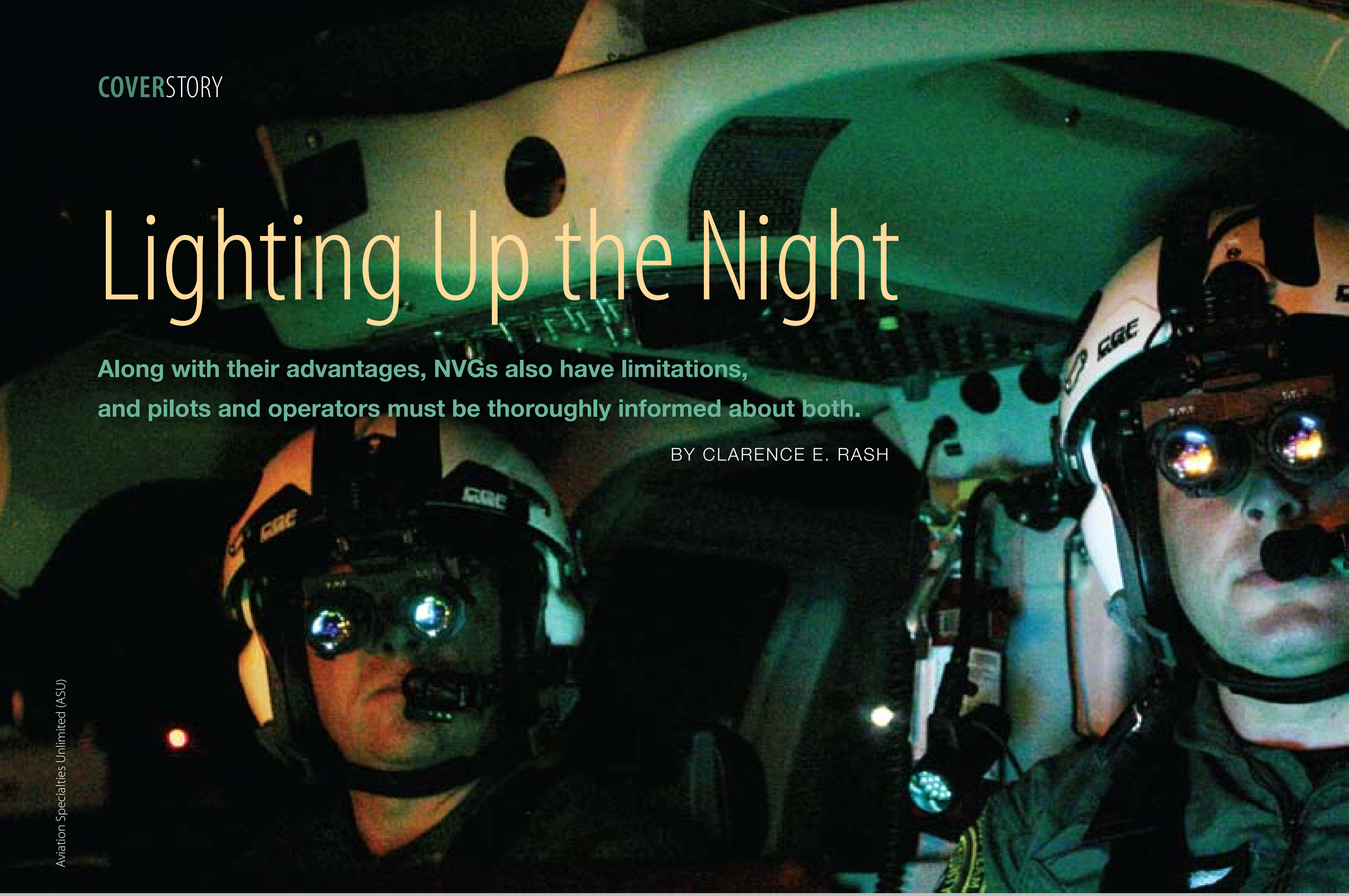

Lighting Up the Night

Along with their advantages, NVGs also have limitations, and pilots and operators must be thoroughly informed about both.

BY CLARENCE E. RASH

Aviation Specialties Unlimited (ASU)

Users of night vision goggles (NVGs) are acutely aware of the advantages these devices offer in improving a pilot's ability to see in darkness and enhancing safety during night flight. They may be less cognizant, however, of some of the limitations that NVGs impose on night visual performance.

As NVG use in helicopter operations increases, pilots and operators must be educated about the capabilities and limitations imposed by NVGs, and the often-misleading effects of NVG imagery on visual perception.

Since 1999, when the U.S. Federal Aviation Administration (FAA) issued the first supplemental type certificate (STC) to permit use of NVGs by a civilian helicopter emergency medical services (HEMS) operator in the United States, NVG use has steadily grown.[1,2]

Brighter Nights

The brighter scene provided by NVGs — which makes it possible for pilots to see objects not otherwise visible — increases situational awareness, enhances safety and improves flight capability.

However, as impressive as these devices are at increasing the ability to see and fly at night, the technology, as many researchers say, "does not turn night into day." Unfortunately, too many pilots carry a mental model of daytime flight into their night operations, not being aware that, even with NVGs, their visual performance is compromised.

Perhaps the most common mistake by pilots flying with NVGs is "overflying" the aircraft — flying too fast to allow for adequate reaction to the sudden detection of an obstacle.

Such a scenario raises the need for two additional operational metrics that should be, but often are not, applied to NVG flight: detection range and recognition range. Detection range is the distance at which the presence of an object can be discovered; recognition range is the distance at which a detected object can be identified as belonging to a category, such as wires, buildings, vehicles or people.

Limitations

The consequences of specific limitations of NVGs (Table 1, p. 16) can be significant, and their cumulative effects in degrading night visual performance provide pilots with a challenging flight environment.[3]

For example, because pilots rely on the quantity and quality of visual information available to them to make decisions that are integral to maintaining safe flight conditions, the NVG's

Although NVGs enable pilots to see objects in the dark that are not visible to the naked eye, they do not "turn night into day."

reduced field of view (FOV) and resolution are the most significant limitations.

The NVG's 40-degree circular FOV is smaller than the normal human binocular visual field of 120 degrees (vertical) by 200 degrees (horizontal). Pilots describe their impression of viewing the outside world through NVGs as "looking through a soda straw." To compensate for this reduced FOV, pilots must continuously scan from side to side, as well as up and down. This is fatiguing, and on long flights, pilots may fail to maintain the scan. Although unaided side and "look-under" vision is important to scan instruments and identify colors of lights outside the cockpit, unaided side vision also is important in detecting other aircraft outside the NVG FOV.

A new generation of cockpit lighting design will allow for internal viewing of instruments but will not artificially lower NVG performance.

NVG resolution, which describes the amount of detail in a scene, has greatly improved since the earliest NVGs were manufactured. Those early devices gave pilots visual acuity of approximately 20/50 — or the metric equivalent, 6/15.[4]

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Modern systems provide resolution equivalent to 20/25 (6/8) visual acuity. However, obtaining this high resolution requires optimal environmental conditions, including high illumination and contrast, clear weather, and an absence of fog, dust and glare sources. During any flight, it is not uncommon for available resolution to be as good as 20/25 and as poor as a completely washed out image.

In addition to reduced FOV and resolution, NVGs have additional limitations that include reduced depth perception, loss of color information and the presence of image noise — which looks sparkly and obscures fine detail — and other defects.

External vs. Internal Light

Perhaps the most overlooked limitation of NVGs is their inability to discriminate between light originating from the external world and light originating inside the cockpit.

NVGs have an "automatic gain control (AGC)," which reacts to the ambient light level by increasing the multiplication factor when the ambient light level decreases and decreasing the multiplication factor when the ambient light level increases. As a result, if the lower light levels in the cockpit can be "seen" within the FOV of the NVGs, then the AGC reduces the system gain. This results in a system gain that is not optimized for the external illumination level, possibly reducing the pilot's night vision capability. This dilemma has driven a new generation of cockpit lighting design, one that will allow for internal viewing of instruments but will not artificially lower NVG performance.[5]

Weighing the Advantages

Operators must weigh the advantages and disadvantages before deciding whether to implement an NVG system.

CareFlight, an Australian HEMS operator, recommends in its *NVG Implementation Guide* that any operator contemplating implementation of an NVG system first conduct a detailed analysis and formulate a business plan.[6]

"Operators considering the NVG technology often have to justify a significant investment and expenditure without having … any clear way of determining the suitability and benefits to their particular operation, let alone a method to determine the implementation costs," the guide says. "If after the analysis phase, it is decided that NVG technology *is* justified in the particular organization, operators are then confronted with trying to implement both a new piece of equipment and a fundamentally new cultural shift."

It outlines a 13-step plan that begins with an analysis of night mission data — "night scene landing conditions, search requirements, terrain encountered and frequency of night operations" — to help determine whether NVGs would benefit the operation. Other steps include determining the availability and cost of NVG technology; assessing client perceptions and expectations; deciding what cockpit modifications are required, their costs and how they should be implemented; and outlining NVG training requirements.

The guide recommends training one or two crews, which then fly for at least three months using NVGs before the operator evaluates their experiences and determines whether changes are needed before other crews undergo training.

"Remember, NVGs will only be of benefit if [their] implementation and ongoing management are properly resourced and structured," the document says.

NVG Limitations and Their Effects on Performance

Visual Limitation	Effects on Performance
Reduced field of view (FOV)	40 degrees circular (normal FOV is 120 degrees by 200 degrees)
Reduced resolution (visual acuity)	Early systems (20/40); newer systems (20/25), but greatly dependent on ambient lighting[1]
Loss of color information	Typically shades of green (or white) against black background
Degraded standard night vision	Reduced light adaptation resulting from NVG imagery in eyes
Presence of halos	Although halo sizes have been reduced in newer systems, bright lights appear surrounded by a glow (halo)[2]
Distortion	Reduced binocular depth perception; problematic only in older devices
Reduced depth perception	Decreased ability to judge distances; can induce visual illusions
Presence of image "noise"	Obscures fine details; problem increases as ambient light level decreases; appears as sparkles or scintillations
Image defects	Can cause distractions; obscures fine detail; defined as various cosmetic blemishes in the NVG imagery resulting from dirt or debris trapped in the system during the manufacturing process (e.g., black spots and white spots)

NVG = night vision goggles

Notes

1. 20/40 vision (metric equivalent 6/12) refers to a person's ability to see clearly from a distance of 20 ft (6 m) what someone with normal vision sees from 40 ft (12 m). The metric equivalent of 20/25 vision is 6/8.
2. The primary concern involves halos that are significantly different in size between right and left NVG tubes and within the FOV. The images do not fuse and appear out of focus.

Source: Clarence E. Rash

Table 1

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Education and Training

Once a decision has been made to implement an NVG system, operators and pilots must be thoroughly familiar with the advantages and disadvantages of flight using NVGs. This can be achieved through educational courses covering the essentials of night vision technologies, offered by the operator or an outside training company. These courses should consist of material that describes the basic principle, design, operation, and care and maintenance of NVGs. FAA requirements also call for instruction in relevant aeromedical factors such as depth perception, range estimation and visual illusions; scene and terrain interpretation; and abnormal operational characteristics of NVGs.

An educational program is not necessarily limited to classroom lectures but may also include use of an eye lane — in which a pilot stands at one side of a dark room and looks through NVGs at an eye chart on the opposite wall to learn to focus the goggles; a terrain board — a miniature layout of the type of terrain where the pilot will operate; or a simulator, as well as computer-based or Web-based training.[7]

Following an initial classroom introduction to the principles and limitations of NVGs, the next step is to allow pilots to experience these limitations firsthand via operational flights. The chief goal of an effective flight training program is to expose pilots to the perceptual differences in NVG-aided night flight, compared with unaided day flight, to dispel any misconception that NVGs can turn night into day.

Flight training should be conducted by a qualified NVG pilot and should include both basic and mission-specific tasks and maneuvers, including NVG operational checks and the impact of internal/external lighting systems on NVG performance; airspace surveillance and obstacle avoidance; departures and approaches, with and without NVGs; NVG malfunction procedures; recovery from inadvertent entry into instrument meteorological conditions; and transitioning between NVG-aided flight and unaided flight.[8]

Research and experience show that pilots need early and continued exposure to the night environment across a broad range of operational conditions and environments to develop good night flying skills and practices.[9]

Hardware

NVG hardware considerations fall into three categories: procurement, inspection, and maintenance and repair. Available systems may include the earliest generation (GEN) of NVGs, or they may be the newest — GEN III+ intensifier tubes; they are priced accordingly (see "How NVGs Work,").

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As with any electro-optical system, sustained proper operation requires regular inspections. On a nightly basis, pilots should conduct a brief preflight operational inspection. First, NVGs should be checked for functionality — checking battery installation and tube luminance balance — and for obvious

How NVGs Work

The night vision goggles (NVGs) used in civil aviation rely on image intensification (I^2) technology to convert both visual light — which can be seen by the naked eye — and near-infrared (IR) light — which cannot — to electrons, which are multiplied (amplified), and converted back into visible light.

All aviation NVGs that are in common use are binocular, helmet-mounted systems with two I^2 tubes and a dual compartment power pack that gives the pilot immediate backup power. The power pack uses AA alkaline batteries.

NVG tubes have three basic components — a photocathode, a microchannel plate and a phosphor screen. All three are sandwiched between two sets of optical elements — input optics that focus the incoming photons onto the photocathode and an eyepiece that focuses the outgoing photons into the eye.

Since their introduction into military aviation in the 1970s and their integration into civil aviation in the 1990s, NVGs have undergone several design changes — mostly based on improvements in I^2 tube performance — referred to as generations (GEN). The current commonly available version, which was fielded in the 1980s, is referred to as GEN III. GEN III+ was developed in 2001 and was intended to be designated as GEN IV (filmless), but was changed back to a thin film design. Technical characteristics of GEN III+ NVGs include a fully overlapped, binocular 40-degree circular field-of-view, and a resolution designed to result in visual acuity of 20/25 (6/8).[1]

User adjustments are provided for fore-aft positioning, vertical height, tilt, interpupillary distance, and both objective and eyepiece focus. If one or more of these adjustments is incorrect, NVG imagery can be degraded.

— Clarence E. Rash

Note

1. 20/25 vision (metric equivalent 6/8) refers to a person's ability to see clearly from a distance of 20 ft (6 m) what someone with normal vision sees from 25 ft (8 m). Normal vision typically is considered to be 20/20 (6/6).

damage, such as a loose mounting bracket, broken knobs/levers or loose wires. Second, all user adjustments should be verified as functional and then optimized by the pilot for his or her requirements. Most important of these is the focus setting. If a commercial NVG focusing apparatus is available, it will produce the most precise focus setting; otherwise, focusing should be performed according to the manufacturer's instructions. Finally, cockpit lighting should be viewed through the NVGs to ensure compatible instrument lighting, dimming as required.

The FAA and NVG manufacturers recommend that NVGs be inspected every 180 days.

Routine care and maintenance by users is necessary to reduce problems during regular use. NVGs should be handled like any device that has delicate optical components in which optical alignment is essential to proper operation.

When NVGs are not in use, the lens caps should be in place, and the device should be stored in its case to reduce the possibility of shock and damage. Batteries should be removed if the device will not be used for an extended period. Regular care should include cleaning lenses with high quality lens cleaning supplies and wiping the exterior with a soft cloth to remove dirt.

If a system is suspected of being defective, repairs should be performed only by certified repair personnel. Users should never attempt to disassemble NVGs.

A logbook should be used for each set of NVGs and should contain a record of hours of usage, reported problems, inspection and calibration dates, and repairs. A record of battery use will ensure that extremely fatigued batteries will not be placed in operational use.

Guidelines and Regulations

The FAA and other civil aviation regulatory agencies around the world have recognized the advantages of using NVG devices in civil aviation to enhance situational awareness during night operations. Standardized terminology, policies and practices are essential for the efficient and effective incorporation of NVGs into civil aviation — and this is only possible through government regulation.

Progress in developing comprehensive regulations and guidelines has been slow, spanning the nearly two decades since NVGs began appearing in civilian helicopters.

Nonetheless, over this period, the FAA has been soliciting and incorporating recommendations from various aviation organizations. In 1999, as a collaborative effort involving the FAA and RTCA,[10] along with EUROCAE, the European Organisation for Civil Aviation Equipment, special committees were formed to develop guidance for introducing NVGs into civil aviation. This effort produced three guidance documents.[11] In addition, in September 2004, the FAA published a technical standard order that discussed minimum performance standards.[12]

Clarence E. Rash is a research physicist with 30 years experience in military aviation research and development. He has authored more than 200 papers on aviation display, human factors and aircraft protection topics.

Notes

1. Salazar, G.J.; Nakagawara, V.B. "Night Vision Goggles in Civilian Aviation." *FAA Aviation News* Volume 40 (May–June 2001): 21–22.
2. FAA. *Fact Sheet: Helicopter Emergency Medical Service Safety*. June 8, 2010. <www.faa.gov/news/fact_sheets/news_story.cfm?newsId=6763>.
3. Rash, C.E.; Manning, S.D. "On the Flight Deck, Lighting Must Satisfy a Variety of Needs." *Human Factors & Aviation Medicine* Volume 50 (September–October 2003).
4. 20/50 vision (metric equivalent 6/15) refers to a person's ability to see clearly from a distance of 20 ft (6 m) what someone with normal vision sees from 50 ft (15 m). Normal vision typically is considered to be 20/20 (6/6).
5. Rash, Manning.
6. CareFlight. *NVG Implementation Guide*. Northmead, New South Wales, Australia.
7. Ruffner, J.W.; Antonio, J.C.; Joralmon, D.Q.; Martin, E. "Night Vision Goggle Training Technologies and Situational Awareness." *Proceedings of Advanced Technology Electronic Defense System Conference/Tactical Situational Awareness Symposium*. San Diego. 2004.
8. New requirement per August 2009 modification to U.S. Federal Aviation Regulations Part 61.31(k), "Additional training required for night vision goggle operations."
9. Ruffner et al.
10. RTCA — organized in 1935 as the Radio Technical Commission for Aeronautics but now known only by the abbreviation — is a nonprofit corporation that develops consensus-based recommendations regarding communications, navigation, surveillance, and air traffic management system issues. RTCA functions as a federal advisory committee, and its recommendations are used by the FAA as a basis for policy, program and regulatory decisions.
11. The documents are DO-268, *Concept of Operations, Night Vision Imaging System for Civil Operators*, published in 2001; DO-275, *Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment*, published in 2001; and DO-295, *Civil Operators' Training Guidelines for Integrated Night Vision Imaging System Equipment*, published in 2004.
12. FAA. Technical Standard Order TSO-C164, *Night Vision Goggles*. 2004.