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FINAL REPORT FOR VISION SCIENCE AND PERSONNEL SUSCEPTIBILITY TASK ORDER 14

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Air Force Research Laboratory
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Human Effectiveness Directorate
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14. ABSTRACT

Northrop Grumman has recently completed work as part of the Vision Science and Personnel Susceptibility Integrated Product Team of the Air Force Research Laboratory, Human Effectiveness Directorate, Directed Energy Bioeffects Division, Optical Radiation Branch (AFRL/RHDO). This report satisfies the requirement for a final report at the end of the period of performance of this work. This effort provided research support to understand vision science and human performance based on vision so as to predict the effects of lasers on vision and human performance. The types of activities included, but were not limited to, basic research into relevant aspect of visual performance and visual adaptation, field and laboratory measurements of laser glare and flashblindness effects, and development and validation of optical safety and effectiveness models,. A total of 11 open literature papers, posters and presentations and 13 Technical Reports (TR's) were completed during the period of performance. The work performed by Northrop Grumman detailed in the report is divided according to project. These projects are; Basic Research; Dazzler/Hornet; Veiling Glare; Cockpit Laser Obscuration Study; HAVE STAN; Federal Aviation Administration; Special Projects and White Papers; Dynamic Glare; Driver Defeat; Multiple Source Glare Effects; Joint Non-Lethal Weapons Directorate - Optical Suppression; and, Joint Non-Lethal Weapons Directorate – Knowledge Base

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1. SUMMARY OF PROJECTS

1.1 Basic Research

Northrop Grumman continued studies on the effects of multiple pulsed light exposures on luminance increment thresholds. The primary objective of the project was to extend the scientific knowledge base on the effects of brief single and multiple pulsed light exposures on the human visual system. A flash-probe approach was developed for these studies, where the threshold for detection of a probe light stimulus, presented to the subject some time after a prior flash of light (an inducing field) is extinguished, is determined.

We used a custom-built two-channel Maxwellian view optical stimulator system to generate adapting flash and probe stimulus fields. By varying key parameters of the adapting flash and the probe stimulus, such as the duration and intensity, and the stimulus onset latency, the adaptive state of the visual system was explored. The results indicate that the visual response to flash-probe stimulation is broadly similar to the probe-sinewave response. These data can be used to test existing and develop new computational models of light adaptation dynamics. [1-4]

1.2 Dazzler/Hornet

Northrop Grumman Corporation developed a laser illuminator concept demonstrator, called the Hornet, which was conceived to be a weapon-mountable, field testable device. The device was intended to enhance mission effectiveness by suppressing adversaries and providing a wider range of options before the application of lethal force is required. The device was designed to increase the stand-off distance, determine intent, and disrupt, delay, and disorient an adversary. The design goals for the device included; be eye-safe, effective in the daytime; be optimized to the photopic spectral sensitivity of the human eye; continuous wave and flicker modes; the size and weight should conform to an M-203 grenade launcher; be powered by readily available commercial off-the-shelf batteries; and need no cooling.

An initial prototype (Hornet 1) was subsequently improved (Hornets 2 and 3), to produce a device that met all the design goals except for spot-size and eye-safety. The final demonstrators exceeded the safe exposure limit when viewed within 22 m. A performance evaluation indicated that the demonstrators would be very effective under dawn, dusk, and night time conditions. The devices were also capable of producing significant glare in the daytime, but little post-exposure visual disturbance was found. The spot-size and the eye-safety problems could be alleviated by increasing the beam divergence and the area of the extended source.[5]

1.3 Veiling Glare

When the human lens is exposed to near-ultraviolet through blue wavelength light, even off the visual axis, the light causes the lens to fluoresce and emit a defocused blue-green light. The light from the lens fluorescence produces a widespread glare on the retina that may mask a broad area of the visual field; we refer to this effect as Veiling Glare. The aim of this effort was to explore the feasibility of using a coherent ultraviolet light source to induce Veiling Glare and thereby temporarily impair an intruder's vision.

A study to characterize the relationship between fluorescence-induced glare from an ultraviolet laser and the laser irradiance was conducted. The results indicated that the glare luminance, estimated using an equivalent background luminance technique, varies non-linearly with respect to laser irradiance, with significantly less veiling glare than expected at high irradiance levels. Nevertheless, at low ambient levels of illumination, exposure to a near-ultraviolet laser at safe exposure levels was found to induce a veiling glare intense enough to impair vision at normal indoor lighting levels, and that may be especially debilitating at night.

In addition, a prototype laser device for demonstrating the utility of ultraviolet lasers as a source of Veiling Glare for visual impairment of observers was developed. An alignment system, to ensure that the recipient receives the optimal exposure dose, was incorporated in the device. This effort included a preliminary design study to determine the most technically feasible and effective way to generate the levels of ultraviolet light required for fieldable devices.[6-8]

1.4 Cockpit Laser Obscuration Study

The Cockpit Laser Obscuration research effort sought to quantify the relationship between laser irradiance levels at the cornea and the resulting angle of visual obscuration due to glare around the laser source. Studies on the effects of laser glare on the ability of observers to detect visual targets were conducted. Laser induced disability glare effects were found to be exacerbated by light scatter through an optical media such as an aircraft windscreen, especially with regard to the detection of small targets at night. The experimental data were fitted to the CIE disability glare function, adjusted for target size, ambient light level, and the presence of an extra ocular scattering element.[9-12]

1.5 HAVE STAN

HAVE STAN was an Air Force Research Laboratory, Directed Energy Directorate (AFRL/RD) program to develop a laser weapon with the capability to distract or disrupt active, or potentially active, hostile personnel. It was superseded by the Aircraft Countermeasure (ACCM) program, a Warfighter Rapid Acquisition Program involving Air Force Special Operations Command, AFRL/RD Scorpworks Lab, Air Force Research Laboratory, Human Effectiveness Directorate (AFRL/RH), Boeing Corporation, and Air Force Materiel Command (AFMC).

Northrop Grumman supported the ACCM project by conducting a human effectiveness modeling analysis on the laser to be used in the ACCM field test. The modeling efforts focused on the potential of the laser system to disrupt the visual performance of a potential adversary through the mechanisms of glare and flashblindness. The laser effectiveness was evaluated through a computer model of laser-vision interaction under a variety of operational situations and system parameters. Northrop Grumman presented the results of this analysis at an ACCM program review.

1.6 Federal Aviation Administration (FAA)

The number of laser incidents involving commercial aircraft is rising each year, coinciding with ready availability of inexpensive laser devices. AFRL/RH and the Federal Aviation

Administration (FAA) are working together to improve aircrew safety in situations where lasers are carelessly or maliciously pointed at aircraft. This program will help define how pilots respond to lasers when pointed at aircraft during flight. In support of this effort, Northrop Grumman and its subcontractor, Taboada Research Instruments, Inc. designed, built and installed a fiber optic motion control laser positioning system in the Boeing 737 flight simulator at the FAA's Mike Monroney Aeronautical Center in Oklahoma City, OK.

Northrop Grumman also supported research which used this system to investigate pilot responses and performance during laser exposures in a simulated flying task, primarily take-offs and landing. Findings from this work will be used to improve understanding of pilots' vulnerability to laser illuminations, and to provide guidelines for laser operations in navigable airspace. In addition, the experimental findings will be used to improve guidance to pilots with regard to their response to illumination by lasers.

Northrop Grumman and its subcontractor, General Dynamics Incorporated also assisted in the development of a training video to be used by the FAA to instruct pilots and flight crew on safe flight communication and operational procedures to be used in the event of an unauthorized laser illumination incident.

1.7 Special Projects and White Papers

Northrop Grumman supported a number of efforts relating to the preparation of posters and presentations for internal visits (Scientific Advisory Board, Air Force Office of Scientific Research) and for external presentation, and the publication of technical reports relating to prior research efforts. Northrop Grumman also assisted with the development of several white papers and proposals for external funding.[13-17]

1.8 Dynamic Glare

The Dynamic Glare research effort sought to extend knowledge on laser disability glare from static situations to dynamic environments, more relevant to operational military environments. Under this program Northrop Grumman supported two experiments. The first experiment examined the effect of laser wavelength on laser disability glare and visual obscuration. The study concluded that using the photopic luminosity function to specify the relative glare efficiencies of laser dazzlers will result in an underestimate of the effectiveness of red and blue laser wavelengths compared to green. A second experiment investigated effects of a green laser on the ability of subjects to negotiate an obstacle course in a simulated driving task was investigated. The study found that continuous and flashing lasers with the same average irradiance had similar effects, although there was a tendency for a flashing laser to disrupt driving more than a continuous laser with the same average irradiance.[18-21]

Northrop Grumman conducted a review of the potential effectiveness of laser glare devices to produce transient visual deficits in military operations. To assess laser glare effectiveness, a modeling analysis was applied using the AFRL/RHDO Visual Effects Analysis Tool. The tool was used to estimate the exposures necessary to maximize the visual obscuration time of a variety of objects under different ambient conditions.[22]

1.9 Driver Defeat

The aim of this program was to evaluate a range of eye-safe laser exposure levels for their potential to stop, deter, or slow vehicles moving through military checkpoints. Two field studies were conducted at Ft Leonard Wood, MO. The first study investigated the range of exposure levels required to achieve significant effects, and evaluated the comparative effectiveness of some Commercial Off-the-Shelf (COTS) devices. The second study compared the effects of red and green continuous and flashing lasers alone, and in combination. Northrop Grumman supported these field trails by providing assistance with the development of human-use protocols, procurement and systems engineering of lasers, optical components, and beam steering and measurement systems, laser safety site surveys and safety measurements, and data collection, analysis and reporting.[23]

1.10 Multiple Source Glare Effects

The aim of this program was to investigate the potential value of using multiple laser disability glare systems to impair visual performance and human performance. Northrop Grumman supported two studies under this effort. The first study sought to determine the effectiveness of obscuration for two simultaneous laser glare sources at different irradiance levels, wavelengths, and glare angles. The study found that two laser sources were more effective than a single source, and the effects could be predicted by combining the effects of single nasal and temporal sources. The second study investigated the effects of multiple red and green COTS laser devices on operationally relevant task performance in a field setting.

1.11 Joint Non-Lethal Weapons Directorate - Optical Suppression

The primary goal of this effort was to conduct a thorough literature search of what is known about the behavior of unruly crowds, with an emphasis on psychological factors. Of particular interest was the potential utility of optical suppression techniques in crowd control situations. Northrop Grumman reviewed the available literature and provided a synopsis of current knowledge with regard to crowd behavior. The efficacy of optical suppression techniques as mission enhancers was discussed. This analysis has potential implications for future development and application of crowd control and crowd dispersion models.[24]

1.12 Joint Non-Lethal Weapons Directorate – Knowledge Base

Northrop Grumman supported the development of a non-lethal novel effects weapons knowledgebase (NEWK) by developing an initial "praxis" for laser dazzlers. The praxis forms the basis of a structured way to summarize subject area and research, and is used to establish relationships between technology, human effects, operational outcomes, and keywords. The laser dazzler praxis described the non-lethal effects of dazzling lasers, and included an overview of physiological and human effects, safety considerations, and operational use considerations, supported with descriptions of COTS devices, research on human effects, and an extensive bibliography.

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