

**POSTER
ABSTRACTS**

Biomediated Nanocluster Sythesis

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When put under the proper conditions, solutions of certain proteins and metal salts will combine into nanoclusters (NCs) and luminesce under UV light. In past experiments, these NCs were created using a stir plate and applying heat for a period of time. Not many studies were done on how to optimize or speed up this task, so that was the main purpose of this work. Using the knowledge that NCs were formed when the protein denatures enough to allow the metal to bind then refolds into the NCs, the energy from the microwave could not denature the proteins to the point where they could not refold. Optimizing the wattage, burst, and rest time was only one of the variables that was altered. The dilutions, pH (1 through 12), type of metal (*HHHHuuCCCC4*, *AAAAAAAAA4*, and *CCCCCCCC4*) and type of protein (bovine serum albumin, trypsin, pepsin, and lysosome) were also varied. The results and the optimal solutions were measured by the strength of the solutions emissions in the 680-720nm range.

KEYWORDS: Nanocluster, Microwave, UV light, Bovine serum albumin, trypsin, pepsin, lysosome, denature

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Hierarchical Assembly of Bio-Templated Nano-wire and Nano-tube Films for Lightweight Multi-functional Materials

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Biological hydrogels can serve as 3-dimensional bio-templates for tunable nano-porous materials that serve both as electrochemical power sources and structural material. We present a general approach to 1) form a biological hydrogel; 2) sensitize the hydrogel bio-template using catalytic palladium ions to mediate the electroless deposition; 3) synthesize 3-dimensional networks of copper and nickel nano-wire films via electroless deposition; 4) synthesize inorganic salt templated square cross-section nano-tubes that can be integrated into a hierarchical nano-material assembly. Such multi-functional electro-mechanical materials are envisioned to decrease the systems mass across a broad range of Army platforms and serve as a nano-architecture for other applications such as photovoltaics, catalytic systems, fuel cells, sensors, and energy absorption.

KEYWORDS: Hydrogel, bio-templates, nano-materials, electrochemical, biotemplating, fuel cells

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Releasing energy from nuclear isomers through atomic-nuclear interactions

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Isomers are unusually long-lived states of atomic nuclei in which energy can be stored for long periods of time—seconds to millions of years or more—compared to typical states that release their energy in nanoseconds or less. If the energy of the isomer can be released in a controlled way, on demand, this could lead to novel future energy and power applications. We are investigating a never before seen effect whereby an atomic process, the capture of a free electron into a bound atomic orbital, induces the excitation of a nucleus out of the isomeric state, subsequently releasing energy on a considerably shorter time scale. Results of a benchmark experiment performed at the Australian National University, involving ${}^7\text{Li}$ ions accelerated onto a ${}^{90}\text{Zr}$ target which fuse together to produce isomeric ${}^{93m}\text{Mo}$ ($t_{1/2} = 6.85$ h), will be presented. These results will be used in conjunction with an experiment to be run at Argonne National Laboratory in the near future, with the aim of the first demonstration of the Nuclear Excitation by Electron Capture phenomenon.

KEYWORDS: Nuclear Isomers; Nuclear Excitation by Electron Capture (NEEC); Atomic-Nuclear Interaction

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Topology Control for Time-Varying Contested Environments

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We consider a problem of topology design and control when some of the links may become unavailable. When a network operates in a contested environment, the operator may wish to alter the network topology to enhance robustness. This may come at the expense of operational costs. We consider a dynamic programming framework where the goal is to minimize time average costs, where costs are the sum of network property cost (e.g. eccentricity), edit costs and maintenance costs. We consider practical low-complexity control algorithms which focus on instantaneous network states. We introduce a horizon-aware modified myopic policy which attempts to reduce average cost by benefiting future costs. We also provide decision rules for different algorithms and characterize expected costs for random hostility models. Our numerical results demonstrate that our modified myopic scheduler outperform other schedulers in terms of average sum cost for various settings.

KEYWORDS: Topology control, dynamic programming, optimization, network science

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Study of Nanocrystalline Deformation Using Virtual Diffraction Characterization

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Controlling the properties of a nanocrystalline metals through grain boundary engineering requires a detailed knowledge of how specific crystalline interfaces contribute to the resulting material behavior. Experimental techniques such as x-ray and electron diffraction generally lack the resolution necessary to determine exact boundary concentrations, making attribution of properties to specific boundaries difficult. In this study atomistic simulations are used to study the mechanical responses of nanocrystalline structures with varied grain sizes and twin densities. To ensure proper attribution of changes to exact structural factors an algorithm was made that would preserve grain shape and grain boundary morphology while altering grain size and twin density. Finally, virtual diffraction analysis is used to link the simulated results to experimentally observable data.

KEYWORDS: Nanocrystalline, Deformation, Molecular Dynamics, Virtual Diffraction

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Laser-Driven Flyer Plates for Shock Loading of Energetic Materials

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A laser-driven flyer plate apparatus is being developed to study the behavior of energetic materials under shock loading. Flyer plates are generated using a ns-pulsed Nd:YAG laser fired through a transparent substrate to which a metal foil has been adhered. The laser is absorbed by the adhesive and back side of the foil, generating a rapidly expanding plasma that ejects a section of the metal foil several hundred microns in diameter at high speeds. Flyer plate speeds over 1 km/s have already been achieved, as measured using a laser interferometer, and higher speeds are possible with further system optimization. These flyer plates will be used to study the behavior of various energetic materials under shock loading through the use of high speed video and time-resolved spectroscopy with a streak camera.

KEYWORDS: Shock Physics, Energetic Materials, Laser-Driven Flyer Plates

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Experiments with GVR-Bot

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A program that is used to take a set of predetermined joint angles to autonomously self-right a packBot was developed and tested on this AIAD. A program that can autonomously determine the correct arm joint angles to move through the self-righting sequence was developed previously by staff at ARL. This new, self-righting program required another program that could use these arm joint angles and put them into a language that the robot could understand. This is the basis for the cadet research and testing.

KEYWORDS: Self-righting, packBot, Arm Joint Angles

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Impacts of Thermally Efficient Structures in Military Microgrids

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A reliable supply of electrical energy is critically important to the United States Armed Forces operating in deployed environments. Providing fuel for generators in these environments entails a high cost and risk due to the enemy threat. Reducing energy requirements by utilizing high thermal efficiency structures can be effective to lower the total load demand for a forward operating base (FOB). The lower load demand allows for a lower operational cost and risk. Prior work has developed high efficiency structures by utilizing structurally insulated panels (SIP-Huts). Results presented here from real world testing show that thermal energy demand for SIP-Huts is reduced by a factor of ten in compared to traditional housing structures. Additionally, representative electric load profiles were developed for small sized FOBs to analyze the impacts of deploying SIP structures across an entire FOB. More specifically, load profiles for 50 and 300 personnel FOBs were developed and presented and were adjusted to account for geographic location. All the profiles emphasized focus on the environmental control unit (ECU) demand. A detailed ECU model, based on real world data, is presented for SIP and traditional housing structures. Corresponding FOB demand profiles for high thermal efficiency structures and traditional FOB structures are presented. These profiles were used to simulate and quantify the impacts of SIP structures and obtain an optimized recommendation of generation resources. SIP structures show a dramatic reduction in energy consumption, peak electric demand, and exhibit an improved load factor. Generation capacity and diesel fuel requirements are correspondingly reduced, allowing for a significant improvement in expenditures and associated resource costs.

KEYWORDS: electric load, electric demand, electric load profile, Military Microgrids

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Hybrid Deterministic-Statistical Models for Simulating Mesoscale Microstructural Evolution

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The underlying microstructural features of materials, e.g. grain size distribution, will have an influence on their macroscopic properties. It is important to have tools that allow us to simulate the evolution of these mesoscale features in an efficient and effective manner. Typically, most models focus on the implementation of deterministic (e.g. phase field) or statistical (e.g. Monte Carlo) models to simulate microstructural evolution. While both have been shown to capture important kinetics and thermodynamics that describe microstructural behavior, there are considerable drawbacks to each, e.g. computational expense. By coupling these techniques, we are able to efficiently simulate complex processes like precipitate nucleation and evolution. Furthermore, these hybrid models retain important physical descriptors that influence microstructural evolution. This poster outlines several of these deterministic-statistical computational techniques as applied to nanoporous network formation and precipitate evolution under irradiation environments.

KEYWORDS: mesoscale simulation, microstructural evolution, Monte Carlo, phase field model

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A Modular Low-Power Cube Satellite Attitude Control System Using Magnetorquers

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In this work, we create a modular control system with magnetorquers that provides single-axis attitude and stability and control for a variety of common CubeSat configurations. We achieve this by analyzing the advantages and limitations of magnetorquers for attitude control, simplifying the controller design challenge, determining a low-power control algorithm, and testing the control solution through simulation. In a system that relies solely on magnetorquers for stability and control, the Earth's magnetic field provides the only stable frame of reference, therefore we are able to take a multi-dimensional control problem that would normally involve greater processing power and reduce it to a simple, one-dimensional control system. Taking also into account a limited power budget, we are able to design a rate-based combinational logic controller that provides attitude control on limited power and static stability with extremely little power. We validate the system with tests for standard attitude commands under different satellite inertial configurations, impulse disturbance torques, constant disturbance torques, and tumble recovery.

KEYWORDS: cube satellites, digital control systems, magnetorquers, attitude control, combinational logic control

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Analysis of Radio Frequency Interference Due to Antenna Vibration

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A novel model explaining a source of radio frequency (RF) interference due to chaotic vibration of antennas is presented. Military and civilian aircraft and ground vehicles vibrate significantly while in operation and transfer these vibrations to surface-mounted antennas. A controlled experiment was created using a flexible monopole antenna driven at 900 MHz with the reflected spectrum measured by a high dynamic range measurement system. When mounted to a vibration generator driven at 150 Hz, the antenna demonstrated chaotic dynamics and produced RF interference larger than is predicted by the well-established Doppler scattering model. The spectral regrowth peaks are offset from the carrier frequency by integer multiples of 150 Hz and are appreciable at sidebands as high the 20th order. A radio signal modulated by a vibrating antenna can cause significant interference to reception at a nearby receiver. Chaotic structural vibrations are theorized to be a significant contributor to co-site interference and would be present in a multitude of military and civilian vehicles, aircraft, and machinery.

KEYWORDS: Co-site Interference, Spectral Regrowth, Chaotic Vibrations, Nonlinear Dynamics, Passive Intermodulation

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Experimental and Modeling Assessment of Ballistic Penetration of Ultra High Performance Concrete

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This work describes the research and testing that was done this summer on the penetration of ultra high performance concrete (UHPC) by a .50 caliber fragment simulating projectile (FSP). Test data were obtained by conducting live experiments on four different types of UHPC. The data were then compiled and analyzed using high speed video and x-ray imaging. Through the use of finite element-based modeling and simulation software (LS-DYNA), a model was created to predict the impact response of a .50 caliber FSP into a UHPC panel target. This work evaluates the effectiveness of the model by comparing the residual velocities of both the simulations and live experiments.

KEYWORDS: Finite Element Analysis, Fragment Simulating Projectile (FSP), Residual Velocity
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Deposition of Explosives by Electrospinning Polymers for Use in Detection

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Explosives detection and analysis continues to be an integral field for the future of our military forces. Pre- and post-blast data is useful to identify explosive signatures in order to provide early detection of explosive materials used by homemade bomb markers. This research is focused on identifying a deposition method for explosive material, which will allow for standard testing of presence and concentration using commonly applied analytical techniques. To accomplish this process, we have developed and optimized electrospinning of an explosive laced polymer as a reproducible deposition method that dispenses a specified amount of explosive. Initial testing was performed on structurally similar non-explosive compounds and progressed to explosive compounds including RDX, DNT, and ammonium nitrate. Limit of detection levels of the compounds are being evaluated for different analytical methods to ensure proper lacing of explosive compound in the polymer. Deposition and detection of varying concentrations were tested.

KEYWORDS: Deposition of Explosives, Electrospinning, Explosive Detection

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West Point's Updated Simulation Center

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The West Point Simulation Center was tasked to remodel the simulation center in order to allow for the creation of a Computer Augmented Virtual Environment (CAVE). My assignment was to help create courses of action for the academy to efficiently and effectively complete the mission. I spent my time at the Institute for Creative Technologies to assist the Simulation Center Director, Mr. Vic Castro, by gaining the first-hand experience of seeing an already established mixed reality environment. My advisor and I wrote a paper with the materials possibly needed and potential costs of updating the center. We presented our findings to Mr. Castro. Construction begin 5AUG15 on updating the center for a CAVE. I will use my initial findings to construct a potential senior research experiment.

KEYWORDS: Computer Augmented Virtual Environment, Simulation Center, Mixed Reality

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Modeling Electrochemical Processes at Multiple Scales for Enhanced Corrosion Protection

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Modeling, from subatomic particles to processing variables, is being used to gain fundamental understanding of complex electrochemical processes to aid in development of corrosion resistant alloys and coatings for Army applications. The modeling is enhanced by integrating multiple length scales as well as working closely with the experimental team to validate model predictions. A specific application of this methodology to investigate corrosion phenomena on magnesium alloys is presented here.

Quantum mechanical (QM) modeling (e.g. density functional theory) is being used to examine the fundamental effect of impurities and alloying on corrosion reaction kinetics and thermodynamics on magnesium-alloy surfaces.^[1] Genetic algorithms (GA) are being applied for crystal structure prediction of secondary phases in binary and ternary magnesium alloys.^[2] These GA predicted structures are then fed into QM models to evaluate the secondary phases for their ability to aid in corrosion inhibition. It was found that alloying with arsenic decreases the corrosion rate of magnesium.^[3] Dynamic corrosion reactions will be simulated using atomistic models (e.g. kinetic Monte Carlo) using materials built from the QM and GA predictions.^[2] Mesoscale models (e.g. phase field method) are being targeted to use for examining electrochemical processing methods, such as electrodeposition, which has been shown to improve corrosion resistance of metals.^[4]

[1] Williams, Kristen, Joseph Labukas, Victor Rodriguez-Santiago, and Jan Andzelm. *Corrosion* 71.2 (2014): 209-223.

[2] Chaudhuri, Santanu, Michael Garvey, Kaushik Joshi, and Krista Limmer (*work in progress*).

[3] Limmer, Krista, Kristen Williams, Joseph Labukas, Jan Andzelm (*to be published*).

[4] Limmer, Krista, Joseph Labukas, Heather Murdoch (*work in progress*).

KEYWORDS: Corrosion, Electrochemical Reaction, Density Functional Theory (DFT), Genetic Algorithm, Crystal Structure Prediction, Kinetic Monte Carlo, Phase Field Method

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Development of Actuator Device to Augment Human Movement

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A powered hip actuator could allow anyone to run a sub four minute mile by replacing work done by the hips and lowering cardio-output. In order to determine a way to mechanically assist in the motion at a controlled level, the device in this paper uses solid rods linked to the knees and is connected to the hips with a harness and powered by a system in a backpack. The feedback control for this device will be programmed with input from angular rate gyro sensors, similar to previous methods that have used gait data. The device will use a pivoting hinge to allow full range of motion for the user. Abduction and adduction will not be restricted, allowing the legs to move laterally when turning or balancing. The motor will apply a torque to the carbon rod running down each leg, creating a force on the knees in their natural line of motion. The motor will apply a force to both legs in both flexion and extension movements. The force on each knee will be approximately thirty pounds. The control system described by Holgate et al. will be the basis for the control design of this hip actuator. Holgate et al. uses a single rate gyro to measure tibia angular velocity of an ankle prosthesis. The stride length and position in the gait cycle are derived. In the present design, rate gyros will be placed on the thighs. The control system will also derive similar variables but it will incorporate a different function based on the angular velocity of the thigh instead of the tibia. This is part of an overall study in conjunction with simulation-based design of a hip actuator to assist running.

KEYWORDS: actuator, simulation, human performance, gait analysis, controls

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An Interdisciplinary Approach to Conducting Title X Live Fire Test & Evaluation (LFT&E) Vulnerability Assessments

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Survivability/Lethality Analysis Directorate's (SLAD) Engineering Analysis Branch (EAB) executes the Army's Live Fire Test and Evaluation (LFT&E) Title X mission through vulnerability assessments of vehicles, munitions, and crewmembers. While some assessments leverage legacy methodologies, most require innovative and deliberate engineering analyses to provide the Army developers valuable information over their systems. The two presented techniques illustrate an application of mathematics to interdisciplinary studies to determine a probabilistic outcome given medium-sized samples in support of the Title X LFT&E mission.

Demonstrating a lethality assessment, the 'frag on frag' analysis captured penetrator witness data to quantify the individual fragment characteristics and applied them as an increasing collective in order to identify an optimization level for a munition that balances fragment mass, velocity, material density, and spatial density in an attempt to discover the appropriate pre-forming of engineered projectiles. Mr. Steve Swann developed and used this technique for two programs, informing and influencing the development of munitions for both the Special Operations community and the conventional Army.

Additionally, in accordance with Title X charter, engineers in EAB determined penetrator characteristic data in order to increase the survivability of US vehicle design. By applying penetrator characteristics, several variants of armor material penetration algorithms, and fault tree analyses, Mr. Patrick Foley identified specific vulnerable areas as candidates for upgrades to increase the overall survivability of the vehicle and its crew.

In an interdisciplinary and complex LFT&E domain, EAB's team of engineers, scientists, and analysts apply a suite of tools, mathematics, and methodologies to ensure the development and fielding of systems onto the modern battlefield, accomplish all requirements, and fulfill the Warfighter needs.

KEYWORDS: Frag on Frag, penetration algorithms, vulnerability assessment

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Large DFT: to 100K atoms and beyond

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A quantum mechanical (QM) approach to materials science provides a gold standard atomistic picture of the mechanisms responsible for a range of phenomena seen in macroscopic and experimental situations. The need to understand materials science problems from atomistic to macroscale was the impetus for ARL to initiate the Enterprise for Multiscale Material Research. This long term project attempts to redefine how materials science questions are posed, and solved. To support this goal, current state-of-the-art QM capabilities need to be extended in the number of atoms which can be treated and the length scale of the dynamics which can be simulated. This extension is referred to as large scale QM, both large spatially and temporally. This will enable fundamental advances in the understanding of materials science problems.

KEYWORDS: linear scaling; density functional theory; purification; sparse matrix; fragmentation

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INVESTIGATING THE EFFECTS OF RELATIVE HIP AND SHOULDER LOADS ON GAIT AND METABOLIC COST

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Soldiers carry heavy loads on the shoulders and hips when moving to and from mission objectives. The load contains mission essential equipment however has detrimental effects on the biomechanical efficiency of the soldier. This work investigates how such loads effect a Soldier's efficiency and ways to mitigate negative affects through ruck sack (MOLLE) weight distribution. Gait and metabolic analysis were used to compare the efficiency of the Soldier with different weight distributions between the hips and shoulders. Gait analysis was measured with a force impact treadmill and motion capture system that calculated the force distribution of the body, and metabolic cost was measured with a VO2 mask that calculated energy expenditure. Research was not completed due to time constraints, but understand of the methods of conducting, collecting, and analyzing gait and metabolic data were gathered to allow further research of gait and metabolic analysis of the Warrior Web Suit at the United States Military Academy.

KEYWORDS: Gait Analysis, Metabolic Cost, Weight Distribution, Motion Capture, Energy Expenditure

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**Axon-Sorting Multifunctional Nerve Guide:
Giving Prosthetics the Sense of Touch (SENSA Project)**

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The goal of the SENSA project is to create a multifunctional nerve guide that can confer sensation to prosthetics. We propose to develop an implantable guide which functionally sorts the regeneration of extending nerves along independent branches: one motor and one sensory. Conferring sensation is entirely possible to achieve, but requires physical separation of sensory axons from motor axons at distal sites of amputation. For this project, we have focused on two areas—1) neuronal growth and guidance and 2) functional scaffold development. For the first area of study, in order to assess control of neuronal growth, we performed growth cone turning assays using dorsal root ganglion (DRG) neurons isolated from embryonic day 7 (E7) chickens. These assays were performed using 7 μm polystyrene beads coupled to trophic factors, such as nerve growth factor (β -NGF). We further characterize these neurons using western blot to assess the activation of relevant downstream signaling pathways in response to trophic factors. For the second area of study, we developed fiber scaffolds composed of 25-50 aligned type I collagen fibers each measuring 20 μm in diameter and spanning 2 cm in length. Prior to *in vitro* evaluation, we sutured and glued nerve guides to culture dishes where they were cross-linked with genipin to limit swelling. E7 DRG or motor neuron explants were seeded at one end of the scaffold and allowed to grow in culture for 2 weeks prior to fixation and imaging. Confocal microscopy revealed axon growth in 3-dimensions along and in-between single fibers, demonstrating a high degree of biocompatibility. Scanning electron microscopy revealed contact-guided growth along the fibers whereby axons spanned up to 1.7 cm in length, yielding an average growth rate of 1.2 mm/day. Most recently, bifurcated conduits consisting of two independent fiber scaffold arrays were assembled into a Y-shaped guide and evaluated in tissue culture. Following evaluation of non-functionalized guides, we plan to evaluate the sorting ability of recombinant β -NGF linked to a single branch.

KEYWORDS: neurotrophin, axon growth, fiber scaffold, regeneration, prosthetic

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STEM AIAD Hampton, Virginia Experience

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We started our trip in Washington DC and learned about the United States Department of Housing and Urban Development (HUD). While we were here we learned about the support that HUD provides to underprivileged communities. We focused more on the help that they provide teaching the children of these communities about the importance of pursuing STEM careers. After this we went to Hampton, Virginia and learned more about the work that this specific city was doing for its lower income communities, we were able to meet with the city leadership and hear about the programs that they are implementing. We also got to witness a ceremony where the navy was building houses for lower income families that qualified and watched a family move into these new houses. The most impacting part of this trip was going to the boys and girls clubs and visiting with the kids and letting them know how important math and science fields are and why STEM is so important. We also answered any questions they had about high school, college, the military, and life in general. Seeing those kids get more and more interested in what we were talking about to the point where they didn't want us to leave in the end was so inspiring. The last thing we did while we were in Hampton was the STEM workshop. We taught the kids how to build and program robots and at the end they had a competition with who programmed the robots the best. They were so happy to all receive their certificates and loved building the robots, this was also an extremely inspiring experience. The last thing that we did on this AIAD was visit the Army Research Labs (ARL) and learn about the different things they are working on for the army. We got to tour two of the labs and see the different types of rooms they had and the different types of work that they do. All in all this was an extremely educational trip and has definitely helped us decide what we want to do if/when we get out of the army.

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Measuring the effects of 5-Fluorouracil on the development of *Plasmodium falciparum* with Flow Cytometry

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The World Health Organization has documented three of the five species of malaria to be treatment resistant.¹ *Plasmodium falciparum*, one such resistant parasite, is known to kill millions of people annually and poses a significant health risk to U.S. Armed Forces deployed globally. We sought to repurpose the anticancer drug, 5-Fluorouracil, as a novel antimalarial treatment in erythrocytes. Flow cytometry, a laser-based, biophysical technology used to count and sort cells was used to determine the effectiveness of 5-Fluorouracil. Experimentally, we developed a flow cytometry staining protocol that can be taught to future cadets and other research institutions. The flow cytometry data shows that erythrocytes treated with 100 μM 5-fluorouracil for 24-hours had lower parasitemia than untreated control flasks. Despite promising initial results, more experiments need to be completed in order to establish 5-Fluorouracil as a possible antimalarial drug; such experiments include varying concentrations of the drug, examining different time courses, and studying the effects on uninfected cells.

KEYWORDS: Plasmodium falciparum, cytometry, erythrocytes

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Autonomous Self-Righting

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A program that is used to take a set of predetermined joint angles to autonomously self-right a packBot was developed and tested on this AIAD. A program that can autonomously determine the correct arm joint angles to move through the self-righting sequence was developed previously by staff at ARL. This new, self-righting program required another program that could use these arm joint angles and put them into a language that the robot could understand. This is the basis for the cadet research and testing.

KEYWORDS: Self-righting, packBot, Arm Joint Angles

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Novel High-Rate Experimental Methods Using Dyneema® Fiber

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Testing Dyneema® fibers using high-rate experiments helps improve the understanding and practicality of a fiber that is currently a component of body armor and vehicular armor for US Army soldiers. High-rate experiments involve rapid tension tests that model how well the fiber reacts under intense stress and strain. Testing crack propagation through epoxies models the material's reaction to high intensity impacts and provides data for future improvement of armor to protect bones, specifically the skull. The testing of these fibers is done by using a high-powered microscope with a camera attached to take a picture of the length of each fiber. From these pictures, measurements are taken to calculate the diameter of each fiber. The fiber is then loaded into a Split-Hopkinson Tension Bar, which pulls the fiber apart at a high rate of speed and measures the length the fiber stretches before breaking. This displacement is then used to calculate the strain of the fiber while the force that pulls the fiber apart, along with the cross-sectional area of the fiber, is used to calculate the stress undergone by the fiber.

KEYWORDS: Dyneema® Fiber, Crack Propagation, Split-Hopkinson Tension Bar

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A Generic Ground-based Self-Righting Case-Study: Packbot®

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Robots operating in field environments face dynamic, uncertain conditions that can cause many platforms to tip over inadvertently. Once overturned, it can be very challenging for even a skilled operator to return the robot to its proper operating orientation without line of sight. Previously, we presented a framework for autonomously self-righting a generic robot on planar ground when possible using its existing morphology. In this work, we demonstrate how that framework can be applied to a robot designed for real-world operation: the 510 Packbot® with Camera Arm (CAM) and Small Arm Manipulator (SAM) payloads. We begin by reviewing the basic principles of the generic framework. We then describe the robot model and interface. Next, we provide the results of our self-righting analysis, including the robot's conformation space map for the shoulder and elbow, and a nodal analysis including its directed graph. An analysis of limitations was also conducted, and may be obtained by contacting the authors. Finally, path plans are shown for example starting states, and were executed by the physical hardware when possible.

KEYWORDS: Self-righting, robot, Packbot

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An Interdisciplinary Approach to Conducting Title X Live Fire Test & Evaluation (LFT&E) Vulnerability Assessments

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Survivability/Lethality Analysis Directorate's (SLAD) Engineering Analysis Branch (EAB) executes the Army's Live Fire Test and Evaluation (LFT&E) Title X mission through vulnerability assessments of vehicles, munitions, and crewmembers. While some assessments leverage legacy methodologies, most require innovative and deliberate engineering analyses to provide the Army developers valuable information over their systems. The two presented techniques illustrate an application of mathematics to interdisciplinary studies to determine a probabilistic outcome given medium-sized samples in support of the Title X LFT&E mission.

Demonstrating a lethality assessment, the 'frag on frag' analysis captured penetrator witness data to quantify the individual fragment characteristics and applied them as an increasing collective in order to identify an optimization level for a munition that balances fragment mass, velocity, material density, and spatial density in an attempt to discover the appropriate pre-forming of engineered projectiles. Mr. Steve Swann developed and used this technique for two programs, informing and influencing the development of munitions for both the Special Operations community and the conventional Army.

Additionally, in accordance with Title X charter, engineers in EAB determined penetrator characteristic data in order to increase the survivability of US vehicle design. By applying penetrator characteristics, several variants of armor material penetration algorithms, and fault tree analyses, Mr. Patrick Foley identified specific vulnerable areas as candidates for upgrades to increase the overall survivability of the vehicle and its crew.

In an interdisciplinary and complex LFT&E domain, EAB's team of engineers, scientists, and analysts apply a suite of tools, mathematics, and methodologies to ensure the development and fielding of systems onto the modern battlefield, accomplish all requirements, and fulfill the Warfighter needs.

KEYWORDS: Frag on Frag, penetration algorithms, vulnerability assessment

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Active Defense Strategies for Limiting Disruption to Service Availability Due to Propagating Malware

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Much of the existing literature on cyber defense focuses on detection and response: developing better detection mechanisms, combating malware that has already been detected, or efficiently patching known vulnerabilities. However, research has shown that many cyber attacks are able to evade detection for a long time, propagating malware throughout a network for months or years undetected. On the other hand, some viral attacks spread very quickly, infecting an entire network before exploited vulnerabilities can be identified or patches developed. Furthermore, lightweight devices are increasingly being used to support tactical operations in the battlefield, which may not have the storage capacity or processing power to run heavy-duty anti-virus or intrusion detection software. In light of these challenges, traditional approaches to network defense do not provide sufficient protection from cyber attack. In this work, we explore active defense mechanisms to limit the spread of malware – detected or not – using only routine computer operations, without requiring any specialized software. In particular, we consider the task of dynamically allocating provision of shared services which potentially contain vulnerabilities, with the goal of maximizing the number of nodes still providing service at the time of a coordinated exploit enabled by propagating malware. We propose a continuous-time stochastic model and derive analytical results for the optimal solution over a class of active defense strategies. We compare the performance of the optimal solution under our theoretical model with other proposed and baseline strategies in a more realistic environment using agent-based simulation.

KEYWORDS: active defense, cybersecurity, virus, worm, propagation, stochastic model,
agent-based simulation, ad-hoc network

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Micro-scale sand particles within the hot-section of a gas turbine engine

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Traditionally, foreign object damage (FOD) has been the primary concern in aviation gas turbine engines. Current state-of-the-art particle separators can remove most of the larger sized particles (greater than ~80 μm) from the inbound air. This, in concert with high-quality, erosion-resistant coatings on the compressor sections, has significantly reduced the risk from FOD. However, smaller particles (consisting of ash, soot, dust, and/or sand) can still pass through the engine. This is especially problematic in the hot-section, where the operating temperatures of modern gas turbine engines typically surpass the melting point of many of these contaminants. The resulting impact, adhesion, melt infiltration and/or glassy solidification of these small particles can significantly damage the hot-section components within the gas turbine engine. Empirical studies have led to a qualitative understanding/description of the resulting damage to the combustor plates and first-stage turbine blades. Yet, a quantitative understanding of the underpinning physico-chemical processes is still lacking. Solving this problem is a complex undertaking, which will involve modeling and experimentation of phenomena at multiple length scales. As part of this effort, finite element codes will determine the relevant temperatures and resulting phase state (fully or partially molten) of the contaminant particles traveling in the hot gases within the combustor and high-pressure turbine sections.

KEYWORDS: sand, gas turbine engine, thermal effects, mechanical effects

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Soldier-Machine Interaction: Wearable Control of Small Tele-operated Ground Robots

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The U.S. Army continues to integrate small, battlefield robots into the force to support intelligence, surveillance, and reconnaissance (IS&R) missions at the platoon level and below. These commercial, off-the-shelf robotic systems require specialized training and increase Soldiers' mental workload given the variation in proprietary control systems with which they are fielded. The goal of this research is to provide a hands-free approach to control small, tele-operated ground robots. The development of this project will require the use of a wearable visual feed-back device and a hands-free method of communication with the GVR-Bot. These devices will be paired via Robot Operating System (ROS). This research will culminate in field testing supported by Army Research Laboratory's Human Research and Engineering Directorate (ARL HRED). This study will attempt to add to the literature on human robot interface with the hope that it will lead to more researches that can increase Soldiers' performance in the field.

KEYWORDS: GVR-Bot, wearable control, Google glass, Myo Band, West Point cadets, robotic, control, human robot interface.

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Hierarchical Assembly of Bio-Templated Nano-wire and Nano-tube Films for Lightweight Multi-functional Materials

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Biological hydrogels can serve as 3-dimensional bio-templates for tunable nano-porous materials that serve both as electrochemical power sources and structural material. We present a general approach to 1) form a biological hydrogel; 2) sensitize the hydrogel bio-template using catalytic palladium ions to mediate the electroless deposition; 3) synthesize 3-dimensional networks of copper and nickel nano-wire films via electroless deposition; 4) synthesize inorganic salt templated square cross-section nano-tubes that can be integrated into a hierarchal nano-material assembly. Such multi-functional electro-mechanical materials are envisioned to decrease the systems mass across a broad range of Army platforms and serve as a nano-architecture for other applications such as photovoltaics, catalytic systems, sensors, and energy absorption.

KEYWORDS: Hydrogel, bio-templates, nano-materials, electrochemical, biotemplating

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Beam Quality Study for Single Mode Oxide-Confined and Photonic Crystal VCSELs

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A high-quality single mode beam is desirable for the efficient use of lasers as light sources for optical data communications and interconnects. To this end, we conducted a study to analyze the beam quality for a number of vertical-cavity surface-emitting lasers (VCSELs). We report on the beam quality and operating range of oxide-confined and photonic crystal (PhC) devices using M2 measurements, voltage and optical output power versus injection current (LIV), and spectral content. We used the collected LIV data to find the operating range of the devices and then characterized the devices over the operating range both in terms of spectral content and M2 value. For single mode devices (characterized as having a Side Mode Suppression Ratio (SMSR) > 20 dB), we further characterized the devices in terms of the root-mean-square (RMS) linewidths. The devices that we use for these characterizations are emitting at ≈ 850 nm with oxide-confined apertures of 2.5 μm , 3.0 μm , 3.5 μm , 4.0 μm , and 4.5 μm and PhC devices with apertures of 5.0 μm and 10.0 μm . The measured M2 values for the oxide-confined VCSELs suggest that the beam propagation factor improves with decreasing aperture size (with the 2.5 μm aperture devices exhibiting near single mode operation across their range of operating currents). PhC VCSELs demonstrated lower M2 values than oxide-confined devices with the same aperture and similar injection current.

KEYWORDS: VCSEL, Photonic Crystal, Oxide-Confined, Operating Range, Beam Quality

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UV Raman Spectroscopy for Detection of Explosive Compounds on Varying Substrates

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Standoff detection of explosives on surfaces can help keep personnel safe.¹ Raman spectroscopy provides an interesting approach to detecting explosives on surfaces; however, there are issues. Raman has an inherently weak signal, so it is useful to take advantage of parts of the UV spectrum to enhance signal intensity.² The surface material underlying the explosives can affect spectra. Using visible excitation, different plate colors produced inconsistent spectra. Lighter panels tended to have higher backgrounds and less pronounced peaks.³ Using UV excitation, all plate colors produced nearly indistinguishable background spectra. Overall, the use of UV excitation is essential because the color of the surface should not affect the produced signal due to a consistent background signal.

KEYWORDS: UV Raman spectroscopy, Explosives detection, Surface contamination detection

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