The Dark and Mysterious World of Night Vision:

Understanding ANVIS/NVIS/NVG Technology in the Cockpit

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Editor's note: This is Part I of a two-part series on night vision technology. This month's article focuses on the technology now available to the general aviation industry. Part II, in next month's Avionics News *issue, discusses the issue of creating an ANVIS-compatible cockpit.*

Part 1: How ANVIS Came to be in the Civil Cockpit

In the beginning, helicopters were pretty much fair-weather aircraft, really suited for day flight only. However, the incredible utility of a stationary flight platform that could land almost anywhere was simply too tempting to ignore, and it wasn't long before that situation changed dramatically.

In particular, military operations had high demands for stealthy night travel, and search and rescue required the ability to see under poor visibility. Twin-engine operation made IFR operation a reality, and full navaids and external lighting made some night operations possible. The last piece of the operational puzzle was enhanced night vision for flight crews, which enabled them to carry out high-risk, insertion and pursuit night missions, which previously seemed impossible.

ANVIS (aviator's night vision imaging system), NVIS (night vision imaging system) and NVG (night vision goggles) are image-intensifying systems allowing aircrews (and others) to see under conditions that normally would look impenetrably dark to the unaided eye. Military requirements for night combat, search and rescue, and surveillance operations drove the development of these systems, but they eventually would spin off into many civil applications.

The first NVIS systems date back to World War II. These systems were designed for tanks to provide night vision shooting capability. They were shrunk down to rifle-mountable systems and became the legendary "starscopes" favored by snipers for low-light shooting.

Relentless technological improvements reduced the components and power requirements to the point where the systems eventually could be helmet/headset-mounted, and NVG systems were born, which provided face-mounted goggles for the wear-

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er. These were adopted by military special forces worldwide for night operations and gave them the ability to work in what seemed like darkness to everyone else.

The tactical advantages in almost every combat and surveillance situation were enormous to those who were NVG-equipped, and the technology became incredibly popular.

First-generation goggles had monocular sensors, so there was no depth perception, which could be disconcerting to the wearer — like wearing bifocals for the first time. Eventually, this shortcoming was remedied with more complex dual-sensor systems, which restored normal stereo vision and full depth perception to the wearer. At that point, the goggles had the potential to work safely for aircrews and dramatically improve their ability for night flight operations. This is how ANVIS systems were born.

The basic building block of all these systems is an image-intensifying tube with high sensitivity to near infrared light as well as some visible light. Near infrared light is made of longer, normally invisible wavelengths beyond 750 nanometers. All of these wavelengths are collected and amplified, then translated to a single common shorter visible wavelength our eyes *can* see. In this way, an image (usually green in color) can be formed from the wideband light energy that is present, but either too low in level to be useful to the human eye or outside the normal wavelength range of human vision.

NVIS devices are similar to forward-looking infrared (FLIR) viewers; however, ANVIS/NVIS/NVG devices look at longer visible and near infrared light, while FLIR emphasizes long-wave thermal infrared detection. In FLIR systems, this allows a hot object (a living person, for example) to be clearly seen against a cooler natural background. ANVIS allows general vision in very low ambient light; FLIR allows thermal infrared radiating objects to be identified from the surrounding visual clutter.

Both systems have significant utility in an aircraft, but they do very different tasks. Their optical relationship is shown below.

It wasn't long before civil pilots wanted what military pilots had for night flight operations. In particular, law enforcement, search and rescue, border patrol, forestry and medevac/EMS all wanted the benefits of ANVIS during their night flight operations. The requirement all these groups share is the need to see clearly during night flight, both for safety reasons and to aid in their primary missions.

For law enforcement, night pursuit, especially in cluttered settings where unexpected obstructions can be anywhere, ANVIS has proven to be a useful tool, but it can be overloaded by high levels of outside light (headlights, streetlights, fires). As a result, it works best when needed in more rural or completely unlit situations.

For border patrol, search-and-rescue and forestry night operations, which almost always are in low-light conditions, the use of ANVIS is especially suitable and can make many night operations as effective as daylight ones. These settings often can be completely devoid of terrestrial light sources; therefore, goggles do especially well here.

Medevac/EMS operations see the greatest use of ANVIS when forced to make a pick-up or transfer in rural, highway or deserted locations, and in helping navigate obstructions for landings. As light levels increase, or in the presence of bright point sources (street lights, headlights, building lights), the goggles can become overloaded right at landing and might need to be flipped up out of view.

It is also possible to enhance night operations via external floodlights, such as Nightsuns. In this case, however, unaided (no goggle) vision is used. If the Nightsun is equipped with a fold-down infrared passband filter (which makes the light appear dark to the normal eye but floods the area with infrared), goggles can be used even when outside conditions would make goggles unusable (heavy overcast, fog and snow) or if stealth is required.

Whether ANVIS works for your situation can be a complicated set of trade-offs, and you should consider some trial flight experiments with goggles and cockpit lighting turned off before undertaking all the costly

<-Shorter Wavelengths | Longer Wavelengths->

Visible Light: 450nm to 750 nm 0.45 to 0.75 microns	**Near IR:** 750nm to 1300nm 0.75 to 1.3 microns	**Mid IR:** 1300nm to 3000nm 1.3 to 3 microns	**Thermal IR:** 3000nm to 30,000nm 3 to 30 microns
What the human eye sees	Present in starlight, and used in IR electronics	Fiber-optic systems and IR remote controls	IR emissions from hot objects
-----------------What ANVIS Sees----------------| |---------What the EYE sees---------|			|--What FLIR sees--| (~3-1- microns)

It is the overlap of sensitivity between vision and ANVIS that creates cockpit problems.

changes needed in the cockpit to fully implement an NVG-compatible environment.

Night vision goggles are a bit of a mixed blessing. While they can allow astounding night vision improvements (up to >50,000 times light amplification), they have a limited tolerance for unwanted or stray light, or light in the wrong color spectrum. These issues create serious integration problems when goggles are used in an "off-the-shelf" cockpit design, and using goggles effectively is a complex logistical problem as a result.

This situation is further complicated by the fact that goggle use is typically only 10 to 20 percent of total flight time for most aircraft; therefore, cockpit designs must be both daylight and NVG compatible, regular night flight compatible and satisfactory to the FAA from a safety standpoint. This is no easy task.

Operationally, the weight and forward position of goggles on the head can induce considerable neck strain in flight crews and, after an hour or so, the thrill of having night vision is somewhat offset by a headache, neck strain and backache. In addition, goggles are "fixed-focus" devices, meaning they can be set for close or far vision, but not both at the same time. Staring through goggles is similar to reading for an extended period with reading glasses — the eye adapts to that focus and has trouble refocusing on different distances. Most people find eyestrain is an inevitable aspect of wearing goggles, and the older you are, the more significant this problem becomes.

ANVIS (as opposed to NVIS) systems generally allow the user to look down without the goggles to examine the instrument panel, then forward through the goggles to see outside terrain, thus avoiding some light overload and focus problems.

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Some Common Operational Questioins:

• **Can ANVIS systems see in total darkness?** Absolutely *not* — there *must* be some optical energy in the passband of the goggles for any image to be visible. Land-based goggles (for foot soldiers) include infrared flood lights to make vision possible in enclosed, completely dark spaces, such as caves or tunnels, but this is not so simple in flight. Some ships use an infrared filtered external floodlight (such as Nightsun) to improve visibility in bad conditions. ANVIS does *not* magically make vision possible in heavy fog, sand storms or rural conditions with overcast skies — although it will certainly improve the vision. It also will *not* reveal many terrain or obstruction features that are matte or generally non-reflective in nature (such as cables, girders, etc.), as it is the *reflected starlight* the goggles detect.

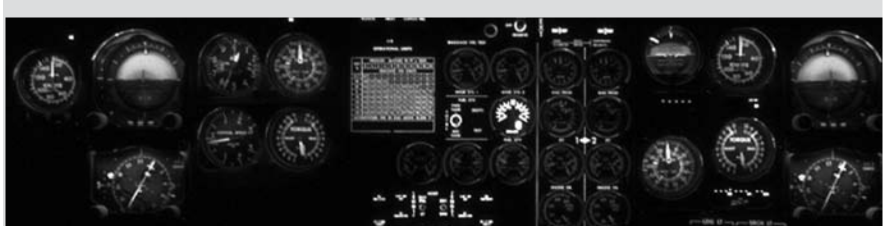
• **Why do night vision images look so "grainy?"** Images are constructed from scattered individual photons and do not have the fully filled appearance of daylight images. Because so little light is involved, each individual photon actually is visible under very low-light conditions.

• **Can a NVIS system allow me to see somebody hiding in the dark?** No, unless they happen to be illuminated by some external light and have reflective clothing. NVIS is *not* FLIR; it cannot really see "hot" objects in the dark — although they might be visible because of other reflected light.

• **Why do cockpit colors have to be shifted to the blue/green region for NVIS compatibility if the flight crew looks down at the instruments *without* the goggles?** This is the best of all the questions. This color shift must be done because the goggles provide huge light amplification, 10,000 to 50,000 times or more. As a result, even small amounts of trace or reflected light in the red to infrared passband of the goggles seriously degrades goggle operation, and it causes blooming and severe visual distraction for aircrews. Even a single glance down with bad cockpit lighting would "blind" the wearer, possibly leading to a flight accident.

• **Is it light if we (humans) can't see it?** Yes, it is simply beyond the passband of *our* eyes, but not for all organisms or optical systems.

• **Can ANVIS/NVG systems be damaged by strong light?** Yes, you can irreparably damage the image intensifier by exposing it to too much light (especially bright sunlight) or bright lights in a dark field, as well as with laser pointers. Damage can include small burn spots or general loss of operation. However, if your goggles are self-powered, always check your batteries first before assuming the goggles are damaged. Battery life can be quite short, so remember to pack some spares.



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And, of course, the final annoyance is the batteries on some self-powered systems could go dead in flight, causing unexpected loss of night vision at the worst time.

It is a requirement for ANVIS use for the cockpit lighting of every night system to be modified to adapt to the special color and low-intensity requirements of this system. (This is covered in detail in the next installment of this two-part series, when we look deeper inside all the technical issues of creating an ANVIS-compatible cockpit.)

The allowable night color spectrum is essentially restricted to the range between violet/blue to yellow, with most lighting implemented in green, centered around 550nm. Standard white or blue/white cockpit illumination is not permitted during ANVIS operations; so the changes can be significant to an existing cockpit.

This color restriction creates some problems when amber and red indicators must be present for FAA safety reasons. Keep in mind, through goggles, everything is the same color — only when looking down, under the goggles, can the flight crew actually determine the true colors in the cockpit instrumentation. Colors from amber to red cause serious blooming in goggles, even at low levels; therefore, stray emissions of these colors can effectively ruin night vision operations. Yellow is the ANVIS warning color, but of course, it still looks green if seen through goggles.

In particular, even if "out-of-band" colors, such as red, are permitted in some indicators based on low likelihood of activation during normal operations, suppression of their infrared signatures must be done, or the resulting bloom in the goggles will make them unusable.

We will examine the technical cockpit problems and their practical solutions in the next issue of *Avionics News*.

Night Vision Quick Terms

ANVIS Aviator's Night Vision Imaging System.

BLOOMING Refers to distorted NVG images surrounded with obscuring halos of light caused by optically overloading the goggles.

CHROMATICITY Color as defined by the CIE chart of XYZ Color Space, Visit this website for a detailed graphical explanation: www.cs.rit.edu/~ncs/color/t_chroma.html.

CLASS A, B or C This is the optical passband definition for specific types of NVIS systems, NVIS-A, and so on. Goggles are of both a specific "generation" and "class."

FLIR Forward-Looking Infrared: A system detecting objects by their long-wave infrared temperature emissions. A system related to NVIS, but in a different optical band.

GENERATION 1st, 2nd, 3rd, etc. Refers to the developmental/performance level of NVG systems. Infrared Light longer than red, above 750nm, although human vision usually stops at about 680nm.

LED Light-Emitting Diode: Solid-state "lamps" with long lifespans (100,000 hours plus).

MIL-STD-3009 The governing specification for ANVIS systems and compatible cockpit radiation.

NR NVIS Radiance: Illumination within the optical passband of the NVIS system.

NRa NVIS Radiance: Illumination within the optical passband of the Class A NVIS system.

NRb NVIS Radiance, illumination within the optical passband of the Class B NVIS system.

NVG Night Vision Goggles.

NVIS Night Vision Imaging System.

NVIS GREEN Green color indicator compatible with NVIS systems (can be Class A, B or C).

NVIS YELLOW Yellow color indicator compatible with NVIS systems (can be Class A, B or C).

NVIS RED Red color indicator compatible with NVIS systems (can only be Class B or C).

PASSBAND The optical wavelength widow (from x nm to y nm) that permits light to pass. ❑