The Dark and Mysterious World of Night Vision:

Understanding ANVIS/NVIS/NVG Technology in the Cockpit

BY WALTER SHAWLEE 2

Editor's note: This is Part 2 of a two-part series on night vision technology. Last month's article focused on the technology available to the general aviation industry. Part II discusses how general aviation is using the technology.

Part 2: ANVIS Science and Getting to ANVIS Compatibility

The basic building block of all night vision systems is an image-intensifying tube, which has high sensitivity to near infrared (IR) light as well as some visible light. Near IR light is made of longer, normally invisible wavelengths beyond 750 nanometers.

All of these longer wavelengths are collected and amplified, then translated to a single common shorter wavelength our eyes actually can see. In this way, an image (usually green in color) can be formed from the wide-band 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.

Technology is relentless, so there are inevitably many versions, called generations, of NVIS. The most commonly used version outside of aviation is first-generation NVG equipment, which uses a simple image-intensifier tube (essentially, a single-element light amplifier tube) and displays on a green phosphor target to the eye. This can provide optical gain of several thousand times and has a few minor operational issues, such as edge blurring, sometimes an audible "whine" from the high-voltage inverter used to energize the tube, some problems with "blooming" from high-intensity lights, and a bit of an after-image.

How ANVIS (aviator's night vision imaging system), NVIS (night vision imaging system) and NVG (night vision goggles) work:

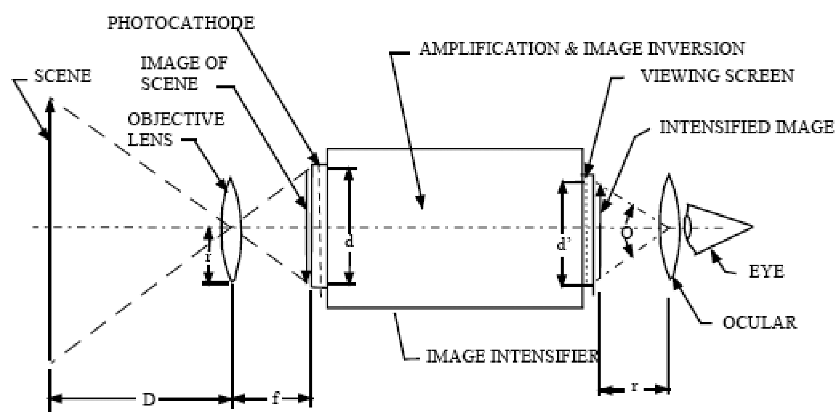


Figure C-1. Diagram of an image intensifier.

First-generation systems, however, are inexpensive and quite versatile, with operational life spans of up to 10,000 hours. Thousands are sold annually as night-spotting scopes for outdoor and hunting applications, as well as for general IR detection. A large number of them are exported from Russia to the United States and worldwide.

Second-generation systems generally are restricted to more professional use because of their higher cost. These systems have an enhanced image intensifier with an MCP, or micro-channel plate, which dramatically boosts electron gains, producing a much brighter and sharper target image from even less light input.

Second-generation systems generally have better lenses and optics as well as quieter or silent power supplies. Export of this technology is generally restricted, but it is still surprisingly available.

Third-generation systems have further image-intensifier tube enhancements, with gallium arsenide (GaAs) added to the photocathode, as well as an ion barrier film added to improve operational tube life. The improvements further enhance low-light performance, but with added cost.

There are many minor variations of this technology, called Gen 3 Omni II, III and IV. These, and more advanced systems, are significantly restricted for export. This generation is used most commonly for civil flight crews and military users, but with a hefty price tag.

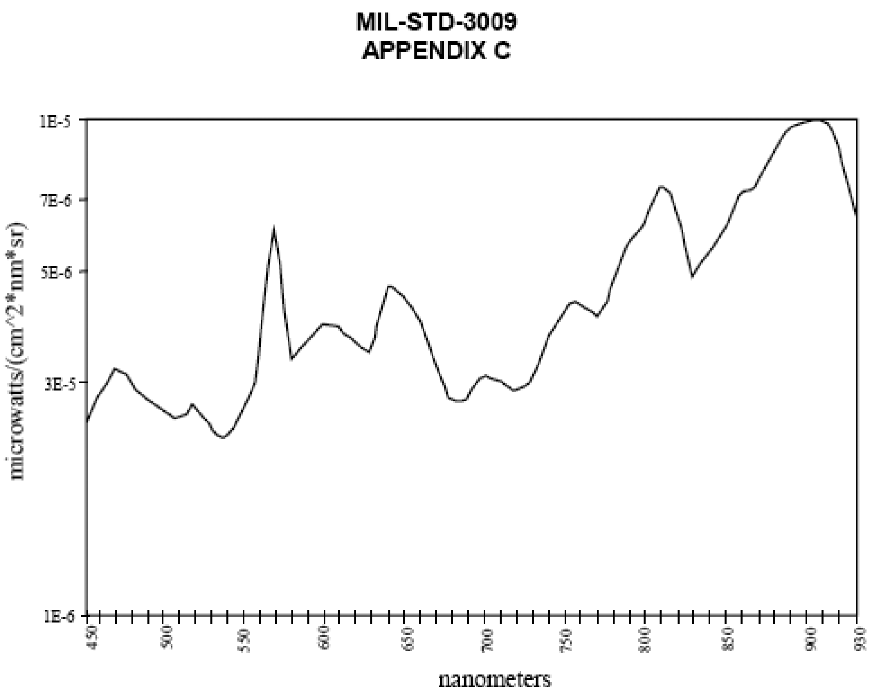
Fourth-generation systems removed the film added in third-generation systems, instead using a gated power supply to enhance operation. This gated or pulsed operation improves contrast and reduces blooming and visible halos. They generally enhance signal-to-noise ratios, so the random graininess or scintillation is largely eliminated.

These systems are not permitted for export or civil sales, and they represent the publicly disclosed state-of-the-art at the moment.

Ultimate optical gains in these advanced systems can be as high as 50,000 times, which poses some operational problems in the cockpit, as any stray light can seriously overload the display and such a wide visual dynamic range is hard to deal with. In addition, pilots sometimes must look down at the instruments with the goggles and, in this situation, cannot drive the goggles into an overload condition without night vision and flight safety outside becoming seriously impaired.

How do these different generations compare in terms of usability? The common method for comparison is the use of a vehicle-sized distant target of known contrast (30 percent) to the background viewed under starlight.

The Available "Night" Ambient Light That Makes Night Vision Possible:



The spectral content above 700-750nm, which is present in starlight, is not visible to the unaided human eye. NVIS systems convert this available energy to shorter wavelengths the eye can see; therefore, allowing vision under circumstances normally appearing "dark" to the unaided human eye. Keep in mind, this light energy must still be present to see something.

To use ANVIS systems, the cockpit must be altered to provide compatible low-light levels at the correct optical wavelengths; if not, the residual light will overwhelm the goggles, making them useless. This cockpit emission is called "(A)NVIS radiance" (AR or NR) and is the total optical emission from 450nm to 930nm. The specific colors within this range are defined as a given chromaticity.

People have various ideas about what constitutes "NVG-compatible," or how to measure or test for it — many of which are ineffective. Making a cockpit environment compatible is a complicated integration task, as many different systems (from different manufacturers and with different dynamic performance) need to be brought into some kind of optical harmony for dimming to low levels and correct coloration/chromaticity and IR suppression.

While there are approved NVIS colors for green, yellow and red (all with highly reduced IR signature), it is important to realize they all look the same when goggles are used — all appearing green to the eyes of the flight crew. For this reason, most goggles used for flight allow the aircrews to look down, below the actual image intensifier, to see the instruments (and their original colors) directly.

Continued on following page

Characteristic	Gen 2 Goggles	Gen 3 Goggles	Gen 4 Goggles
Detection Range (meters)	To 170m	To 240m/360m depending on specific versions	To 430m
% Improvement Over Gen 2	0%	40% to 110%	153%
Typical Deployed Systems	Night-spotting scopes, early goggles	AN/AVS-6 stereo AN/PVS-5 originally AN/PVS-7 currently	

ANVIS/NVIS/NVG TECHNOLOGY

Continued from page 39

Performance of the environment, lighting and ANVIS system was described originally in MIL-L-85762, and is now in the updated specification MIL-STD-3009. It is important to realize the sensitivity of each generation of goggles is different, and there are three different NVIS classes, complicating the problems of compatibility as well as exact color and level requirements. There is no single definition of "compatible."

Different Types of NVIS Systems

Class A NVIS is defined as having a low-end optical cut-off of 625nm, allowing nap-of-the-earth flight and the widest possible use of ambient light to identify terrain features. This cut-off makes the use of red and full-color multi-function displays impossible (as anything in the orange-red region would flood the goggles), but it provides high-optical sensitivity in flight.

This system is common in low-flying helicopters and sometimes is called rotary-wing NVIS. The compatible cockpit illumination, or NVIS radiance, is called NRa.

Class B NVIS is defined as having a low-end optical cut-off of 635nm, allowing wider color use in avionics systems, but it has reduced sensitivity as a result. This system generally is used in higher-flying aircraft, where terrain following is not required, and sometimes is called fixed-wing NVIS. The compatible cockpit illumination, or NVIS radiance, is called NRb.

The proposed Class C NVIS has a low-end optical cut-off of 670nm, allowing full use of red, and it has a secondary peak at 540nm, allowing the use of HUD systems working in this color range. The compatible cockpit illumination, or NVIS radiance, is called NRc.

Generally speaking, NRa systems can be said to work everywhere, but NRb systems might interfere with Class A goggles. Class C goggles are newly defined, very specialized and require a custom light environment.

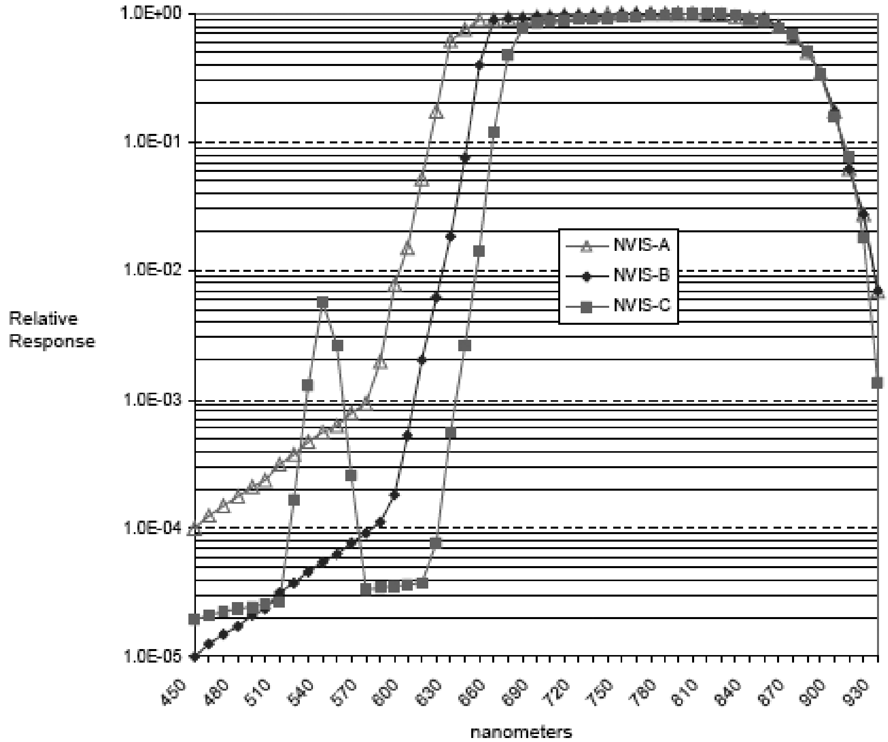


Figure 1.
Relative spectral response characteristics of Classes A,B and C NVIS.

Note from the response curves (in the graph above), the goggles are about 1,000 to 10,000 times less sensitive to light in the 450 (blue) to 600 (orange-red) range than in their design target of about 750nm in the IR range. As light moves to the redder region (longer wavelengths), the difference drops to a factor of 10 to 100, which explains why goggles are seriously affected by even a small amount of light in the wrong spectral range.

To achieve compatible operation, it is critical to suppress emissions in the red to IR range from cockpit displays, lights and equipment as much as possible. This is done by selection and design or through optical filtering of the light emitters.

Unfortunately, the eye is not a very useful tool for making this judgment. For example, things that look green (including LEDs) also could contain significant IR energy at the same time, which the unaided eye cannot detect. This unwanted IR signature manifests as bright blooming (and subsequent loss of sensitivity) in ANVIS goggles.

While blooming is easy to see, it is not so easy to characterize. Many people struggle with colored filters (typically green) to achieve NVIS compliance, but often this is inadequate, leading to many cockpit problems during goggle use because of un-suppressed high IR emissions even in green-colored displays.

Making the Cockpit Compatible

When looking at lamps, filters, panels and other illuminated objects, your cockpit instrument optical energy emitted must be within the NVIS radiance range and chromaticity compatible with your type of aircraft and ANVIS system. In the helicopter world, they are concerned mainly with

NRa or Class A (A)NVIS systems and compatible illumination.

Generally speaking, emission must be suppressed above 600nm (red and beyond), and acceptable emission normally peaks at about 530-550nm (aqua to green). You generally would select illumination filters identified as NVIS Green A for normal lighting and NVIS Yellow A for alerts in a helicopter.

Colors & Filtering

Optical filters often can be found with a white illumination source (either LEDs or lamps). This technique is a holdover from originally using and filtering "white" incandescent lamps, and it is the least efficient way to achieve NVIS compatibility today.

White LEDs have the least efficiency, lowest life span, narrowest operating temperature range, significant IR signatures, and poor energy content in the desired green region. The use of deep green LEDs eliminates the unwanted IR signature and provides nearly perfect chromaticity and radiance with virtually no secondary filtering.

Panel or instrument lighting that is intrinsically NRa-correct consumes less power, is less expensive to build, is more reliable and is easier to implement than a complex filtered system.

NVIS lamp filters are a restricted item for export, adding many complications to materials handling, security and purchasing; therefore, new design strategies for ANVIS compatibility make a good deal of sense.

The use of broadband optical filters (originally designed for plasma displays) makes it possible to suppress IR emissions from any type of optical display (from a CRT to gas plasma) while retaining normal operation and color. These filters can be useful in converting a cockpit to an ANVIS-compatible environment.

To aid in analysis and correction of lighted cockpit systems, an IR passband filter (which passes IR but blocks visible light) can be used in front of the test item; 720nm is a good filter choice as it passes virtually all IR emissions. Re-examine the test item with even early first-generation goggles — anything now visible is IR (unwanted) emission and will require IR-specific optical filtering, not a color filter to eliminate.

Backlit LCD displays can be especially difficult to filter adequately; however, neutral gray IR filter films and materials are readily available to solve this problem. Keep in mind, colored optical filters might not have IR blocking ability, despite their big shift in visible color.

While LEDs generally are narrowband emitters (except for white), colors of yellow and warmer might contain unexpectedly large amounts of IR emission, and even green LEDs might have enough IR emission to be unacceptable under the huge image-intensification factor of ANVIS goggles.

Color filters to achieve the desired chromaticity and IR blocking filters to suppress out-of-band IR signatures typically are required to achieve full NVIS compliance.

Dimming

One common problem in an integrated cockpit is that systems can dim differently. This problem often can be improved by adding series resistors (adequately rated for power) from the common dim bus to individual items that are simply too bright. Series resistance, diodes or even power zeners (to create a large dimming voltage gap) all can serve to equalize the distributed bus to specific problem units.

NVG operations generally occur with the dimming bus set below 12V DC in a 28V aircraft — often a problem zone for some systems, especially those with LED backlighting, which might extinguish at 9V DC, a typical NVG setting.

Matching NRa levels is a complicated task and requires a broadband NVIS radiometer (optical power meter) with sensitivity corrected for the blue-green spectrum. Most of the optical test instruments widely available are for fiber-optic-based measurements, which all are red to infrared, and thus have poor or no blue-green characteristics. Some optical spectrum analyzers and NVIS radiometers work over the full required range and provide good analytical tools for the design and characterization of NVIS systems.

Watch out for some surplus optical analyzers, as they are meant for fiber-optic analysis and only cover 600-1600nm. They can see unwanted IR emissions but not allowable emissions from 400-600nm; therefore, they have limited utility in NVIS testing except as unwanted IR detectors.

Acceptance Testing

Final acceptance testing of a completed cockpit design is always up to the flight crews with the specific ANVIS helmet hardware they select, but the task can be made easier by some careful design and measurement in advance.

Even for ships tasked for NVG operation, actual NVG use is often less than 10 to 20 percent of flight hours, and for the other 80 to 90 percent of the time, the systems must be usable in conventional lighting conditions.

There are many onboard systems that cannot be chromatically modified because of FAA flight safety and approval issues, and every cockpit winds up being a blend of optimized and somewhat incompatible items in the civil world.

Small IR signatures not affecting operational use or occurring only during critical airframe waning functions often are of no consequence to the real NVIS environment, but they can be a big approval distraction while people

Continued on following page

ANVIS/NVIS/NVG TECHNOLOGY

Continued from page 41

argue over them.

There are several good reading tests outlined in the MIL standards, which allow for quick judgment of ANVIS suitability. The general rule is, nothing illuminated on the panel should force more than a 2-point larger font increase in the test text to achieve readability once the cockpit lights are on. The panel lighting generally reduces overall sensitivity of the goggles and makes reading the reference text more difficult.

Faults with NVIS-compliant hardware can manifest as blooming, annoying glare and significantly reduced sensitivity of the goggles because of light interference. Impaired external vision can be a serious safety issue, and the cockpit cannot be accepted as compliant until the flight crew feels there is no degradation in this area, regardless of measurements, standards or test data.

This can be a frustrating experience, but good communication and frequent exchange of data between vendors, flight crews and installers make it feasible, although unavoidably time-consuming the first time.

Have fun in the dark. ❑

If you have comments or questions about this article, send e-mails to avionicsnews@aea.net.

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.

GENERATIONS 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.