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CONCEPT OF OPERATIONS
Night Vision Imaging System for Civil Operators

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Prepared by SC-196
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FOREWORD

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EXECUTIVE SUMMARY

The hours of darkness add to a pilot's workload by decreasing those visual cues commonly used during daylight operations. The decreased ability of a pilot to see and avoid obstructions at night has been a subject of discussion since aviators first attempted to operate at night. Technology advancements in the late 1960s and early 1970s provided military aviators some limited ability to see at night and therein changed the scope of military night operations. Continuing technological improvements have advanced the capability and reliability of night vision imaging systems to the point that they are receiving increasing scrutiny are generally accepted by the public and are viewed by many as a tool for night flight.

Simply stated, night vision imaging systems are an aid to night VFR flight. Currently, such systems consist of a set of night vision goggles and normally a complimentary array of cockpit lighting modifications. The specifications of these two sub-system elements are interdependent and, as technology advances, the characteristics associated with each element are expected to evolve. The complete description and performance standards of the night vision goggles and cockpit lighting modifications appropriate to civil aviation are contained in the Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment.

An increasing interest on the part of civil operators to conduct night operations has brought a corresponding increased level of interest in employing night vision imaging systems. However, the night vision imaging systems do have performance limitations. Therefore, it is incumbent on the operator to employ proper training methods and operational procedures to minimize these limitations to ensure safe operations. In turn, operators employing night vision imaging systems must have the guidance and support of their regulatory agency in order to safely train and operate with these systems.

The role of the regulatory agencies in this matter is to develop the technical standard orders for the hardware as well as the advisory material and inspector handbook materials for the operations and training aspect. In addition, those agencies charged with providing flight weather information should modify their products to include the night vision imaging systems flight data elements not currently provided.

An FAA study (DOT/FAA/RD-94/21, 1994) best summarized the need for night vision imaging systems by stating, "When properly used, NVGs can increase safety, enhance situational awareness, and reduce pilot workload and stress that are typically associated with night operations."

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1 INTRODUCTION

The desired integration of aviation night vision imaging system (NVIS) technology into civil aviation requires the successful interface of numerous disciplines. Presently, three documents will be used to fully and completely describe the various elements of a successful NVIS program, the complete discussion of these NVIS disciplines is distributed across the Concept Of Operations, the Minimum Operations Performance Standards (MOPS) for the NVIS Equipment, and the Training Guidelines. There is crossover from document to document and the Concept of Operations contains some areas more specific than others when there is no associated document more appropriate to the information. Items such as hardware specifications or training are specifically provided for in the MOPS and Training Guidelines and therefore, are treated superficially by the Concept of Operations.

1.1 Purpose

The purpose of this document is to describe the concept of operations supporting the implementation of aviation NVIS technology into the national airspace system (NAS) by civil aviation operators. This paper discusses the terminology, capabilities, limitations, operations, training and other supporting agencies for NVIS. The focus of the paper is the safe and efficient implementation of NVIS during various phases of flight. The goal of implementing NVIS into the NAS is to improve an operator's situation awareness during night visual flight rule (VFR) operations without compromising safety.

1.2 Background

In 1971, the US Army adopted night vision devices for use in aviation. By the late 1980's many military trained night vision goggle (NVG) helicopter pilots were in the civil industry. The demand for night vision technology was spreading to the civil sector.

In 1989, Rocky Mountain Helicopters, a Part 135 air ambulance operator, informed the FAA of their intention to start employing NVGs in their single pilot operations.

In 1990, the Federal Aviation Administration (FAA) stated that Night Vision Enhancement Devices (NVEDs) are considered an appliance and that if an applicant wanted approval for operation with an NVED, a minimum operational performance standard (MOPS) would need to be developed and accepted by the FAA.

In 1994, the FAA released a study, Night Vision Goggles in Emergency Medical Service (EMS) Helicopters. The report stated that "NVGs are a viable tool during the enroute and terminal operations during certain EMS scenarios. When properly used, NVGs can increase safety, enhance situational awareness, and reduce pilot workload and stress that are typically associated with night operations."

In 1996, Rocky Mountain Helicopters again approached the FAA with a plan to utilize NVGs. The FAA coordinated with the US Army to review training, operational, and goggle standards. The FAA determined that the critical issues to be resolved were pilot training, NVG certification standards and approval, and aircraft lighting. In order to expedite the program, the first several operator approvals were completed through the Supplemental Type Certification (STC) process.

The FAA also coordinated effort with the Helicopter Operations Sub-Committee of the European Joint Aviation Authorities (JAA). It was agreed between all parties that NVGs were to be utilized as an aid to VFR flight and that VFR minimums would not be reduced.

1.3 Premise

Night vision imaging systems are an aid to night VFR flight.

2 TERMINOLOGY

2.1 Night Vision Goggles

A NVG is a binocular appliance that amplifies ambient light and is worn by an operator. The NVG enhances the operator's ability to maintain visual surface reference at night.

2.1.1 Type

Type refers to the design of the NVG with regards to the manner in which the image is relayed to the operator. A Type 1 NVG is one in which the image is viewed directly in-line with the image intensification process. A Type 1 NVG is also referred to as "direct view" goggle. A Type 2 NVG is one in which the image intensifier is not in-line with the image viewed by the operator. In this design, the image may be reflected several times before being projected onto a combiner in front of the operator's eyes. A Type 2 NVG is also referred to as an "indirect view" goggle.

2.1.2 Class

Class is a terminology used to describe the filter present on the NVG objective lens. The filter restricts the transmission of light below a determined frequency. This allows the cockpit lighting to be designed and installed in a manner that does not adversely affect NVG performance.

2.1.2.1 Class A

Class A or "minus blue" NVGs incorporate a filter, which generally imposes a 625 nanometer cutoff. Thus, the use of colors in the cockpit (e.g., color displays, color warning lights, etc.) may be limited. The blue green region of the light spectrum is allowed through the filter.

2.1.2.2 Class B

Class B NVGs incorporate a filter that generally imposes a 665 nanometer cutoff. Thus, the cockpit lighting design may incorporate more colors since the filter eliminates some yellows and oranges from entering the intensification process.

2.1.2.3 Modified Class B

Modified Class B NVGs incorporate a variation of a Class B filter but also incorporates a notch filter in the green spectrum that allows a small percentage of light into the image intensification process. Therefore, a Modified Class B NVG allows operators to view fixed heads-up display (HUD) symbology through the NVG without the HUD energy adversely affecting NVG performance.

2.1.3 Generation

Generation refers to the technological design of an image intensifier. Systems incorporating these light-amplifying image intensifiers were first used during WWII and were operationally fielded by the US military during the Vietnam era. These systems were large, heavy and poorly performing devices that were unsuitable for aviation use, and were termed Generation I (Gen I). Gen II devices represented a significant technological advancement and provided a system that could be head-mounted for use in

ground vehicles. Gen III devices represented another significant technological advancement in image intensification, and provided a system that was designed for aviation use. Although not yet fielded, there are prototype NVGs that include technological advances that may necessitate a Gen IV designation if placed into production. Because of the variations in interpretations as to generation, NVGs will not be referred to by the generation designation.

2.1.4 OMNIBUS

The term OMNIBUS refers to a US Army contract vehicle that has been used over the years to procure NVGs. Each successive OMNIBUS contract included NVGs that demonstrated improved performance. There have been five contracts since the mid 1980s, the most current being OMNIBUS V. There may be several variations of NVGs within a single OMNIBUS purchase, and some NVGs from previous OMNIBUS contracts have been upgraded in performance to match the performance of goggles from later contracts. Because of these variations, NVGs will not be referred to by the OMNIBUS designation.

2.1.5 Resolution and Visual Acuity

Resolution refers to the capability of the NVG to present an image that makes clear and distinguishable the separate components of a scene or object.

Visual acuity is the relative ability of the human eye to resolve detail and interpret an image.

2.2 Aviation Night Vision Imaging System (NVIS)

The Night Vision Imaging System is the integration of all elements required to successfully and safely operate an aircraft with night vision goggles. The system includes at a minimum NVGs, NVIS lighting, other aircraft components, training, and continuing airworthiness.

2.2.1 Look Under (Underview)

Look under is the ability of operators to look under or around the NVG to view inside and outside the aircraft.

2.3 NVIS Lighting

An aircraft lighting system that has been modified or designed for use with NVGs and which does not degrade the performance of the NVG beyond acceptable standards, is designated as NVIS lighting. This can apply to both interior and exterior lighting.

2.3.1 Design Considerations

As the choice of NVG filter drives the cockpit lighting design, it is important to know which goggle will be used in which cockpit. Since the filter in a Class A NVG allows wavelengths above 625 nanometers into the intensification process, it should not be used in a cockpit designed for Class B or Modified Class B NVGs. However, since the filter in a Class B and Modified Class B NVGs is more restrictive than that in a Class A NVG, the Class B or Modified Class B NVG can be used with either Class A or Class B cockpit lighting designs.

2.3.2 Compatible

Compatibility, with respect to an NVIS system, includes a number of different factors: compatibility of internal and external lighting with the NVG, compatibility of the NVG with the crewstation design (e.g., proximity of the canopy or windows, proximity of overhead panels, operability of controls, etc.), compatibility of crew equipment with the NVG and compatibility with respect to color discrimination and identification (e.g., caution and warning lights still maintain amber and red colors). The purpose of this paragraph is to discuss compatibility with respect to aircraft lighting. An NVIS lighting system, internal and external, is considered compatible if it adheres to the following requirements:

1. The internal and external lighting does not adversely affect the operation of the NVG during any phase of the NVIS operation.
2. The internal lighting provides adequate illumination of aircraft cockpit instruments, displays and controls for unaided operations and for “look-under” viewing during aided operations.
3. The external lighting aids in the detection and separation by other aircraft.

NVIS lighting compatibility can be achieved in a variety of ways that can include, but is not limited to, modification of light sources, light filters or by virtue of location. Once aircraft lighting is modified for using NVGs, it is important to keep in mind that changes in the crewstation (e.g., addition of new display) must be assessed relative to the effect on NVIS compatibility.

2.4 NVIS Operation

A night flight wherein the pilot maintains visual surface reference using NVGs in an aircraft, which is NVIS approved.

2.4.1 Aided

Aided flight is flight with NVGs in an operational position.

2.4.2 Unaided

Unaided flight is a flight without NVGs or a flight with NVGs in a non-operational position.

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3 SYSTEM DESCRIPTION

3.1 NVIS Capabilities

NVIS generally provides the operator an image of the outside scene that is enhanced compared to that provided by the unaided, dark-adapted eye. However, NVIS may not provide the user an image equal to that observed during daylight. Since the user has an enhanced visual capability, situational awareness is generally improved.

Forward looking infrared (FLIR) devices, synthetic vision devices and aircraft head-up displays (HUDs) can also provide imagery and information useful during night operations. However, the scope of this document is limited to NVIS.

3.1.1 Critical Elements

The following critical elements are the underlying assumptions in the system description for NVIS:

1. Aircraft internal lighting has been modified or initially designed to be compatible.
2. Environmental conditions are adequate for the use of NVIS (e.g., enough illumination is present, weather conditions are favorable, etc.).
3. The NVIS has been properly maintained in accordance with the minimum operational performance standards.
4. A proper preflight has been performed on the NVIS confirming operation in accordance with the continued airworthiness standards and training guidelines.
5. The operator(s) has been properly trained and meet recency of experience requirements.

Even when insuring that these conditions are met, there still are many variables that can adversely affect the safe and effective use of NVIS (e.g., flying towards a low angle moon, flying in a shadowed area, flying near extensive cultural lighting, flying over low contrast terrain, etc.). It is important to understand these assumptions and limitations when discussing the capabilities provided by the use of NVIS.

3.1.2 Visual Acuity

The typical unaided eye with a daytime visual acuity of 20/20 may yield a nighttime unaided visual acuity to 20/200 or worse. The improved resolution capability of newer generation NVGs may allow for a comparative visual acuity of 20/30 or better under optimal conditions.

3.1.3 Situation Awareness

Situation awareness, being defined as the degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time, is improved at night when using NVG during NVIS operations. This is achieved by providing the operator with more visual cues than is normally available under most conditions when operating an aircraft unaided at night. However, it is but one source of the factors necessary for maintaining an acceptable level of situational awareness.

3.1.3.1 Environment Detection and Identification

An advantage of using NVIS is the enhanced ability to detect, identify, and avoid terrain and/or obstacles that present a hazard to night operations. Correspondingly, NVIS aid in night navigation by allowing the aircrew to view waypoints and features.

Being able to visually locate and then (in some cases) identify objects or areas critical to operational success will also enhance operational effectiveness. Finally, use of NVIS may allow an operator to detect other aircraft more easily.

3.1.4 Emergency Situations

NVIS generally improve situational awareness, facilitating the operator's workload during emergencies. Should an emergency arise that requires an immediate landing, NVIS may provide the operator with a means of locating a suitable landing area and conducting a landing. The pilot must determine if the use of NVIS during emergencies is appropriate. In certain instances, it may be more advantageous for the operator to remove the NVG during the performance of an emergency procedure.

3.2 Night Vision Goggles

A Night Vision Goggle is head-worn, and consists of a binocular imaging assembly, a mounting interface, operator controls, a power module and a low-power indicator. The binocular imaging assembly (herein referred to as binocular) is attached to a head borne platform (usually a flight helmet) via the mounting interface. Generally, the mounting interface allows the binocular to detach during adverse G-loading conditions. Operator controls enable the user to position the binocular for optimum line of sight, field of view and focus. A battery power module provides sufficient electrical power for operation of the binocular. The power module includes both primary and secondary sources. Each source is capable of independently operating the binocular, and for equal duration. The power module may also include provisions to interface with an external power source. In this instance, the power module supplies uninterrupted power to the binocular in the event of failure of the external power source. A low-power indicator signals the user to select the spare power module source when primary power is no longer sufficient to operate the binocular. The low-power indicator is visible to the user.

The binocular consists of two independent channels, with each channel presenting collimated scene information directly to one eye. Filters designed to facilitate the compatibility of cockpit lighting are provided in each channel. Channels contain one (or more) objective lens(es), image intensifier tube(s) and eyepiece lens(es). Binoculars may include other optical components, including: combiners, prisms, beam-splitters, cameras, and displays. In addition to scene information, binoculars may present injected HUD information. Each channel contains one (or more) image intensifier tube(s). The image intensifier consists of a photo-cathode, micro-channel plate, phosphor screen and power supply. The power supply automatically adjusts gain for optimized performance. In some instances the image intensifier power supply is remotely located. The image intensifier is not susceptible to electromagnetic interference.

3.2.1 NVG Head Up Display (NVG HUD)

The NVG HUD provides critical, real-time, flight, navigation, and aircraft data in the field of view of the NVG. The NVG HUD enables the operator to obtain flight information while using the NVGs, minimizing the requirement to look under the NVGs

for this information. This further improves situational awareness and spatial orientation while reducing workload during NVIS operations.

A NVG HUD consists of an electro-optical display device, typically mounted to one of the channels of the NVG. A typical NVG HUD consists of a display unit and a display driver. The display unit may be a small Cathode Ray Tube or Flat Panel Display with associated optical combiner components. The display driver receives aircraft instrumentation data and converts it into symbology for display unit injection into the operator's NVG field of view.

3.3 NVG Limitations

3.3.1 NVG Design Characteristics

There are certain limitations inherent in the current NVG design. However, the enhanced visual capabilities outweigh the disadvantages.

3.3.1.1 Visual Acuity

The operator's visual acuity with NVGs is less than normal daytime visual acuity.

3.3.1.2 Field of View

Unaided field of view (FOV) covers an elliptical area that is approximately 120° lateral by 80° vertical, whereas the field of view of current Type I NVG systems is nominally 40° and is circular. Both the reduced field of view of the image and the resultant decrease in peripheral vision can increase the operator's susceptibility to misperceptions and illusions. Proper scanning techniques must be employed to reduce the susceptibility to misperception and illusions.

3.3.1.3 Field of Regard

The NVG has a limited FOV but, because it is head-mounted, that FOV can be scanned when viewing the outside scene. The total area that the FOV can be scanned is called the field of regard (FOR). The FOR will vary depending on several factors: physiological limit of head movement, NVG design (e.g., protrusion of the binocular assembly, etc.) and cockpit design issues (e.g., proximity of canopy or window, seat location, canopy bow, etc.).

3.3.1.4 NVG Weight & Center of Gravity

The increased weight and forward CG projection of head supported devices may have detrimental effects on operator performance due to neck muscle strain and fatigue. There also maybe an increased risk of neck injury in crashes.

3.3.1.5 Monochromatic Image

The NVG image appears in shades of green. Since there is only one color, the image is said to be "monochromatic". This color was chosen mostly because the human eye can see more detail at lower brightness levels when viewing shades of green. Color differences between components in a scene helps one discriminate between objects and aids in object recognition, depth perception and distance estimation. The lack of color variation in the NVG image will degrade these capabilities to varying degrees.

3.3.1.6 Ambient or Artificial Light

The NVG requires some degree of light (energy) in order to function. Low light levels, non-compatible aircraft lighting and poor windshield/window light transmissivity, diminish the performance capability of the NVG. It is the pilot's responsibility to determine when to transition from aided to unaided due to unacceptable NVG performance.

3.3.1.7 Daytime Use for NVGs

NVGs are intended to be used at night. NVGs will not be able to aid an operator in decreased daytime visibility conditions. In fact, exposure to bright light sources for extended periods could damage or significantly reduce the life of the intensifier tube.

3.3.2 Physiological and Other Conditions

3.3.2.1 Cockpit Resource Management

Due to the inherent limitations of NVIS operations, there is a requirement to place emphasis on NVIS related Cockpit Resource Management (CRM). This applies to both single and multiple operator cockpit environments. Consequently, NVIS flight requires effective CRM between the operator(s), controlling agencies and other supporting personnel. An appropriate venue for addressing this issue is the pre-flight NVIS mission brief.

3.3.2.2 Fatigue

Physiological limitations that are prevalent during the hours of darkness along with the limitations associated with NVGs, may have a significant impact on NVIS operations. Some of these limitations are the effects of fatigue (both acute and chronic), stress, eyestrain, working outside the operator's normal circadian rhythm envelope, increased helmet weight, aggressive scanning techniques associated with NVIS, and various human factors engineering concerns that may have a direct influence on how the operator works in the aircraft while wearing NVGs. These limitations may be mitigated through proper training and recognition, experience, adaptation, rest, risk management, and proper crew rest/duty cycles.

3.3.2.3 Overconfidence

Compared to other types of flight operations, there may be an increased tendency by the operator to over estimate the capabilities of the NVIS.

3.3.2.4 Spatial Orientation

There are two types of vision used in maintaining spatial orientation: central (focal) vision and peripheral (ambient) vision. Focal vision requires conscious processing and is slow, whereas peripheral information is processed subconsciously at a very fast rate. During daytime, spatial orientation is maintained by inputs from both focal vision and peripheral vision, with peripheral vision providing the great majority of the information. When using NVGs, peripheral vision can be significantly degraded if not completely absent. In this case, the operator must rely on focal vision to interpret the NVG image as well as the information from flight instruments in order to maintain spatial orientation and situation awareness. Even though maintaining spatial orientation requires more effort when using NVGs than during daytime, it is much improved over night unaided

operations where the only information is obtained through flight instruments. However, anything that degrades the NVG image to a point where the horizon is not visualized and/or ground reference is lost or significantly degraded will necessitate a reversion to instrument flight. Making this transition quickly and effectively is vital in order to avoid spatial disorientation. Additionally, added focal task loading during the operation (e.g., communications, looking at displays, processing navigational information, etc.) will compete with the focal requirement for interpreting the NVG image and flight instruments. Spatial disorientation can result when the task loading increases to a point where the outside scene and/or the flight instruments are not properly scanned. This potential can be mitigated to some extent through effective training and experience.

3.3.2.5 Depth Perception & Distance Estimation

When flying, it is important for operators to be able to accurately employ depth perception and distance estimation techniques. To accomplish this, operators use both binocular and monocular vision. Binocular vision requires the use of both eyes working together, and, practically speaking, is useful only out to approximately 100 feet.

Binocular vision is particularly useful when flying close to the ground and/or near objects (e.g., landing a helicopter in a small landing zone). Monocular vision can be accomplished with either eye alone, and is the type of vision used for depth perception and distance estimation when viewing beyond approximately 100 feet. Monocular vision is the predominant type of vision used when flying fixed wing aircraft, and also when flying helicopters and using cues beyond 100 feet. When viewing an NVG image, the two eyes can no longer provide accurate binocular information, even though the NVG used when flying is a binocular system. This has to do with the way the eyes function physiologically (e.g., accommodation, stereopsis, etc.) and the design of the NVG (i.e., a binocular system with a fixed channel for each eye). Therefore, binocular depth perception and distance estimation tasking when viewing terrain or objects with an NVG within 100 feet is significantly degraded. Since monocular vision does not require both eyes working together, the adverse impact on depth perception and distance estimation is much less, and is mostly dependent on the quality of the NVG image. If the image is very good and there are objects in the scene to use for monocular cueing (especially objects with which the operator is familiar), then distance estimation and depth perception tasking will remain accurate. If however, the image is degraded (e.g., low illumination, airborne obscurants, etc.) and/or there are few or unfamiliar objects in the scene, depth perception and distance estimation will be degraded to some extent. In summary, operators using NVG will maintain the ability to accurately perceive depth and estimate distances, but it will depend on the distances used and the quality of the NVG image.

Operators maintain some ability to perceive depth and distance when using NVGs by employing monocular cues. However, these capabilities may be degraded to varying degrees.

3.3.2.6 Instrument Lighting Brightness Considerations

When viewing the NVG image, the brightness of the image will affect the amount of time it takes to adapt to the brightness level of the instrument lighting, thereby affecting the time it takes to interpret information provided by the instruments. For example, if the instrument lighting is fairly bright, the time it takes to interpret information provided by the instruments may be instantaneous. However, if the brightness of the lighting is set to a very low level, it may take several seconds to interpret the information, thus increasing

the heads-down time and increasing the risk of spatial disorientation. It is important to ensure that instrument lighting is kept at a brightness level that makes it easy to rapidly interpret the information. This will likely be brighter than one is used to during unaided operations.

3.3.2.7 Dark Adaptation Time from NVG to Unaided Operations

When viewing an NVG image, both rods and cones are being stimulated (i.e., mesopic vision), but the brightness of the image is reducing the effectiveness of rod cells. If the outside scene is bright enough (e.g., urban area, bright landing pad, etc.), both rods and cones will continue to be stimulated. In this case there will be no improvement in acuity over time and the best acuity is essentially instantaneous. In some cases (e.g., rural area with scattered cultural lights), the outside scene will not be bright enough to stimulate the cones and some amount of time will be required for the rods to fully adapt. In this case it may take the rods one to two minutes to fully adapt for the best acuity to be realized. If the outside scene is very dark (e.g., no cultural lights and no moon), it may take up to five minutes to fully adapt to the outside scene after removing the NVGs. The preceding are general guidelines and the time required to fully adapt to the outside scene once removing the NVG depends on many variables: the length of time the NVG has been used, whether or not the operator was dark adapted prior to flight, the brightness of the outside scene, the brightness of cockpit lighting, and variability in visual function among the population. It is important to understand the concept and to note the time requirements for the given operation.

3.3.2.8 Complacency

Operators must understand the importance of avoiding complacency during NVG flights. Similar to other specialized flight operations, complacency may lead to an acceptance of situations that would normally not be permitted. Attention span and vigilance are reduced, important elements in a task series are overlooked, and scanning patterns, which are essential for situational awareness, break down (usually due to fixation on a single instrument, object or task). Critical but routine tasks are often skipped.

3.3.2.9 Experience

High levels of NVIS proficiency, along with a well-balanced NVIS experience base, will help to offset many of the visual performance degradations associated with night operations. NVIS experience is a result of proper training coupled with numerous NVIS operations. An experienced NVIS operator is acutely aware of the NVIS operational envelope and it's correlation to various operational effects, visual illusions and performance limitations. This experience base is gained (and maintained) over time through a continual, holistic NVIS training program which exposes the operator to NVIS operations conducted under various moon angles, percentage of available illumination, contrast levels, visibility levels, and varying degrees of cloud coverage. An operator should be exposed to as many of these variations as practicable during the initial NVIS qualification program. Continued exposure during the NVIS recurrent training will help strengthen and solidify this experience base. .

3.3.2.10 Recency of Experience

NVG flight skills are more perishable than day VFR flight skills and as such require increased recency of flight experience to retain proficiency.

4 OPERATIONS

Operations procedures must accommodate the capabilities and limitations of the systems described in Section 3 as well as the restraints of the operational environment.

4.1 Personnel Considerations

4.1.1 Minimum Crew

The minimum crew for night vision goggle operations shall be the higher of either the minimum crew specified by the aircraft type certificate or the minimum crew required for the aircraft operation.

4.1.2 Pilot Eligibility

Prior to undergoing NVIS training, a pilot shall meet the following prerequisites. This will ensure that the pilot is in a position to understand the theory being taught and have the necessary skills to fly safely when performing NVIS operations.

1. At a minimum, hold a private pilot certificate.
2. About 54% of the civil pilot population wears some sort of ophthalmic device to correct vision necessary to safely operate an aircraft. The applicability of NVGs to various ophthalmic devices used by civilian pilots has not been properly researched. The use of inappropriate ophthalmic devices with NVGs may result in vision performance decrement, fatigue, and other human factor problems, which could result in increased risk for aviation accidents and incidents.
3. In addition, the following should be adhered to pending further research:
 - a. Operator must have two functional eyes, both correctable to 20/20 acuity.
 - b. Operator must meet color vision standards.
 - c. Operator must not have any reduction in the field of vision.
4. The following instrument flight experience is recommended prior to the commencement of NVIS flight training:
 - a. Have an instrument rating OR
 - b. Have completed 30 hours of actual or simulated instrument time:
 - 1) Of this training, at least 15 hours of that instrument flight training be from an authorized flight instructor in an actual aircraft of which 5 hours must be in the aircraft category for which the NVIS endorsement is being sought.
 - 2) Of this training, a maximum of 10 hours may be performed in an approved flight simulator or approved flight training device.
 - 3) Of this training, 10 hours must be done at night in an actual aircraft.
5. Have 20 hours of night unaided VFR flight.
6. Have at least 250 total hours of flight time as a pilot, of which 50 hours can be in an approved flight simulator or approved flight training device, that is representative of the aircraft category that will be used for NVIS training.

7. Have attended an NVIS training course that follows a syllabus recognized by one's appropriate regulatory agency. This training can be conducted either by a qualified NVIS instructor or an authorized operator. This course should include a minimum of 5 separate flights, of not less than 1 hour per flight, of NVIS flight training, all of which would be conducted by an authorized NVIS instructor in an NVIS approved aircraft. Regardless of these minimum flight time requirements, proficiency in the designated flight maneuvers must be achieved.

4.1.3 Pilot Qualifications

A pilot who desires to act as a pilot in command during night vision goggle operations shall receive and log ground and flight training as detailed in an authorized course syllabus from an authorized instructor and obtain a log book endorsement certifying the pilot has satisfactorily accomplished the ground and flight training.

4.1.4 Pilot Recency of Experience (also see 3.3.2.8)

4.1.4.1 General

In order to carry passengers the pilot must, within the preceding two calendar months:

1. Perform and log three area departure and arrival tasks using night vision goggles.
2. Perform and log three tasks of transitioning from aided night vision goggle flight to unaided flight without the use of night vision goggles and then back to aided night vision goggle flight.
3. Perform and log three takeoffs and landings using night vision goggles if the pilot is approved to use night vision goggles during the takeoff and landing phases of flight.
4. Perform and log three hovering tasks using night vision goggles if the pilot is approved to use night vision goggles during the hovering phase of flight.

4.1.4.2 High Latitude Operations

Maintaining currency and proficiency with NVGs during the summer months will challenge pilots and operators. Operators are unable to use NVGs due to insufficient night flying environment available. A properly structured training program is required to re-orient pilots back to NVG operations for the winter flying season.

4.1.5 Instructor Qualifications

A flight instructor may not give the training to act as a pilot in command for night vision goggle operations unless that flight instructor:

1. Holds a pilot certificate and flight instructor certificate with the applicable category and class rating that the night vision goggle training is being given in.
2. Holds, a type rating, if a type rating is appropriate, on the flight instructor's pilot certificate that the night vision goggle training is being given in.
3. Is pilot in command qualified for night vision goggle operations, in accordance with the applicable regulations in the aircraft that the night vision goggle training is being given in.

4. Has logged at least one hundred night vision goggle operations as the sole manipulator of the controls.
5. Has logged at least twenty night vision goggle operations as sole manipulator of the controls in the category, class, and type (if class and type are appropriate) of the aircraft the night vision goggle training is being given in.
6. Is current and qualified to act as a pilot in command in night vision goggle operations in accordance with the applicable regulations.
7. Has a logbook endorsement from the applicable regulatory agency authorized to provide that endorsement and that endorsement must state the flight instructor is authorized to perform the night vision goggle pilot in command qualification and recency requirements of the regulations.

4.1.6 Flight and Duty Time Limitations & Rest Requirements (also see 3.3.2.2)

The current flight crew flight time, duty time, and rest requirements applicable to the operation being conducted are considered adequate for night vision goggle operations.

4.1.7 Additional Personnel Qualifications

All additional personnel (such as crewmembers, medical personnel, or observers) required for the NVIS operation shall be required to wear approved NVGs and must receive ground and flight training as detailed in the training guidelines.

4.2 Operating Environment Considerations

4.2.1 Weather and Atmospheric Obscurants

Any atmospheric condition, which absorbs, scatters, or refracts illumination, either before or after it strikes terrain, may reduce the usable energy available to the NVG.

4.2.1.1 Weather

During NVIS operations, operators can see areas of moisture that are dense (e.g., clouds, thick fog, etc.) but may not see areas that are less dense (e.g., thin fog, light rain showers, etc.). The inability to see some areas of moisture may lead to hazardous flight conditions during NVIS operations and will be discussed separately in the next section.

The different types of moisture will have varying effects and it is important to understand these effects and how they apply to NVIS operations. For example:

1. It is important to know when and where fog may form in the flying area. Typically, coastal, low-lying river, and mountainous areas are most susceptible.
2. Light rain or mist may not be observed with NVIS but will affect contrast, distance estimation, and depth perception. Heavy rain is more easily perceived due to large droplet size and energy attenuation.
3. Snow occurs in a wide range of particle sizes, shapes, and densities. As with clouds, rain, and fog, the denser the airborne snow, the greater the effect on NVG performance. On the ground, snow has mixed effect depending on terrain type and the illumination level. In mountainous terrain, snow may add contrast, especially if trees and rocks protrude through the snow. In flatter terrain, snow may cover high contrast areas, reducing them to areas of low contrast. On low

illumination nights, snow may reflect the available energy better than the terrain it covers and thus increase the level of illumination.

All atmospheric conditions reduce the illumination level to some degree and recognition of this reduction with NVGs can be difficult. Thus, a good weather briefing, familiarity with the local weather patterns and understanding the effects on NVG performance are important for a successful NVIS flight.

4.2.1.2 Deteriorating Weather

It is important to remain cognizant of changes in the weather when using NVGs. It is possible to “see through” areas of light moisture when using NVGs, thus increasing the risk of inadvertently entering IMC. Some ways to help reduce this possibility include the following:

1. Be attentive to changes in the NVG image. Halos may become larger and more diffuse due to diffraction of light in moisture. Scintillation in the image may increase due to a lowering of the illumination level caused by the increased atmospheric moisture. Loss of scene detail may be secondary to the lowering illumination caused by the changing moisture conditions.
2. Obtain a thorough weather brief with emphasis on NVG effects prior to flight.
3. Be familiar with weather patterns in the flying area.
4. Occasionally scan the outside scene. The unaided eye may detect weather conditions that are not detectable to the NVG.

Despite the many methods of inadvertent IMC prevention, one should have established IMC recovery procedures and be familiar with them.

4.2.1.3 Airborne Obscurants

In addition to weather, there may be other obscurants in the atmosphere that could block energy from reaching the NVG, such as haze, dust, sand, or smoke. As with moisture, the size and concentration of the particles will determine the degree of impact. Examples of these effects include the following:

1. High winds during the day can place a lot of dust in the air that will still be present at night when the wind may have reduced in intensity.
2. Forest fires produce heavy volumes of smoke that may cover areas well away from the fire itself.
3. The effects of rotor wash may be more pronounced when using NVGs depending on the material (e.g., sand, snow, dust, etc.).
4. Pollution in and around major cultural areas may have an adverse effect on NVG performance.

4.2.1.4 Winter Operations

Using NVGs during winter conditions provide unique issues and challenges to pilots.

4.2.1.4.1 Snow

Due to the reflective nature of snow, it presents pilots with significant visual challenges both enroute and in the terminal area. During the enroute phase of a flight the snow may cause distractions to the flying pilot if any aircraft external lights (e.g., anti-collision beacons/strobes, position lights, landing lights, etc.) are not compatible with NVGs. In the terminal area, whiteout landings can create the greatest hazard to unaided night operations. With NVGs the hazard is not lessened, and can be more disorienting due to lights reflecting from the snow that is swirling around the aircraft during the landing phase. Any emergency vehicle lighting or other airport lighting in the terminal area may exaggerate the effects.

4.2.1.4.2 Ice Fog

Ice fog presents the pilot with hazards normally associated with IMC in addition to problems associated with snow operations. The highly reflective nature of ice fog will further aggravate any lighting problems. Ice fog conditions can be generated by aircraft operations under extremely cold temperatures and the right environmental conditions.

4.2.1.4.3 Icing

Airframe ice is difficult to detect while looking through NVGs. The pilot will need to develop a proper crosscheck to ensure airframe icing does not exceed operating limits for that aircraft. Pilots should already be aware of icing indicator points on their aircraft. These areas require consistent oversight to properly determine environmental conditions.

4.2.1.4.4 Low Ambient Temperatures

Depending on the cockpit heating system, fogging of the NVGs can be a problem and this will significantly reduce the goggle effectiveness. Another issue with cockpit temperatures is the reduced battery duration. Operations in a cold environment may require additional battery resources.

4.2.2 Illumination

NVGs require illumination, either natural or artificial, to produce an image. Although current NVG technology has significantly improved low light level performance, some illumination, whether natural or artificial, is still required to provide the best possible image.

4.2.2.1 Natural Illumination

The main sources of natural illumination include the moon and stars. Other sources can include skyglow, the aurora borealis, and ionization processes that take place in the upper atmosphere.

4.2.2.1.1 Moon Phase

The moon provides the greatest source of natural illumination during nighttime. Moon phase and elevation determines how much moonlight will be available, while moonrise and moonset times determine when it will be available. Lunar illumination is reported in terms of percent illumination, 100% illumination being full moon. It should be noted that this is different from the moon phase (e.g., 25% illumination does not mean the same

thing as a quarter moon). Currently, percent lunar illumination can only be obtained from sources on the Internet, military weather facilities and some publications (e.g., Farmers Almanac).

4.2.2.1.2 Lunar Azimuth and Elevation

The moon can have a detrimental effect on night operations depending on its relationship to the flight path. When the moon is on the same azimuth as the flight path, and low enough to be within or near the NVG field of view, the effect on NVG performance will be similar to that caused by the sun on the unaided eye during daytime. The brightness of the moon drives the NVG gain down, thus reducing image detail. This can also occur with the moon at relatively high elevations. For example, it is possible to bring the moon near the NVG field of view when climbing to cross a ridgeline or other obstacle, even when the moon is at a relatively high elevation. It is important to consider lunar azimuth and elevation during preflight planning. Shadowing, another effect of lunar azimuth and elevation, will be discussed separately.

4.2.2.1.3 Shadowing

Moonlight creates shadows during nighttime just as sunlight creates shadows during daytime. However, nighttime shadows contain very little energy for the NVG to use in forming an image. Consequently, image quality within a shadow will be degraded relative to that obtained outside the shadowed area. Shadows can be beneficial or can be a disadvantage to operations depending on the situation.

4.2.2.1.3.1 Benefits of Shadows

Shadows alert aircrew to subtle terrain features that may not otherwise be noted due to the reduced resolution in the NVG image. This may be particularly important in areas where there is little contrast differentiation; such as flat featureless deserts, where large dry washes and high sand dunes may go unnoticed if there is no contrast to note their presence. The contrast provided by shadows helps make the NVG scene appear more natural.

4.2.2.1.3.2 Disadvantages Due to Shadows

When within a shadow, terrain detail can be significantly degraded, and objects can be regarding flight in or around shadowed areas is the operator's response to loss of terrain detail. During flight under good illumination conditions, an operator expects to see a certain level of detail. If flight into a shadow occurs while the operator is preoccupied with other matters (e.g., communication, radar, etc.), it is possible that the loss in terrain detail may not have been immediately noted. Once looking outside again, the operator may think the reduced detail is due to an increase in flight altitude and thus begin a descent - even though already at a low altitude. Consideration should be given during mission planning to such factors as lunar azimuth and elevation, terrain type (e.g., mountainous, flat, etc.), and the location of items significant to operation success (e.g., ridgelines, pylons, targets, waypoints, etc.). Consideration of these factors will help predict the location of shadows and the potential adverse effects.

4.2.2.1.4 Skyglow

Skyglow is an effect caused by solar light and continues until the sun is approximately 18 degrees below the horizon. When viewing in the direction of skyglow there may be enough energy present to adversely affect the NVG image (i.e., reduce image quality).

For the middle latitudes the effect on NVG performance may last up to an hour after official sunset. For more northern and southern latitudes the effect may last for extended periods of times (e.g., days to weeks) during seasons when the sun does not travel far below the horizon. This is an important point to remember if planning NVG operations in those areas. Unlike skyglow after sunset, the skyglow associated with sunrise does not have an obvious effect on NVG performance until fairly close to official sunrise. The difference has to do with the length of time the atmosphere is exposed to the sun's irradiation, which causes ionization processes that release near-IR energy. It is important to know the difference in these effects for planning purposes.

4.2.2.2 Artificial Illumination

Since the NVGs are sensitive to any source of energy in the visible and near infrared spectrums, there are also many types of artificial illumination sources (e.g., flares, IR searchlights, cultural lighting, etc.). As with any illumination source, these can have both positive and detrimental effects on NVG utilization. For example, viewing a scene indirectly illuminated by a searchlight can enable the operator to more clearly view the scene; conversely, viewing the same scene with the searchlight near or within the NVG field of view will reduce the available visual cues. It is important to be familiar with the effects of cultural lighting in the flying area in order to be able to avoid the associated problems and to be able to use the advantages provided. Also, it is important to know how to properly use artificial light sources (e.g., aircraft IR spotlight). It should be noted that artificial light sources may not always be available or dependable, and this should be taken into consideration during flight planning.

4.2.3 Terrain Contrast

Contrast is one of the more important influences on the ability to correctly interpret the NVG image, particularly in areas where there are few cultural features. Any terrain that contains varying albedos (e.g., forests, cultivated fields, etc.) will likely increase the level of contrast in a NVG image, thus enhancing detail. The more detail in the image, the more visual information aircrews have for maneuvering and navigating. Low contrast terrain (e.g., flat featureless desert, snow-covered fields, water, etc.) contains few albedo variations, thus the NVG image will contain fewer levels of contrast and less detail.

4.3 Aircraft Considerations

4.3.1 Lighting

Factors such as aircraft internal and external lighting have the potential to adversely impact NVG gain and thus image quality. How well the windshield, canopy, or window panels transmit near infrared energy can also affect the image. Cleanliness of the windshield directly impacts this issue.

4.3.2 Cockpit Ergonomics

While wearing NVGs, the operator may have limited range of head movement in the aircraft. For example, switches on the overhead console may be difficult to read while wearing NVGs. Instruments, controls, and switches that are ordinarily accessible, may now be more difficult to access due to the extended mass (fore/aft) associated with NVGs.

In addition, scanning may require a more concentrated effort due to limited field of view. Lateral viewing motion can be hindered by cockpit obstructions (i.e. door post or seat back design).

4.3.3 Windshield Reflectivity

Consideration within the cockpit and cabin should be given to the reflectivity of materials and equipment upon the windshield. Light that is reflected may interfere with a clear and unobstructed view. Items such as flight suits, helmets, and charts, if of a light color such as white, yellow, and orange, can produce significant reflections. Colors that impart the least reflection are black, purple, and blue. This phenomena is not limited to windshields but may include side windows, chin bubbles, canopies, etc.

4.4 Industry Considerations

As previously stated, NVIS is considered an aid to night VFR flight. Therefore, the introduction of NVIS into civil aviation should enhance operational capability in a safe and efficient manner.

4.4.1 Agriculture

The aerial application of chemicals is highly dependent on, and limited by, the stability, or instability, of the air at ground level. The economic liability of damage to non-target areas caused by wind driven drift of the product once it is released from the aircraft severely limits the application times available to many operators. The ability to conduct spray operations at night, due to typically low winds and the lack of thermals, with the aid of NVIS would greatly increase the number of usable hours an operator could have aircraft working.

Night applications would not necessarily be limited to the spraying of traditional crops. The same stable atmospheric conditions present at night are beneficial to operations involving the spraying of herbicides over forests and right of ways. It may also be desirable to apply pesticides at night to reduce the risk of humans being exposed to the material. As an example, large-scale operations to eradicate insects such as the gypsy moth in state and national forests would be viable candidates for night operations. There are currently government operated mosquito controls employing NVGs and the possibility of civil operators following suit certainly exists.

4.4.2 Air Medical Operations

The air medical industry with its 24-hour operations was the original applicant for the implementation of night vision technology in the civil sector. The primary interest within the air medical community stems from the desire for enhanced obstacle detection and avoidance. This community also has a continuing need to land at unimproved, unlighted areas.

4.4.3 Fire Fighting

The airborne fire fighting community views night vision technology as a means to extend the operating hours of aerial application. Currently night fire fighting activities are limited due to the inability of flight crews to detect obstacles. The fire fighting units also have a need, similar to the air medical industry, to respond to emergency situations on a 24-hour basis.

4.4.4 Law Enforcement

In order to improve the overall range of mission capabilities in the Law Enforcement Community, the use of Night Vision devices were implemented. Of the devices used, thermal imaging systems and NVGs, night vision goggles have perhaps improved the pilot's situational awareness during night operations the most. Pilots are now able to respond to ground personnel and electronic sensor information in a more timely and direct manner and doing so with tactics normally used in daytime law enforcement missions. Some examples of tactics employed by the law enforcement community are:

1. Terrain Masking to Avoid Detection
2. Multi-Helicopter Operations
3. Air to Ground Agent Tactical Operations
4. Air to Air Operations in Multi-ship Flights
5. Personnel and Vehicle Detection and Apprehension
6. Swat Team and Covert Operations

NVGs have enhanced the overall mission performance of law enforcement. Pilots are capable of flying, at night, to some of the most remote and sparsely populated areas in the US. They are able to navigate their way visually to the target location and perform their usual mission in a more safe and expeditious manner.

4.4.5 Offshore

Offshore operations are conducted in a low contrast environment, which is not always favorable to night vision goggle application. Suitability of NVIS to offshore operations must be made on an operations specific basis.

4.4.6 Other

This list of industries considered is by no means exhaustive. Representatives of the above industries were consulted in the preparation of this Concept of Operations. However, other industries may well have legitimate interests and corresponding considerations for the use of NVIS.

4.5 Generic Operating Considerations

This section lists operating topics and procedures, which should be considered when employing NVIS. The list and associated comments are not to be considered all inclusive. NVIS operations vary in scope widely and this section is not intended to instruct a prospective operator on how to implement an NVIS program.

4.5.1 Normal Procedures

4.5.1.1 Scanning

When using NVGs there are three different scan patterns to consider and each is used for different reasons: instrument scan, aided scan outside, and unaided scan outside. Normally, all three are integrated and there is a continuous transition from one to the other depending on the mission, environmental conditions, immediate tasking, flight altitude and many other variables. For example, scanning with the NVG will allow early detection of external lights. However, the bloom caused by the lights will mask the aircraft until fairly close or until the lighting scheme is changed. Once close to the aircraft (e.g., approximately one-half mile for smaller aircraft), visual acquisition can

possibly be made unaided or with the NVG. Whether to use the NVG or unaided vision depends on many variables (e.g., external lighting configuration, distance to aircraft, size of aircraft, environmental conditions, etc.). The points to be made are that a proper scan depends on the situation and variables present, and that scanning outside is critical when close to another aircraft. Additionally, for a multi-crew environment, coordination of scan responsibilities is vital.

4.5.1.1.1 Instrument Crosscheck Scan

In order to effect a proper and effective instrument scan, it is important to predict when it will be important. A start can be made during preflight planning when critical phases of flight can be identified and prepared for. For example, it may be possible when flying over water or featureless terrain to employ a good instrument crosscheck. However, the most important task is to make the appropriate decision during flight as conditions and events change. In this case, experience, training and constant attention to the situation are vital contributors to the operator's assessment of the situation.

4.5.1.1.2 NVG Scan

To counteract the limited field of view, operators should continually scan throughout the field of regard. This allows aircrew to build a mental image of the surrounding environment. How quickly the outside scene is scanned to update the mental image is determined by many variables. For example, when flying over flat terrain where the highest obstacle is below the flight path, the scan may be fairly slow. However, if flying low altitude in mountainous terrain, the scan will be more aggressive and rapid due to the presence of more information and the increased risk. How much of the field of regard to scan is also determined by many variables. For example, if a pilot is anticipating a turn, more attention may be placed in the area around the turn point, or in the direction of the new heading. In this situation, the scan will be limited briefly to only a portion of the field of regard.

As with the instrument scan, it is very important to plan ahead. It may, for example, be possible to determine when the scan may be interrupted due to other tasks, when it may be possible to become fixated on a specific task, or when it is important to maximize the outside scan. An important lesson to learn regarding the NVG scan is when not to rely on visual information. It is easy to overestimate how well one can see with NVGs, especially on high illumination nights, and it is vital to maintain a constant awareness regarding their limitations. This should be pointed out often during training and, as a reminder, should be included as a briefing item for NVG flights.

4.5.1.1.3 Unaided Scan

Under certain conditions, this scan can be as important as the others can. For example, it may be possible to detect distance and/or closure to another aircraft more easily using unaided vision, especially if the halo caused by the external lights is masking aircraft detail on the NVG image. Additionally, there are other times when unaided information can be used in lieu of or can augment NVG and instrument information.

4.5.1.1.4 Scan Patterns

Environmental factors will influence scan by limiting what may be seen in specific directions or by degrading the overall image. If the image is degraded, aircrew may scan more aggressively in a subconscious attempt to obtain more information, or to avoid the chance of missing information that suddenly appears and/or disappears.

The operation itself may influence the scan pattern. For example, looking for another aircraft, landing zone, or airport may require focusing the scan in a particular direction. In some cases, the operation may require aircrew in a multiplace aircraft to assign particular operators responsibility for scanning specific sectors.

The restrictions to scan and the variables affecting the scan pattern are not specific to night operations or the use of NVGs, but, due to the NVG's limited field of view, the degree of impact is magnified.

4.5.1.2 Pre-Flight Planning

4.5.1.2.1 Departure/Enroute/Destination Weather

Terminal and area forecasts should be obtained and analyzed with particular emphasis on temperature/dew point spread, cloud cover and visibility, sunset, civil and nautical twilight, moon phase, moonrise and moonset, and moon and/or lux illumination levels, during all phases of flight.

4.5.1.2.2 Night VFR

NVIS are not intended for use in IMC. NVIS is to be used during VMC conditions. Rules for cloud clearance and visibility must be adhered to.

4.5.1.2.3 Illumination Criteria

The operator must establish acceptable illumination criteria and provide a means for determining illumination levels in the operational area. Clear starlight may provide sufficient light for some NVIS operations.

4.5.1.2.4 NVIS Pre-flight

Operator checks for the NVGs should start with maintenance forms and records. An inspection of the power pack, visor, mount, power cable and the binocular assembly should be performed in accordance with the Operators Manual. A low battery indicator check should also be performed.

To ensure maximum performance of the NVGs, proper alignment and focus must be accomplished following the equipment inspection. Improper alignment and focus may degrade NVIS performance.

4.5.1.2.5 Aircraft Pre-flight

A normal pre-flight inspection should be conducted prior to an NVIS flight with emphasis on proper operation of the NVIS lighting. The aircraft windshield must also be clean and free of major defects, which might degrade NVIS performance.

4.5.1.2.6 Equipment

To effectively fly an NVIS operation (see also 3.3.2.5), the equipment required for NVIS operations should be those instruments and equipment specified within the current applicable regulations for VFR day and night operations. In addition the following equipment must be installed and operational: NVIS lighting system; two-way radio communication system; generator or alternator of adequate capacity; gyroscopic pitch

and bank indicator and a radio altimeter. All NVIS equipment, including any subsequent modifications, shall be approved.

4.5.1.2.7 Route Planning

The operator must assess factors that will affect the NVIS operation. A good route study for terrain, obstacle clearance, surface contrast, illumination levels, and reflectivity should be considered, as well as a review of NOTAMS for unlit towers

4.5.1.2.8 Obstacles

Although night operations under VFR conditions can be flown unaided, NVIS can enhance the operator's ability to see and avoid obstacles and other aircraft. While natural obstacles such as hills and mountains can be seen through NVGs, some man-made obstacles cannot. An example is power lines. The poles may be seen, but not the wires.

4.5.1.2.9 Risk Assessment

A risk assessment is suggested prior to any NVIS operation. The risk assessment should include as a minimum:

1. Illumination Level
2. Weather
3. Operator recency of experience
4. Operator experience with NVG operations
5. Operator vision
6. Operator rest condition and health
7. Windshield/window condition
8. NVG tube performance
9. NVG battery condition
10. Types of operations allowed
11. External lighting environment

4.5.1.3 Departure

4.5.1.3.1 Controlled vs. Uncontrolled Airspace

NVIS operations do not change the requirement to comply with the applicable airspace rules.

4.5.1.3.2 Heliport vs. Remote Area Considerations

Operations on or in the near vicinity of a heliport can be conducted with or without NVGs. Heliports are usually illuminated as well as the obstacles in the approach/departure paths.

A remote area is a site that does not qualify as an airport, heliport or vertiport as defined per one's applicable regulations. Remote area landing sites do not have the same features as a heliport, so extra care must be given to locating any obstacles that may be in the approach/departure path. Consideration should be given to employing additional personnel (See 4.1.7) to scan the opposite side or in back of the helicopter due to limited field of view (See 3.3.1.2) and field of regard (See 3.3.1.3). Applicable landing area lighting requirements must be complied with.

4.5.1.4 Enroute

4.5.1.4.1 Elevated Terrain

Safety may be enhanced by NVGs during operations near elevated terrain at night. The obscuration of elevated terrain is more easily detected with NVGs thereby allowing the operator to make alternate flight path decisions.

4.5.1.4.2 Over Water

Flying over large bodies of water with NVGs is difficult because of the lack of contrast in terrain features. Reflections of the moon or starlight may cause disorientation with the natural horizon. The radio altimeter must be used as a reference to maintain altitude.

4.5.1.5 Arrival

4.5.1.5.1 Airport and Heliport Landings

Normally there is sufficient light at an airport that NVGs are not needed. In some cases, NVGs may be used depending on several variables: brightness level of the runway lights, width of the runway, presence of threshold lights, proximity of brightly illuminated hangers, etc. Whether or not to use NVGs for airport or heliport landings depends on the effect from these variables and the resulting impact on the quality of the NVG image.

4.5.1.5.2 Low Ambient Illumination Sites

A reconnaissance must be made prior to descending at an unlighted remote site. Some features or objects may be easy to detect and interpret with the unaided eye. Other objects will be invisible to the unaided eye, yet easily detected and evaluated with NVGs.

4.5.1.5.3 Reconnaissance

The reconnaissance phase should involve the coordinated use of NVGs and white lights. The aircraft's external white lights such as landing lights, searchlights, and floodlights, should be used during this phase of flight. The operator should select and evaluate approach and departure paths to the site considering wind speed and direction, and obstacles or signs of obstacles.

4.5.1.6 Landing

Once a reconnaissance is completed, the operator can start the approach and landing. Care must be exercised to continuously look for obstacles along the arrival path.

4.5.1.6.1 Sources of High Illumination

Sources of direct high illumination may have the potential to reduce the effectiveness of the NVGs. In addition, certain color lights, such as red, will appear brighter, closer and may display large halos.

4.5.2 Emergency Procedures

No modification for NVG operations is necessary to the aircraft emergency procedures as approved in the Operators Manual or approved Checklist. Special training may be required to accomplish the appropriate procedures.

4.5.3 Inadvertent IMC

Some ways to help reduce the potential for inadvertent flight into IMC conditions are:

1. Obtaining a thorough weather brief (including pilot reports);
2. Being familiar with weather patterns in the local flying area;
3. By looking beneath the NVG at the outside scene.

However, even with thorough planning a risk still exists. To help mitigate this risk it is important to know how to recognize subtle changes to the NVG image that occur during entry into IMC conditions. Some of these include the onset of scintillation, loss of scene detail, and changes in the appearance of halos.

5 TRAINING

To provide an appropriate level of safety, training procedures must accommodate the capabilities and limitations of the systems described in Section 3 as well as the restraints of the operational environment.

To be effective, the NVIS training philosophy would be based on a two-tiered approach: basic and advanced NVIS training. The basic NVIS training would serve as the baseline standard for all individuals seeking an NVIS endorsement. The content of this initial training would not be dependent on any operational requirements. The advanced training would build on the basic training by focusing on developing specialized skills required to operate an aircraft during NVIS operations in a particular operational environment. Furthermore, while there is a need to stipulate minimum flight hour requirements for an NVIS endorsement, the training must also be event based. This necessitates that operators be exposed to all of the relevant aspects, or events, of NVIS flight in addition to acquiring a minimum number of flight hours.

5.1 Pilot Ground Training

The ground training necessary to initially qualify a pilot to act as the pilot of an aircraft using night vision goggles must include at least the following subjects:

1. Applicable aviation regulations that relate to NVG limitations and flight operations.
2. Aeromedical factors relating to the use of NVGs to include how to protect night vision, how the eyes adapt to operate at night, self imposed stresses that affect night vision, effects of lighting (internal and external) on night vision, cues utilized to estimate distance and depth perception at night, and visual illusions.
3. NVG performance and scene interpretation.
4. Normal, abnormal, and emergency operations of NVGs.
5. NVIS operations flight planning to include night terrain interpretation and factors affecting terrain interpretation.

5.2 Pilot Flight Training

The flight training necessary to initially qualify a pilot to act as the pilot of an aircraft using NVGs may be performed in an aircraft, flight simulator, or flight training device and must include at least the following subjects:

1. Preparation and use of internal and external aircraft lighting systems for NVIS operations.
2. Preflight preparation of NVGs for NVIS operations.
3. Proper piloting techniques (during normal, abnormal, and emergency aircraft operations) when using NVGs during the takeoff, climb, enroute, descent, and landing phases of flight that includes unaided flight and aided flight.
4. Normal, abnormal, and emergency operations of the NVGs during flight.

5.3 Training for Additional Personnel

Additional personnel must be trained to operate around aircraft employing NVIS. These individuals must complete all phases of NVIS ground training that is given to pilots. Due to the importance of crew coordination, it is imperative that all operators be familiar with all aspects of NVIS flight. Furthermore, additional personnel may have task qualifications specific to their position in the aircraft or areas of responsibility. To this end, they should demonstrate competency in those areas, both on the ground and in flight.

5.4 Support Personnel Training

Non-flying personnel who support NVIS operations must also receive adequate training in their areas of expertise. The purpose is to ensure, for example, that correct light discipline is used when helicopters are landing in a remote area.

5.5 Recurrent and Refresher Training

To address those situations where qualified NVIS operators have failed to remain current, the requirements for recurrent training must be detailed to ensure that these individuals are still safe and effective when performing NVIS operations. Regardless of currency status, every operator must also participate in annual refresher training consisting of both ground and flight training.

5.6 Flight Training Conditions

All NVIS operators should be exposed to a variety of ambient light and weather conditions. Thus, there is no requirement for minimum illumination levels or weather limits, except those stipulated by regulations, for training.

6**CONTINUED AIRWORTHINESS**

The reliability of the NVIS and safety of operations are dependent on the operators adhering to the instructions for continued airworthiness. Personnel who conduct the maintenance and inspection on the NVIS must be qualified and possess the appropriate tools and facilities to perform the maintenance.

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7 OTHER SUPPORTING AGENCIES

7.1 Weather Facilities

Weather facilities may not be aware of the information needed to conduct NVIS flight. The operator should make the effort to request at least the following information in addition to that normally requested for night VFR: cloud cover and visibility during all phases of flight, sunset, civil and nautical twilight, moon phase, moonrise and moonset, and moon and/or lux illumination levels, and unlit tower NOTAMS.

Those agencies charged with providing flight weather information need to modify their products to include the NVIS flight data elements not currently provided.

7.2 Air Traffic / Airports / Airspace

The goal of using NVGs is to enhance night VFR operations. With that in mind, this enhancement should not create undue burden or extra operational requirements to the National Airspace System (NAS). Air traffic, airport facilities, and airspace control shall not have any new requirements due to the use of NVG operations.

As mentioned in the background section of this document, the military has utilized many different types of goggles for over the past decades. Some of these older versions created difficulty for the user to fly into high ambient lighted, urban areas or well-lit airports. Many military airports would have been required to reduce their airport lighting, if goggle operations were in effect around the airfield. Today's NVGs have overcome most of these difficulties and now are more tolerant of high ambient external lighting environments. Thus, NVG operations should not require airports to reduce any ambient lighting in the vicinity of the airfield.

In addition, many military NVG operations at joint use airfields were required to announce "Goggle Operations" or "Aided Operations" to air traffic control when entering the airfield's airspace. One purpose for this practice was to alert air traffic control that the night VFR pattern would have aided (NVG operations) and unaided (non-NVG operations) traffic. Air traffic control and NVG operators perceived that the flow of VFR traffic may require different priority based on this enhanced see and avoid capability of NVGs. For example, if an aided operation wanted to land at a military airfield along with an unaided operation, air traffic may decide to give the unaided traffic priority, since the aided traffic would have better see and avoid capability to maneuver the aircraft easily. However, aircraft performance and other issues determine maneuverability and the flow of traffic is still night VFR with no extra operating requirements for the NVG operator.

Another purpose for the NVG announcement to air traffic control was to suffice any potential need for special services for a NVG operator who was intended to operate within the vicinity of the airfield (i.e., removal of runway lighting). However, in both situations, NVG operators should not impose special airfield lighting requirements nor should its priority in VFR traffic change. In essence, NVG operations should be seamless to air traffic and airspace controllers, and to airfield facilities.

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Appendix A
MEMBERSHIP

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MEMBERSHIP

Special Committee 196

Night Vision Goggle (NVG) Appliances and Equipment

Concept of Operations: Night Vision Imaging System for Civil Operators

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Federal Aviation Administration
Litton Industries, Inc.

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Federal Aviation Administration
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U. S. Air Force Research Laboratory
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Appendix A

A-2

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Appendix B
ACRONYMS

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Appendix B – ACRONYMS

AC	Advisory Circular
AGL	Above Ground Level
ATC	Air Traffic Control
CONOPs	Concept of Operations
CG	Center of Gravity
CRM	Cockpit Resource Management
DOD	Department of Defense
DOT	Department of Transportation
EFIS	Electronic Flight Instrumentation Systems
EMS	Emergency Medical Service
FAA	Federal Aviation Administration
FLIR	Forward Looking Infrared Radar
FOR	Field of Regard
FOV	Field of View
GEN	Generation
HUD	Head Up Display
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IR	Infrared
JAA	Joint Aviation Authorities
MOPS	Minimum Operational Performance Standard
NAS	National Airspace System
NOTAMS	Notices to Airmen
NVD	Night Vision Device
NVED	Night Vision Enhancement Device
NVG	Night Vision Goggle
NVIS	Night Vision Imaging System
SC	Special Committee
TFR	Temporary Flight Restrictions
VA	Visual Acuity
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

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Appendix C

GLOSSARY

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Appendix C – GLOSSARY

1. **ABSORPTANCE.** The ratio of the radiant energy absorbed by a body to that incident upon it.
2. **AIDED.** A term used to describe those times when NVGs are being used as an aid to night vision.
3. **ALBEDO.** The ratio of the amount of light reflected from a surface to the amount of incident light.
4. **AUTOMATIC BRIGHTNESS CONTROL (ABC).** One of the automatic gain control circuits found in second and third generation NVG devices. It attempts to provide consistent image output brightness by automatic control of the microchannel plate voltage.
5. **AUTOMATIC GAIN CONTROL (AGC).** Comprised of the automatic brightness control and bright source protection circuits. It is designed to maintain image brightness and protect the user and the image tube from excessive light levels. This is accomplished by controlling the gain of the intensifier tube.
6. **BLACKBODY.** An ideal body of surface that completely absorbs all radiant energy falling upon it with no reflection.
7. **BLOOMING.** Common term used to denote the “washing out” of all or part of the NVG image due to de-gaining of the image intensifier tube when a bright light source is in or near the NVG field of view.
8. **BRIGHT SOURCE PROTECTION (BSP).** Protective feature associated with second and third generation NVGs that protects the intensifier tube and the user by controlling the voltage at the photocathode.
9. **BROWNOUT.** Condition created by blowing sand, dust, etc., which can cause the operators to lose sight of the ground. This is most commonly associated with landings in the desert or in dusty LZs.
10. **CIVIL NAUTICAL TWILIGHT.** The time when the true altitude of the center of the sun is six degrees below the horizon. The illuminance level is approximately 3.40 lux and is above the usable level for NVG operations.
11. **DIOPTER.** A measure of the refractive (light bending) power of a lens equal to one over the focal length of the lens in meters. Also, used to indicate the eyepiece focus setting needed to adjust the NVG image to compensate for people that require corrective lenses.
12. **DIRECT VIEW IMAGE NVG (TYPE I).** Any NVG which displays the intensified image on a phosphor screen in the user’s direct line of sight.
13. **ELECTRO-OPTICS (EO).** The term used to describe the interaction between optics and electronics, leading to transformation of electrical energy into light or vice versa.
14. **ELECTROLUMINESCENT (EL).** Referring to light emission that occurs from application of an alternating current to a layer of phosphor.
15. **FOOT-CANDLE.** A measure of illuminance; specifically, the illuminance of a surface upon which one lumen is falling per square foot.

16. **FOOT-LAMBERT.** A measure of luminance; specifically the luminance of a surface that is receiving an illuminance of one foot-candle. Also, equal to $1/\pi$ candela per square foot.
17. **GAIN.** When referring to an image intensification tube, the ratio of the brightness of the output in units of foot-lambert, compared to the illumination of the input in foot-candles. A typical value for a GEN III tube is 25,000 to 30,000 FI/fc. A “tube gain” of 30,000 FI/fc provides an approximate “system gain” of 3,000. This means that the intensified NVG image is 3,000 times brighter to the aided eye than that of the unaided eye.
18. **HALO.** A bright circular “ring” surrounding a point light source that is caused by electron scattering in the intensification process. The intensity and size of the halo will vary depending on the ambient illumination, the intensity of the light source, the wavelengths being generated by the light source, the design of the image intensifier, and other factors. The halos from several light sources may coalesce to form larger appearing halos and may result in blooming of the image.
19. **ILLUMINANCE.** Also referred to as illumination. The area density of luminous flux (visible light power) on a surface at any given point. Foot-candles (lumens/square foot) and lux (lumens/square meter) are common units to measure illuminance.
20. **IMAGE INTENSIFIER.** An electro-optic device used to detect and intensify optical images in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. The component that actually performs the intensification process in a NVG. This component is composed of the photocathode, MCP, screen optic, and power supply. It does not include the objective and eyepiece lenses.
21. **INCANDESCENT.** Refers to a source that emits light based on thermal excitation, i.e., heating by an electrical current, resulting in a very broad spectrum of energy that is dependent primarily on the temperature of the filament.
22. **INFRARED.** That portion of the electromagnetic spectrum in which wavelengths range from 0.7 microns to 1 millimeter. This segment is further divided into near infrared (0.7-3.0 microns), mid infrared (3.0-6.0 microns), far infrared (6.0-15 microns), and extreme infrared (15 microns-1 millimeter). A NVG is sensitive to near-infrared wavelengths approaching 0.9 microns.
23. **IRRADIANCE.** The radiant flux density incident on a surface usually measured in watts per square centimeter or watts per square meter. This is similar to illuminance except that it includes all wavelengths of light whereas illuminance includes only visible wavelengths as weighted by the human visual sensitivity curve (photopic curve).
24. **LUMEN.** A measurement of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle intensity.
25. **LUMINANCE.** The luminous intensity of a surface in a given direction per unit of projected area. This measure of light most closely approximates the human visual sensation of brightness. It is typically measured in units of foot-lamberts or candela per square meter (nits).
26. **LUX.** A unit measurement of illumination. The illuminance produced on a surface that is one-meter square, from a uniform point source of one-candle intensity, or one lumen per square meter.

27. **MICROCHANNEL PLATE.** A wafer containing between 3 and 6 million specially treated microscopic glass tubes designed to multiply electrons passing from the photocathode to the phosphor screen in second and third generation intensifier tubes.
28. **MICRON.** A unit of measure commonly used to express wavelength in the infrared region; equal to one millionth of a meter.
29. **NANOMETER (nm).** A unit of measure commonly used to express wavelength in the visible and near infrared region; equal to one billionth of a meter.
30. **NIGHT.** The time between the end of evening civil twilight and the beginning of morning civil twilight as published in the American Air Almanac.
31. **NIGHT VISION DEVICE (NVD).** An electro-optical device used to provide a visible image using the electromagnetic energy available at night.
32. **NIGHT VISION GOGGLE (NVG).** When referring to NVGs used for aviation purposes; a head-mounted, lightweight, self-contained binocular system consisting of two independent monocular intensifier tube assemblies.
33. **PHOTON.** A quantum (basic unit) of radiant energy (light).
34. **PHOTOPIC VISION.** Vision produced as a result of the response of the cones in the retina as the eye achieves a light adapted state (commonly referred to as day vision).
35. **PROJECTED IMAGE NVG (TYPE II).** Any NVG which projects the intensified image on a see-through medium in the user's line of sight.
36. **RADIANCE.** The flux density of radiant energy per unit solid angle per unit-projected area usually measured in watts per steradian per square centimeter or watts per steradian per square meter. This is similar to luminance except that it includes all wavelengths of light (ultra-violet through infra-red) whereas luminance includes only those wavelengths that are visible to the human eye. Radiance and luminance are not interchangeable terms.
37. **REFLECTIVITY.** The fraction of energy reflected from a surface.
38. **SCINTILLATION.** Noise in the NVG image that appears as a sparkling or snow-like effect that typically appears when the NVG is operated in an area of low illumination.
39. **SCOTOPIC VISION.** That vision produced as a result of the response of the rods in the retina as the eye achieves a dark-adapted state (commonly referred to as night vision).
40. **SITUATIONAL AWARENESS (SA).** Degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time.
41. **STARLIGHT.** The illuminance provided by the available (observable) stars in a subject hemisphere. The stars provide approximately 0.00022 lux ground illuminance on a clear night. This illuminance is equivalent to about one-quarter of the actual light from the night sky with no moon.
42. **STEREOPSIS.** Visual system binocular cues that are used for distance estimation and depth perception. Three dimensional visual perceptions of objects. The use of NVGs seriously degrades this aspect of near-depth perception.

- 43. **TRANSMITTANCE.** The fraction of radiant energy that is transmitted through a layer of absorbing material placed in its path.
- 44. **ULTRAVIOLET.** That portion of the electromagnetic spectrum in which wavelengths range between 0.1 and 0.4 microns.
- 45. **UNAIDED.** Term used to describe those times when NVGs are not being used (i.e., normal night vision is not being aided).
- 46. **WAVELENGTH.** The distance in the line of advance of a wave from any one point to the next point of corresponding phase; is used to express electromagnetic energy including IR and visible light.
- 47. **WHITEOUT.** A condition similar to brownout but caused by blowing snow.

Appendix D

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Appendix D – REFERENCES

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