FAA Milestone 1 Report for Inter-Agency Agreement DTFA01-02-X-02017 Calibrated Lighting Simulator for NVIS Assessment

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Introduction

This report is the first contractually required deliverable under the terms of the Interagency Agreement between the FAA and AFRL/HE. The purpose of this report is to describe and document the lighting simulator that has been developed to serve as the primary tool to investigate night vision imaging system (NVIS) lighting compatibility with night vision goggles (NVGs). Cockpit lighting can interfere with the proper operation of NVGs in several specific ways. In each interference mechanism the effect on the image seen through the NVGs is to reduce the light level or contrast of the useful image (the view outside the aircraft). The concept behind this NVIS lighting simulator (NLS) is to duplicate, in a precisely controlled manner, the types of lighting interference mechanisms that can occur in the cockpit. Ideally, the NLS should provide multiple adjustable levels of potentially interfering (non-compatible) light in a highly repeatable fashion. This will enable the systematic investigation of proposed NVIS lighting evaluation methods in a laboratory environment. It should be stressed that this entire research effort is directed only at the NVIS lighting interference with the operation of the NVGs and does not address other important aspects of a full NVIS assessment such as day light and night time readability of cockpit instruments.

The major interference mechanisms that can be studied with the NLS are:

1. Cockpit displays or light sources that reflect off the windscreen that are within the field of view (FOV) of the NVGs thereby producing an interfering image within the FOV of the NVGs
2. Lighting sources within the FOV of the NVGs, but not in a windscreen reflection geometry (if strong enough these can cause the automatic gain control to activate, thereby lowering the luminance of the exterior world scene)
3. Lighting sources outside the FOV of the NVGs that produce an irradiance at the objective lens of the NVGs that can cause scattered light within the NVG (flare) producing a loss of image contrast
4. Lighting sources within the cockpit that irradiate other objects (such as pilot clothing) that in turn reflect in the windscreen within the FOV of the NVGs.

By using the NLS, ANY method of assessing NVIS lighting interference/compatibility can be compared to the baseline military method described in Mil Std 3009 and in Mil Spec 85762A.

Description of NVIS Lighting Simulator

Basic Design Concept

Figure 1 shows a drawing of the NLS in its basic, Mode 1 configuration. The lower box is a light-tight aluminum box with a translucent top. The interior of the box is illuminated with a combination of blue-green and infra-red LEDs, which produce a uniform luminance/radiance top surface. In the Mode 1 configuration shown the translucent top is reflected in the transparency (clear plastic – the line shown at a 45 degree angle with respect to the box surface) producing a virtual image through which the observer must look. In this configuration, there are at least two distinct interference mechanisms: loss of scene contrast due to the image reflected in the transparency and loss of scene contrast due to non-compatible light striking the objective lens of the NVG (light scatter).

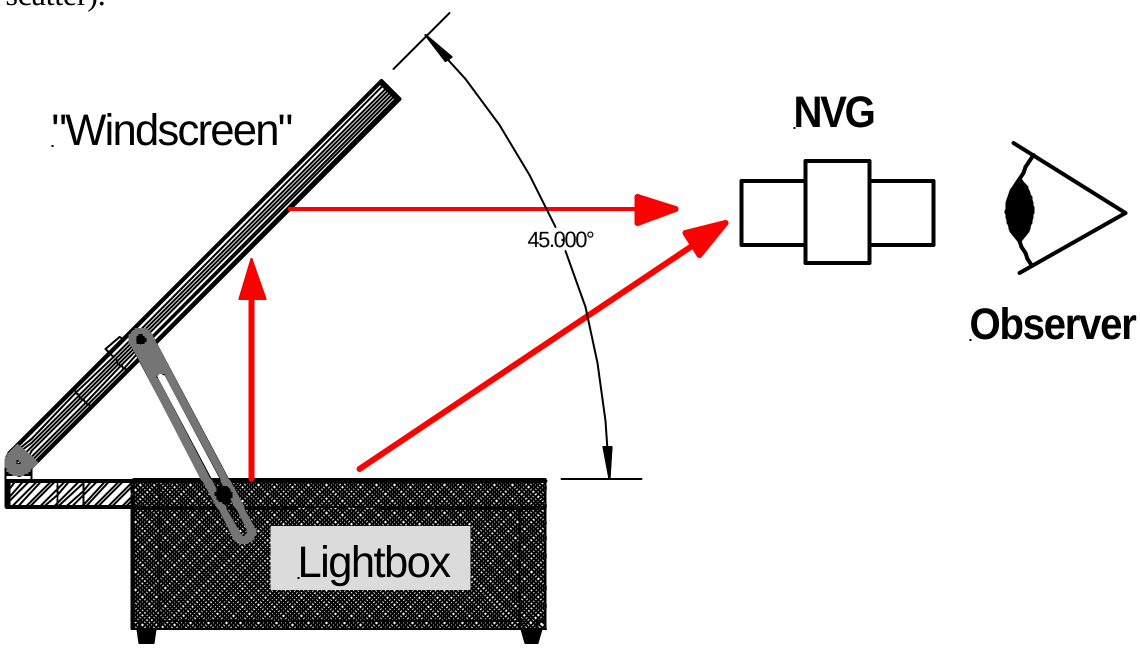


Figure 1. NVIS Lighting Simulator (NLS) in Mode 1 configuration.

The Mode 1 configuration shown in Figure 1 is probably the most severe interference mechanism since the observer must look directly through a reflected image in order to see the outside world scene (AND light can impinge directly on the objective lens causing light scatter or "flare").

In Figure 2, the NLS is shown in the Mode 2 configuration. In this configuration light can reach the objective lens of the NVG but there is no path for the light to reach the transparency (simulated windscreen), so there is no reflected image through which to look. This configuration should result in a lower interference effect for the same level of NVIS radiance of the translucent surface. For either Mode 1 or Mode 2 a template (vugraph) can be placed over the surface of the translucent surface to simulate an actual cockpit display or instrumentation set.

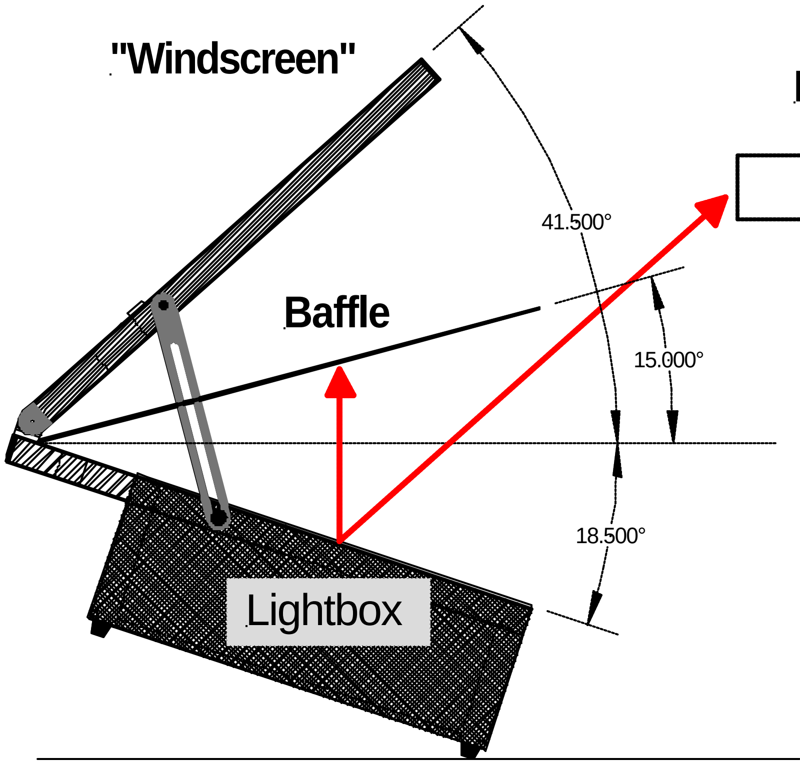


Figure 2. NVIS Lighting Simulator in Mode 2 configuration, light from the emissive surface cannot reflect from the "windscreen" but can cause scatter in the objective lens.

Figure 3. Photographs of the NVIS Lighting Simulator (NLS) in Mode 1 (left) and Mode 2 (right) configurations.

Operating configurations

The NLS has both visible (blue-green) and invisible (infra-red) LEDs that can be independently activated to illuminate the translucent surface. This permits the investigation of different ratios of usable visible light to infra-red (IR) light simulating different levels of NVIS compatibility. The green LEDs can be set to 2 fixed levels (high and low), the IR LEDs can be set to any of 5 pre-selected levels (adjusted using trim pots), and the IR LEDs can be used alone or in conjunction with the green LEDs. In addition, the system can be put into variable mode to permit the subject to adjust the lighting levels to "operationally suitable levels," simulating current actual NVIS assessment procedures. The following is a summary of the controls for the NLS (see figure 4).

NLS Controls and Functions

Power On/Off	- controls power for the LEDs
Cntrl Panel On/Off	- controls lighting for the control panel
Grn Hi/Lo	- selects high or low light setting for green LEDs
Both/Grn/IR	- selects IR LEDs only, green LEDs only, or both
IR (1 – 5)	- selects level of IR LED setting (1 through 5)
VAR On/Off	- selects variable or fixed mode for ALL LEDs
VAR	- ten turn pot to adjust lighting level when in VAR ON mode

Figure 4. NVIS Lighting System control panel

Spectral content

Figure 5 shows the spectral distribution of the "IR" LEDs used to produce NVIS incompatible lighting. Figure 6 is a graph of the spectral distribution of the blue-green LEDs and the spectral sensitivity of the NVGs with "A" and "B" minus blue filters.

Figure 5. Spectral distribution of the "IR" LEDs used in the NLS.

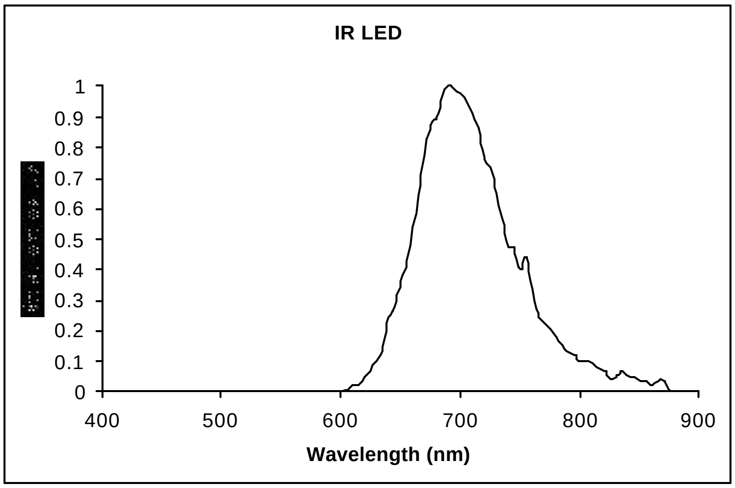
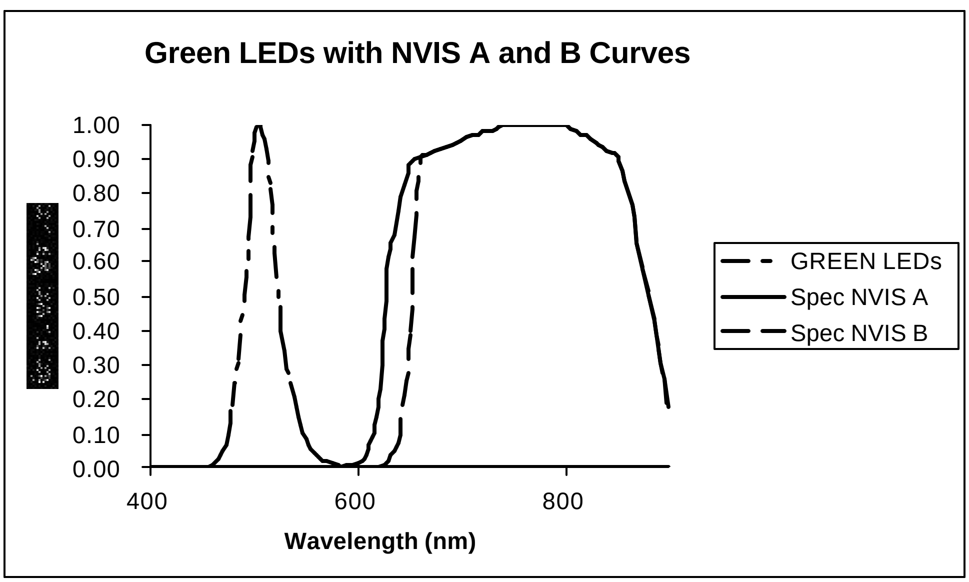


Figure 6. Spectral distributions of the green LEDs used in the NLS. The spec values for NVIS A and NVIS B are shown for comparison.



By adjusting the relative amounts of the green and IR LEDs, it is possible to generate combinations that meet or exceed the Mil Std 85762A spec values.

Assessment of NVIS Lighting Simulator

Basic characteristics

The NLS was designed to be "transportable" so that it could be easily sent to various locations and set up for testing. The system is powered by a small power supply plugged into 115 VAC, 60 hz power but it can also be powered by battery if necessary.

Radiance/Luminance stability

In order to have confidence in the NVIS compatibility testing accomplished using the NLS it was necessary to insure that the luminance and NVIS radiance levels produced are reasonably constant and repeatable (no significant short term or long term drift). Table 1 is a summary of the data collected to document drift. All values of Table 1 are in foot-lamberts and are the luminance of the output of an NVG as it was positioned to image the NLS translucent surface. As can be seen from Table 1 stability of the NLS is excellent.

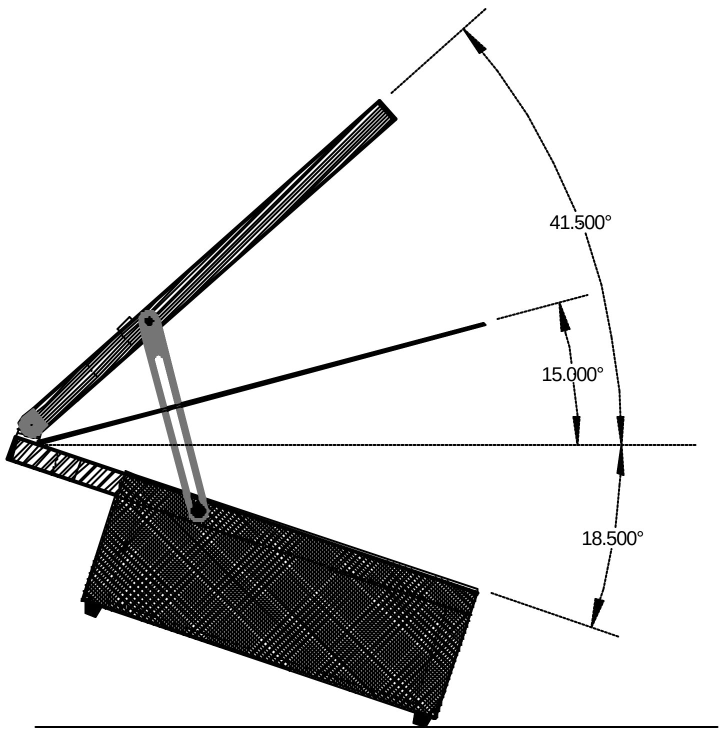
Table 1. NLS radiance drift over time (all values in foot-lamberts)

Time	IR-1	IR-2	IR-3	IR-4	IR-5	Green Hi	Green Low	Off
5/21/02								
7:00	1.346	0.920	0.558	0.354	0.107	0.425	0.071	0.000
10:00	1.354	0.924	0.557	0.354	0.107	0.430	0.071	0.000
1:00	1.349	0.925	0.560	0.355	0.109	0.431	0.072	0.002
4:00	1.348	0.923	0.557	0.353	0.105	0.433	0.070	0.000
5/22/02								
7:00	1.342	0.924	0.561	0.355	0.105	0.428	0.069	0.000
10:00	1.387	0.944	0.569	0.360	0.108	0.435	0.071	0.000
1:00	1.342	0.922	0.557	0.354	0.106	0.426	0.070	0.000
4:00	1.342	0.921	0.556	0.353	0.105	0.428	0.069	0.000
5/23/02								
7:00	1.342	0.922	0.557	0.353	0.106	0.427	0.069	0.000
10:00	1.340	0.919	0.554	0.351	0.106	0.428	0.069	0.000

Avg:	**1.349**	**0.924**	**0.559**	**0.354**	**0.106**	**0.429**	**0.070**	**0.000**
S.D.	**0.014**	**0.007**	**0.004**	**0.002**	**0.001**	**0.003**	**0.001**	**0.001**
% S.D.	**1.0**	**0.8**	**0.7**	**0.7**	**1.3**	**0.7**	**1.6**	

Calibration methodology

The NLS was calibrated by using an Instrument Systems model 320 spectro-radiometer to measure the luminance and NVIS radiance (both "A" and "B") of the NLS for all pertinent settings (green high and low and IR 1 through 5). Table 2 shows the repeatability of the NVIS radiance measurements made using the IS320 for one particular set of values (used in pilot studies) of the 5 IR LED settings. Some of the variability could be attributed to variation in radiance/luminance uniformity across the translucent surface (see Figure 7).



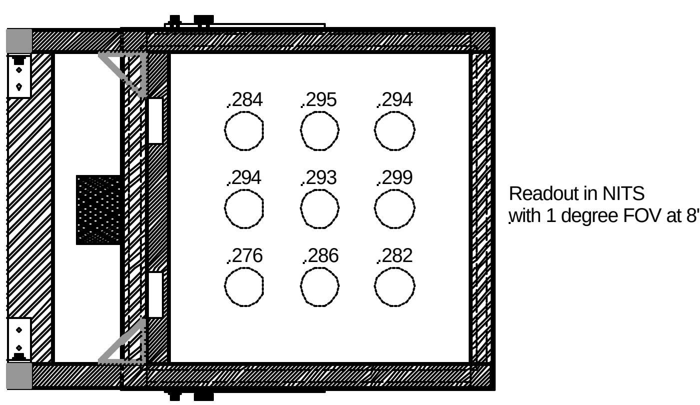


Figure 7. Geometry of NLS for Mode 2 operation (upper drawing) and luminance uniformity of NLS emissive surface (lower drawing).

Table 2. Repeatability of measured NVIS radiance values for one set of IR (1-5) LED values. All numbers are in watts/cm^2-sr weighted by NVIS A or NVIS B as noted.

	IR1	**IR2**	**IR3**	**IR4**	**IR5**
NVIS A	1.11E-09	7.60E-10	4.54E-10	2.59E-10	6.50E-11
	1.12E-09	7.43E-10	4.16E-10	2.63E-10	6.63E-11
	1.11E-09	7.42E-10	4.34E-10	2.58E-10	6.30E-11
Average	1.11E-09	7.48E-10	4.35E-10	2.60E-10	6.48E-11
S.D.	**9.00E-12**	**1.03E-11**	**1.87E-11**	**2.44E-12**	**1.66E-12**
% S.D.	**0.8**	**1.4**	**4.3**	**0.9**	**2.6**
NVIS B	1.06E-09	7.29E-10	4.35E-10	2.49E-10	6.27E-11
	1.07E-09	7.12E-10	3.98E-10	2.51E-10	6.42E-11
	1.06E-09	7.09E-10	4.17E-10	2.48E-10	6.08E-11
Average	1.06E-09	7.16E-10	4.17E-10	2.49E-10	6.26E-11
S.D.	**8.39E-12**	**1.06E-11**	**1.86E-11**	**1.46E-12**	**1.68E-12**
% S.D.	**0.8**	**1.5**	**4.5**	**0.6**	**2.8**

The "% S.D." rows in Table 2 list the standard deviation of the NVIS measurements as a percentage. It is apparent from the fairly low percentage values (0.8 to 4.3 percent) that the measurements are reasonably repeatable and the NLS provides a stable radiance output.

Conclusions

With the recent addition of the variable luminance control, the NLS is now ready to be used to assess various methods of determining the NVIS compatibility that can be compared to the baseline method. Its flexibility in simulating two different interference modes, variable NVIS compatibility level, and radiance/luminance stability make it ideal to systematically investigate multiple NVIS compatibility assessment techniques in a relatively short time.

References

MIL-STD-3009, 2 February 2001, *Department of Defense Interface Standard for Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible*.

MIL-L-85762A, 26 August 1988, *Military Specification, Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible*.

Inter-Agency Agreement DTFA01-02-X-02017 (February 2002) Between the Federal Aviation Administration (FAA) and the Department of Defense Air Force Research Laboratory (AFRL/HEC, Wright-Patterson AFB.