MASTER OF SCIENCE IN APPLIED PHYSICS

THE COMBAT SYSTEM DESIGN AND TEST CRITERIA FOR IGUANA™ ARMORED VEHICLES

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Ground vehicle mobility advances for the future combat vehicles fleet will be achieved through smaller and lighter systems with improved weapon stabilization, improved ride and agility, and reduced acoustic/IR signatures. The Iguana™, a tracked vehicle concept based on a recently patented suspension and track design, could deploy to hot spots world-wide on peacekeeping and combat missions which require extra flexibility to adapt to diverse terrain, weather, and threat conditions. A sophisticated sensor suite integrated with weapon systems will guarantee battlefield dominance and vehicle survivability can be enhanced with revolutionary composite armor. Hybrid electric drive will mainly enhance survivability, fuel economy, stealth, operational capability and acceleration performance. Power electronics developments will speed up the transformation from conventional gas engines to hybrid armored vehicle drive systems. This thesis presents a combat system integration process for an Iguana™ based armored vehicle. It lays out steps to be taken in conceiving and developing the armored vehicle starting from the Mission Need Statement. Scenarios are used to create a context within which to define realistic operational requirements. Functional flow modeling for the interoperable reconnaissance, forward observer and anti-guerrilla version armored vehicles provides the analytical basis for defining subsystem characteristics. A particularly important operational need is for night vision sensors. The U.S. Army Night Vision and Electronic Sensors Directorate's FLIR92 and ACQUIRE computer programs are used to establish feasible Iguana™ thermal night vision device performance requirements.

DoD KEY TECHNOLOGY AREA: Ground Vehicles

KEYWORDS: Combat System, Armored Vehicle, FLIR92, ACQUIRE, Composite Armor, Hybrid Electric Drive, Mobility, Mission Need Statement, Operation Requirement Document

VISUAL ANALYSIS OF A RADIO FREQUENCY TRACKING SYSTEM FOR VIRTUAL ENVIRONMENTS

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A variety of position tracking technologies have been utilized for virtual environments. Each has a different set of strengths and weaknesses which are usually compared on paper with numbers or generic statements. This thesis develops a methodology for the creation of 3D visualization tools to analyze position tracking technologies and their effectiveness under specific conditions. The methodology includes developing the questions, the models, the simulations, the visualization, and the rendering.

This thesis applies the methodology to Advanced Position Systems, Inc.'s RF tracking system which can be easily configured for large volume spaces, unlike any of the other technologies. The analysis asks "How does the positioning of the receivers affect the relative accuracy throughout the target volume?". The model uses the solution to the Time Difference of Arrival (TDOA) equations used by the system and the simulation evaluates the position error throughout the volume with a constant error in the TDOA measurements. Point icons represent the data and the Virtual Reality Modeling Language renders the visualization. The asymmetric error profile revealed by this 3D visual analysis arises from the asymmetric arrangement of the TDOA measurements and is not readily apparent with other analytical techniques.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Simulation, Visualization, Tracking

FUSION NEUTRON TRANSIENT EFFECTS TO CHARGE COUPLED DEVICE CAMERA IMAGES

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A charge coupled device (CCD) camera's images were degraded by neutron-induced blemishes, called stars, while being irradiated with 14 MeV neutrons (n) from the Rotating Target Neutron Source. This thesis analyzed simulated images for a CCD camera operating during neutron irradiation. The simulated images were created to provide data to help determine how much shielding a CCD camera would require while being used as a diagnostic tool during inertial fusion events at the National Ignition Facility. The simulated images were created from data obtained at the Rotating Target Neutron Source. The Contrast Transfer Function (CTF), autocorrelation function, and visual comparisons were used as measures of the transient effects of the neutron irradiation on the simulated images. The CTF and visual image quality started to degrade significantly at neutron fluences around 10^8 n/cm^2. The autocorrelation function determined that the average size of neutron-induced star was 4 x 4 pixels. Increasing neutron fluence produced image changes that could be explained by a variation in sensitivity across the camera face or (more likely) by increased Charge Transfer Inefficiency (CTI) with increasing charge loading of the CCD.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Neutron Irradiation, Charge Coupled Device Camera, Contrast Transfer Function

VALIDATION/EVALUATION OF POLARIZATION VERSION OF SEARAD MODEL

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Until recently no standard atmospheric propagation codes included the effects of polarization. Recently a research grade upgrade to MODTRAN (Zeisse, NRaD) has allowed the polarized case. This upgrade, called SEARAD, calculates the infrared polarization of sea surface radiance. Data available in the EOPACE data base were used for a direct comparison of the code prediction to the measurements. The data consist of polarized and unpolarized images of the R/V POINT SUR in the Long Wave Infrared (LWIR), taken with the AGA 780 camera during an experiment conducted in San Diego Bay in April 1996. Meteorological, geographical, and external ship temperature data were recorded along with the images. The analysis of the EOPACE data was conducted by using IDL (Interactive Data Language) analysis programs and included

34 sets of images. The sea pixels were extracted from the images, and correlated with meteorological, and geographical data to provide input to the SEARAD code. The comparison of the experimental data with the SEARAD predictions yielded an average error of 1.57 $Wm^{-2}sr^{-1}$ in unpolarized sea radiance, which is within approximately 5% of the experimental radiance, and an average 0.51 absolute difference between the predicted and experimental degree percentage of polarization.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Infrared Sensors)

KEYWORDS: Infrared Radiation, Radiance, Degree of Polarization, Atmospheric Propagation Codes

MODELED DETECTION AND RECOGNITION RANGE FOR A POLARIZATION FILTERED FLIR SENSOR

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A model has been developed to evaluate the influence of polarization filtering on the detection and identification range of a thermal sensor. The scenarios evaluated were based on environmental parameters and ship temperatures recorded during the EOPACE measurement series in San Diego Bay in 1996. These scenarios represent a FLIR sensor on a platform in level flight at 100 m or 1000 m approaching a ship target represented as a gray body at the recorded ship hot-spot temperature. The polarized version of the SEARAD sea radiance code was used to provide sea background radiance and propagation characteristics for both ship target and background. Apparent Temperature Difference was calculated versus range for horizontally polarized and unpolarized imaging. Maximum range was determined for both cases by comparison to a generic Minimum Resolvable Temperature function representing a typical LWIR Common Module FLIR. Preliminary results for the polarized case predict greater apparent temperature difference at ranges to around 10 kilometers. Unresolved apparent anomalies in the computed results suggest that target temperatures are under-estimated. Empirical correction of the zero range temperature difference suggests polarized identification ranges of the order of 25 to 30 km. Improvements to the modeling are proposed.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

KEYWORDS: Forward Looking Infrared (FLIR), Apparent Temperature Difference, Common Module FLIR, Minimum Resolvable Temperature Difference (MRTD), SEARAD

DESIGN AND CONSTRUCTION OF AN EXPANDABLE SERIES TRANS-AUGMENTED ELECTROMAGNETIC RAILGUN

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Long range maritime land attack can be accomplished with today's chemically propelled munitions only by sacrificing responsiveness. Projectiles launched with electromagnetic forces can achieve velocities above 2-3 kilometers per second. The technical challenges to be overcome before electromagnetic launch can be considered practical for maritime land attack include development of high density pulsed power supplies, high current power switching and a long life launcher. To investigate electromagnetic launch technology a 1.2 meter railgun was constructed. It was designed to allow augmentation and various bore configurations. The railgun power unit consists of two 11 kV, 830μf capacitors discharging through a 7μH inductor coil. A crowbar circuit provides capacitor protection. Operational testing of the firing circuit, instrumentation,

power unit, and launcher structure was satisfactory. The 7μH coil induced currents within the power unit, which adversely effected triggering circuitry. The molybdenum projectiles initially tested proved disappointing due to their tendency to meld with the copper rails. An extended current pulse resulting from such a meld caused failure of the crowbar circuit, which curtailed further testing. The induction coil could safely be discarded, and a revised crowbar circuit will prevent further failure. Future operational testing will focus on alternative armature materials and designs and on operational methods.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Directed Energy Weapons

KEYWORDS: Electromagnetic Railgun, Electromagnetic Launch, Railgun Augmentation

COMPACT CO_2 LASER DESIGN AND ANALYSIS

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CO_2 lasers, among the most efficient and powerful of all lasers, have many applications in industrial and medical fields. Unfortunately, their typical bulky size and fragility tend to limit their use in austere military environments.

The purpose of this thesis is to present and analyze a new optical cavity design that can possibly fill the need for a compact, high power, ruggedly packaged infrared laser. Such a system could be used for targeting, communications, or field medical use.

The analysis involves entering design parameters into a commercial software program and simulating the behavior of a collimated laser beam within. While results identify significant optical aberration flaws, the extensive design revision needed does not preclude eventual construction.

DoD KEY TECHNOLOGY AREA: Other (Lasers)

KEYWORDS: Carbon Dioxide, Lasers, Infrared

HIGHLY PERVIOUS LIQUID METAL TARGET SYSTEMS FOR RADIOACTIVE ION BEAM GENERATION

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Radioactive ion beams (RIBs) of ^{69}As are currently needed for fundamental nuclear physics research and can be produced abundantly by proton bombardment of a liquid Ge target. In this thesis, a series of highly pervious liquid target designs were developed with mean diffusion paths several orders of magnitude less than traditional, pool-type, liquid targets. Experiments have been performed to identify materials (substrates) capable of suspending, through wetting, very thin layers of liquid Ge. Four candidate Ge-substrate target systems have been designed, and ^{69}As production may be significantly increased over previous targets. The target systems designed include liquid Ge coated onto: (i) an inclined W plane, (ii) a long thin Mo wire birdsnest, (iii) a SiC weave, and (iv) SiC coated C foam. A universal Ta target holder coupling the target to an ion source has also been designed and features a cooled re-circulating baffle for testing of each of the above target concepts. The results of long-term heating tests on the Mo wire birdsnest show its lifetime to be less than 100 hours; however, future online tests of short duration will test ^{69}As production for the birdsnested target. Ge did not wet the SiC weave target. The methods and design formulations developed in this thesis are applicable to a variety of RIB species produced from liquid targets.

DoD KEY TECHNOLOGY AREAS: Directed Energy Weapons, Manufacturing Science and Technology (MS&T), Other (Nuclear Physics Research)

KEYWORDS: Radioactive Ion Beam, Isotope Separation Online, Germanium, Arsenic, Holifield Radioactive Ion Beam Facility, HRIBF, Oak Ridge National Laboratory, ORNL, Liquid Metal Targets

DAMAGE PRODUCED BY THE FREE ELECTRON LASER

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The first damage experiments produced by a Free Electron Laser (FEL) were conducted at the Department of Energy's Thomas Jefferson National Accelerator Facility (TJNAF). In the past, only large-scale laser experiments were thought to properly model lasers for weapons applications. Scaled down procedures developed in this thesis allowed the FEL, with a few hundred watts of power, to characterize the damage produced by a megawatt weapon's scale laser. With a power density of 10 kW/cm^2, the TJNAF FEL bombards targets with a steady stream of tens of millions of pulses per second. Each pulse contains 50 MW of power in short bursts lasting 4 x 10^{-14} seconds each. No previous laser experiments have been conducted to explore the effects of the FEL short pulses. Target materials were obtained from the Naval Surface Warfare Center (NSWC), Port Hueneme. Data were collected and analyzed using video cameras and optical microscopes, and irradiated at TJNAF. This thesis was a productive cooperation between NPS, TJNAF, and NSWC Port Hueneme, to the benefit of DoD.

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

KEYWORDS: Free Electron Laser, Directed Energy Weapons, Ship Defense

EXPERIMENTAL DAMAGE STUDIES FOR A FREE ELECTRON LASER WEAPON

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Laser material damage experiments for this thesis were the first ever conducted at the new Department of Energy's Thomas Jefferson National Accelerator Facility (TJNAF) free electron laser (FEL) user laboratory. In the past only large-scale laser experiments were thought to properly model weapons applications. Experimental procedures developed in this thesis allowed a scaled-down laser of a few hundred Watts to characterize the damage from a weapon-scale one million Watt laser. The TJNAF FEL has the power of a microwave oven concentrated into a beam the size of a pencil lead. The unique TJNAF FEL beam bombards the target with a steady stream of tens of millions of pulses per second each containing 50 million Watts of power in a short burst of 4 x 10^{-13} seconds. No other laser combines these characteristics, and no experiments have previously been done to explore the effects of the FEL pulse. Target materials were obtained from the Naval Research Laboratory (NRL) and from Naval Surface Warfare Division (NSWD), Port Hueneme. Data were collected and analyzed using video cameras, optical microscopes, and a scanning electron microscope (SEM). This thesis has been a productive cooperation among NPS, TJNAF, NRL, and NSWD Port Hueneme, to the benefit of DoD.

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

KEYWORDS: Free Electron Laser, Directed Energy Weapons, Laser Damage Experiments