be delivered. PNVG I-Configuration 1, will have four deliverables.

The PNVG module will attach to a unique "universal connector", the same connector used with the Visually Coupled Acquisition and Targeting System (VCATS) daytime helmet module. VCATS is currently being evaluated as part of an advanced technology

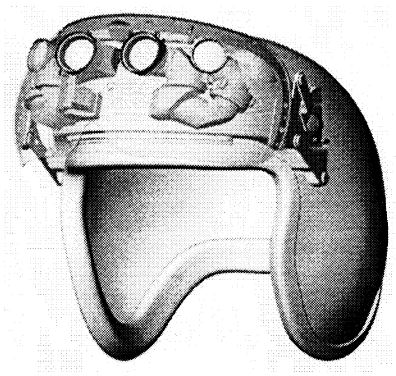

Figure 5. PNVG I in stow position (Patent Pending)

demonstration at the 422nd Test and Evaluation squadron at Nellis AFB. The universal connector provides aircraft data and power to the PNVG module. This configuration also features a 640x480 active matrix electroluminescent display (AMEL) for symbology overlay and a magnetic head-tracker with electronics located in the REM. PNVG I-Configuration 2, a stripped down version of Configuration 1, will have two deliverables. Configuration 2 does not include an AMEL display, magnetic head-tracker, or electronics package. Since the majority of the HGU-55P helmets are not equipped with the VCATS universal connector, a special banana clip mount has been designed that will accept the PNVG module on any HGU-55P helmet. Because there is no aircraft power being provided through a universal connector for configuration 2, system power will be supplied by the two "AAA" alkaline batteries located in the REM.

PNVG II DESCRIPTION

An alternative approach to PNVG I has been developed. The partial overlap 100° H X 40° V intensified FOV is maintained but the system resembles the currently fielded aviator NVGs (Melzer & Moffit, 1991). Whereas PNVG I mates to only the HGU-55P helmet, PNVG II (Figure 6) is compatible with any helmet that incorporates the standard ANVIS mounting bracket. This will allow any warfighter to assess the utility of a panoramic night vision scene given they have the proper bracket. If testing proves that the panoramic scene is required but the PNVG I approach is preferred, a development effort will have to address the specific design issues necessary to mate it with a particular helmet type.

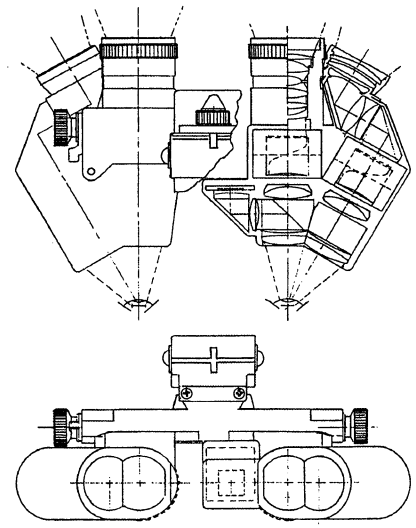

Figure 6. PNVG II (Patent Pending)

Similar to the PNVG I, the central 30° H X 40° V FOV is completely binocular while the right 35° is visible only to the right eye and the left 35° is visible only to the left eye. Additionally, a thin demarcation line separates the binocular image from the outside monocular image. PNVG II utilizes the newly developed 16mm image intensifier tube but requires image inverting fiber optics (the outer channel fiber optics are the same length as the inner channel). Dual fixed eyepieces, tilted and fused together, and four objective lenses (the inner two adjustable and the outer two fixed) remain part of the optical approach. The non-folded inner optical channels are designed with extremely fast F/1.05 objective lenses. The folded outboard channels use the PNVG I inner channel optics with F/1.17 objective lenses. Eyepiece effective focal length is 24mm while the physical eye clearance has been significantly increased to 27mm. All of the mechanical adjustments currently available on the AN/AVS-6 and AN/AVS-9 remain (i.e. tilt, independent inter-pupilary distance adjustment, up/down, fore/aft). Power for the PNVG II will be provided via the batteries that are currently integrated with the AN/AVS-6 and AN/AVS-9 mounting systems. Therefore, no special power provisions are necessary.

Three configurations of PNVG II will be delivered. PNVG II-Configuration 3 will have only one deliverable but it will feature a 640x480 AMEL display. Additionally it will have a Class B, leaky green filter incorporated into the objective lens. PNVG II-Configuration 4 will have three deliverables but will not include the AMEL display. One of the three will use the Class B, leaky green filter while the remaining two will use a Class A filter. The final deliverable, PNVG II-Configuration 5, is intended for ground applications and will be integrated to a special

hand-held "PIRATE" mounting system including its own batteries and a single infrared diode. This configuration will not include an AMEL display and the objective lens will be unfiltered (i.e. no class A or B filters).

PNVG TEST PLAN

A critical step in the development of the PNVG system is the completion of performance-based field evaluations. It is important to have an empirical basis for determining the cost/benefit afforded by the capabilities of the PNVG compared to present NVGs. Toward this end, a two-pronged multi-phased evaluation program is being planned. The testing activities will occur both in the laboratory (simulation facilities) and during operational flights. Ideally, to maximize how well findings can be generalized from the laboratory to the field, subject matter experts (appropriately rated pilots) will serve as experiment participants for both phases. The evaluation and experimental design is being structured to include both fixed- and rotary-wing applications.

It is anticipated that the use of the PNVG technology will result in both performance and behavioral differences when compared to conventional NVGs. The evaluation methodology is being designed to investigate these differences via the performance operationally representative tasks which hold practical significance. Included are both flight and target search tasks. Subjective feedback will also be collected to compare the different FOV technologies in terms of pilot preference, subjective workload, and subjective situation awareness.

The first phase of the evaluation is comprised of a series of simulation trials. The purpose of using the simulator as an initial evaluation step is to validate the test methodology in a relatively quick and inexpensive manner. Unique to the simulation trials will be those tasks which are impractical or exceedingly dangerous for actual flight trials. The basic tasks which prove to be sensitive performance discriminators in simulation will be replicated in flight test.

The following are example tasks and measures presently being considered for the empirical evaluation:

Simulator Tasks: These tasks will include a manipulation of flight symbology in addition to the PNVG / conventional NVG comparison. The simulation trials will be developed for and run in the Air Force Research Laboratory's Synthesized Immersion Research Environment Facility (SIRE) or similar high-resolution large dome simulator (Geiselman, Brickman, Hettinger, Hughes, DeVilbiss, & Haas, 1998).

Fixed-wing simulator tasks: The purpose of the PNVG technology is to afford the pilot daytime-like performance under conditions of degraded vision (i.e. night). Representative tasks for the evaluation will include those which are difficult during extremely low light level night operational conditions. Also included are primary tasks such as target search and identification, low altitude navigation, dive-toss bombing, formation flight, blacked out runway landings, etc. For all of these tasks, simulation catch trials will be developed to include critical events such as terrain obstructions, airborne threats (potential midair), and runway incursion. These events will be included in the experimental design as secondary measures of situation awareness and task saturation.

Performance measures will be collected and analyzed to help determine the effects of changes in FOV and the addition of symbology on performance during trials of the aforementioned primary tasks and critical events. Behavioral measures in the form of head movement and position data will be analyzed to investigate the effects of the independent variables (e.g. no aid vs. NVG vs. PNVG with and without symbology) on pilot line-of-sight variability (including the proportion of head-out and head-up time as a result of the display manipulations), rate-of-translation, reversals, search patterns, and fixation area. Subjective feedback will include pilot preference questionnaires, subjective workload ratings (i.e. NASA task loading index: NASA-TLX (Hart & Staveland, 1988)) and subjective situation awareness comparisons (i.e. Cognitive Compatibility Situation Awareness Rating Technique: CC-SART (Taylor, 1995)).

Fixed-wing flight test: To the extent possible, the fixed-wing in-flight evaluation tasks will include replications of the simulation tasks. Similar objective and subjective measures will be collected and analyzed. The planned operational evaluations will be conducted in F-15C aircraft at Nellis AFB, Nevada by the 422nd Test and Evaluation Squadron.

Rotary-wing evaluation: The rotary-wing simulation tasks will include elements similar to the fixed-wing evaluations. These include target search and identification, landing, critical events (i.e. wire crossing during terrain masking maneuvers). In addition, methodology from previously performed simulation studies and flight evaluations will be replicated for the purposes of the present evaluation. For instance, standardized helicopter handling qualities maneuvers have been successfully demonstrated as sensitive evaluation variables for similar display FOV research (Szoboszlay, Haworth, Reynolds, Lee, & Halmos, 1995). These tasks, and their associated performance measures, will be modified for use as both simulation and flight trials to

meet the objectives of the current evaluation. Flight testing will be completed at Ft. Belvoir and the NASA Ames Research Center (Szoboszlay et. al., 1995). The rotary wing tests will include behavioral and subjective measures similar to those presented in the fixed wing section.

CONCLUSION

The PNVG conceptual working model developed under the phase I SBIR demonstrated the feasibility of a very wide FOV image for night operations. The eleven advanced technology demonstrators being delivered under phase II will allow the warfighter to evaluate the operational utility of the PNVG. As a result of both the performance-based simulator and field evaluations, a better understanding will be gained of the PNVG's impact on such areas as improved situational awareness, reduced fatigue during long missions, ejection compatibility, and overall increased mission performance and safety.

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BIOGRAPHIES

Jeffery L. Craig is an Industrial and Systems Engineer working for the Air Force Research Laboratory. A graduate of Ohio State University in 1982, Mr. Craig has been employed at Wright-Patterson Air Force Base in Ohio since receiving his diploma. His current position is managing the Night Vision Operations Program within the Visual Display Systems Branch. Early projects to his credit are NVG compatible cockpit lighting, NVG head-up displays and NVG covert landing aides. More recent efforts have centered around enhanced NVG development in particular the panoramic NVG program.

Eric Geiselman received a M.A. in Human Factors/Experimental Psychology from the University of Dayton in 1991. In 1988 he received a B.S. in Psychology also from the University of Dayton. Mr. Geiselman is currently employed by Logicon Technical Services as a Senior Human Factors Engineer supporting the Air Force Research Laboratory (AFRL) Synthesized Immersion Research Environment (SIRE), Wright-Patterson Air Force Base, Ohio. Mr. Geiselman is a commercial pilot and flight instructor with instrument, seaplane, and glider ratings.