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External Position Lighting Effects on Night Vision Goggle Performance (Reprint)

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Army aviation depends heavily on image intensification (I^2) devices to extend operations into the night. Such devices are light amplification systems that adjust their amplification factor (gain) according to the level of ambient illumination. However, these night vision goggles (NVGs) are unable to distinguish between light originating from the exterior scene and light originating from either instruments inside the cockpit or lights mounted to the aircraft. Consequently, the NVG may lower gain unnecessarily, and in doing so, degrade image quality. The compatibility problem is most apparent when light in the red part of the spectrum is present. This is the problem with the UH-1's red lateral position lights. These lights flood into the cockpit, affecting NVG performance - the presence of fog and other weather heightens this effect. A solution to this problem has been to mask appropriate upper and lower portions of the two red position lights, thereby reducing the NVG degradation. However, this solution appeared to conflict with Federal Aviation Regulation (FAR) lighting intensity distributions for each of the two lights. We calculated that the FAR could be satisfied at a distance of one rotor disk radius by masking 82 degrees of each respective position light

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EXTERNAL POSITION LIGHTING EFFECTS ON NIGHT VISION GOGGLE PERFORMANCE

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SUMMARY
Army aviation depends heavily on image intensification (I^2) devices to extend operations into the night. Such devices are light amplification systems that adjust their amplification factor (gain) according to the level of ambient illumination. However, these night vision goggles (NVGs) are unable to distinguish between light originating from the exterior scene and light originating from either instruments inside the cockpit or lights mounted to the aircraft. Consequently, the NVG may lower gain unnecessarily, and in doing so, degrade image quality. The compatibility problem is most apparent when light in the red part of the spectrum is present. This is the problem with the UH-1's red lateral position lights. These lights flood into the cockpit, affecting NVG performance – the presence of fog and other weather heightens this effect. A solution to this problem has been to mask appropriate upper and lower portions of the two red position lights, thereby reducing the NVG degradation. However, this solution appeared to conflict with Federal Aviation Regulation (FAR) lighting intensity distributions for each of the two lights. We calculated that the FAR could be satisfied at a distance of one rotor disk radius by masking 82 degrees of each respective position light (leaving 98 degrees unmasked). Objective video recordings and test pilots' subjective observations indicate a significant reduction in NVG degradation with the 82-degree masking scheme as compared to operations with unmasked position lights. The 82-degree masking scheme meets the FAR requirements while reducing simultaneously the performance degradation of the NVG devices. We will show a composite video with observations at the meeting.

INTRODUCTION

In the 1970s, the Department of Defense (DoD) decided to improve the Army's ability to fight in low light conditions. In compliance with that decision, the U.S. Army borrowed image intensification (I^2) technology from the National Aeronautics and Space Administration (NASA). However, since NASA originally developed this technology to allow astronauts to see on the dark side of the moon, modifications were necessary given the requirements of the Army environment. The first image intensifiers, now called Night Vision Devices (NVDs), began to appear on the ground in use by tankers, the infantry, and other units. Army aviation, as an integral part of the combined arms team, developed the necessary tactics and equipment to allow Army aircraft to train and fight effectively at night. This I^2 technology has greatly enhanced U.S. Army aviation operations since its acceptance into Army aviation's rotary-wing program, and today's aviation commanders depend heavily on these devices to extend their operations into the night.

Notwithstanding, NVDs have their limitations. For instance, aircraft interior and exterior lighting can cause problems due to the I^2 device's inability to distinguish between light originating from the outside scene and light originating from other sources within its field-of-view (FOV) (i.e., cockpit lighting, aircraft position lighting, and other auxiliary lighting). In response to such lights, these devices adjust their amplification factor (gain) downward according to the level of ambient illumination, and in doing so, can cause degradation in the resulting image, to the extent that visual information may be lost.

Early in the process of testing and training on NVDs, aviators found that lights having wavelengths in the red and near-infrared degraded the goggle's effectiveness more so than other lights. As most cockpits used red lights in order to avoid adversely affecting night vision adaptation, corrective action became necessary. The Army conducted various studies to develop alternatives [1,2,3] that led to the modification of aircraft cockpits to replace the existing red lighting with NVD compatible blue-green lighting. This lighting does not significantly reduce the aviator's natural night adaptation, nor does it interfere with NVDs since the lights emit in a part of the spectrum not amplified by NVDs[1]. The Army developed Maintenance Work Orders (MWOs) to retrofit existing aircraft cockpits with the modified lighting, and to date, the majority of the fleet has been modified. MIL-L-85762A establishes night vision imaging systems (NVIS) compatibility requirements for cockpit/interior lighting [4].

However, in addition to cockpit lights, aircraft also use exterior lights (i.e., anticollision lights, rotating beacons, landing lights, search lights, and position lights). MIL-L-6503H is the primary exterior lighting specification used by the Army [5]. This latter specification has not been revised to take into account present mission and training requirements in the I^2 environment. Exterior lighting compatibility problems have been recognized, but only limited technical evaluations have been performed. The Department of the Navy recognized exterior lighting compatibility problems during the Research, Development, Test, and Evaluation (RDT&E) of the A-12 program [6] and developed test procedures for evaluating lighting compatibility in an effort to integrate exterior lighting for I^2 operations. In 1990, the U.S. Army Aviation Training

[1] Class A third generation aviator's night vision imaging systems (ANVIS), with the 625 nm minus-blue filter, are highly responsive to light emitted through red and clear filters but not to light emitted through green filters. Second generation systems are responsive to light transmitted through red, clear, and green filters due to their wide sensitivity range extending across the visible spectrum.

Brigade (ATB) and the U.S. Army Aeromedical Research Laboratory (USAARL) surveyed Army aviation field units to identify problems experienced with helicopter-mounted exterior lighting during NVD operations [7]. The UH-1 results showed that the left (red) lateral position light and the rear (white) tail position light were too bright for formation flight. The right (green) lateral position light was not a problem. Additionally, the left side light put the right side of the aircraft in a shadow, and the red light floods into the cockpit, degrading I^2 performance significantly; the presence of fog and other weather heightens this effect. In response to exterior lighting compatibility problems, the Army modified searchlights and landing lights with "pink light" filters and low-wattage bulbs to make them compatible with NVDs. However, anticollision lights, rotating beacon, and position lights continue to present NVD-related problems.

In attempts to minimize the degradation of I^2 performance, modifications have been made to position lighting in Army aviation tactical and training environments. Two fielded approaches to the position lighting problem are operating position lights in the dim mode and partial masking. Dim mode operation of position lighting on Army helicopters is available by using a switch to reduce the intensity of all exterior lighting. However, Snook, et al. show aircraft position lights in the dim mode fail to meet Federal Aviation Administration (FAA) illumination requirements [7]. Masking configurations were developed to decrease the angular distribution of position lighting without decreasing intensity. This partial masking modifies existing aircraft by taping and or painting the glass dome of the position lights, thus cropping the pattern of light emitted. The masking is designed to cover the position lights only at specific areas where emitted light may enter the crew compartment or distract aircraft in formation. Presently, only one MWO authorizes modifications to meet requirements of night formation flight, and it applies only to the UH-1, not all Army aircraft [8].

While partial masking of position lights reduced degradation of I^2 imagery, this modified lighting appeared to conflict with requirements established by the FAA for light distribution and intensities. However, Army aircraft had been flying with masked red position lights, under a FAA sanctioned waiver [9], which allowed U.S. Army tactical helicopters conducting NVD flight training to fly without lighted position lights under certain restrictions. The exemption expired on December 31, 1996 and a subsequent aviation safety-action message directed the mandatory inspection and removal of any materials that obscured normal operation of UH-1 position lights [10].

The Army opted not to request continuing extensions of the exception that waived the minimum lighting requirements. Under such a waiver, Army and civilian aviators were still being put into preventable dangers. Aircraft operating with inadequate exterior lighting, or lighting incompatible with NVDs, were at a greater risk for mishap. Thus, the ideal solution was to develop aircraft exterior lighting that complied with FAA requirements and did not degrade NVD performance. This solution would cancel the need for another FAA waiver and would enhance civilian and military aviation safety.

FAA Lighting Regulations and Exemption 3946D

The FAA requires that Army aircraft using the National Airspace System (NAS) meet specific criteria for exterior lighting angular distribution and intensities sufficient to provide aircraft position information. On the UH-1 utility helicopter, these exterior lights include two red lateral position lights on the left side of the aircraft and two green lateral position lights on the right side. Federal Aviation Regulations (FARs) (paragraphs 1387-1393 of Parts 27 and 29) address angular intensity distributions for exterior lights [11], and specifications in MIL-L-6503H are based upon these requirements [5]. In general, the specifications state that position lights shall provide their greatest intensities in the forward and rear directions of the aircraft during flight (Figure 1). However, these requirements were developed prior to the introduction of I^2 devices in aviation and were based on unaided (naked eye) viewing. As outline previously, in an I^2 environment, the spectral distribution and intensity requirements for aircraft exterior lighting can be detrimental and result in hazardous flying conditions.

FAR Part 91 and Army Regulation (AR) 95-1 require position lights to be on at all times during periods of darkness [11, 12]. Additionally, in accordance with AR 95-1 and AR 95-2, U. S. Army aircraft operating in the NAS must meet the requirements set forth in the FARs unless the FAA grants an exemption [12,13]. AR 95-2, paragraph 9-2, stipulates the limited exceptions for NVD flight in Army aircraft. As mentioned previously, the FAA granted an exemption that allowed U.S. Army tactical helicopters conducting NVD flight training to fly without lighted position lights under certain restrictions [9]. Specifically, the exemption permitted lights-out operations in certain phases of NVD device training within well-defined and controlled areas when two or more helicopters were involved, and then only with advanced coordination with other nonparticipating parties. For all other areas in the NAS, authorization was given for position lights to be on dim at altitudes up to 500 feet (152.5 m) above ground level (AGL) provided the aircraft was not within 5 nautical miles of any public use airport. Problems arose when aided formation flights, operating with modified lighting (masked or dimmed lighting), transitioned from military airfields to training areas at altitudes above 500 feet AGL in compliance with local noise abatement practices. In these situations, there were concerns that unaided civilian traffic could not visually acquire and appropriately respond to aircraft operating with modified lighting configurations.

To be proactive to this problem, USAARL conducted a study to document the intensity distributions of several masking schemes [7]. Included was the current (until December 1996) masking scheme of blackening the lower half of the upper red position light and the upper half of the lower red position light. Data from this study showed, as expected, that each position light did not individually meet the FAA regulation. However, given that the UH-1 has two lateral position lights per side, USAARL set out in March 1997 to determine if the presence of the two position lights did not, together, meet the FAR, since the FAR was based on a single lateral position light per side. This paper reports the results of the 1997 study. In addition to the "two light" question, this study helps determine actual levels of ANVIS degradation by exterior lighting, evaluates potential solutions to affordably modify the fleet to eliminate NVD degradation in compliance with the FAA regulations, and recommends the safest and most cost effective solution. The recommendations herein should reduce or eliminate liability exposure due to questionable operations within the NAS.

METHODS and RESULTS

We used a two-phase approach to investigate these issues. The first phase was a limited investigation of position light effects on NVD performance inside the cockpit (endogenous effects) as well as the effects on other pilots outside the cockpit (exogenous effects). The second phase addressed the problem of position light modifications and FAR compliance.

Endogenous effects of masked and dimmed lights

A UH-1 was positioned heading north in a relatively dark corner of Lowe Army Airfield, Fort Rucker, Alabama. After the end of nautical twilight, video recordings from the left seat were made using a single ANVIS tube optically coupled with a commercial camcorder. The FOV for the camcorder with the intensifier tube was approximately 45 degrees, showing the 40-degree circular intensifier image. The aircraft position light combinations were bright and dim, masked and unmasked, and with and without fuselage lights and rotating beacon.

An Air Force Tri-bar resolution chart was positioned 66 and 178 feet (20.13 and 54.29 m) from the left seat observer, perpendicular to the aircraft alignment outside the left window. At 66 feet, the red position lights increased the luminance and resolution of the Air Force chart, but the trees in the background were barely visible in the bright mode. The white fuselage lights and rotating beacon had negligible effects. The green position lights did not affect ANVIS performance[2]. All observers considered the decrease in visibility in the left hemisphere around the aircraft as very undesirable – decreasing both depth perception and visual acuity. They also reported excessive glare inside the cockpit, on the upper windscreen, and left cargo door. Masking the position lights and operating in the dim mode significantly improved visibility. However, comparisons between these two alternatives showed that the dim mode improved visibility much more than masking. When the chart was moved out to 178 feet, all observers could recognize the largest bar patterns for this field chart (-6,1) with 20/40 resolution. Black and white rectangles (12x16 inches; 30.5x40.6 cm) were taped to the back of the resolution chart. Even at that distance, the illumination increased the apparent brightness of the rectangles, showing the standard field resolution charts are too small to show the effects from the red position light.

Endogenous effects also were recorded in flight at Runkle Army Helicopter Stagefield, under 38 percent moon illumination[3]. The primary areas of interest for the flight observations were the altitude-related effects during take-off and landings. In flight, bright unmasked position lights did not interfere with visibility at low level altitudes between 50 and 100 feet (15 to 30 m) above the trees. However, reflections seen in the windscreen interfered with outside vision and were distracting. In this mode, a dimming of the horizon from activation of the automatic brightness control (ABC) was apparent within 25 feet of the ground and progressively worsened with decreasing altitudes. Pilots stated that in this mode, hovering, take-off, and landing would be unsafe. In the bright masked mode, pilots noted a slight dimming of the horizon, but only within a few feet of the ground. Pilots considered this decrement acceptable. In the dim mode, both masked and unmasked, outside vision with ANVIS was acceptable, but the masked lights improved outside and inside vision more by comparison.

In addition to these observations, USAAVNC had their instructor pilots fill out surveys after each NVG flight for a month to document their impressions of the various configurations. One concise and insightful response is quoted below:

> "...Below 100 feet the [unmasked] red position lights over-powered the IR band pass filter to the 10-12 O'clock position. This bright line of light continually moved back and forth with each minor heading change and became annoying. Out of the left side, the very high humidity was sensed by the NVGs automatic brightness control circuits and detail, texture, and contrast of the trees and ground was diminished. In these conditions, or worse, I would be hesitant to turn left (a normal instinct) to find a quick landing spot due to a precautionary landing. To the right front, the visual scene was normal. Dealing with two different visual environments while teaching IERW [initial entry rotary wing] students NVG flight pushes our safety factor. ... [Masked] the 82-degree[4] and 90-degree configurations were not noticeably different from each other. Both significantly reduce the effects noted above and greatly improve visibility outside the cockpit." [anonymous]

Exogenous effects of masked and dimmed lights

We used three UH-1 aircraft in flight to document detection and recognition of exterior lighting arrangements and to demonstrate the effects of modified configurations on other pilots outside the cockpit (i.e., multi-ship

[2] A senior UH-1 instructor pilot noted that unaided vision was decreased when the green lights were not masked.

[3] Without moon illumination, these reported effects from the position lights would be worse, and a little better with higher moon illumination.

[4] See FAA Compliance section.

operations). Simultaneous video recordings were made using a low light black and white charged-coupled device (CCD) video camera (which approximates the sensitivity of the human eye) and a commercial camcorder optically coupled with a single ANVIS tube. To simulate the eye response, a near infrared-attenuating filter was placed on the CCD camera in an attempt to match the apparent intensity of the green and red position lights. The focal length on the CCD camera was selected to produce approximately 20/20 vision for the viewing distance when viewed on a good monitor. The field of view for the CCD camera was approximately 6.5 degrees horizontally and the FOV for the camcorder was as described previously. The recordings were made from the walkway on the control tower of Lowe Army Airfield. The walkway is approximately 50 feet (15 m) AGL. Moon illumination was 4 percent with an altitude of 8 degrees above the horizon. The sky was overcast with visibility greater than 7 miles (11 km). Position light configurations were bright and dim, with and without the white fuselage lights. One aircraft had position lights masked as previously approved for NVD flight. The anti-collision lights were activated at all times.

Three UH-1 aircraft that were scheduled for NVG training executed prearranged take-offs and multiple passes at an altitude level with the control tower using an extended right traffic pattern. The traffic patterns were south of the tower with the aircraft pass closest to the tower when traveling from west to east. After the passes, the aircraft departed the area using either the south or north corridors. The UH-1s were easily visible for miles from all angles and under all viewing conditions. However, the white fuselage lights tended to mask the color of the red and green position lights in all configurations. The red and green position lights without the white fuselage lights, even when masked and in the dim mode, could be distinguished at comparable or greater distances than in the bright mode, unmasked, when the white fuselage lights were activated. Additionally, the anti-collision lights tended to mask position lights with increasing viewing distances.

FAA Regulatory Compliance

The UH-1 uses Whelen Engineering W1285 PR & PG position lights with Grimes Aerospace Corporation type III reflector bulbs rated for 28 volts direct current (VDC) manufactured to specifications in MIL-L-6363F [14]. These lights conform to Part 21 of the FAR, and are certified under FAA TSO-C30b [11,15]. Thus, the issue of compliance in the UH-1 does not concern the lights, but rather the configuration and placement of these lights. FARs, Parts 27 and 29, specify that forward position lights be spaced as far apart laterally as practicable; for fixed wing aircraft this is achieved by placing one position light on each wingtip [11]. Modifications are necessary for rotary-wing aircraft to meet the intent of the regulations. On helicopters, the greatest lateral distances are across the midsection of the fuselage since there are no wings. In which case, design specifications allow supplemental position lights to be installed in any location necessary to meet the minimum light distribution requirements. The specifications also allow shields to be installed to eliminate pilot annoyances[5] [16, 17, 18]. The UH-1 has two position lights on each side providing redundant intensity distribution within the 360-degree sphere around the aircraft. This begs the question, "Does the previously approved masking scheme of blackening the bottom half of the upper red position light and the top half of the lower red position light meet the angular lighting intensity requirements of the FAR?"

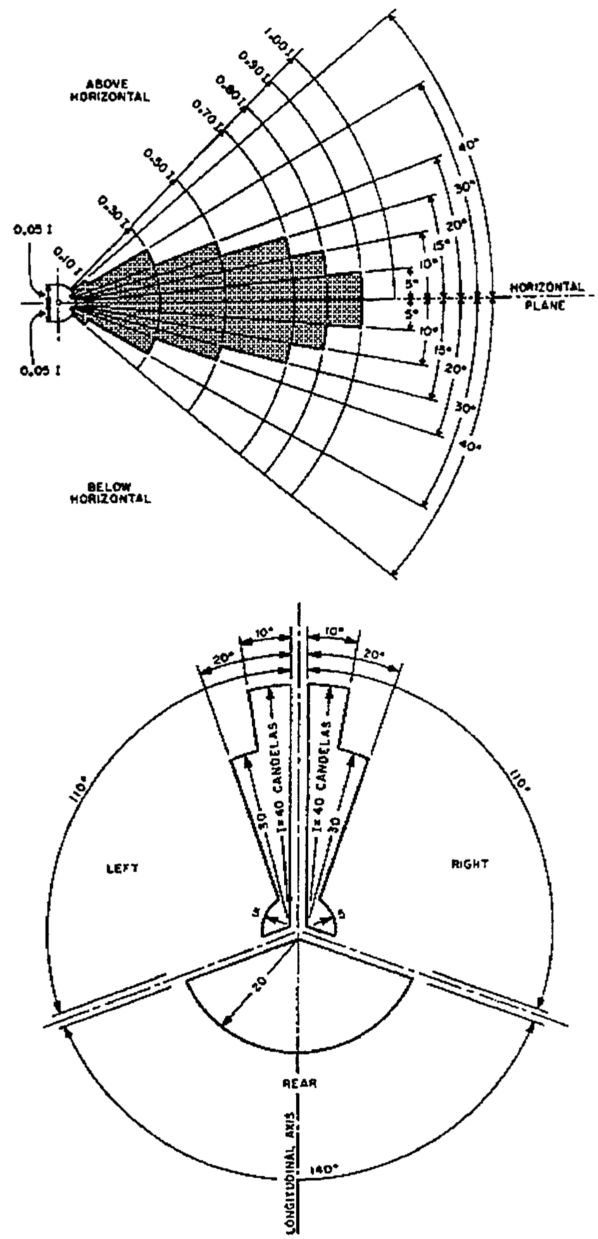

Figure 1. Position light minimum intensities in the vertical (top) and horizontal planes (bottom) [19].

[5] Currently, the forward angles (approximately 60 degrees) of the red anticollision light are blocked to reduce interference to the NVGs.

The FARs define intensity requirements for individual light units measured from "dead ahead" within angular cones of 110 degrees horizontal by ±90 degrees vertical for the lateral position lights. Figure 1 depicts the minimum FAR intensity distribution requirements [19]. In the horizontal direction, the highest minimum intensities are required between 0 to ±20 degrees; beyond that, the intensity requirements drop off sharply. In the vertical direction, the highest minimum intensity is required at 0 degrees with respect to the horizontal plane of the aircraft centered at the lamp filament[6]. At positions above and below 0 degrees vertical, the intensity requirements drop off as multiples of the highest value. Based on the distribution of intensity requirements, the critical region for the lateral position lights can be defined as the cone between 0 to ±20 degrees in the horizontal and vertical angular directions.

Snook et al. [7] measured baseline intensity distribution profiles for position lights operating in bright and dim modes. Measured intensity profiles were compared to FAA requirements to determine the acceptability of dim mode operation and the impact of masking on light intensity distributions. They demonstrated that the luminance intensities of lateral position lights for the upper and lower horizontal angles were symmetrical. However, the horizontal and vertical angular intensity requirements are designed to optimize aircraft visibility in all directions within a 360-degree sphere. Thus, the 90-degree masking scheme does not meet intensity requirements for the area between the lights, since the lights are separated vertically by 4.8 feet. With these requirements as they are defined, it seems any masking of the position lights is unacceptable with respect to FAA regulations. Nevertheless, it may be possible to develop acceptable modified lighting for I^2 compatibility via the modification of the current definition.

Given the redundant intensity distribution within the 360-degree sphere around the aircraft, it stands to reason that the redundant (overlapping) light could be eliminated (masked) leaving a sphere of light around the aircraft within the FAR intensity requirements. Simple geometry and trigonometry give us the tools to calculate the appropriate angles for such masking. Ignoring penumbral effects, refraction of light due to edges, atmospheric bending etc., one can argue that the 90-degree masking scheme results in a "dark alley" between the upper and lower position lights since parallel lines do not converge (Figs. 2 and 3). However, light patterns from masking angles less than 90 degrees must converge. Using the following formula, the point of convergence was calculated for one rotor disk radius assuming FAA compliant illuminance values for the required angular distributions around the left side of the aircraft.

$$\tan\theta = \frac{r_c}{\frac{1}{2}d}$$

Where r_c = the radius of the rotor disk corrected for offset of the position light from the mast
d = the distance between the position lights

The radius of the rotor disk is 289.6 inches (24.1 ft; 7.36 m). This value corrected for position light offset is 235.6 inches (19.63 ft; 5.98m). The vertical distance between the two lights is 57.6 inches (4.8 ft; 1.46 m). The resulting value is 82.25 degrees, and rounding down for a more conservative 82-degree masking scheme (98 degrees unmasked) results in a lighting distribution pattern from the two lights that converges 7.6 inches (19.36 cm) inside the rotor disc. At this distance, a point source of light (luminance) from one of the two lights would be visible that meets any given angular intensity requirement (Figs. 2 and 3). Note that this requirement is satisfied only by allowing angular cone vertices to move from one light to the other as measurements transverse the equator of the sphere.

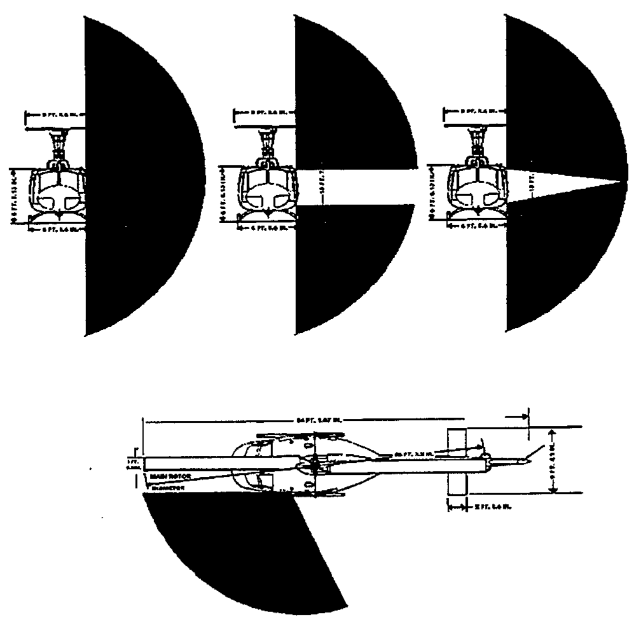

Figure 2. Side angular illuminance coverage for unmasked (left), 90-degree mask (center), and 82-degree mask (right). Horizontal coverage (bottom) does not change with masking pattern.

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[6] FAR requirements are stated in terms of *luminance*, the light intensity or luminous flux emitted from an infinitely small point source, where light flux is the rate or flow of visible energy. Intensity measurement of a light source generally is performed indirectly with instrumentation that measures *illuminance*. Illuminance is the density of luminous flux incident upon a surface. Intensity of a point light source can be calculated from illuminance using the inverse square law [7]:

$$\text{Illuminance (foot-candles)} = \frac{\text{intensity of source (candelas)}}{\text{distance (feet)}^2}$$

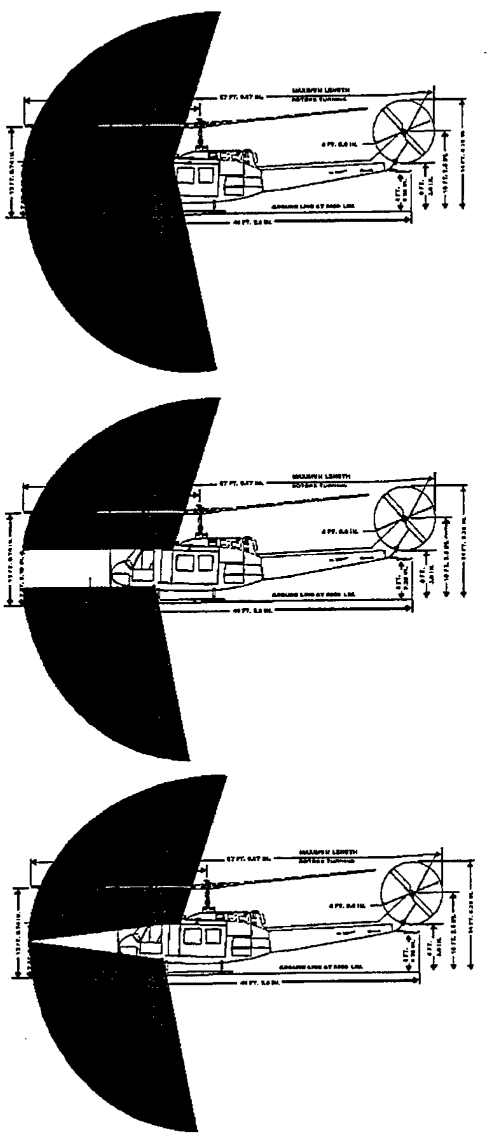

Figure 3. Forward angular illuminance coverage for unmasked (top), 90-degree mask (center), and 82-degree mask (bottom).

Video recordings were made using the single ANVIS tube and commercial camcorder described previously. These data show that NVD performance with the 82-degree masking scheme was equivalent to levels recorded under the old 90-degree masking scheme. Subsequently, USAAVNC requested that the U.S. Army Aviation and Troop Command (ATCOM) allow Fort Rucker UH-1s to be re-masked enabling data collection and validation of the 82-degree scheme. Data collected from USAAVNC's instructor pilot survey clearly indicate that the 82-degree masking scheme directly reduced NVD operational risks. Pilots reported that there were no problems with degradation or depth perception in NVD flight modes, and that the new masking scheme was just as effective as the old 90-degree masking scheme. Based on these data, the Army rescinded the earlier position light ASAM [10], and issued an ASAM directing the re-masking of both the red and green position lights according to the exact specifications of the 82-degree masking scheme [20].

CONCLUSIONS and RECOMMENDATIONS

The FAA establishes standards of exterior lighting to reduce the likelihood of aviation mishaps, to include mid-air collisions. Since 1978, the Army has been flying UH-1 aircraft exempt from current regulations under FAA waiver 3946D. This waiver expired on 31 December 1996. The goal of this project was to provide the Army aviation community with a standardized, permanent external light configuration that would satisfy unit training and mission needs for I^2 devices while maintaining adequate position light intensity distributions required by the FAA.

The FAA designed intensity distribution requirements to provide optimum visibility for aircraft operating in the NAS. Current requirements were developed for civil air-space operations prior to the introduction of I^2 devices into aviation. These standards were defined with the intention of maximizing unaided detection of aircraft in periods of reduced visibility and low illumination. Yet, in order for night missions to be performed safely and efficiently, aircraft position lighting must be compatible in both the civilian and military operating arenas. The integration of image intensifiers into Army aviation has greatly expanded mission capabilities. However, due to the operating characteristics of I^2 devices, the configuration for position lighting is not compatible with, and can have a negative impact on, the safety of mission execution. In attempts to alleviate the degradation of I^2 imagery by position light sources, the Army aviation community has modified lighting strategies to include operating with position lights in dim mode and operating with masked position lights in bright and dim modes under a FAA approved exemption. Modified exterior lighting or lights-out operations present an increased risk of possible mid-air collision with both civil and military aircraft[7].

This is not only a UH-1 problem: the OH-58 has the same problems as the UH-1; the UH-60 left lateral position light is too bright and creates excessive glare in aircraft crew compartment; and AH-1 crews report that the left lateral position light is too bright for formation flight and distracts the crew [7]. Consequently, many units address taping or painting of their position lights in unit standard operating procedures (SOPs) when conducting night aided formation flight. According to aviators surveyed, over 50 percent of Army aviation units were operating in the NAS with modified exterior lighting that did not comply with FARs.

The phenomenon that causes the decrease in NVD performance from the red position lights is due to activation of the ABC in the power supply of the NVD.

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[7] The U.S. Army Safety Center (USASC) notes that the risk of flying with unmasked lights exceeds the risk of colliding with other aircraft. There are no accidents in which position light masking was a contributing factor nor have there been any collisions or near-misses between Army aircraft with masked lights and civilian aircraft since the practice of masking was started 20 years ago.

Illumination from the red position lights floods into the cockpit and reflects off the ground around the aircraft, reducing the amplification of the goggles and reducing visibility of distant obstacles. The problem of light flooding into the cockpit/crew compartment from the lateral position lights is attributable in part to the location of the light units above and below the crew doors. One alternative for alleviating this problem would be to relocate the lateral position lights so that light emitted into the cockpit/crew compartment is reduced or eliminated. However, this may introduce new problems with FAA compliance depending on the eventual configuration and placement of the lights. Alternatively, the lighting industry is developing "NVD friendly" position lights using narrow bandwidth light emitting diodes (LEDs) with reduced near-infrared radiation. Both of these materiel solutions are relatively expensive as compared to the previously available options.

Of the previously available options (dim mode vs. masked), data show that the dim mode improved visibility more than masking. Dim mode is one of three selectable positions on Army helicopters (bright, dim, and off). Although intensities in the current dim mode fall below FAA requirements for flying in the NAS, incrementally dimmed steps between bright and dim modes are potentially feasible and offer a potential solution to the problem. Reportedly, Naval helicopters use a seven-step dimming switch where intensity at each dimming step is one-half that of the next higher step [6]. The primary exterior lighting specification for naval aircraft is MIL-L-006730C, which is based upon the same FAA intensity requirements as the Army specification MIL-L-6503H [16, 5]. Variable dimming on Army helicopters would allow flexibility for I^2 operations in restrictive environments.

Comparatively, masking is the most cost-effective solution. We calculated that the FAR could be satisfied at a distance of one rotor disk radius by an 82-degree masking scheme (leaving 98 degrees unmasked). Video recordings clearly document the objective effects of this masking scheme on NVD performance inside the cockpit (pilot's view), as well as the effects on other pilots outside the cockpit (i.e., multi-ship operations). Pilots' subjective observations indicate the new scheme significantly reduces NVD degradation as compared to operations with unmasked position lights. Additionally, there were no subjective conspicuity differences noted between the 90-degree and the 82-degree masking schemes. However, given the observation that fuselage and anticollision lights on the UH-1 cloaked the position lights, the issue of inter-aircraft I^2 degradation due to external lighting problems should be investigated further. Additionally, the global issue of lighting and masking problems on other aircraft deserves immediate attention.

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