The Southern Maryland Initiative for Energetics Capability Development

Annual Report

February 1, 2010

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Foreword

This document entitled the *Southern Maryland Initiative for Energetics Capability Development: Annual Report FY10* provides an overview of accomplishments, ongoing activities, and future plans of the CECD/ETC Enterprise in Southern Maryland. It is the sixth in a series of documents for the *Southern Maryland Initiative for Energetics Capability Development: A Response to Emerging National Needs.*

Southern Maryland has a long history of contribution to the field of energetics development for ordnance applications. The base at the Naval Surface Warfare Center Indian Head Division (NSWCIH) has been a leader in Navy ordnance development and testing for over 100 years. The Energetics Technology Center (ETC) was established *to be a catalyst for research, development, prototyping, education, and training in Southern Maryland and to facilitate, in partnership with NSWCIH, Southern Maryland becoming a world class Center of Excellence in Energetics*. This need for energetics and energetic systems arises from two pressing issues, both critically linked to U.S. national security: the first to regenerate the energetics professional workforce and the second to develop ever more sophisticated systems in a timeframe that will ensure that the Department of Defense has the state-of-the-art capabilities.

The CECD/ETC team, working together with the College of Southern Maryland (CSM), NSWCIH, and other entities, conducts a wide range of scientific and technology activities, policy/planning studies, and workforce development programs to advance the development of energetic systems and recapitalize the nation's energetics workforce. Recently, we have proposed working with ARL and a contract is under negotiations. In anticipation of this activity, we have appointed Professor Thomas Klapötke as Professor of Mechanical Engineering and Chemistry at the University of Maryland, College Park. His new appointment will enable Professor Klapötke to work with us as well as ARL and NSWCIH since his expertise in synthesis of propellant and explosive ingredients is of interest to all entities.

The CECD/ETC team has met all the milestones established in the FY09 and earlier plans. The ETC is now a fully functional non-profit organization with 10 full-time employees and 9 part-time employees and consultants. Currently, CECD and ETC are working on a number of projects supported by NSWCIH and ONR. These are in the areas of nanotechnology, energetic materials, virtual environments, energy, traumatic brain injury, and workforce development. Some examples of our current work are included in this report.

The United States Congress has provided funds for programmatic support of the ETC and enhancing the work of the CECD. These funds have been crucial to achieving our objectives in

establishing Southern Maryland as an Energetics Hub. The continuation of this support is vital for growing a strong presence in this field and in partnership with NSWCIH establishing a world class Center of Excellence in Energetics.

Davinder K. Anand
Professor and Director
CECD

Robert Kavetsky
CEO
ETC

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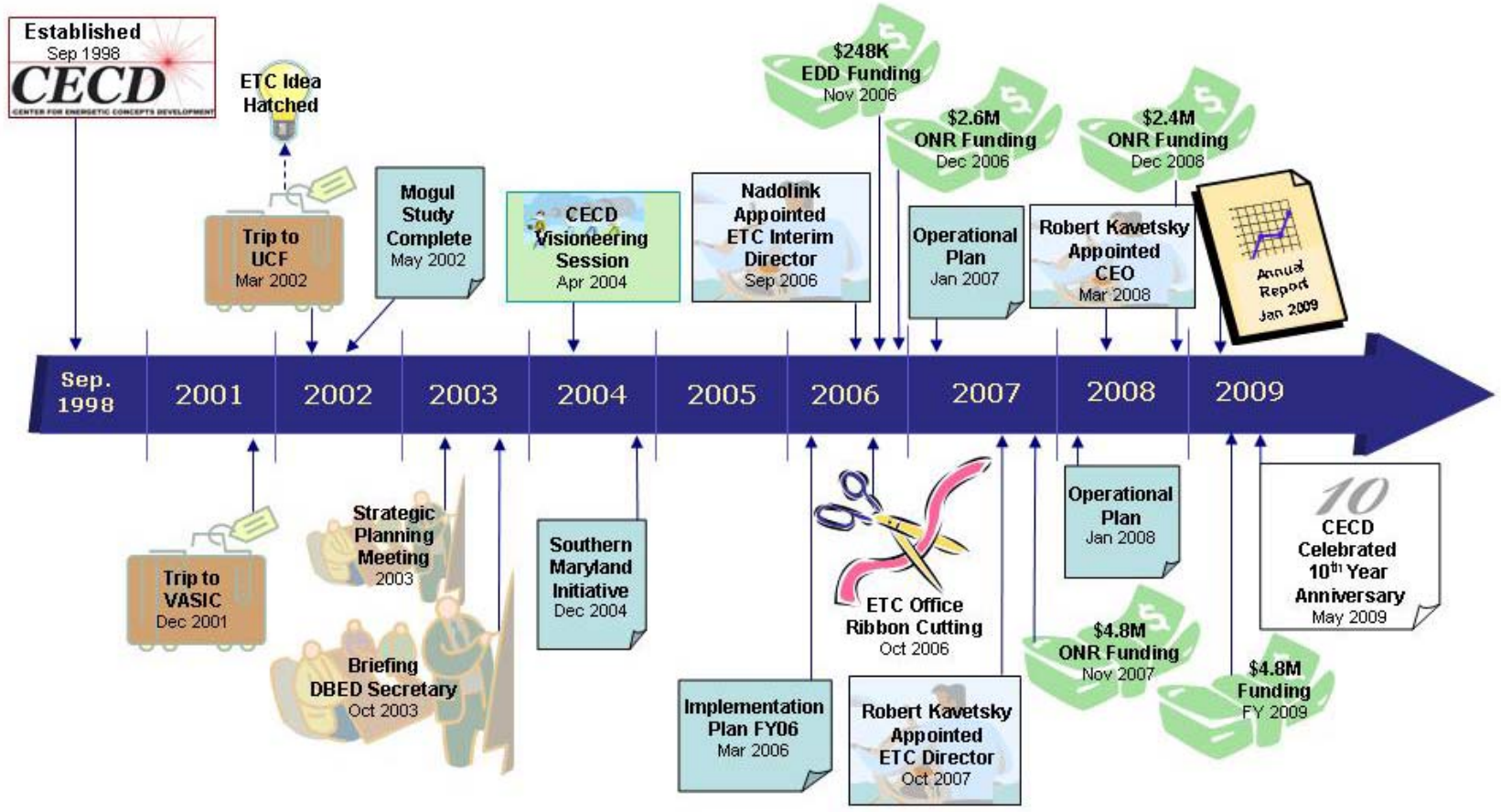
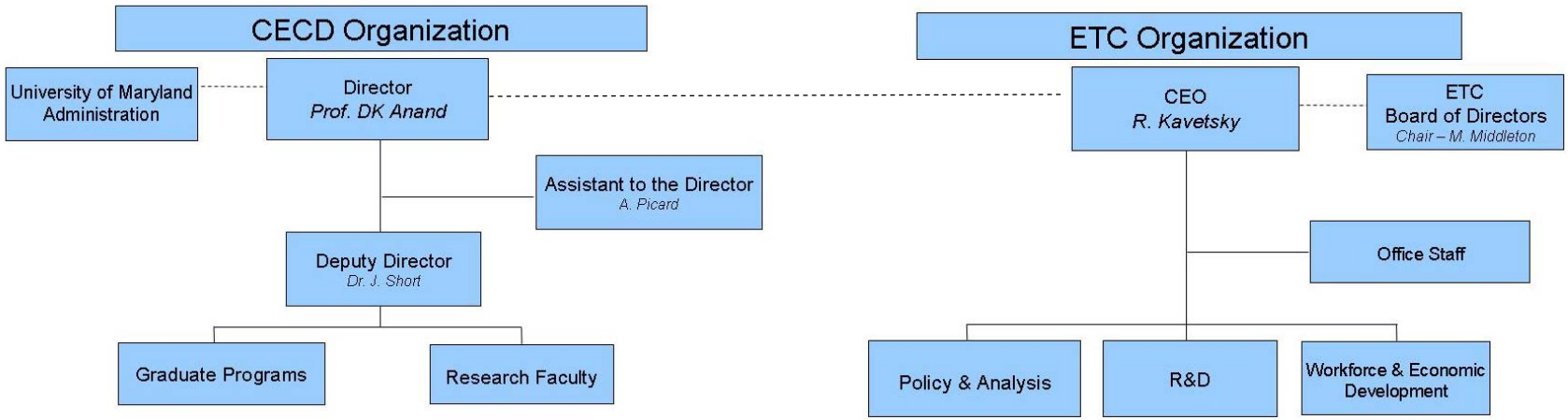
Growth of the CECD/ETC Enterprise



CECD/ETC Enterprise



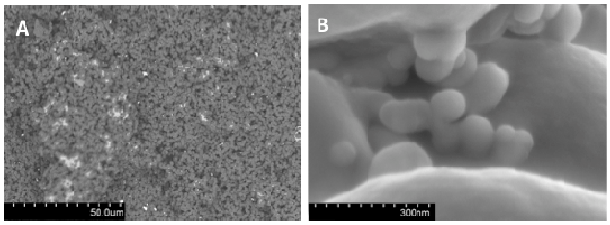
Contract Performance

Nanotechnologies for Trace Explosives Detection

The development of novel nanotechnology-enabled materials for label-free and real-time trace explosive detection is under investigation. Specifically, we are developing functionalized nanoporous materials as novel surfaces for ultrasensitive analysis of adsorbed explosives by surface-enhanced Raman spectroscopy (SERS). Label-free detection is critical for robust, inexpensive and field deployable explosive sensors. To this end, SERS has emerged as a highly promising analytical technique. Raman-scattered photons from molecules adsorbed onto a metal surface provide a unique spectral fingerprint that can be used for molecular sensing and identification. The ability to measure trace levels of analyte molecules is due to the well-known Raman signal enhancement resulting from large electromagnetic fields at the interfaces between metal nanoparticles. Although the Raman effect itself is inherently weak, SERS involves the use of metal nanoparticles as an excitation substrate, and has been shown to provide up to 14 orders of magnitude enhancement to the Raman signal, ultimately enabling single molecule detection under appropriately controlled conditions. In addition to providing exquisite detection sensitivity, the identification of various chemicals and biomolecules has been demonstrated using SERS by interrogating the spectral signatures produced. Thus SERS is an exceptionally promising spectroscopic method for emerging platforms for trace explosives detection.

In this work, we have demonstrated the use of nanostructured porous surfaces with high specific surface areas for enhancing analyte adsorption and increasing SERS signals through optical interactions with the structured substrates. Techniques for covalently attaching metal nanoparticles to the porous materials have been developed as a robust alternative to simple physical adsorption used in many existing SERS systems. Three specific material systems are being explored in this effort, namely polymer monoliths, nanofilament silicon dioxide, and porous anodic alumina. These surfaces provide access to a range of bulk and surface chemistries as well as pore morphologies for the SERS surfaces. Common features shared by each of these surfaces include amenability to low-cost fabrication, high optical transmission over the wavelength range of interest for SERS detection, and readily tunable surface properties.

Our results reveal that porous anodic alumina membranes with adsorbed gold nanoclusters provide the highest sensitivity, with a demonstrated detection limit in the low pg/mL range for nitrotoluene explosives. This is one of the first demonstrations of label-free SERS detection of explosive materials. Unlike our previous work, using nanofilament silicon surfaces for explosive detection and laser desorption/ionization, the nanoporous alumina SERS technology offers real-time detection with simple optical instrumentation suitable for integration into a compact and field-deployable system. For the coming year, we will focus on improving the detection limit through better control of nanoparticle clustering within both polymer monolith and alumina nanopores. In addition, the use of metal nanoparticles functionalized with capture probes within the porous surfaces will be evaluated as a straightforward approach to providing improved selectivity for specific classes of analytes. In this way the resulting surfaces will provide multi-level analyte identification by combining SERS signature evaluation with filtering of selected molecular classes, for example using cysteine as a capture probe for nitrotoluene explosives.



(a) SEM micrograph showing chemically immobilized polymethacrylate polymer monolith and embedded metal nanoclusters; (b) SEM micrograph revealing a metal nanocluster attached to the monolith matrix.

Contract Performance

Distributed Control of Residential Energy Systems (DCRES)

Introduction

Residential space heating and cooling typically consumes about half of the energy used in a household, and about 9% of the total energy consumed in the US. One proposed technique to reduce energy consumption is through smart thermostat control strategies. The vast majority of new and existing residential construction utilizes a single sensor for control of HVAC systems. It was recently suggested that smart control of thermostats using multiple, distributed sensors can decrease energy usage up to 79% in cooling systems operating in dry climates (Pleasanton, CA). The goals of this research are to verify this claim and its applicability to homes in the humid mid-Atlantic region.

Experimental Work

A single family, two-story, 2350 ft^2 detached home in the mid-Atlantic region was instrumented with wireless temperature and humidity sensors in the kitchen, central hallway, dining room, family room, and three upstairs bedrooms. Another sensor was placed outside. The sensors communicated with a single controller that determined whether or not cooling should be provided to the home based on ASHRAE's Predicted Percent Dissatisfied (PPD), a quantity that combines the effects of temperature and humidity into a single perceived measure of comfort. Control strategies tested included single point control, control of the average of all monitored PPD, minimizing the aggregate PPD of all rooms, and maximizing the number of rooms to be below a threshold PPD.

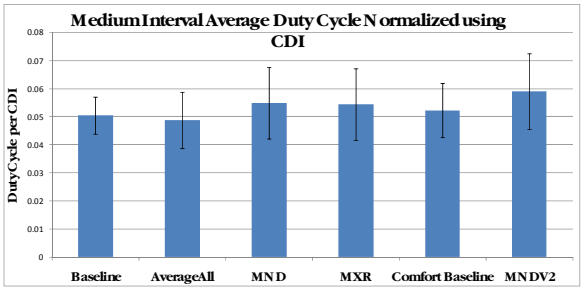
Results

Data was obtained from the beginning of June through the end of August. To account for the large variation in weather conditions between the testing days and periods of the day, Cooling Degree Days (CDD) and Cooling Degree Intervals (CDI) were used during the analysis of the energy and comfort performance of the strategies. The initial conditions of the house during the test days were shown to have a large impact on when and how each strategy cools the house. To obtain a fair comparison that eliminates the effect of the strategy used the previous day, time intervals were taken from each test day starting and ending at similar conditions. A correction factor was also used to adjust the energy consumption for strategies that operated at different comfort levels. The results showed that all the tested control strategies resulted in statistically similar energy consumption, indicating the distributed control of a single actuator does not save energy. Additional data to quantify the effect of control strategy on heating will be obtained in December 2009.

Expected Outcomes

The performance of various control strategies for winter heating as well as summer cooling in a humid environment will be experimentally evaluated and compared with simulations to evaluate their effectiveness. The simulations will also help in creating a system theoretic model for the thermal dynamical system.

Wireless Temperature/Humidity Sensor



Summary of Results: Duty Cycle Per CDI for Various Control Strategies, Summer Cooling

Contract Performance

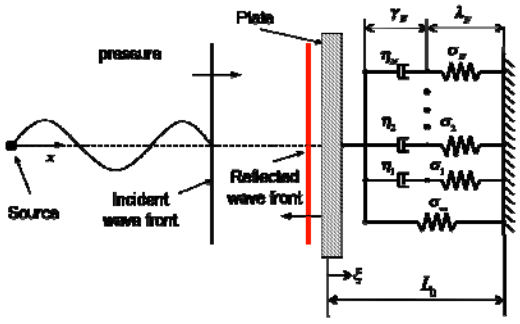
Blast Wave Interactions with Soft Tissue Matter

Background

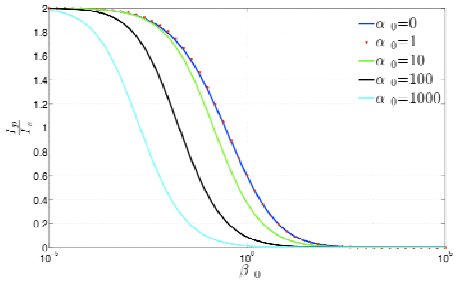
The interaction of blast waves with the human head involves propagation of nonlinear stress/strain waves within the brain, and this propagation is characterized by the transfer of a large amount of energy at high strain rates in a short time window. Experiments with swine and rat brain tissue subjected to tension, compression, and shear loads indicate that brain tissue behaves as a nonlinear visco-elastic material. Brain tissue material nonlinearities and heterogeneity are likely to produce localization of stresses and strain, and this localization may help understand mechanisms of brain injury.

Current Studies

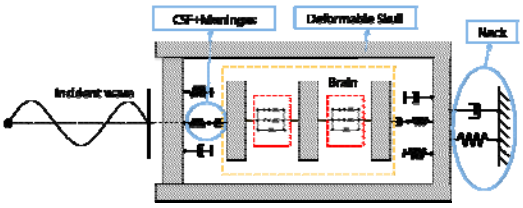
The current studies have been carried out with the aim of developing reduced-order models to aid the following: i) obtain fundamental insights into wave propagation phenomena in the skull-brain system, ii) understand the influence of nonlinear visco-elastic properties on the dynamic behavior of rod-like structures, and iii) experimental characterization of soft tissue. The spatially one-dimensional studies are based on multi-degree-of-freedom models, while the spatially two-dimensional studies have been carried out by using a finite element package (see figures for model description and results).



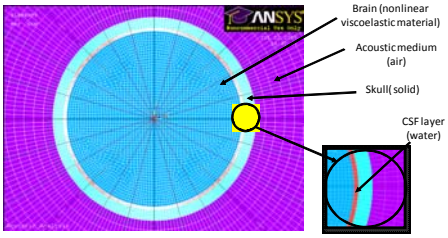
Model for Studying Wave Interactions with Plate Supported by Nonlinear Visco-elastic Element



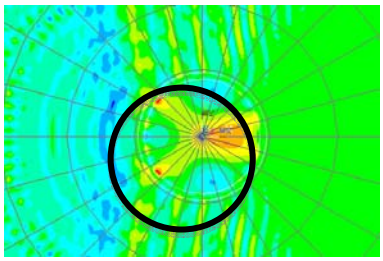
Ratio of impulse transmitted to excitation impulse acting on plate supported by nonlinear visco-elastic element. Such charts can be modified by using empirical factors to account for air compressibility effects.



Multi-Degree-of-Freedom Model for Studying Response of Skull-Brain System to Blast Waves



2D Finite Element Model for Studying Blast Wave Interactions in Skull-brain System



Results of Finite Element Studies Showing Wave Propagation Inside the Head (Black Cylinder)

The predictions of the reduced-order models can help understand the role of material nonlinearity in determining the blast response as well as guide the formation of a complete response picture through detailed three-dimensional simulations.

Contract Performance

Health Monitoring of Energetic Materials

The motivation for this research is to develop a new technique for characterizing mechanical properties of highly-filled polymers (i.e., composites with high volume fractions of solids fill like propellants) in situ (i.e., inside of the material). The basic concept we have developed is as follows:

- Place a piece of Shape Memory Alloy (SMA), as an active element which is capable of recovering large amounts of plastic deformation upon heating, inside of the highly-filled polymer to act as an actuator (i.e., load-inducing system).
- Heat the SMA to recover deformations that can be detected using a strain sensor, such as a fiber-optic Fabry-Perot strain sensor, and related to mechanical properties depending upon the initial amount of plastic deformation in the SMA and the thermal history for recovery.
- To relate the deformation to properties of the highly-filled polymer, the properties and recovery strain of the SMA need to be determined a priori depending on the preparation of the actuator, and then the response of the highly-filled polymer depending on its properties can be assessed both computationally, using Finite Element Analysis and experimentally, using strain sensors or full-field deformation measurement techniques like Digital Image Correlation (DIC).

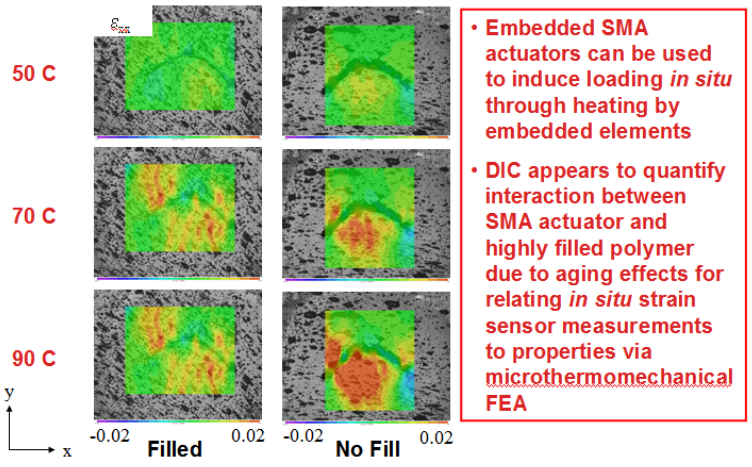
Experimental Methods

We have developed a semi-inert energetic material simulant for propellants in this work that consists of HTPB-PAPI as an energetic binder and 200 and 90 micron diameter KCl particles to simulate energetic AP crystals. An SMA ribbon is embedded within the propellant stimulant that is pre-deformed into an approximately 90^{o} bent profile to act as an actuator. After curing a circular specimen of the energetic material with the SMA actuator in an open aluminum mold, it is then placed into a novel measurement system that uses DIC to track the interaction of the SMA actuator with the energetic material as it straightens out during heating on top of a hot plate.

Accomplishments

We have been able to demonstrate the following using a variety of actuator and energetic material configurations:

- Molding processes have been shown to be capable of creating model structures for health monitoring of energetic materials with embedded SMA actuators.
- A new technique based on DIC has been developed for characterizing the evolution of deformations during heating of the SMA actuator embedded in an energetic material.
- DIC has been demonstrated to quantify interaction of SMA actuators and energetic material simulants during heating.
- Embedding SMA actuators before curing produces stronger interactions than after curing.
- Embedded SMA actuators both before and after curing have much stronger interactions than passive elements like aluminum.
- New micro-thermomechanical FEA models are currently under development to relate the energetic material-actuator interaction and fiber optic strain gage measurements to changes in properties of the propellant simulant due to aging.



Contract Performance

A Simulation-Based Framework for Generating Planning Logic for Autonomous Unmanned Vehicles

Traditionally, innovation and discovery have been the domain of highly creative individuals who rely on their intuition and insights to develop new knowledge, ideas, concepts, and products. Recent advances in the high fidelity simulations enable us to do an accurate analysis of proposed solution. The advent of low-cost, high-performance computing architectures enables us to explore a very large number of solutions in a short period of time. Advances in procedural representations enable us to automatically generate complex candidate solutions.

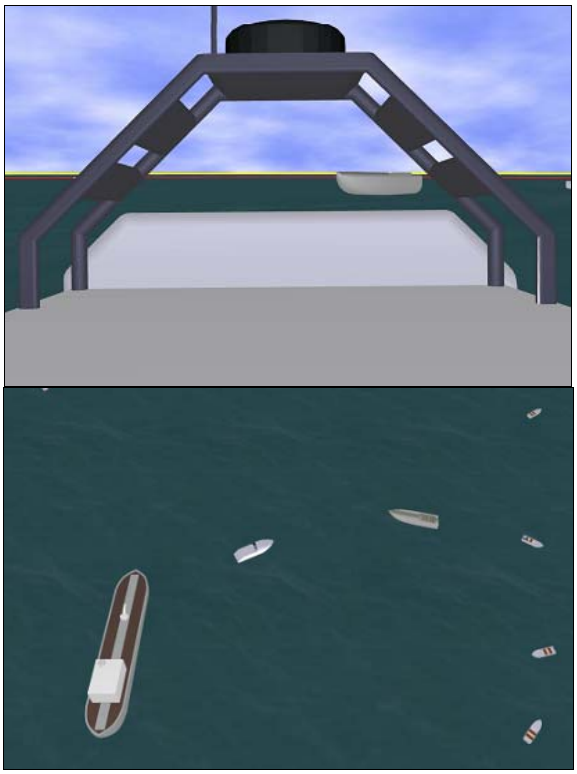
A major issue in the development of increased autonomy for robotic vehicles such as unmanned vehicles is the time and expense of developing the software necessary to handle a large variety of missions and all the variations in the encountered environments. This is a truly challenging task and requires writing hundreds of thousands of lines of code by human programmers. We have developed a new approach for developing planning logic that operates autonomous unmanned vehicles. This new approach takes advantage of the significant progress that has been made in virtual environments and machine learning.

We have used unmanned sea surface vehicles (USSVs) as our demonstration platform. The basic idea behind our approach is as follows. The USSV explores the virtual environment by randomly trying different moves. USSV moves will be simulated in the virtual environment and evaluated based on their ability to make progress towards the mission goal. If a successful action is identified as a part of the random exploration, then this action will be integrated into the logic driving the USSV.

To assess the performance of our system, we have developed a virtual environment-based game that allows human players to play against each other or against the computer. In the game, the player controlling the intruder boat must reach a protected target, while the player controlling the USSV must block and delay the intruder as long as possible.

This game allows us to measure and compare human performance to machine generated logic performance. The game software consists of two parts: a scene graph based on the Object-Oriented Graphics Rendering Engine (OGRE) and game logic. The game logic is responsible for the rules of the game, game logging and replay, boat behaviors, and scoring. Behavior of the boats is encapsulated in a set of classes. Once models of all the boats are loaded into the scene, a physics-based kinematic model is used to govern boat behavior. The game logic uses a combination of randomly generated structured motion and path planning to generate movements for friendly vessels. In human versus human mode the game is played on two computers over a network using User Datagram Protocol and a client-server architecture. All games can be logged and later played back.

Our results show that a genetic programming-based synthesis framework is capable of generating decision trees expressing useful reactive blocking logic.



Virtual Environment for Simulation

Contract Performance

Tools and Techniques for Prognostics and Health Management

Prognostics is the process of predicting the future reliability of a product by assessing the product's extent of deviation or degradation from its expected normal operating conditions. PoF-based prognostics utilizes knowledge of a product's life cycle loading conditions, geometry, material properties, and failure mechanisms to estimate its remaining useful life. Data-driven prognostics uses statistics and probability for analyzing current and historical data to estimate remaining useful life. The fusion approach combines the PoF and data-driven approaches to provide online diagnosis and estimation of remaining useful life of a product.

Testing an Approach

Traditional methods used to monitor interconnect reliability are based on the measurement of DC resistance since it is well-suited for characterizing electrical continuity, but is not useful for detecting a partially degraded interconnect. Degradation of interconnects, such as cracking of solder joints due to fatigue or shock loading, usually initiates at an exterior surface and propagates towards the interior. At frequencies above several hundred MHz, signal propagation is concentrated at the surface of interconnects, a phenomenon known as the skin effect. Many types of electronic products require transmission of signals in the GHz range. For these products even a small crack at the surface of an interconnect may adversely affect the performance. RF impedance monitoring offers a more sensitive and reproducible means of sensing interconnect degradation than DC resistance. In order to demonstrate this, a simple test vehicle that contained two solder joints was developed and employed under cyclic stress conditions. Figure 1 shows the setup schematic. Simultaneous measurements of DC resistance and time domain reflection coefficient as a measure of RF impedance were conducted to allow a direct comparison of their respective sensitivities in detecting physical degradation of the solder joints. The RF impedance was observed to increase in response to the early stages of cracking of the solder joint while the DC resistance remained constant. Failure analysis revealed that the RF impedance increase resulted from a physical crack, which initiated at the surface of the solder joint and propagated only partway across the solder joint. Figure 2 shows the plot of RF impedance and event detector data.

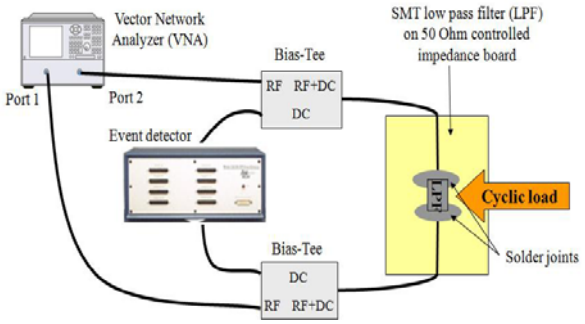


Figure 1: Schematic of Test Set-up

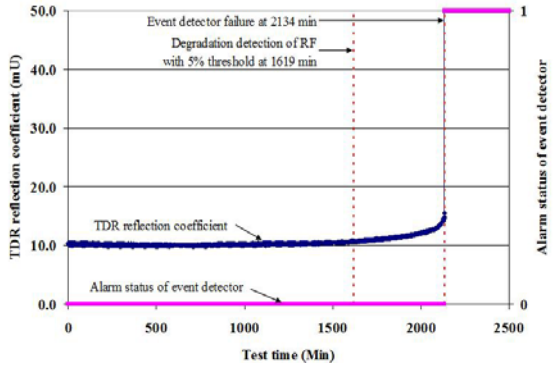


Figure 2: Comparison of Techniques

Conclusions

These results indicate that RF impedance can serve as a non-destructive early indicator of solder joint degradation. The continuous monitoring of RF impedance during a stress test provides a direct means of monitoring the health of an interconnect. RF impedance monitoring can be used as a prognostic tool. In situ measurements of the failure precursor can be used to trigger an alarm to provide condition-based maintenance, thereby increasing product availability, reducing unplanned downtime, and bringing substantial savings in operational, repair, logistical, and liability costs. This technique can improve real-time reliability prediction of electronic products when incorporated into sensing circuitry in the product.

Contract Performance

High Energy Launch Systems and Projectiles

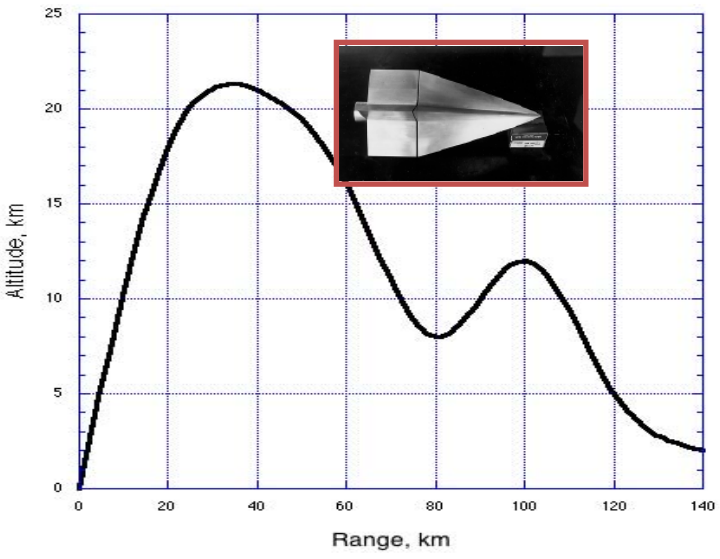
Energetic materials and high-energy launch technologies offer the possibility of boosting payloads and warheads to very high accelerations, either above the atmosphere or at long ranges on earth's surface. In particular, energetic materials derived from nanoparticle formulations can yield rocket fuels with extremely high energy release rates, resulting in very high initial thrust profiles. Similarly, electromagnetic launch systems currently under development with both the U.S. Navy and U.S. Army hold the promise of gun systems that can launch non-symmetric projectiles with high initial velocities.

Traditional space launch systems tend to have moderate initial thrust levels, with relatively modest thrust-to-weight ratio. This means that conventional rockets begin their flight with thrust that is only marginally greater than weight, and thus initial accelerations are modest. This leads to an overall inefficient launch system. On earth, high-acceleration launch systems could be used for projectiles with extreme range. Traditional projectile systems are limited to at best a few tens of kilometers; and though concepts have been proposed for staged guns that can shoot projectiles hundreds of kilometers, longer-range flight has generally required the use of rocket systems. Developments in electromagnetic launch methods now make practical the delivery of tens of kilograms of projectile up to 150 kilometers or more. This would have significant military applications.

In both the space launch and gun cases described above, a key element is the efficient aerodynamic design for an object that will be accelerating to very high speed in a relatively dense portion of the atmosphere. The aerodynamic forces on an object are proportional to the local air density and the square of the velocity; power required to fight that drag scales with the cube of the velocity. Thus, there is considerably more drag on an object that begins low in the atmosphere at high velocity, as compared to the one with smaller acceleration. There is a similar problem for high-speed energetic projectiles. Emerging from a gun barrel at extreme initial velocities will also include significant initial drag unless the object is carefully designed.

A parametric examination of aerodynamic performance, including requirements for both lift and drag, has been conducted. The goal is to first determine if performance goals are achievable – for instance, can a projectile reach a desired 150 km with realistic, achievable aerodynamic coefficients? To this end, optimized trajectories with varying aerodynamic performance have been explored.

In some cases, the derived geometries may be highly non-traditional. Projectiles with high aspect ratio, or efficient shockwave utilization, might be a likely outcome. Using aerodynamic optimization techniques, coupled to the optimal trajectory approaches, these configurations will be explored with an eye towards their practicality and performance across a wide flight envelope. Variable geometry designs are also being examined.



Altitude Versus Range for a Low-Drag Projectile. Goal Is to Exceed 150 km Range.

Contract Performance

Self Adjusting Vacuum Grips for Mechanical Testing of Small, Very Soft Biological Tissue

Introduction

Brain tissue in model animals must be mechanically tested to lay the scientific foundation for clinical evaluation of human traumatic brain injury. Mechanical tests are performed on soft biological tissue, such as cardiovascular tissue, ligaments, skin, etc, to measure the deformation as a function of load, to determine the fracture load and to make other similar measurements in order to predict the in vivo behavior both of healthy and diseased tissue. One of the difficulties in mechanical testing of soft biological tissue is that of gripping the specimen so that a tensile test including load to fracture, creep and stress relaxation, may be conducted. The usual problems are that it is easy to crush or tear the soft specimen in the grips and that the specimen slips from grips. Also as soft tissue is loaded, the specimen thins in the grips so that the grips have to be continually closed to maintain the hold on the specimen during the test. Making the adjustment manually risks disturbing the specimen.

Vacuum devices have been used for decades in industrial applications to lift objects. For example, in the small office offset printing press of 50 years ago, vacuum lifts each sheet off the stack of paper to be printed to the rollers that draw the sheet through the press. A typical low-tech mechanism is a simple suction cup with a handle that is attached to the device to be lifted.

Design Work

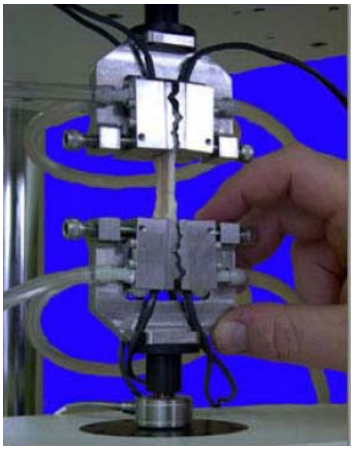
The tissue must be gripped under a light and easily controlled load in order to minimize damage to the specimens from the grips. The grips must be capable of applying forces of less than 10 Newtons.

A common technique used in grips for soft biological tissue is to apply air pressure to one end of pivoted grips so that the free end clamps the specimen. A problem with this method is that enough force may be inadvertently applied to crush the tissue. The force is held constant by the fixed air pressure. Even with if the air pressure is manually controlled, the force does not automatically adjust to thinning of the specimen. In the proposed design, the vacuum induced pulls grip blocks to the specimen, exerting a small load that is large enough to hold the specimen under typical test loads.

The constraints on the design are: 1. The grip must be able to withstand a load of 250N and must hold a specimen with cross-section in the range of 2 by 2 to 25 by 10 mm; 2. The grip cannot deform more than 0.01 mm under 250N; 3. The grip must operate in 50-100°F and 80-100% relative humidity; 4. The weight of material in the upper grip must be less than 2N; 5. The grip face must generate a frictional force of 25N; and 6. The vertical dimension of the face must be greater than 8 mm.

The designed grip must perform the following functions: 1. Secure the specimen during the test; 2. Create friction between the specimen and the face of the grip; 3. Adjust for specimen size; 4. Align the specimen to prevent bending and twisting of the specimen; 5. Ensure the specimen is vertical; 6. Allow hydration of the specimen; and 7. Permit optical measurement of the specimen deformation.

The design is to be validated by using it to test very soft rat brain tissue. An invention disclosure for a version of these grips designed for larger samples of moderately soft tissue such as artery tissue has been submitted to the University of Maryland Office of Technology Commercialization.



Commercial Bose Grips

Contract Performance

Synthesis and Characterization of Novel Energetic Materials

In 2009, the CECD appointed Professor Thomas Klapötke as Visiting Professor of Mechanical Engineering and Chemistry at the University of Maryland, College Park. He also has an Energetics Technology Center appointment as Visiting Scientist. The appointments will also enable Prof. Klapötke to work with NSWCIH and ARL. In October, two Klapötke research associates, Dr. Joerg Stierstorfer and Mr. Franz Martin did the first CECD synthesis of energetic ingredients in a campus laboratory established by Professor Michael Zachariah. Before returning to Munich in early November, they made as much as two grams of RDX and equal amounts of other experimental energetic compounds.

Aberdeen Enthusiasm for CECD Synthesis

Dr. Betsy Rice, a research chemist in the ARL Weapons and Materials Research Directorate is Klapötke's closest Army associate. As a consequence of Department of Defense Base Realignment and Closure decisions made in 2005, considerable growth is coming to Aberdeen in 2011. New facilities being constructed create the potential for growth of Dr. Rice's energetics research program. That growth stimulates the CECD growth into synthesis chemistry. In anticipation of the new Aberdeen chemistry laboratories, Dr. Rice filled two postdoctoral positions with synthesis chemists. Dr. Rice sent two chemists, Dr. Kim Spangler and Dr. Matt Sherrill, not experienced in energetic synthesis, to CECD to learn from Dr. Joerg Stierstorfer and Mr. Franz Martin.

Dr. Rice is enthusiastic about the future of this new collaboration, "my postdocs are very excited about [the time spent] with Klapötke's associates. Aberdeen needs to start getting University of Maryland students up here. It is a very exciting venture." Rice continues: "I could not be more pleased with the three-week collaboration between my ARL postdocs and the LMU students at the UMD labs. The interaction turned out better than I thought possible, mainly because it provided my students with extraordinary tutelage in a new research effort."

Dr. Kim Spangler and Dr. Matt Sherrill, are equally optimistic. From Dr. Spangler: "Joerg and Franz relayed their experiences and taught me techniques that are not typical of a traditional synthetic chemistry curriculum." Dr. Sherrill spent three months with Prof. Klapötke in Munich, "I hope the Aberdeen collaboration with Maryland and LMU will continue to provide opportunities in the future." That future will be enabled early in 2010 when an LMU postdoctoral student arrives at College Park to work with Prof. Zachariah and his students. The plan then is to continue the operation of the CECD synthesis laboratory into the future with Prof. Zachariah's students and LMU research associates.

LMU on CECD Collaboration

Dr. Stierstorfer and Mr. Martin echo Dr. Sherrill's remarks. From Dr. Stierstorfer "We … gained experience in many constructive and interesting discussions within the CECD and the ARL. All our endeavors are dedicated to strengthening our very good partnerships within the United States." Mr. Martin continues on the same theme "Collaboration requires agreement on the goals of the efforts, an understanding of how the goals will be attained, and an awareness of the state of the collaborative effort."

F. Martin, E. Byrd, K. Spangler, B. Rice, J. Stierstorfer, and M. Sherrill

Contract Performance

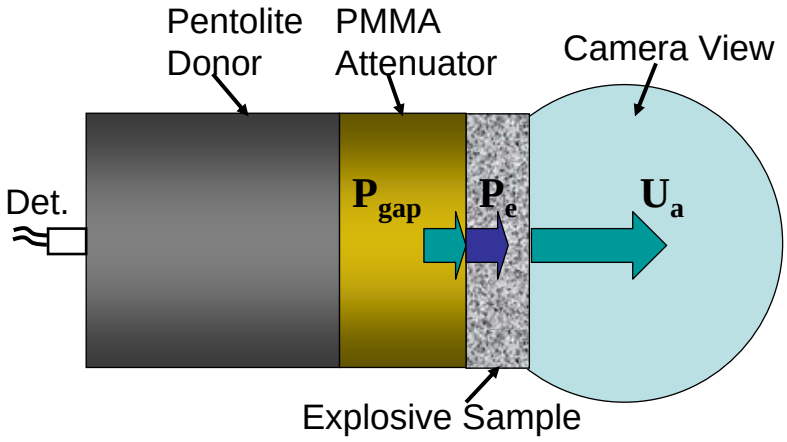
Energetic Materials Research

Working with industry partners we have developed a thermodynamically consistent equation of state surface for 6061 solid aluminum and updated the melting phase line for aluminum. This equation of state is designed to be readily used in the two-dimensional Second-order Hydrodynamic Automated Mesh Refinement Code (SHAMRC). This equation of state allows hydrodynamic code calculations to evaluate the use of various porous aluminum cases for air blast enhancement. Future work will be to develop a thermodynamic surface for the melt phase of aluminum.

Results of our work entitled "Changes in Run Distance Observed in Two Explosives at the Threshold for Sustained Ignition Using the Modified Gap Test" were presented July 3, 2009 at the Shock Compression of Condensed Matter APS Meeting**.** This paper is being published in the conference proceedings book**.** The results show that sensitivity of industrially prepared explosives changes due to localized variations in density and variation in explosive particle size. This shows that shock sensitivity needs to be given as a range of input stresses rather than just a single input stress. It also shows that sample quality control is required for research experiments.

We have also served the detonation science community by participating on the Los Alamos National Laboratories LDRP (Laboratory Director's Research Program) review panel for "Hot Spot Physics and Chemistry in Energetic Materials Initiation".

A series of lectures on shock wave and detonation physics were given at NSWCIH. This included a short course on shock wave thermodynamics of condensed matter and several sessions on detonation physics as part of the NSWCIH Basic Ordnance Course. An invited seminar to the Western Illinois University Physics Department on basics of shockwave was also given.



Modified Gap Shock Sensitivity Test Arrangement to Measure Sample Surface Velocity

Contract Performance

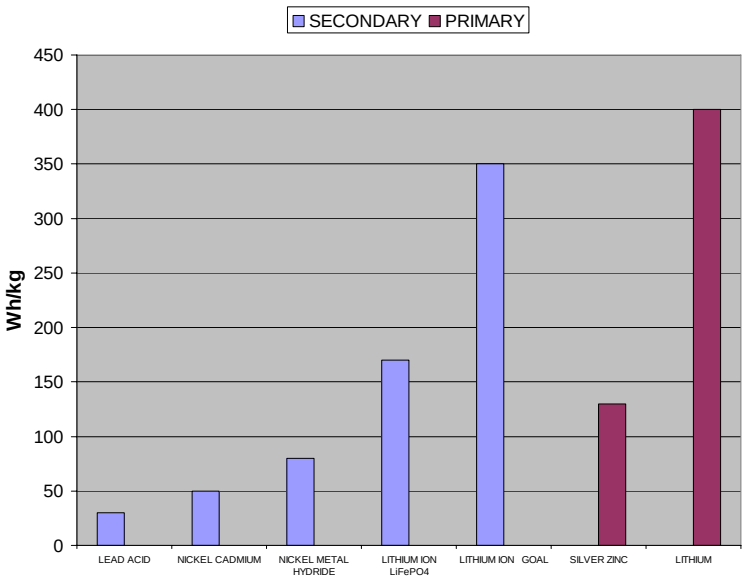
Weaponizing UUVs

This task was conducted in support of an ONR global brief to CNR on foreign technology that could be applied to US or an adversary's UUV in the next decade. In particular, the study was to focus on power and autonomous operations. Data mining techniques were employed to determine where the bulk of the research and development efforts are being conducted.

For power, the study concentrated on battery and fuel cell technology in Asia and Europe. Much of the ongoing battery research and development is being driven by the requirements of all electric vehicles. Current hybrid vehicles typically use nickel-metal hydride batteries. Lithium-ion batteries have the potential to provide much higher energy densities, increase endurance and eliminate heavy metal. Li-ion batteries are also attractive for UUV applications because they do not produce any gas during recharge. The issues surrounding the Li-ion batteries include cost, reliability, safety, and recharge rate. Much of the research is being conducted in the US at various universities and laboratories while the Asian and European organizations focus on engineering and manufacturing. China, Japan, and South Korea are the major players in Asia; and France, UK, and Germany are the major players in Europe. As with consumer electronics, battery production is tied closely to the end product. Therefore, Europe and the US are playing catch up to Asia to support their future automobile production.

Similarly, fuel cell basic research is being conducted in the US, while Asia and Europe concentrate on bringing the technology to market. Asia and Europe have fleets of fuel cell powered buses operating in demonstration projects. Asia also has developed fuel cells for residential power generation as well as larger units for commercial power generation. The technology is centered on proton exchange fuel cells (PEFC) and solid oxide fuel cells (SOFC) for vehicle power and residential power. Direct methanol fuel cells (DMFC) are also being marketed for small consumer electronics. The issues with the PEFC are purity of hydrogen fuel and cost of precious metal catalyst. The issues with the SOFC are high operating temperature, long startup times, and utilization of waste heat. Much of the research is conducted on fuel cells utilizing atmospheric air as the oxidizer, while anaerobic applications require another source such as hydrogen peroxide.

Autonomous operation includes path planning, navigation, obstacle avoidance, target recognition, and engagement. Outside of military applications, UUVs are applied to oceanography research and offshore oil exploration. The research facilities and exploration companies are increasing their use of autonomous operations. The Asian focus is on long distance inertial navigation and control, sensor development and fusion, individual and swarm operations, collision avoidance, and hydrodynamic design and analysis. The European focus is also on long range missions, navigation and control, and power management. The major players in Asia and Europe are Australia, Japan, Singapore, India, South Korea, China, UK, Germany, France, Italy, Spain, Portugal, and the Netherlands.



Comparison of Battery Technology

Contract Performance

Workforce Development

Our workforce development activities are carried out at four levels:

- Graduate education conducted by CECD
- A Cohort Program at the undergraduate level at the College of Southern Maryland (CSM)
- Summer internships at ETC
- Support of Science, Technology, Engineering, and Mathematics (STEM) Program by ETC

The graduate education program involves offering courses at UMCP campus as well as on the web. Last year we had 22 students taking graduate classes. Of these, 18 students were working for their MS degree and 4 students working for their PhD degree.

The Cohort Program conducted with CSM is presented in a separate report.

The STEM Program included:

- Co-organizing and sponsoring the Second Youth in Technology Summit held at the College of Southern Maryland in October 2009, drawing over 500 students and teachers.
- Bringing together Education Outreach Coordinators from NSA, NASA, Northrop-Grumman, and Pax River to provide a forum for information sharing and collaboration.
- Establishing a firm partnership with Charles County Public Schools by providing technical assistance to expand and enhance STEM curriculum and learning experiences.

Our summer internship program was designed to attract diverse, highly qualified prospects to careers in defense laboratories, NSWCIH contracted with ETC to recruit, support, and nurture six interns in the summer of 2009 (ETC funded an additional intern, allowing a total of 7 students to receive a ten-week paid internship). Four of the interns were from the University of Maryland, one was from the Norfolk State University, one was from Virginia Tech, and one was from Howard University; three were women; three were from minority groups. The results were outstanding. All seven interns expressed strong interest in pursuing work in a defense lab following graduation. One intern wrote: "Your ceaseless effort created one of the best internship programs I could have hoped for and also created a once in a lifetime experience." ETC has been asked to provide ten interns to NSWCIH for the summer of 2010.

ETC is also working with NSWCIH on a new initiative to create a regional learning and education center for veterans with disabilities. NSWCIH will identify internships and jobs for the veterans, while ETC will coordinate support services, education, and training to allow the wounded warriors to transition successfully to the positions. The Navy benefits by filling its gaps in its technical workforce, while the nation gains by ensuring that its debt is paid to those who have given so much.

Business Development

CECD and ARL Collaboration

On 9 October 2009, the CECD submitted a collaborative research proposal to the Army Research Laboratory. CECD now operates under its 3rd 5-year collaborative research contract with NSWCIH. With a firm research foundation established with Indian Head, CECD envisions a similar research collaborations with other entities in Maryland. Like the Indian Head proposal , the proposal to ARL is a 5-year contract valued up to $10M. It proposes the ARL and the CECD perform fundamental research, technology transfer, graduate education, and other collaborative activities.

University research combined with innovative science, technology, and analytic capability at the ARL can provide warfighters with capabilities to succeed on the battlefield.

The ARL and CECD have an outstanding staff of scientists and engineers, experienced technicians (or students), and a variety of experimental facilities. Both are skilled at research intended to enhance lethality and survivability of weapon systems, and the individual soldier. Both can create technology for affordable and scalable weapons effects across the full spectrum of operations.

Expected to be first in the collaboration is the research of Visiting Professor Thomas Klapötke. Klapötke is also Chairman of the Inorganic Chemistry Department at Ludwig-Maximilian University in Munich, Germany. For a number of years Dr. Betsy Rice of the Weapons and Materials Research Directorate at Aberdeen has sponsored Klapötke's LMU research. A CECD goal is to accelerate the pace of Klapötke's research through mutually supportive research programs at College Park, Munich, Aberdeen, and Indian Head by reducing the time it takes to go from synthesis of a new energetic ingredient to manufacturing scale-up and use in practical propellant or explosive formulations.

Education and Administration

The CECD will tailor graduate education for the ARL. The graduate program will include four parts:

- Traditional graduate school program
- A targeted distance learning program
- A certificate program
- A continuing lecture series

The CECD will be administered at the University of Maryland, College Park, under the direction of Professor Davinder K. Anand and Visiting Professor James Short. Both have been associated with CECD since its inception in 1998. Dr. Short, Deputy Director, will have responsibility for the ARL contract.

Business Development

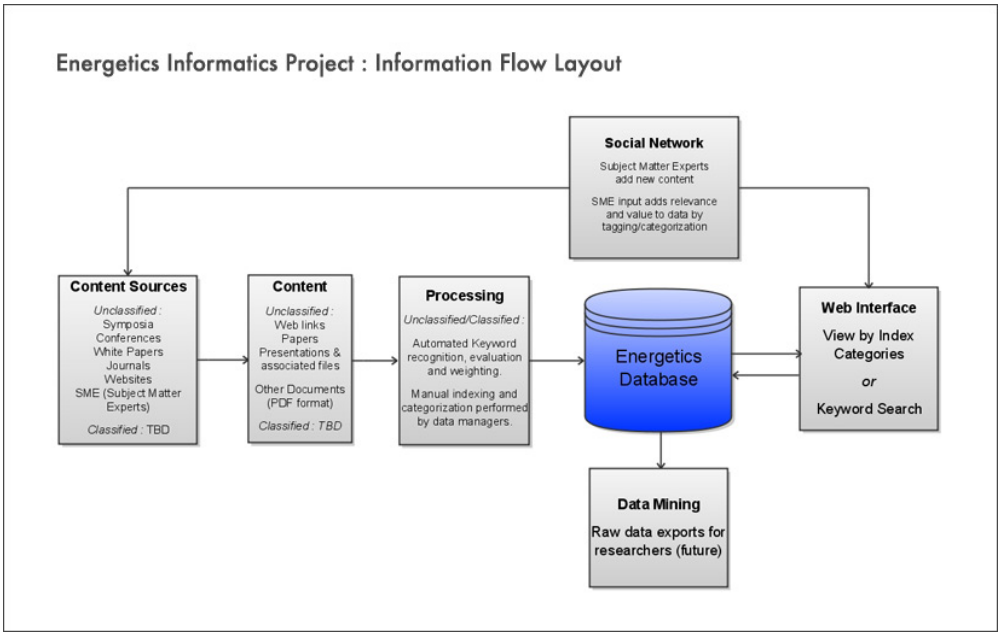
Energetic Data Warehouse

NSWCIH has a strong need to retain, organize, and deliver current and future Energetics data that is both timely and relevant to the community. These data will be taken from a variety of sources – journals, conferences, whitepapers, websites, symposia, and any other appropriate data sources. It will then be processed, tagged, indexed, and stored in a central database, utilizing current state of the art COTS technology available for automated recognition, keyword processing, and categorization of multiple data file types. Once the data is in place the system will allow for easy retrieval via web-based portal using either a category index or keyword search engine.

Procedures will be put in place to continually gather and funnel data into the system, both in an automated manner and with the assistance of a team of data managers to keep the data up-to-date and relevant. Beyond the initial system development and implementation, future work includes adding a social networking component to the system, allowing subject matter experts in the Energetics community to add, categorize, and build overall value and relevance to the existing data in the database.

Important considerations will be scalability (growth), security (user and system safeguards), timely delivery of information (bandwidth), and ease of use (must be seen as a value-added). The repository of information will have COTS front-end, ad hoc query capability to enable analyses by a subject matter expert (SME), web-portal promoting first responder and emergency planner teaming, collaboration, streaming-news analyses, and sharing of lessons learned.

The focus of this project will at first be restricted to unclassified Energetics data, but will later transition to inclusion of classified Energetics data. The scope of the project will initially be limited to NSWCIH, but upon successful design and implementation, it is anticipated that the project will expand in scale to cover all U.S. Energetics data, then to include worldwide resources. This will provide an efficient and effective resource for not only NSWCIH personnel but also the Energetics community at large, for both information retrieval and data mining usage.



Business Development

Energetics Knowledge Retention Project

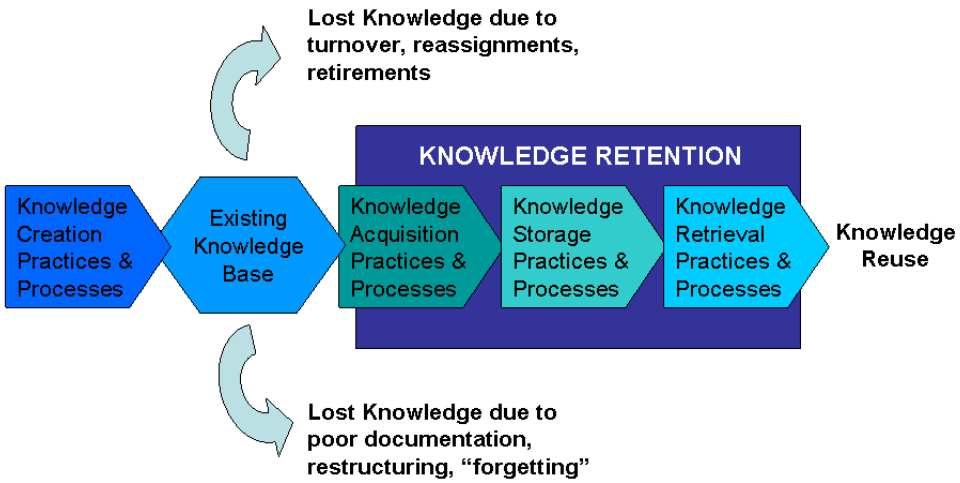
In response to the Navy's concern of the looming loss of experienced workers from the baby boom generation who will transition to retirement in the next five to ten years, we will focus on two elements of workforce development: 1. Knowledge Retention and 2. Conducting rigorous analyses of workforce trends within DON, with a specific focus on the Energetics workforce.

A useful model of the knowledge retention activities that must be reinvented, reinvigorated, and/or reimplemented is provided by David W. DeLong in his study, *Lost Knowledge: Confronting the Threat of an Aging Workforce*.

The Energetics Technology Center will design and implement a pilot program with the NSWCIH to put in place processes and programs for ensuring retention of explicit, implicit, and tacit knowledge critical to maintaining the Navy's and the Nation's Energetics capability in the future. This effort in the Energetics community could then be applied to other critical technical knowledge areas of the Navy. Building on Delong's insights, we will identify Triage Knowledge at Risk, a secure, on-line community of practice composed of practitioners in the field of Energetics, identify the "DNA" of 3 possessors of identified critical knowledge subject matter, use this information to understand the unique set of training, education, experience, and personal need for Energetics Informatics System, and finally a vehicle to retain the services of retiring personnel with critical knowledge and experience. Add to this a deliberate program of mentoring to connect this knowledge and experience base with those who will be charged with carrying on work in the critical knowledge area.

This effort will preserve critical explicit, implicit, and tacit knowledge as the baby boom generation of engineers and scientists at NSWCIH transition from the workforce. More importantly, it will identify and model critical processes to improve succession planning across the energetics enterprise and provide key insights and best practices that could be applied to other technical knowledge areas in other key Navy enterprises.

Knowledge Retention Activities



Source: David W. DeLong, Lost Knowledge: Confronting the Threat of an Aging Workforce, Oxford University Press, 2004.

Business Development

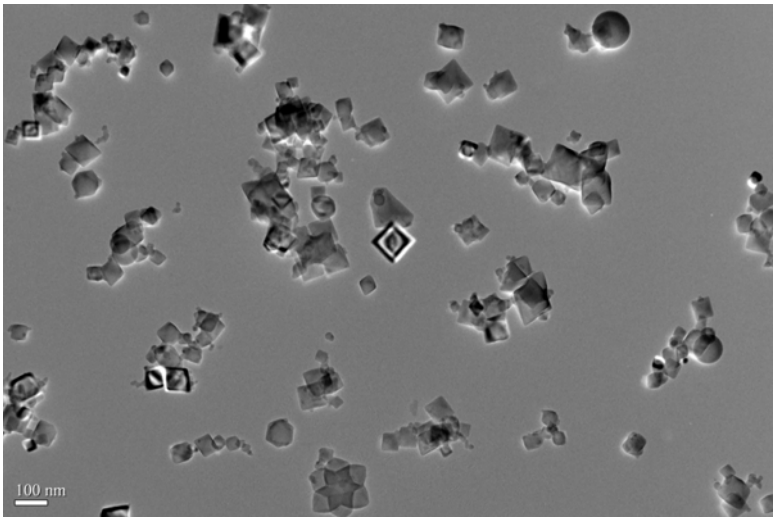
Aerosol-Based Metal Nanoparticle Preparation and Passivation

Metal-based energetics are proven to have much higher energy densities than conventional CHNO systems. However, the application of these materials is limited by the lack of availability of fine-grained reactives that are surface-passivated to maximize energy yield. In this proposal we build on our prior work on the liquid phase synthesis of nanoaluminum and self-assembly of monolayer coatings to develop an aerosol route that has the potential for scale-up. The purpose of this proposal is to build the necessary science and technology base to efficiently scale-up both the production and passivation of nanoaluminum. Preliminary studies at UMD, using trisobutylaluminum, tibAl, have demonstrated not only that we can produce nanoluminum but that the majority of particles can be grown in the gas phase as single crystals. Such material has not been seen before.

The figure below shows crystalline Al particles produced by cracking tibAl at 350ºC in the presence of H2. This method is attractive in that the process uses no solvent and produces an apparently narrow size distribution of Al particles. The particle size can be influenced by parameters such as precursor flow rate, furnace temperature, subsequent sintering of the particles, etc.

The objective of this program is to develop a medium scale aerosol production apparatus to make nanoaluminum that can be directly surface functionalized with energetic content passivating agents in a one-step continuous flow process.

Of critical importance in this program is the surface passivation of the nanocrystals. This will be accomplished by the exploration of several possible passivating agents that have stored potential energy. These will include metal coatings, fluorocarboxylic acids, and high nitrogen-based compounds. In the latter case, we will be working with Professor Thomas Klapötke, who is an expert on such compounds. He will develop the appropriate energetic ligands that can both passify the nanocrystal and provide added energy content.



TEM Images of Nanocrystals of Aluminum Produced by Aerosol Process at UMD

Business Development

Preliminary Work on Generation of Autonomy Software for Unmanned Ground Vehicles

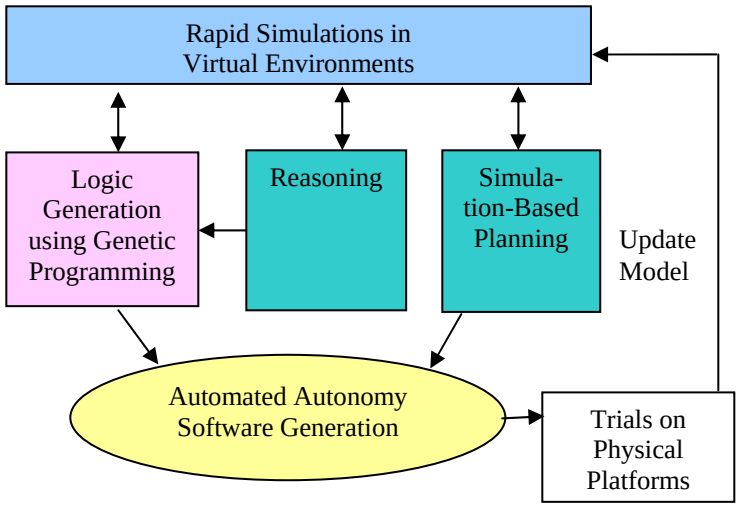
The development of autonomous unmanned ground vehicles (UGVs) requires deployment of automated planners. The process of humans conceiving logic behind the automated planner and realizing the logic into code is a time consuming task. We are exploring the development of a new approach for synthesizing planning software that operates autonomous UGVs. This new approach takes advantage of the significant progress that has been made in virtual environments and machine learning. Our idea involves having the autonomous UGV develop the required planning rules and software itself by placing the autonomous UGV in a virtual environment and then having it accomplish its mission objective in this environment through trial and error. The reasoning process will be used to manage the search space and eliminate the impossible moves. Physical tests will be used to calibrate the simulations in the virtual environment.

Based on our discussion with ONR Code 30, we have developed a proposal for advancing this field. Our objective is to develop a computational framework and software for automated generation of planning and control algorithms and software for autonomous UGVs supporting small units conducting ECO/EMO. We are interested in demonstrating the following capabilities:

- Software will be automatically generated through simulations via a combination of brute force trials and reasoning.
- Logic will be represented in a form which facilitates human verification.
- Software will be automatically updated for changes in vehicle designs.

Our technical approach will involve the following steps:

- We plan to work with ONR Code 30 to select a representative demonstration mission.
- We plan to assist ONR Code 30 in developing requirements for the vehicles for the selected mission by evaluating existing UGV platforms.
- We plan to identify and acquire terrain modeling software and vehicle dynamics modeling software.
- We plan to utilize meta-modeling techniques for developing computationally efficient simulations.
- We plan to extend the genetic programming framework by including new reasoning-based operators to speed up the logic generation process.
- We plan to study the APIs for the existing UGV controllers to identify the programming language and primitives to be used in the software.



Automated Generation of Autonomy Software

Business Development

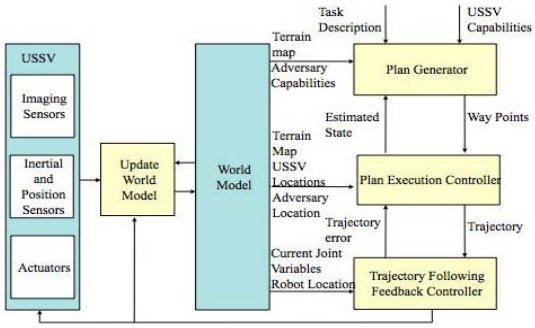
A Computational Framework for Optimal Semi-Autonomous Operation of USSV Teams

Complex naval missions often require deployment of teams of Unmanned Sea Surface Vehicles (USSVs) and human operators. These missions may possibly consist of many heterogeneous tasks. An important aspect of the mission planning is the task assignment process for the USSVs. Due to the dynamic nature of the environment, tasks may continuously vary depending upon the state of the environment. Thus, mission planning is not an off-line process but on-line in nature and needs to be performed continually throughout the mission to update the task assignments based on external events.

A key component of mission planning is to decide whether to operate a particular USSV autonomously or in a teleoperated mode. Based on the current state of the autonomous operation technology in crowded environments and severe weather conditions, the teleoperation performance is significantly better than the autonomous operation. However, teleoperation leads to additional operation cost to the mission. In uncluttered environments, the autonomous operation performance can match that achievable by teleoperation. Moreover, operating all the USSVs continually, using the teleoperation mode requires a large number of highly trained human operators, leading to a higher operation cost. On the other hand, completely autonomous operation of all USSVs may lead to poor mission performance.

Depending on the environment encountered during a mission, sections of the workspace may be ideal for autonomous operation and portions of it may require teleoperating the USSVs. Hence, in the near foreseeable future, USSV team operations are expected to be semi-autonomous in nature. In order to achieve optimal semi-autonomous operation, several important factors need to be considered. The optimal number of human operators needed for a mission specific value function is an important challenge. The value function for a mission will need to account for both the mission cost and the mission performance. Utilizing a small number of operators may lead to lower mission cost but also poor mission performance implying poor mission value. On the other hand, using too many operators may lead to a higher cost and provide incremental improvement in the mission performance, thereby again resulting in a low mission value.

Hence, addressing the aforementioned questions will require task performance models for both teleoperation as well as autonomous operation. High fidelity simulations will be utilized for characterizing the performance of teleoperation and autonomous operation modalities. The figure provides a detailed description of our simulator for simulating the autonomous mode.



Framework for Autonomous Operations

Additionally, a control policy will be developed for the USSVs and the operators so as to optimize a given value function over the duration over the mission. The value function is mission dependent but broadly reflects the tradeoff between the performance metric and cost of employing human operators in teleoperating the USSVs. The performance of the semi-autonomous system depends on a number of criteria such as vehicle team structure (size and heterogeneity), role allocation/level of autonomy (level of automation, neglect times), vehicle task allocation (level of coordination), and the nature of operation (interaction times, situational awareness, switching times, and attention allocation strategies). Thus, a fine-grained simulation model will be used to evaluate a scoring function or the cost-to-go function to iteratively change the control policy. In order to implement the control policy in real time, a database containing the scoring functions for various policies will be utilized.

Business Development

The Wounded Warrior Project at Indian Head

The projected loss of experienced workers from the baby boom generation who will transition to retirement in the next five to ten years is a significant problem for the Navy and DoD. This is aggravated by the shortage of scientists and engineers being produced by the universities that are capable of doing classified work. A possible partial solution is *to more aggressively look at the pool of service veterans, especially those wounded warriors, capable of filling critical science, engineering, and technician positions as a critical part of an overarching human capital strategy for the DON* .

The attributes of veterans which make them highly desirable to the defense labs are:

- They possess appropriate clearances
- They are not averse to the type of work
- They often have hands-on experience in areas of electronics, engineering, etc.
- They have technical training
- They have experience as the end user of energetics materials, weapon systems, and other military systems
- There appears to be a groundswell of support building towards the idea that the federal government should become less dependent on contractors and thus will need more federal workers at a time when veterans are a declining part of the federal workforce.

NSWCIH Workforce

In 2009, ETC began working with NSWCIH on a new initiative to create a regional learning and education center for veterans with disabilities. Indian Head will identify internships and jobs for the veterans, while ETC will coordinate support services, education, and training to allow the wounded warriors to transition successfully to the positions. This program should begin in 2010.

The initial goals of this program will be:

- Place veterans with disabilities in meaningful, fulfilling work that challenges them and uses their skills and knowledge to the fullest extent possible.
- Create a vibrant center that directly supports veterans with disabilities by removing obstacles to workforce re-entry and providing training and other support services through connections and partnerships with federal, state, and local agencies.
- Build partnerships in the community to create pathways for permanent job placement for veterans with disabilities.
- Become part of a national network for veterans job preparation and re-entry into the workforce.

Expectations for veterans hired through the program should be established early on and they should address the employment issues experienced by the federal installations (e.g., the need for qualified project managers, trained technicians, and employees with an understanding of the federal acquisitions process) and should be focused on the areas, where the installation has need for deep knowledge.

Close relationships should be developed with the colleges and universities the veterans are most likely to attend. Efforts should be made to ensure that those veterans who pursue higher education are part of a learning community. Additionally, the engagement of women veterans in non-traditional careers is an area requiring further consideration.

Photography by Thai Nguyen

Business Development

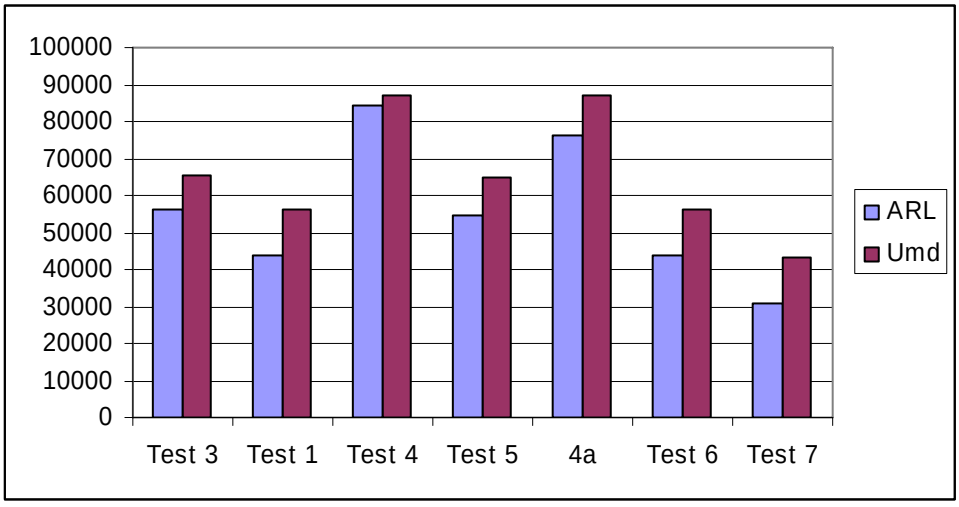
Small Scale Model Testing in Investigations of Energetic Materials in the Dynamic Effects Laboratory

Full scale explosive testing is very expensive and the violence associated with it makes visualization and instrumentation quite difficult. Very small scale testing has been shown to be able to predict quite accurately, in some situations, the results of full scale testing. Small scale testing is cost efficient and more easily observed and more easily instrumented. Over the past 10 years small scale testing has been used to successfully study the response of structures and soils to explosive detonation. We have used small scale testing to predict full scale results in underwater cratering and channeling, the movement of obstacles underwater, the loading (both pressures and impulse) on military vehicles, the positive effects of bottom shaping for military vehicles, and the positive effects of mitigation techniques on the loading on military vehicles. In all cases, the small scale testing results have been supplied to code developers within the DOD to develop their computer simulations and in all cases have been used to develop scaling laws that would be applicable to full scale situations.

Impulse Measurements

More recently, the DOD has become very interested in knowing more about the loading on vehicles which are subjected to the detonation of buried mines beneath them. The figure below shows a comparison of the small scale results extrapolated to 5 to 10 pounds of TNT with various stand-off distances and depths of burial to the response of target plates weighing up to approximately 30,000 pounds. In these tests the full charge size was either 5 pounds of TNT or 10 pounds of TNT and the largest charge size used in the small scale test was 3.3 gm. The stand-off distances of the target plate ranged from 0 (plate on the ground) to 16 inches (for 10 lb TNT) and the depth of burial of the full size charges ranged from 4 inches to 12 inches.

It is apparent that small scale testing can be used quite effectively to not only provide valuable data to assist in the development of DOD computer codes but also if the tests are carefully conducted to predict the results for full-sized explosive testing.



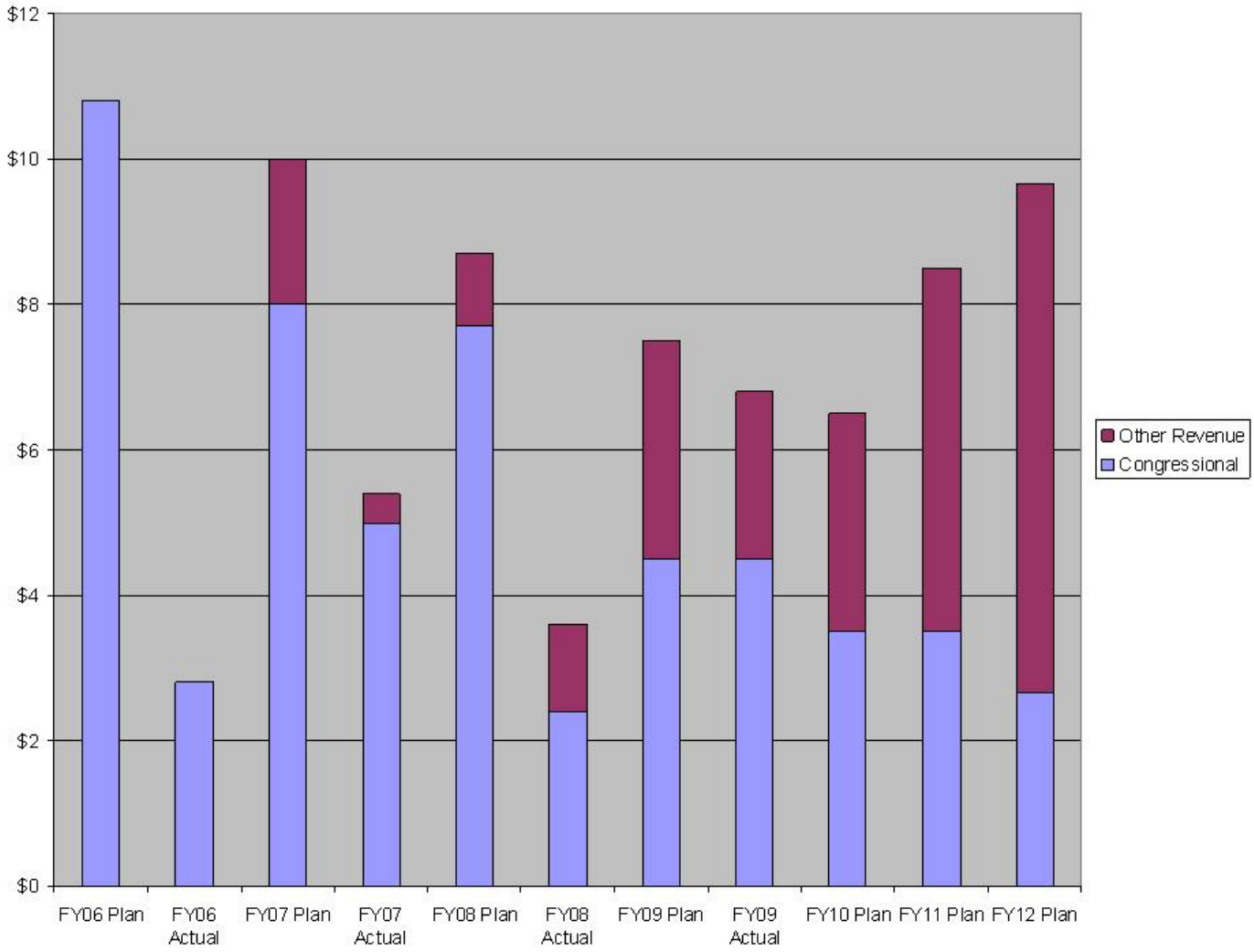
Comparison of Small Scale Predictions with Full Scale Results – Impulse.

Revenues

Our main goal for technical and workforce development-related efforts is to execute a program that enhances our pre-eminence in energetics and related technologies. Specific objectives are: 1. To grow and expand core CECD research thrusts; 2. To initiate ETC technology development projects that result in additional revenue coming into the ETC; and 3. To build a long-term technical foundation that is recognized as an important part of the national security infrastructure.

CECD/ETC and NSWCIH leadership continue to have strategic planning discussions to ascertain how best to utilize funding for the long-term benefit of the Energetics community, and the leadership role envisioned for NSWCIH and its CECD/ETC partner. These discussions will continue to shape our business plans in the future.

In 2009, we continued to build a strong revenues stream through projects funded by NSWCIH, ONR, and NSWCDL.



CECD/ETC Revenues

The Indian Head Science and Technology Park

The Indian Head Science and Technology Park* will be built on a 277 acre site in Bryans Road, Maryland. This employment center is a public/private partnership between Charles County Government and a joint venture formed by Facchina Companies and Corporate Office Properties Trust.

The vision is to create a campus of office buildings, research facilities, and manufacturing facilities that will become the anchor of an "Energetics Corridor" along Indian Head Highway. The site of the park and all the buildings will be designed, built, and operated in an environmentally responsible manner. The Park stretches from Indian Head Highway/Route 210, just south of the intersection with route 227 in Bryans Road to Route 224 where it intersects with Bumpy Oak Road just south of the Maryland Airport. This location compliments and supports the Bryans Road sub-area plan and benefits from proximity to the upgraded Maryland Airport.

The current schedule is for build-out in about 15 years.

The County is responsible for bringing public infrastructure to the site (water and sewer). All construction, all infrastructure within the park (roads, telecommunications, water, and sewer), and all site work, buildings, landscaping, parking areas, etc., will be paid for by private dollars.

The Tech Park will have up to 1.3 million square feet of offices, research, and employment space on 277 acres, creating about 1500 new, high paying jobs in Charles County. Approximately 50 acres have been set aside for technology-based manufacturing.

For additional information, please contact:

Economic Development & Tourism Department
103 Centennial Street, Suite C
La Plata, MD 20646
Tel.: 301-885-1340
keethm@charlescounty.org

Rendering of Future Indian Head Science and Technology Park (Courtesy of Facchina Corporation, La Plata, Maryland)

*Excerpted from "Indian Head Science and Technology Park Global Energetic and Applied Research Center: Frequently Asked Questions"

Energetics Research, Education, and National Security

The national security benefits of the Southern Maryland Initiative fall into a variety of categories. The Initiative enables the country to maintain an ordnance technology edge; heighten national security; improve warfighting effectiveness; produce commercial applications; enhance our national position for technological international competitiveness; provide a pool of talent for industry; and create a knowledge feed stream for a broad range of related high technology areas.

The advancements in the fundamental sciences of explosives, propellants, and electronics will naturally provide spin-off applications that will become benign civilian products in the international marketplace. Concurrently, the initiative will provide a pool of talent for industry and create a knowledge feed stream for a broad range of related high technology areas. Both of these things are inherent elements of improved national security. As the ordnance industry ages, it, too, will need to rejuvenate its workforce with appropriate talent. The initiative will provide a comprehensive function to create the solution to this need. Not all individuals trained and experienced through the Initiative are expected to remain in Southern Maryland. It is a natural event in our society that individuals seek to better themselves, and the Center will provide a ready pool of talent to be recruited at the time that industry needs them. This, combined with the continual feed stream of ordnance knowledge produced in the Center, will strengthen and enhance our national security.

The CECD/ETC Enterprise clearly provides significant and substantial benefits for our national security.

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