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Panoramic Night Vision Goggle-Maintainer's Perspective

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ABSTRACT

Future night vision goggle (NVG) capabilities have dramatically improved with the advent of the "Panoramic Night Vision Goggle" (PNVG) systems. Ingenious uses of optics and image intensifier tubes have significantly expanded the pilots' field of view (FOV) wearing NVGs from 40 degrees to a 100 degrees FOV. Flight and laboratory tests have demonstrated a marked increase in situational awareness in concert with the 160 percent-increased FOV. Additionally, test and evaluation sorties on multi-type airframes have won high accolades from pilots all too familiar with flying with the older 40-degree FOV goggles. However, despite these innovations, there remain design hurdles critical to fielding and sustaining these new devises. A modular platform concept is proposed for the PNVG II version. This would give maintainers flexibility in minimizing maintenance downtime by eliminating common solder repairs typically found in current NVG designs. A modular design would also allow the image performance to be assessed using the recently purchased and costly Hoffman ANV-126 tester. Advanced optical designs on the PNVG prohibit the same field level repairs that are being performed on currently fielded NVGs with more simple lenses. Modular lens sections would allow a lens change as quick as a photographer using a 35mm camera would. This modular design concept will prevent services from having to revert to a centralized depot-level repair of these high demand devises. An item that can be repaired in the field is an item that's available for sortie generation. Night vision goggle maintenance in the Air Force has evolved into a self-sustained operation that's given it's users shorter maintenance repair times and higher availability rates for these devises. There's never been a better time for a modular NVG design than with the advent of the PNVG system.

INTRODUCTION

There are two configurations of the Panoramic Night Vision Goggles and several versions of each, incorporating various features. The first configuration, PNVG I, was designed primarily for use in high performance aircraft. Its robust design integrates frame, lens and goggle components enabling retention of the devise during an ejection. PNVG II incorporate the same field of view as version I, but utilizes the more traditional frame assembly designed to integrate with current NVG helmet mounts. The PNVG II prototype design borrowed off-the-shelf frame components for its frame and mount assemblies. This allowed the PNVG II to integrate with all the conventional NVG aviator helmet mounts in the US inventory. In addition to aligning the NVG mount design with helmet mounts already in service, it also saved the cost of redesigning a new frame assembly. The uses of these type frames were convenient in allowing test and evaluations of the PNVG's advances in optics and image intensifiers. However, many of the benefits gained using off-the-shelf frame assemblies will be significantly offset if they're used during production. This paper will primarily focus on improvement opportunities desired for current NVG frame assemblies and required for future PNVG II assemblies. The term PNVG will refer to the PNVG II configuration unless otherwise indicated.

BACKGROUND-MAINTENANCE HISTORY

PNVG's technological design advancement brings with it sustainment issues common to most system advances. Typically the more complex a system, the larger the logistical footprint. This point becomes more critical when considering the hazardous two-prong arenas the PNVGs will be used, flight and war. This paper will discuss some of the challenges and concerns anticipated during the final design and sustainment phases of this important new system. To appreciate these issues, one must be familiar with the evolution of NVG maintenance in the Air Force.

In the "early days" of NVGs in the Air Force, field technicians performed only visual inspections of NVG systems. If there were any anomalies noted, the goggles were packaged and sent to the depot for more in-depth examination. Aircrew Life Support technicians maintaining the goggles wouldn't see the goggles again for several weeks. This created an unacceptable turn-around time for these high demand devises. This drove the evolution of a two-tier *field* maintenance program, Intermediate-Level (I-Level) and Organizational-Levels (O-Level).

The O-level technicians still performed only visual inspections but began utilizing a hand-held *Assessor* that provided a resolution grid. The *Assessor* allowed technicians to quickly assess the NVG's image qualities for obvious defects in various light conditions. Distortion inspections however, required the technician to fabricate a tic-tac-toe type grid to access the goggles for image distortion. Another target was necessary to measure the size and position of dark spots in the image intensifier tubes that would obscure the pilots' view. Once again, if any defects were suspected, the goggles were sent to the higher I-level maintenance.

Avionics (Sensors) technicians assumed the I-Level maintenance duties. I-Level maintenance tasks included all inspections and repairs necessary to maintain the goggles. With the additional maintenance tasking came a more sophisticated test set, the TS-3895. Like the hand-held Assessor, the TS-3895 test set provided a basic resolution target that allowed the technician to assess the NVGs visual clarity, in both the high and low light conditions. It also provided the means to check the goggles' electrical functions for excessive current drain and the operation of the power packs. I-level technicians were qualified to perform all authorized repairs on the night vision goggles including soldering and nitrogen purging.

Although very dedicated, the Avionics technician's support of the NVG program was often secondary to their primary support of the aircraft's' ship-side avionics. This two-tier maintenance program did reduce repair times compared to sending NVGs off base, but still lagged behind the ever-increasing demand for an even shorter turn around time by the user.

The proliferation of NVGs further burdened the Avionics branches as reflected in the increased turn-time for I-level NVG maintenance. Another factor was the aggressive force reductions that lessened the maintainers available to perform the maintenance.

Life Support Command Managers saw opportunities to reduce the maintenance turn-time by further reducing the maintenance levels maintaining their NVGs. They began training their O-Level technicians to assume I-Level duties. Those trained were provided the TS-3895 tester in addition to nitrogen for purging. These new I-Level maintainers performed all NVG inspections and repairs except soldering.

Soldering night vision goggles requires a "High Reliability" solder certification due to the goggles critical nature. Due to the frequent turnover of active duty technicians, it was frustrating to continually pay for this training. Many units continued to rely on the Avionics technicians for solder support via local support agreements. Since solder-repairs were relatively uncommon NVG maintenance tasks, it made more fiscal sense to establish local support agreements for soldering than to invest in costly repetitive solder training. Once again the goggles were being sent away for solder-type repairs. Avionics frequently lacked either the manpower or time to quickly perform these solder repairs while also maintaining their own equipment. Although mission-ready rates for night vision goggles are not tracked, any experienced NVG technician would attest to the lengthy downtimes for goggles requiring extensive repairs.

Life Support Command Manager's once again moved to make for more mission ready devises. They increased the manning at units maintaining night vision goggles. Additionally, solder training was added as a recommended *optional* training requirement to the Aircrew Life Support career field. However, many Life Support units have opted for continued use of the local support agreement with the Avionics shops.

The following discussions propose particular design concerns to current NVG systems that could and should be resolved with production of any PNVG II systems. They are areas affecting reliability and ready-rates for these critical devises.

MAINTENANCE/DESIGN LIMITATIONS

a. Soldering

Despite the simplicity in design, NVG repairs requiring soldering are extremely time-consuming. Two thin wires bring current via the helmet mount, from the power pack into the image intensifier tubes inside the monocular housing. Very often these wires break from another design flaw that will be described later. Anytime the wires break, the monocular housing holding the wires must be either replaced or the wires reattached to their solder point. Prior to any soldering, the image intensifier tubes *must* be removed. Any heat conduction down the wires from the solder iron would irreparably damage the costly image intensifier tubes. This leads to lengthy repairs and excessive down times.

b. Lengthy Repairs

Even the most common and simple NVG repairs are very time consuming. Scratched lenses and broken monocular housings have become common as both the use and life of the goggles increase. Replacing the lenses or tubes first require draining the goggles of their nitrogen charge. The lens assemblies are first removed to gain access to the intensifier tube. After the tube is removed, the monocular housing is disassembled from the pivot adjustment shelf (PAS) to gain access to the wires requiring soldering. The damaged housing is then removed by de-soldering the wires joining the housing to the printed circuit board. The new housing is installed and the new wires soldered in place. The goggles' components are then reattached to the housing. However, as part of the re-assembly of the NVG, the technician must still adjust the eyepiece and objective lens assemblies for proper focus.

This lengthy repair process is very common and takes an <u>*experienced*</u> technician at least two hours. If the technician is not familiar with these procedures and forced to rely on the technical order, add at least four more hours. However, if the damaged goggles were sent to an Avionics back-shop, an average of at least *two days* turn time can be expected. This time-consuming repair process has become even more common as the aging goggles require replacement of tubes, lenses and housings.

Many units currently maintain *several* spare goggles to allow for this now accepted high maintenance down time. This costly way of ensuring mission readiness is an unlikely answer when considering the potential high-cost of PNVGs. The maintenance downtime of NVGs could be significantly reduced with basic design improvements.

c. Purge Valves

Night vision goggles' current design require a nitrogen charge in the monocular housing to prevent damaging moisture from entering the inner housing where the image intensifiers are stored. NVG's are charged with nitrogen through a process called Purging.

During purging, the outer purge valve is removed to allow insertion of a metallic adapter into the plastic sleeve. Inserting the metallic adapter into the threaded plastic sleeve frequently results in stripped threads. When this occurs, the entire monocular housing must be replaced as described above. Once the adapter is in place, the inner purge valve is loosened to allow a flow of nitrogen that's being blown in from the outer valve.

To gain access to the inner valve, an offset (L-shaped) screwdriver is recommended in the technical order. Despite using the proper tool, the space between the housings is too tight to effectively accommodate any tools. This usually results in damaged aluminum valves or plastic valve sleeves as the technician tries to vent the nitrogen. The purge procedure was rewritten establishing an alternate purge method that called for use of only the outer valve. Although this eliminated further damage to the inner purge valve and port, it was not as effective a purge method.

The new procedure, "Zero Pressure," required the removal of the outer purge valve to allow insertion of the nitrogen. Once the system was charged, the nitrogen line was removed so that the valve could be reinstalled. This exposed the nitrogen filled chamber to the atmosphere as the technician reinstalled the valve, leaving zero pressure in the chamber.

Cross threading is an extremely common problem while inserting either the metal purge adapter or the metal purge valve into the plastic sleeve. When cross threading occurs the entire monocular housing must be replaced.

The system's design would be dramatically improved by providing more creative and less labor intensive means to eliminate moisture from the image intensifier tube chamber. Perhaps the use of a moisture absorbent liner or a desiccant-type devise could be incorporated in future designs.

Improved purge valves could also be the answer to this dilemma. Future housing designs could utilize valves similar in design to those found on pneumatic tires. This would allow the technician to quickly purge the chamber with nitrogen by attaching a gas-station type hose to the valve. Depressing the valve's nipple would easily purge the chamber during both filling and repairs. This would dramatically extend the life of the housing by eliminating damages incurred during the purging processes utilizing today's methods and designs.

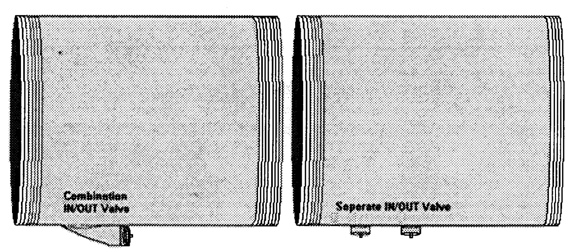

Figure 1. Purge Valves

d. Housings

Housings were recently improved by eliminating the saddle to housing configuration. Previously, the "saddle" was glued to the monocular housing and served to join the housing to the PAS. This saddle to housing bond point was often damage by aircrews during removal of the goggles. They would remove the NVGs by grasping them with one hand and forcing the goggles away. Although not recommended, this action was sometimes necessary as the flyers were often flying the jet with their other hand.

This removal process would often over-torque the bond joint causing it to snap.

Another housing design limitation is the threaded sleeve on top of the housing that holds the adjustment Inter-Pupillary Distance (IPD) screw. The metal screw turning within the plastic threads quickly strips the threads requiring the replacement of the entire monocular housing.

The addition of metallic threaded sleeve into the plastic housing would dramatically extent the housing's life. A replaceable *lightweight* durable sleeve made from advanced composites would be ideal. This low cost alternative would allow technicians to replace the damaged threaded section instead of the entire housing. Although this might add some weight to the goggle, it would significantly improve the goggle's durability while lowering the overall maintenance cost.

e. Knobs

Ergonomically designed adjustment knobs for Tilt, Fore/AFT, and IPD would dramatically enhance any future designs. Compare the infinity focus adjustment knobs of the AN/AVS-6 to the AN/AVS-9 (F4949). The F4949's knobs are superior to the knobs of the AN/AVS-6. They're designed for flyers wearing flight gloves. Bigger knobs are easier to find and use.

The current Tilt lever is difficult to locate and cumbersome to use-especially while wearing flight gloves. Imagine performing these adjustments while wearing three layers of gloves, as is done when flyers' are suited for a chemical environment. Keep in mind that the Tilt, Vertical & Fore/Aft are actually used *in flight,* as opposed to the IPD and diopter focus knobs which are only used during preflight adjustments. Rocker-type knobs, like those found on many binoculars might prove ideal for most of the NVG adjustments.

f. In-Flight Goggle Storage

An A-10 mishap involving a NVG storage case tangling with the flight controls has drawn new concern for the design of NVG storage cases and alternate storage methods. This is particularly true for the fighter community since there's limited cockpit space to store a box-shaped case. A small, firmly padded helmet bag-type design would protect the goggles and could be easily stored in either their flight suit leg pocket or map bins. Another concept is a hard-mount on the interior of the flight station. The pilot could remove the goggles and attach them to this mount.

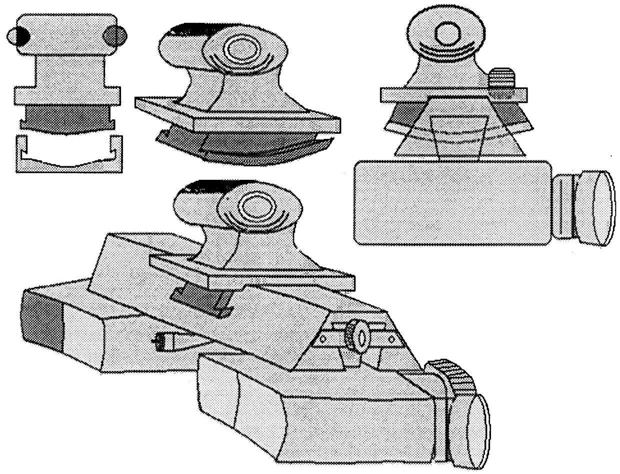

Figure 2. Increased Tilt

g. Increased Adjustment Range

Increasing the range of mechanical motion in future goggle designs would allow better fit for the aircrews. One way is to provide a wider range of tilt. Current goggles provide only $\pm$ 4 degrees tilt from the center position. A wider range would improve the optical alignment process by making it quicker and more personally accommodating. It would also help helicopter gunners and loadmasters look down easier with less neck strain.

Increased Fore and Aft movement would allow a more comfortable wear for flyer's wearing prescription spectacles. It would also improve the look-under capability required when scanning gages.

h. Wire-to-Circuit Board Design

Current from the helmet mount is delivered to a flexible circuit board in the pivot and adjustment shelf (PAS). The current is then delivered to the image intensifier tubes via two wires extending from the monocular housing. The two wires are soldered to the flexible circuit board and tend to flex at the solder joint as the housing is moved side-to-side during IPD adjustments. These adjustments are performed during the preflight optical alignment process. The flexing of the wires at the solder joint eventually causes either a cold solder joint where no current is flowing, or causes the wire to completely break. When this occurs, the image either flickers or will not illuminate, thus requiring the extensive repairs described earlier in "Lengthy Repair."

A more durable electrical system is needed to enhance in the next generation of night vision goggles and is proposed in the following section.

i. Excessive Housing "Wobble"
The monocular housings rest on a pin that runs the length of the pivot adjustment shelf. The housings slide side-to-side along the pin as the user adjusts the goggles for proper inter-pupillary distance or IPD. There's an inherent wobble of the monocular housings as they ride on this pin. The wobble is not dramatic, but certainly effects how the image is transmitted to the user's retina.

Technicians invest time ensuring the focal points on the eyepiece lenses are parallel or collimated. The monocular housings are held parallel when they're inserted into the ANV-126 tester's ports. The housings wobble defeats the collimating efforts attained during optical adjustments. Improved precision in the mechanical movements of future NVG designs is needed to eliminate or reduce this wobble.

MODULAR DESIGNS
Current NVGs utilize designs requiring lengthy repair processes to perform even the most simple repair tasks. The following modular designs proposals attempt to suggest various design improvement opportunities that would dramatically reduce the maintenance turn-times while extending the overall life of future NVG systems.

a. Rapid Repair
A more robust electrical system requiring minimal (or none) solder repairs would be ideal. One such system could be a *track-type* system similar to those found in track lighting systems. This concept would allow rapid repairs to extensively damaged systems. The technician could quickly "slide" the faulty component from the track and replace it with a spare. This would enable the technician to quickly replace the damaged component with a serviceable one without hampering the mission.

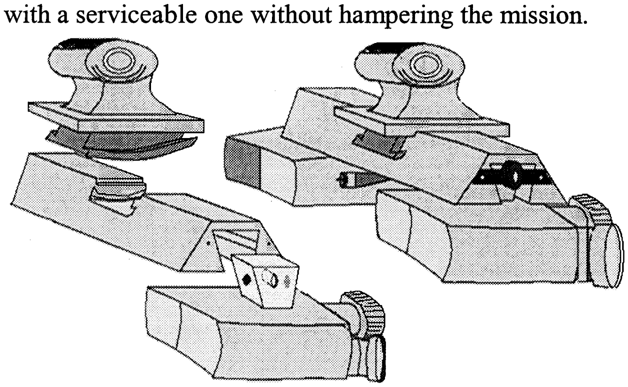

Figure 3. Modular NVG Design

b. Preventive Maintenance
A modular NVG design would allow incorporation of preventative maintenance procedures to current maintenance schedules. Removing abrasive components such as sand would decrease the maintenance downtime while extending the life of the overall system. A modular design would allow the goggles to be easily "broken-down" and cleaned in the way someone might breakdown a weapon for cleaning.

c. Tester Compatibility
PNVGs will require routine inspections for image qualities such as resolution and gain that are currently performed using the newly purchased ANV-126 Hoffman testers. The ANV-126 tester has two ports to accommodate the two objective lenses found in current NVG designs. However, the *four* objective lenses found on the PNVG will prevent technicians from performing these critical checks using the tester's current design. The tester would require extensive modification to accommodate the four objective lenses.

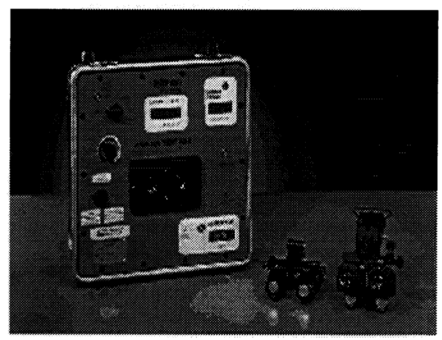

Figure 4. Hoffman AN-126 Tester

According to the tester's item manager, the Air Force recently spent approximately $5M outfitting units with these new high-tech testers. A modular design would allow the PNVG to easily integrate with the new ANV-126 tester by allowing the technician to separate the goggle sides and independently inspect them in the tester. The tester would still require minor modifications such as an adapter plate and power cord. The cost associated with these modifications would pale compared to a complete redesign and/or purchase of the new testers.

d. Optics
It's assumed the lenses on any future NVG designs will eventually require repairs due to normal wear. The complexity of the folded optics on the PNVG's outboard objective lenses is beyond the repair capabilities of both technicians and support equipment currently in the field. Based on the problems described earlier, returning to a depot-level repair system is a highly undesirable scenario.

A modular lens design would solve this dilemma. Lenses could be designed in modular sections and would incorporate the complex folded optics found in the outboard objective lenses. Additionally, the PNVG eyepiece lenses incorporate a two-section lens design. Any damage to either of the sections will require the replacement of both lenses. Like the objective lenses described earlier, repair of these lenses is beyond the capabilities of both technicians and equipment currently in the field.

Lens modules could be designed with bayonet-type fitting like those found on camera lenses. This would allow for quick repairs to damaged lenses. Modular lenses would also allow NVGs to be quickly modified with different coated lenses to meet various cockpit and mission configurations. The ability to easily change lenses will so ensure the ability of the PNVGs to evolve with the development of new optical coatings and lens configurations.

e. Pivot Adjustment Shelf Components

A system utilizing individual components for its pivot adjustment shelf would provide several advantages. It would allow the technician to replace the specific faulty sub-component instead of the entire assembly. Cost savings are the obvious benefits realized with this concept. Another benefit would be allowing technicians to disassemble the NVG for preventive maintenance as described above.

Conclusion

Lessons learned in recent and not-too-distant conflicts demand inter-changeable components and rapid repair capabilities in modern weapon systems. Users have grown to rely heavily on night vision technologies and expect these important systems to be available when needed in the next conflict. Any future NVG system must be easily maintained at the field level.

Although these design suggestions would require some investment, they are long over due. Their incorporation would certainly yield a product that's much easier to use, maintain and sustain during any future war-environment. The current monocular housing and PAS designs were great 15 years ago, but have been slow to evolve into more maintenance and user-friendly designs. There are many improvement opportunities available for those willing to invest in them.

The push in optical and tube design that PNVG's have made needs to be met with a similar advances platform design. Hopefully this will spark innovation in creating a new NVG mount design that blends weight concerns with both the functionality and sustainability of the devises.

Tomorrow's combat missions will be built on the assumption of the availability of night vision goggles and regardless of their complexities, will be expected to be available and ready for mission use-not awaiting repairs. The advent of Panoramic Night Vision (PNVG) escalates this concern. The PNVG will have twice as many lenses and tubes as do conventional NVGs. Logically, the potential for system failure is multiplied by as many.

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BIOGRAPHY

MSgt Mike Sedillo is the Superintendent, Visual Display System's Branch at the Air Force Research Laboratory. He maintained NVG systems for ten years and helped write two NVG technical orders and several Life Support-related manuals. He recently spent 5 years teaching NVG maintenance as the senior military instructor at the Aircrew Life Support technical school. He has a BS in Occupational Education and is currently assisting in the test and evaluation of the PNVG system.