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Night Vision Goggle Cockpit Integration

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ABSTRACT

Retroactively introducing night vision goggles to aircraft whose initial design did not account for them often poses safety and operational concerns. The addition of extra devices, such as Night vision goggles (NVG), are of particular concern in the fighter community. Fighter pilots must continue to contend with where to stow the NVG's during landing and take-off phases of flight until an ejection-safe NVG is fielded. This issue was highlighted recently when an NVG storage case became entangled in the flight controls of an A-10 attack aircraft. In the cargo and bomber communities, non-NVG compatible lighting often poses problems impacting the performance of the goggles. The prohibitive cost of major aircraft lighting modifications often force aircrews to improvise, adapt and overcome the limitations of the cockpit design to perform their missions. Occasionally aircraft System Program Office's (SPO) attempt to solve some of these problems with partially effective low-cost-alternative solutions. Retroactive solutions to effectively introduce and integrate NVGs must be well thought out with the safety of the aircrew as the primary concern. Methods of retrofitting the B-1 Bomber with a light-weight light-blocking curtain will be addressed. Additionally, results of a comparative study on various types of batteries will be presented, with possible solutions for eliminating NVG storage cases from the fighter cockpits concluding this paper.

INTRODUCTION

B-1 Curtain

As night vision goggle performance factors improve with such advances in optical lens coatings and reduced halo intensifier tubes, cockpit integration of these and other devises must constantly be considered in their development and implementation. Fabrics' qualities within the cockpits should be considered prior to introducing NVG's to new weapon systems. Fabrics with high-sheen characteristics reflect excess light causing glare, bloom, and system gain reduction in the NVG's. Many of these aspects although superficial in comparison to other flight issues, could negate the intended weapon system improvements.

An effort to improve the lighting in the B-1 was initiated at the B-1 SPO, Wright-Patterson AFB. Incompatible lighting in the front cockpit was corrected with the addition of a "Christmas Tree" lighting modification. This relatively inexpensive modification involves the installation of a string of NVG-compatible lights around the flight instruments, similar to those used to decorate a tree. These lights enable the crew to look under the NVG's to observe their instruments with their naked eyes without the light effecting the NVG's performance. However, since the Offensive and Defensive System Officers ("Back-seaters) don't require NVG's, lighting modifications were not made to their stations, leaving full spectrum lighting in the aft compartments.

This created problems with incompatible lighting flooding into the forward flight station degrading the NVG's performance. When exposed to excessive light, the NVG's auto-gain feature activates reducing the level of light intensification as a means of protecting the system from over light saturation. The gain reduction results in a general reduction of goggle performance and thus visual acquity to the user.

A means to stop the transition of light from the back to the forward area was needed. A prototype curtain was locally fabricated using a heavy black nylon fabric as a first attempt to stop the "bad" light. They selected a black fabric, as it was perceived to have lower reflectivity. The curtain was installed in the hallway between the fore and aft flight-stations, and then evaluated on the ground for form and function. When viewed through NVGs, the curtain appeared to "glow" from the transmission of non-compatible lighting through the weave of the fabric. A non-porous material was needed to stop the light's transmission. The evaluators improvised and modified the curtain by attaching material from a 35mm projector screen onto the back of the nylon curtain. Although this modification successfully blocked the transmission of light when viewed through NVGs, the resulting curtain was very bulky and concerns of reflectivity and general safety surfaced. The prototype curtain was sent to the Air Force Research Laboratory for spectral evaluation. The materials were immediately recognized as unsuitable for the typical military flight environment. The flammability of the nylon was the first concern and although the characteristics of the projector screen material were unknown, the safety and availability of the material would likely be questionable for general application in fielding the design.

<u>Sample Selection</u>

Efforts to find replacement materials began immediately. Materials had to have low reflectivity and low or zero light transmission. The materials also needed to be fire resistant for use in the cockpit environments.

The samples identified in Table-1 were selected for evaluation. Several of the samples, such as the flight clothing and B-52 material, were materials already approved for use in flight environments. The other samples were selected based on the known flame resistant qualities of both Nomex™ and fiberglass.

Flight clothing was selected for evaluation since their use in flight environments had already been established. Evaluating the flight clothing would also provide a baseline of reflectance levels already tolerated in the cockpits.

SAMPLE #	Description
1	Teflon-Coated Fiberglass (55-5)
2	Teflon-Coated Fiberglass (55-10)
3	Mylar Sandwich
4	Rubber-coated Cotton (two-sides)
5	Flat-Black Rubberized
6	Proto-type (Nylon/screen)
7	NOMEX-Black
8	NOMEX-Sage green
9	TCTO Curtain (Urinal)
10	B-52 Curtain-Cotton (un-coated)
11	B-52 Curtain-Cotton (rubber coated)
12	Green Flight Jacket (CWU-36/P)
13	Teflon-Coated Nomex (63-10)

Table 1. Subject Samples

<u>Set-up & Testing-Transmission</u>

The samples were measured for both light transmission and spectral reflective qualities using the following methods. During transmission evaluation, a Hoffman ANV-120 integrating sphere provided a calibrated light source for transmitting light through the subject materials. Any light transmitted was captured and intensified using an NVG (model AN/AVS-9) on the other side of the subject material. A luminance probe measured the goggles output luminance before and after the subject material was inserted in the light path between the light sphere and the NVG. Light transmitted through the fabric would be a percentage of the light originally measured in the sphere.

The NVG'S were focused to infinity and eyepiece lenses set at zero-diopter using the Hoffman ANV-126 and then centered on the sphere's output. After a brief NVG warm-up, the luminance in the sphere was adjusted to (1.980×10^{-3} Foot-Lamberts). A reference reading was recorded before measuring the samples by placing the luminance probe in the center of the sphere's output. The sample-reading would later be divided by this reference-readings to determine the percentage of light transmitted. Zero light transmission was the desired readings with eight samples meeting this goal. (see Table 2)

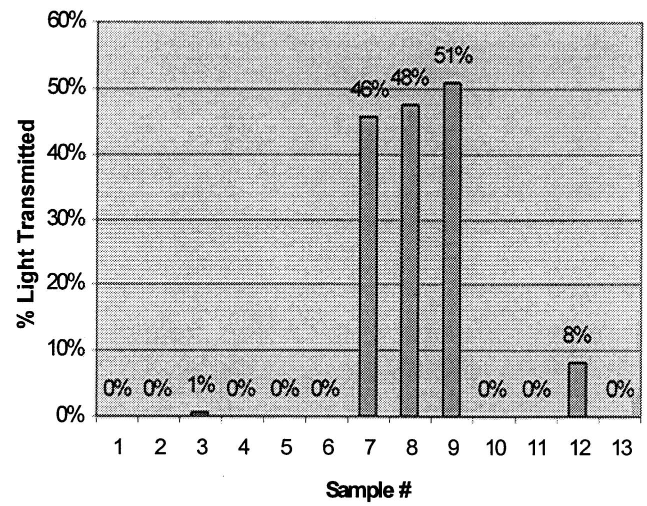
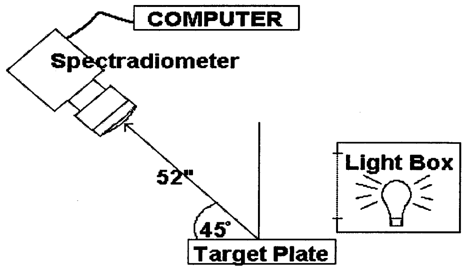


Table 2.Transmission

<u>Set-up & Testing-Spectral Reflectance</u>

Assessing the spectral reflectance qualities of the fabrics involved bouncing a 2856K light source off the subject materials and measuring the reflected light using a spectradiometer. A reference reading of the light source was directly measured to calculate the percentage of light reflected. This would provide the "spectral" reflectance of the material samples.

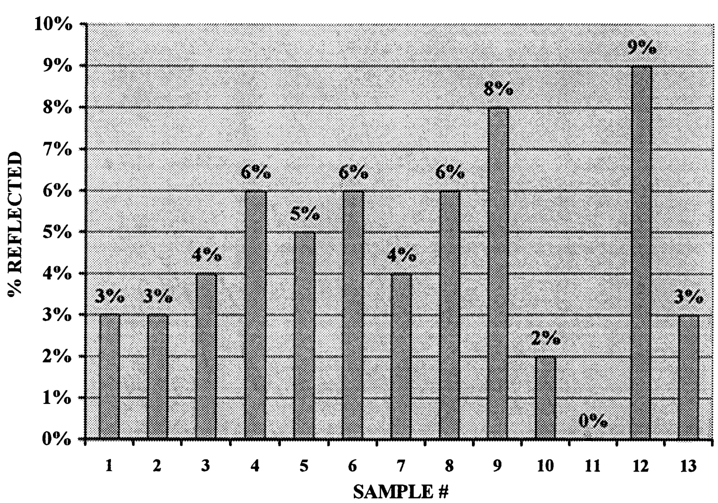
Figure 1. Measuring Spectral Reflectance



We placed the 2856K light source at a 90° angle to the sample surface and parallel to the original reference measurement axis. The spectradiometer was positioned 45° off the original measurement axis with the lens positioned 52" and centered from the target area to adjust for the focal length of the spectradiometer.
After a 15-minute warm up for the light source, the samples were positioned flat against the target plate and individually scanned and recorded on a laptop computer. The 2856k source was then placed in the sample location and centered in the field of measure for the spectradiometer. A scan of the light source was taken from the same 45° off axis target plate location. This reading would serve as the base line for division of the sample scans giving us the spectral reflectance qualities of the materials. See Table 3 for results.

Table 3. Spectral Reflection Results

The Teflon™-coated fiberglass and Nomex™ materials (samples 1, 2 & 13) performed well exhibiting relatively low reflectance and zero transmission. Just as important,



both qualities were achieved with a single fabric-layer design as opposed to Sample 11, which was the two-layer bulky B-52 curtain. Sample 5 performed well with zero-reflectance, but lacked the necessary flame protection qualities. The original curtain (sample #6), performed well in the transmission tests, but faired relatively poorly when assessed for reflection. It's bulkiness and flammability did not help it's case either. Sample #4 did well in the tests, but was not selected due to flammability concerns.

The relative high reflectivity of standard flight clothing was validated in both this study and in the 1994 B-1 Night Vision Enhancement Project Report, with the need to consider newer, lower reflective fabrics cited.[1]

The manufacture of the Teflon-coated materials, CS Hyde Company, boasts flame resistant qualities in the fiberglass samples, but these fabrics tended to be less pliable with a tendency to crease when folded. This would likely effect the long-term durability of the curtains. We selected the Nomex™ fabric because of it's pliability, flame resistant qualities and from it's prior approval for use in flight environments.

CS Hyde fabricated a proto-type curtain using the Teflon-coated Nomex™. The curtain was evaluated for form and function on the B-1 bombers at Ellsworth AFB, ND with highly positive results. If approved for use, the entire B-1 bomber fleet will likely receive copies of these new light-blocking curtains.

This study was successful in discovering a new lightweight material solution for inexpensively retrofitting the B-1 bombers for NVG operations. Additionally, the B-52 bomber fleet and other airframes could benefit by adopting this new curtain in exchange for their two-layer cumbersome cotton curtains.

Powering NVG's

Field units have loudly expressed their disdain for products powered by lithium or "exotic" batteries. They're justifiably concerned about with the availability of custom designed/special purpose batteries either prior to short notice deployment or when deployed to remote locations. There's a strong preference for a battery that's available at any "grocery store" worldwide.

Lithium batteries pose many logistical problems for supervisors in the field. Storage, disposal and transportation of these hazardous items increases the supervisors workload and budget requirements. With reduced manpower levels across the DOD, supervisors are adamant about minimizing procedures for common tasks. Having to dispose of environmentally hazardous lithium batteries is an arduous task they would prefer to eliminate. Additionally, shipping these items during deployments dramatically increases the paperwork and stress prior to a deployment. But is the use of lithium batteries justified with improved performance?

A two-fold study was conducted to both compare lithium and alkaline batteries and to base line the battery consumption rates of the four-tube (image intensifier) Panoramic Night Vision Goggle (PNVG) system. We anticipate the requirement of this data during final critical design and logistical decisions for the new Integrated PNVG (IPNVG) system.

During the test, we compared the 3.6V AA-size lithium and AAA-size alkaline batteries for endurance under maximum current draw conditions for the four-tube PNVG systems. The 3.6 volt lithium battery is the same battery currently used to power the goggles in the field. The "Banana" mount must have extender caps installed prior to using this AA full-sized battery. We also ran a test with a two-tube, AN/AVS-9 (F4949) NVG for comparison.

EQUIPMENT:

- 7101B Hewlett-Packard strip chart recorder
- 1980A Pritchard™ photometer S/N C-512
- VARIAC Voltage Control
- 4-Watt light bulb w/ holder
- Lab jack
- Foam core lined box 21" h x 20" w x 19" d
- SAFT™ Battery, Lithium 3.6V (AA-size)
- Kodak™ Battery, 1.5 (AAA-size)
- Energizer™ Battery, 1.5 (AAA-size)
- PNVG II, Configuration 4, S/N 0001
- PNVG I, Configuration 2, S/N 0002
- F4949D, S/N 3873

We lined a box with white foam core to provide a relatively even luminance into the goggles objective lenses. The box was placed on its side on an optical table and a lab jack placed six inches into the box. The jack would be used to elevate the goggles into the center of the box opening. A foam core baffle was then placed in front of the lab jack to reflect light back into the box cavity. We then centered a 4-watt light within in the box, in front of the baffle and plugged the light into a variable power controller. The lab jack was raised to approximately center the goggles to be measured in the box. (See Figure 2)

Once initial set-up was accomplished, we calibrated the photometer and placed the detector head perpendicular to the opening of the box approximately one meter from the box opening. This would allow sufficient distance to focus the detector onto the output of the subject NVG.

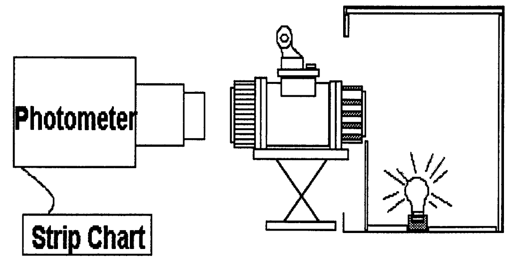


Figure 2. Battery Consumption Test

We selected the 20-minute measuring aperture and a (10:1) scale for low magnification and a strip-chart recorder was attached to the photometer to record the luminance levels. We checked the scale on the recorder and zeroed it to the output of the photometer and set the strip chart recorder to 10V and 1 in/hour scale as a compromise between sensitivity and readability.

The goggles were positioned onto the lab jack and the photometer was focused onto the output of the left channel of the F4949 goggles, and the left-central channel of the PNVG's. We adjusted the 20-minute aperture of the photometer's detector to be overfilled by 2/3 to maximize luminance input. With the basic test set-up accomplished, we turned out the lights and started the strip chart recorder. The photometer measurement aperture was opened and the goggle battery pack switched "ON".

The variable power controller for the 4-watt light bulb was "zeroed" then switched "ON". While watching the luminance level on the photometer, we slowly increased the light bulb's intensity. The intensity was carefully adjusted until the goggles out-put leveled off, indicating activation of the goggles' protective gated power supply system. We then reduced the goggle output by 10% by reducing power to the 4-watt bulb.

Once initiated, we monitored the test hourly. The batteries all supplied consistent power as indicated by the level luminance readings on the strip charts. We concluded the tests when the readings on the strip chart "nosed over" indicating a drop in goggle output luminance caused from a lack of sufficient current to the image intensifiers. At the conclusion of the tests, the photometer's aperture was closed and all associated equipment was shut down.

Two unusual observations were noted during the tests. The first was an asymmetric luminance degradation of the optical channels towards the end of the battery life when testing the four-tube PNVG systems. The output of the left out-board channel was noticeably brighter than the adjacent optical channels. The luminance levels degraded from right to left with the right most channel being the most dim.

Another interesting characteristic we noted was a high rate of flashing in all optical channels when the PNVG I's with AAA batteries reached approximately 1.97 vdc. The image intensifiers began an on/off oscillation at a rate similar to the flash rate of the low battery indicator.

The four-tube PNVG's with the AA Lithium batteries averaged 7.45 hours while the other four-tube PNVG version averaged 11.18 hours using the AAA alkaline batteries. Both battery types would provide sufficient energy to power either a two-tube or four-tube NVG system on a typical 4-5 hour mission. (see Table 4.)

Using the aircraft's power to energize helmet accessories would be ideal for both the user and the maintainers. For the maintainers, a ship-side power supply would reduce the logistical footprint during deployments. However, maximum commonality in aircraft and man-side components must be stressed.

NVG In-flight Storage

Storing NVG' in a fighter cockpit poses serious concerns. Currently, NVGs are removed during critical phases of flight to include landings and take-offs. When removed, today's goggles are placed in their storage case, which typically is the size of a lunch box. When the carry strap of one of these cases became entangled in the flight controls of an A-10 attack jet, the immediate removal of the straps was orderd Air Force wide. However, the issue of storing the case in the jet remains. With the tight confines of today's modern fighter aircraft, there's hardly room for any additional items. The ideal solution would be to simply eliminate the need to remove and store the NVG's. The helmet-mounted Integrated Panoramic Night Vision Goggle (I-PNVG) will solve this as it will remain attached to the pilot's helmet during all phases of flight. They will have the capability to be removed from the pilots' field of view by simply rotating them to an up and stowed position, but will drop down during ejection to provide wind blast protection. (see Figure 3)

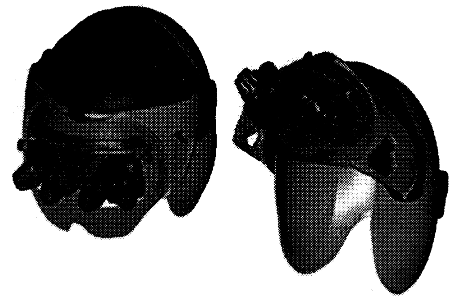


Figure 3. Integrated PNVG

However, until these goggles are fielded, an interim solution to safely stow the today's goggles needs to be devised. An early attempt to solve this problem was initiated by designing an NVG storage bracket for attachment to the inside of the cockpit wall. The goal was to find a design solution that would not require aircraft modifications, would be inexpensive to produce, and could integrate in a maximum number of airframes.

The first bracket design utilized an ANVIS-style NVG helmet mount that allowed the NVG's to easily click in and out of the bracket. The intent of this design approach was to use the unoccupied oxygen regulator storage bracket as a mounting point. Since the actual oxygen regulator would be attached to the pilot's torso harness in-flight, the regulator *storage* bracket would be available for use during flight to mount an NVG storage bracket. (see Figure 4)

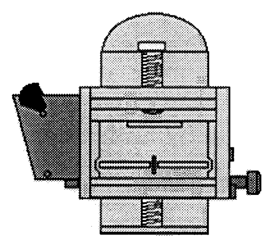


Figure 4. Initial NVG Cockpit Mount-Version I

However, during field evaluation we discovered a couple of problems with this design. The pilots we interviewed explained that the wall-mounted regulator brackets were seldom in serviceable condition due to their flimsy mounting points. In the F-16, the bracket is attached to a thin sheet of a plastic-like material. This caused the NVG storage bracket to wobble during use. The bracket moved during installation and removal making it unstable to use.

Additionally, the position of the wall bracket posed some possible spatial disorientation issues. Since the bracket was positioned on the lower right wall behind the ejection seat, the pilots would have to turn their heads down and to the right during storage and removal of the NVGs. Placing the head at these axis, particularly at night could cause the pilots to experience some levels of spatial disorientation.

The pilots recommended we alter our design to mount the bracket on the canopy's hand rail, or what they referred to as the "towel rack." The hand rails are used to manually lift the canopy open during an emergency ground egress. The right-side hand rail is used to stow a portable floodlight. When not flying, the floodlight is attached to the right lower panel, but during night flights, is brought forward and attached to the rail via a small, adjustable clamp. We redesigned our NVG storage bracket to mount to the same style clamp as is used with the floodlight. (See Figure 5)

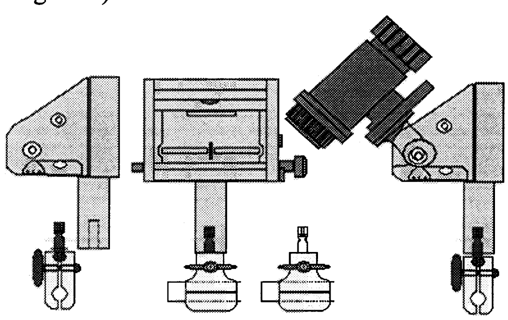


Figure 5. NVG Cockpit Mount-Version II

The design is simple and inexpensive to produce. We sent the newly designed mount to the 113th F-16 Fighter Squadron in Terra Haute Indiana for further assessment and are awaiting feedback to finalize the design. If the design proves worthy of implementation, flight safety in the fighters could be improved with the removal of the NVG storage case. Pilots will be able to safely store their NVG's without having to fumble for storage cases, and the storage cases will no longer pose threats as loose objects within the cockpit. This improved design should also minimize spatial disorientation events by allowing the pilots to store their NVG's without having to turn their heads.

In conclusion, we must ensure integrating future cockpit technologies are well considered to minimize or eliminate retrofitting with band-aid solutions. When selecting power sources for these technologies, logistical support issues must be considered on how they'll impact the manning at the gaining support units, regardless of the edge these additions contribute. If they can't be sustained logistically, they're of no use to the war-fighter. Recommend inviting troops from "the trenches" during early design considerations to add insight to potential designs and identify unanticipated limitations.

ACKNOWLEDGEMENTS

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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 spent 5 years teaching NVG maintenance as the senior military instructor at the Aircrew Life Support technical school. He has a BS in Education and recently received an associates degree in Aircrew Life Support Technologies. MSgt Sedillo is currently engaged with the joint Integrated Panoramic Night Vision Goggles program.