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HIGH LEVEL Vis-IR STIMULATED NVG TRAINING

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ABSTRACT

Physically accurate Night Vision training for flight simulation is provided by combining standard issue NV goggles, a VITAL X image generator and database, and the AVIOR®VisIR laser projection system.

The AVIOR®VisIR projector contains an IR laser that overlays an independent infrared image onto the out-the-window scene drawn by an RGB laser. The RGB laser provides a high-contrast scene optimized for unaided viewing while the IR laser provides a physically accurate stimulation of standard issue Night Vision Goggles (NVG). The visible and infrared projections can be driven from independent IG channels without sacrificing physical accuracy in either projection. As a cost saving option, a single IG channel can drive both projections via one of two "clone" transform techniques without significantly sacrificing physical realism. These clone operating modes are features of the AVIOR®VisIR projector.

VITAL X's physics-based display system model takes into account real-world radiances, projector spectral and dynamic behavior, as well as spectral and dynamic responses of the NVGs. As a result, deterministic integration of the high contrast AVIOR®VisIR laser projector with different goggle types is straightforward.

INTRODUCTION

The use of night vision goggles is becoming more important for both military operations and civilian missions. In military operations, the night offers protection from visual detection by hostile forces; however, visual reconnaissance is also considerably limited. For this reason, operational forces have long been using night vision devices to enhance their visual perception. As passive sensors, ambient light intensifiers offer the optimum capability for night vision devices – "seeing without being seen" – without the need for additional illumination. For civilian missions, especially rotary wing ones, the situational awareness provided by using NVGs increases safety in dense urban areas and unfamiliar, close contact environments.

However, the effective use of night vision goggles requires thorough training. Their special characteristics demand a specific set of skills be developed. Night vision goggles have a narrow field of view showing monochromatic, grainy images with limited resolution. NVGs also exhibit effects such as haloing, smearing, and blooming around bright light sources. This is why intensive NVG training is important in assuring the overall success of the mission. Simulators offer an safe environment to accomplish this before the pilots or soldiers encounter these often extreme situations in life threatening situations.

NIGHT VISION TRAINING IN SIMULATORS

Night vision training in simulators can be accomplished using two basic methods. Pilots can either be trained with simulated goggles or the display system can stimulate standard issue goggles.

Night vision training with simulated goggles replicate standard issue NVGs by building in small displays in place of the light intensifier tubes. The NV image is then generated by a dedicated IG channel that must have a sophisticated model for how each type of goggles reacts under specific physical stimuli. Additionally, pilots must wear a head tracking system in order to generate the appropriate view within the IG.

Simulated goggles also incur additional disadvantages. The cockpit structure, instruments, and lighting can not be observed through simulated goggles. All such information must be replicated virtually within the IG. Pilots typically complain about goggle and head tracker discomfort, as well as about the shortcomings of the cockpit simulation and overall NVG realism compared to their original equipment.

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In contrast, optimum training with high realism can be achieved when the trainee is able to use his own original night vision goggles in the simulator. The actual goggles are “stimulated” by the out-the-window display. It is important that the projectors used have a good black level in order to provide good night scene realism.

Traditional out-the-window projectors have limited energy in the NVG passband. As a result, the image typically needs to be color shifted with a red cast to sufficiently stimulate NVGs. Therefore night scenes observed with the naked eye may be reddish or even too bright. In addition to the red cast, the stimulated NV image may show a limited dynamic range and lack of NV effects like halos or blooming.

To overcome this obstacle, the AVIOR®VisIR laser projection system overlays two images as on the screen 1) a visible dark night scene and 2) an infrared image, which effectively stimulates the goggles but is invisible to the naked eye. As a result, the visible and NVG images can be independently controlled, and the proper balance of visible and NVG stimulation can be achieved (Reference 1).

The AVIOR®VisIR projection system has been integrated with a variety of Image Generators. A particularly good combination is the AVIOR®VisIR coupled with the FlightSafety VITAL X IG. The VITAL X provides a traceable real-world illumination model and physics-based rendering, which are used to advantage in controlling the AVIOR®VisIR’s inherent ability to properly stimulate the NVGs. See Reference 2.

AVIOR®VisIR LASER PROJECTION

The AVIOR®VisIR laser projection basically consists of a laser source that generates a laser beam. This beam is intensity-modulated with the video signal and then transferred via an optical fiber to a projection head where a two-axis scanner deflects the modulated laser beam in horizontal and vertical directions, writing an image line-by-line directly onto the screen.

In the AVIOR®VisIR projector, a solid-state laser oscillator generates red green and blue laser beams for writing the visible image onto the screen. The RBG laser beams are then externally modulated via acousto-optical modulators and recombined into one single beam. The RGB laser beam is coupled into the optical fiber and transferred to the projection head.

A second laser source located inside the projection head generates the fourth wavelength near 830 nm for the invisible IR image. A small semiconductor laser diode is directly current-modulated with the video signal. The resulting beam is coupled into a fiber and combined with the RGB laser beam in the projection head. The projection head consists of an extremely fast rotating polygon mirror which deflects the incoming video-modulated laser beam horizontally writing a line. A second galvanometric mirror is responsible for the vertical deflection retrace down to the next line and the retrace between frames.

The two overlaid images are written onto the screen with a composite four-wavelength Vis-IR laser beam pixel by pixel and line by line similar to how an electron beam in a

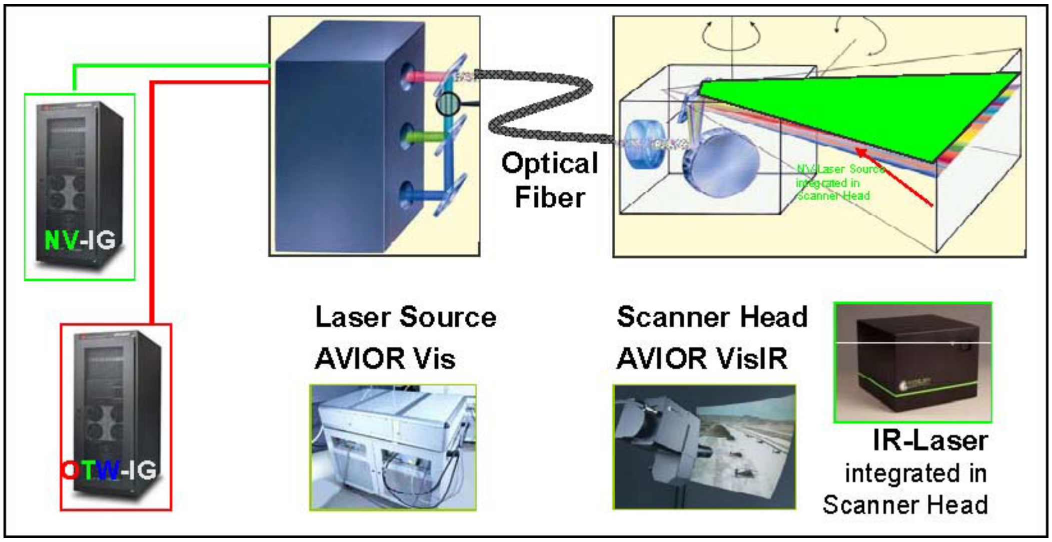


Figure 1 Principal set-up of the AVIOR®VisIR laser projection system.

cathode ray tube (CRT) writes an image onto a phosphor screen. The AVIOR®VisIR projector has a UXGA resolution (1600 x 1200 pixels) with a fixed frame rate of 60 Hz.

VITAL X IMAGE GENERATOR

We successfully integrated the AVIOR®VisIR laser projector with the FlightSafety VITAL X image generator. VITAL X is well suited for high-quality NVG stimulation. VITAL X provides a deterministic, traceable illumination model that generates scene visual illumination and NVG irradiance as a function of the "percent lunar illumination" and weather conditions commonly provided in pilot flight briefings. The instantaneous illumination is determined by the pilot briefings and the current ephemeris or alternatively by the moon elevation manually entered by the instructor. VITAL X uses high-dynamic range rendering and dithering techniques within a floating-point CPU/GPU pipeline to carry the high intrinsic dynamic range out to the projector through 8-bit DVI video. For a given flight briefing, the night-scene view and associated NVG stimulation thus matches the real-world to the extent possible given the characteristics of the display at hand.

FlightSafety has developed an analysis technique for optimizing the performance of an NVG stimulation system given projector characteristics. That technique focuses on the ratio of the energy in the NVG passband to the energy stimulating normal unaided vision. Traditional display systems generate insufficient NVG stimulus and a red boost is usually required to achieve reasonable simultaneous aided and unaided views. See Reference 2 for details. The ratio technique assists in making optimal tradeoff decisions between NVG quality and unaided scene quality. Fortunately, the AVIOR®VisIR, with its internal IR laser, can readily achieve both real-world NVG stimulation levels and real-world unaided out-the-window visual scene illumination with low black levels. As a result, the ideal scene illumination and NVG irradiance dictated by the VITAL X real-world illumination model can be achieved without compromise.

CLONE MODE OPERATION

The highest quality NVG stimulation is achieved when a single projector is driven by two image generator channels via two video links. One video link drives the visible RGB laser, and the other link drives the IR laser and is dedicated to NVG stimulation. However, excellent performance can still be achieved via a single IG channel and a single video link using the AVIOR®VisIR's "clone mode". Clone mode operation reduces cost and complexity of the display system.

With clone mode operation, the IG video channel is split into two video streams within the projector. One stream connects to the Vis RGB part of the AVIOR® laser projector, and the other stream connects to the internal IR laser. One of the two streams can undergo a programmable video transformation that can be used in variety of ways to simultaneously optimize the Vis RGB display and the IR laser display as derived from the single video signal. Two basic clone mode approaches were evaluated during the AVIOR® VisIR integration with the VITAL X IG.

Figure 2 AVIOR®VisIR projection head writes an image generated with VITAL X image generator.

Clone Mode 1

In a first alternative, the image generator generates the bright IR image with full dynamic range which is projected by the AVIOR® IR laser projector and which stimulates a brilliant NV image in the goggles with high contrast. The video signal for the visible projection is modified such that only the brightest parts of the image are unaffected while darker parts become increasingly darker resulting in a projected visible image with darkened textures, dim sky and ground structures but with glistening bright artificial lights inducing halos in the NV image.

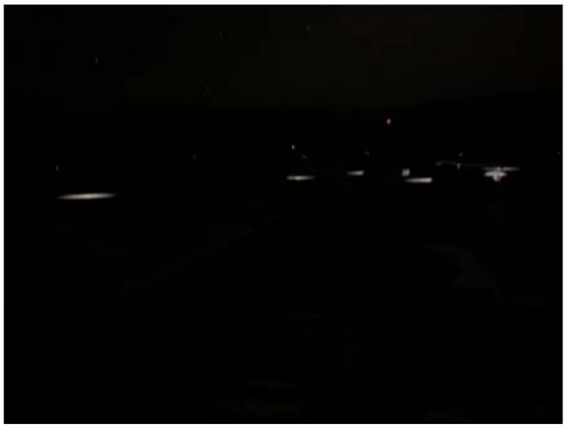
Clone Mode 1 provides a good simultaneous match between the basic dynamic ranges of goggles and of the visible scene; however, it also requires carefully controlled tone mapping of computed light sources. "Tone mapping" is defined as the optimal conversion of physics-model high-dynamic range floating point quantities to display levels that are within the capabilities of a lower-dynamic range display. Under tone mapping, a lightpoint physical brightness on the display matches that in the real-world if that brightness is achievable. Alternatively, if the real-world brightness is not achievable, the tone mapping process produces a display value that maintains the pilot's subjective or relative sense of brightness. Optimal tone mapping changes with the requested illumination level. As a result, basic Clone Mode 1 operation with VITAL X tended to have artifacts associated with objects at mid-level brightnesses. Clone Mode 1 is suitable for basic applications with simple, tightly controlled tone mapping; however, operation with fully dynamic tone mapping systems such as VITAL X requires that the IG tone map be dynamically coordinated with the projector's internal transformation, which is an interesting topic for future integration improvements. Regardless, we achieved much better integration results using Clone Mode 2.

Clone Mode 2

In Clone Mode 2, the IG generates a normal high-dynamic range visible dark night scene, which is directly applied to the AVIOR® Vis laser. That same video signal undergoes a basic power law "gamma" transformation and is applied to the AVIOR® IR laser for NVG stimulation.

The gamma modification amplifies the lowest light levels relatively more than the medium or high brightness levels. The extremely dark parts of the scene projected with the AVIOR® IR laser projector are realistic in the goggles. Brighter objects or artificial lights induce blooming in the goggles. The specific gamma function used is tuned to assure that dither noise associated with the high dynamic range video input is not objectionable in the goggles.

(a) Scenario in daylight



(b) Scenario at night

(c) Scenario observed through NVG

Figure 3 Scenario with urban terrain generated with VITAL X fro mission training in a simulator using Clone Mode 2.

NVG STIMULATION IN A SIMULATED WORLD

Clone Mode 2 operation of the VITAL X image generator and the AVIOR®VisIR laser projector is shown in the following pictures of a helicopter mission in Afghanistan. The images were directly photographed from the projection screen. Figures 3 to 5 show the scenario first in day time, second in the visible night scene which is of course mostly black, and at last in the NV image photographed through the goggles.

Figure 3 shows urban terrain containing many artificial lights, which are seen at full intensity in the unaided view and which generate strong NV effects in the NVG.

Figure 4 shows an AVIOR®VisIR scenario with buildings near an airfield. At night these buildings are well-lit and generate strong NV effects and blending in the NVG.

Finally, Figure 5 presents non-urban area scenario in a strong dark environment. In this environment, the terrain is dark at night and only the burning object could be seen visually. The NVG image shows all the details of the terrain and the blooming image of the bright, burning object.

CONCLUSION

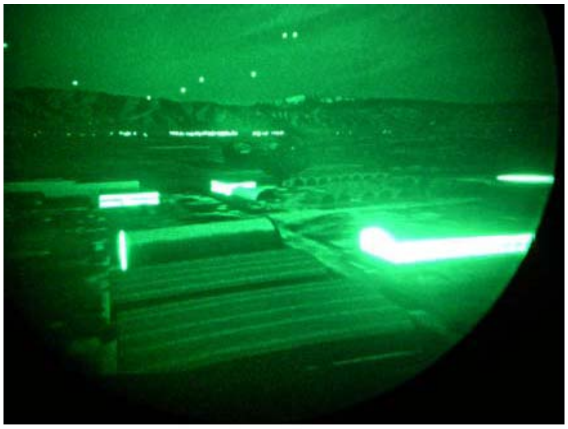
The AVIOR®VisIR laser projection system provides the following fundamental benefits:

- The addition of an internal IR laser allows fully independent control of the visible and stimulated NVG presentations allowing an ideal balance of visible scene illumination and NVG stimulation to be achieved.
- The intrinsic laser black level approaches that of CRTs thus providing realistic night scene black levels. The IR laser also has intrinsically high contrast, which enhances the NVG image.
- The 830 nm IR laser frequency enhances NVG stimulation across goggle types.
- The optional Clone Mode reduces cost while retaining high-quality stimulation.
- High levels of stimulation inherently provide realistic goggle blooming.

The described visual system with the VITAL X image generator and the AVIOR®VisIR laser projection system is a unique, very high quality NVG stimulation facility for optimized training of aircrews using their original NVG equipment in a simulated world.

(a) Scenario in daylight

(b) Scenario at night



(c) Scenario observed through NVG

Figure 4 Scenario near an airfield with well-lit buildings generated with VITAL X for mission training in a simulator.

(a) Scenario in daylight

(b) Scenario at night

(c) Scenario observed through NVG

Figure 5 Scenario in a non-urban area generated with VITAL X for mission training in a simulator.

ABOUT THE AUTHORS

Dr. Hubert Burggraf is Vice President and Head of the division Display and Laser Systems in the business unit Simulation and Training at Rheinmetall Defence Electronics GmbH in Bremen, Germany. He has for more than 25 years experience in the areas of laser development, laser-optical sensors, optical signal processing, laser-based combat simulation, visual systems, PC-based image generators, laser projection systems and night vision simulation. He published/holds a set of papers/patents in these fields.

Dr. Wilfried Plass has now 10 years of experience as display system engineer within the flight simulation department at Rheinmetall Defence Electronics GmbH in Bremen, mainly accompanying the introduction of the AVIOR® laser projection system into flight simulation displays. He graduated in physics at the University of Bielefeld, Germany, and received an engineering PhD from the University of Stuttgart, Germany, mainly working on high power optics and ultra short laser pulses.

Dr. Charles J. Lloyd has 23 years of experience in the area of display systems and applied vision research at such organizations as the Displays and Controls Lab at Virginia Tech, the Advanced Displays Group at Honeywell, Lighting Research Center at Rensselaer Polytech, Visual Performance Inc., and BARCO Projection Systems. Charles now works at FlightSafety International where he manages the development of next-generation display and alignment systems. Charles has published/presented more than 50 papers in the field.

Steven G. Nigus is Director of Engineering for the Visual Simulation Systems division of FlightSafety International in St. Louis, MO. He has been designing visual systems for 25 years and has performed various system design and engineering management functions in the development of the VITAL 7, 8, 9, and X visual system generations. Mr. Nigus is currently managing FlightSafety's visual system hardware, software, and display product engineering activities. He received his bachelor's degree in electrical engineering from the University of Missouri at Rolla and did his graduate work at Iowa State University. Steve has published 12 conference papers on visual simulation.

Brian K. Ford is a Lead Realtime Software Engineer at FlightSafety International Visual Simulation Systems. For the past 11 years, he has been designing systems architecture and network communications for VITAL 8, 9 and X visual systems, as well as sensor features including video target tracking. He is currently designing the VITAL 9 and X CDB publisher integrations. Previously, he spent 5 years at the University of Missouri's Advanced Technology Center applying virtual reality and multimedia for use in elementary, secondary, and undergraduate education. He received Bachelor of Science degrees in both Electrical and Computer Engineering from the University of Missouri, Columbia.

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