The University of Maryland and
the Faculty and Staff of
the Center for Energetic Concepts Development

Welcome You to the

Celebration of the Center's Tenth Anniversary

Inn and Conference Center
Adelphi, Maryland

May 28, 2009

AGENDA

10:30 a.m.	Refreshments
10:45 a.m.	Formal Remarks
	Professor Davinder K. Anand *Chancellor William E. Kirwan* *Senator Thomas (Mac) Middleton* *Mrs. Mary Lacey* *Mr. Steve Mitchell*
	Current Research
	Professor Don L. DeVoe *Professor Satyandra K. Gupta* *Mr. Darrin Z. Krivitsky* *Professor James Short*
12:00 p.m.	Group Photo
12:15 p.m.	Lunch
	Delegate John L. Bohanan *Professor Melvin Bernstein* *Professor Millard Firebaugh* *Mr. Dick Myers*
1:25 p.m.	Concluding Remarks

CECD─THE FIRST DECADE

On December 14, 1998, the University of Maryland and the Indian Head Division of the Naval Surface Warfare Center signed a cooperative agreement to create the Center for Energetic Concepts Development (CECD), formalizing their alliance and giving roots to seed ideas that had been generated long before. Instrumental in creating CECD were: Dr. Davinder K Anand, Dr. Ron Armstrong, Dr. William Fourney, Ms. Evan Crieri, Dr. Chester Clark, Dr. James Short, Mr. Robert Kavetsky, Ms. Lisa Davie, Mr. Mark Eagles, and Ms. Penny Kennedy. Also present at the ribbon cutting that December day were UMD and NWSC officials: Dr. D. C. Mote, Jr., Dr. William Destler, Mr. Roger Smith, Dr. Ira Blatstein, and CAPT John Walsh.

The original agreement envisaged research, graduate education, technology transfer and exchange of technical personnel. The agreement also included a significant cost share from the University of Maryland.

On December 14, 2008, CECD turned 10 and celebrates its achievements in advancing the field of energetics and training the next generation of energetics experts. Some important activities over the ten-year period include the following:

- CECD/NSWC IH Collaboration has led to the signing of two five-year cooperative agreements for a total of $8.9M in CECD research covering 130 technical projects.

- Fifty-two scientists and engineers from NSWC and 31 faculty and researchers from UMD worked on those projects.

- CECD established a graduate program to train the next generation of high technology experts in the field of energetics. Some of the graduate courses have been taught by prominent NSWC IH scientists.

- From 2003-2008, University of Maryland awarded 26 MS degrees and 11 PhD degrees supported by CECD funds and free tuition provided by The University of Maryland.

- In 2004, CECD formalized The Southern Maryland Development Initiative for Energetic Capability and signed an MOU with NSWC IH and CSM.

- In 2006, CECD played a key role in establishing the Energetics Technology Center (ETC), a private, non profit enterprise, with 501(c)(3) status, in La Plata, Maryland.

The achievements over the last ten years clearly show that the CECD/NSWCIH relationship is a very successful collaboration. Today, CECD continues to work with NSWC IH and ETC to conduct a wide range of science and technology activities to advance the development of energetic systems and to recapitalize the nation's energetics workforce.

CECD ACTIVITIES

The CECD has a history of research related to energetic materials development for explosives and missile propellants. The importance of lower cost, higher performance, and insensitivity are understood within the CECD. Also understood is the value of tailoring energy release rates, performance, and vulnerability characteristics of gun, missile, and warhead munitions.

Research in energetics today comprises not only the traditional work in formulations, but manufacturing and packaging of the energetic materials in weapons as well. This includes the entire gamut of engineering, design, test and evaluation, prototyping, and in some cases, manufacture of the product itself. Faculty affiliated with the CECD has been engaged in a number of these activities. These include:

- Laser Induced Breakdown Spectroscopy
- Functionally Graded Materials
- MEMS
- Sensor Technology
- Design Knowledge Archiving and Retrieval
- Data Mining
- Port Safety
- Twin Screw Mixing
- Training in Virtual Environments

In addition, CECD has been engaged in a number of specialized studies such as undersea warheads and weapons design, life cycle engineering, risk reduction of POD fires, and the effects of mid-frequency sonar on fishes.

CECD also supports a graduate program specifically designed for NSWCIH. This graduate program consists of four parts, viz.

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

Now with a solid foundation and history, the CECD seeks to serve a wider array of DoD laboratories interested in the advancement of energetics science.

Ultra Sensitive Detection of Low-Vapor Pressure Compounds by Ion-Nucleation Detection (INDe)

Professor Michael Zachariah

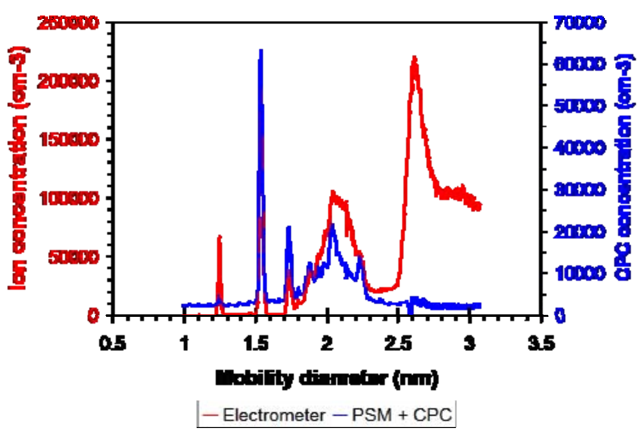
We are working to develop an ultra-sensitive method (sub-PPT) for nearly single-molecule detection of explosives and other low-vapor pressure compounds, that will improve sensitivity by several orders of magnitude over traditional ion-counting. The basic concept relies on a new approach to measure the presence of a molecule. Unlike traditional mass-spectrometry or optical methods that rely on a direct transduction of an electrical signal coming from the analyte (which greatly limits sensitivity), *our method relies on the very rapid gas-to-liquid transition an ion can induce in a super saturated environment to create a micron sized droplet with an ion as its seed.* Our approach has the potential to measure molecules one at a time by using each molecule as the site for growth of a droplet. The resulting droplet, which contains one analyte species, can then be detected with a commercial particle counting apparatus or any other light scattering approach remotely located. We call this approach Ion Nucleation Detection (INDe). By incorporating this approach into traditional ion-mobility spectrometry (IMS), we expect to improve the sensitivity of the IMS by replacing the widely used Faraday plate sensor with a particle size magnifier (PSM) and a condensation particle counter (CPC).

A system including an atmospheric pressure ion-mobility spectrometer coupled to an electrospray source was developed to generate a steady source of ions of defined size. A first and ultimately second generation ion-magnifier was designed and constructed. The performance of a particle size magnifier (PSM) was tested using electro-sprayed tetra-alkyl ammonium ions and clusters thereof as nanoparticle standards, with diameters in the sub 2 nm range. Subsequent ion-mobility separation generates a continuous source of size selected ions.

The ions were detected by both a Faraday cup electrometer, and the PSM. Inside the PSM, the ion flow was turbulently mixed with a jet of a hot nitrogen flow, saturated with dibutyl phthalate (DBP). This allowed for heterogeneous nucleation of DBP onto the nanoparticles, which grew into droplets.

The performance of the PSM for tetraheptyl ammonium bromide (THAB) is shown in the figure below. The red curve shows the number concentrations of THAB as measured by the electrometer and the blue curve shows the PSM as a function of mobility diameter.

The INDe system is able to track the ion counts with the same precision as the electrometer implying that the concept has been demonstrated. With our current configuration, we find we lose sensitivity to detection to ~1.24 nm, while our target molecule, TNT is ~ 0.75 nm. To decrease the lower size limit and increase concentration sensitivity will require a redesign of the PSM. Currently, a new PSM is being tested that should improve the turbulent mixing rate and thus the separation between homogeneous and heterogeneous nucleation zones, such that we can operate at higher supersaturation ratios. We plan to investigate other working fluids besides DBP, which is currently used.



CECD

Health Monitoring of Energetics

Dr. Hugh Bruck

Sensing of Strain in Energetics

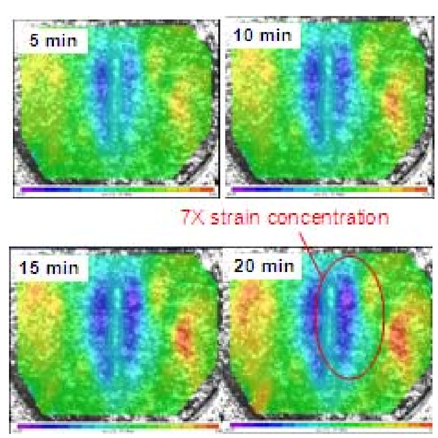
We have developed a technique for sensing strain in energetics, using Digital Image Correlation (DIC) to track a speckle pattern with a video camera in order to obtain the 2-D deformation fields that characterize strain such as those that develop during curing/aging of a polymer. In the DIC technique, a deformed image is correlated with a reference image to determine the displacement fields associated with the change in position of a subset of the image, typically an area of 100 pixels by 100 pixels. Numerous subsets are correlated over the entire area of interest in the image in order to obtain a displacement field. 2-D splines are then fit to the displacement fields in order to obtain strain fields, typically using an area of 51 data points around each displacement location.

Characterization of Simulants

Sample tested was a highly filled propellant stimulant known as "Polycrete", which had approximately 88 wt. % solids loading, similar to a propellant. The polymeric binder for Polycrete is a fast-curing, two-part elastomer, similar in mechanical behavior to a propellant binder, and consisted of a mixture of filler sizes ranging uniformly from 50 microns to approximately 2 mm. For the speckling pattern, a combination of white spray paint, solid particles, and aluminum specks were used. From the strain results obtained from DIC over the first hour for this sample, it became apparent that there were trends which were not physically consistent with the curing behavior. For example, the average shear strain was significantly higher than the normal strains. However, almost all of the strains were nearly negligible (less than 100 microstrain) compared to the base polymer. This indicates that there is significant constraint from the filler phase on the polymer curing, and subsequently very high stress development that can lead to faster deterioration and defect development due to aging.

Integrated Sensors

Hard electronic components for sensors have also been integrated into polymers to understand the effect of the sensor on the evolution of strain during curing and during operation of the electronic component. The electronic component was placed in the polymer prior to solidification. The evolution of the strain fields near the electronic component is shown below using DIC contour plots of transverse strain. These results can be used to resolve the strain concentration near the embedded component due to its constraint on the deformation of the polymer, which is about 7X that of the matrix and can lead to premature debonding. Thus, it may be necessary to encapsulate the component in a material, such as a softer polymer, that may reduce the strain concentration due to the constraint of the electronic component. It has also been possible to measure the effects of operating the electronic component and model it with thermomechanical Finite Element Analysis (FEA). Results have indicated that there are very rapid increases in temperature and strain within the polymer adjacent to the electronic component. The axial strains appear to be far less significant than the transverse, which indicates that the component will debond from the polymer and fail to accurately monitor the health of the energetic if the interfacial strength is not adequate. Thus, this technique will serve as a tool for developing appropriate embedded sensor technology.



Virtual Training Studio

Professor Satyandra K. Gupta

We have developed a personal virtual environment (PVE)-based virtual assembly system called Virtual Training Studio (VTS). The current system focuses mainly on the cognitive aspects (e.g., ability to recognize the correct part, to correctly orient the part in space, remembering the right assembly sequence). The PVE consists of a head mounted stereo display with head tracking and a wand for user interaction. This PVE gives the user a complete 3D immersive experience during virtual assembly. The VTS aims to improve existing training methods through the use of a virtual environment-based multi-media training infrastructure that allows users to learn using different modes of instruction presentation while focusing mainly on cognitive aspects of training.

The Virtual Training Studio is a suite of tools, which currently consists of the Virtual Author, Virtual Workspace, and Virtual Mentor. With Virtual Training Studio, training instructors have the option of employing multi-media options such as 3D animations, videos, text, audio, and interactive simulations to create multi-media training instructions. The virtual environment enables trainees to practice training instructions, using interactive simulation and hence reduces the need for practicing with physical components.

Training

Trainers and trainees interact with the system, using a Head-Mounted Display (HMD) and a wireless wand. Four optical trackers (infrared cameras) and two gyroscopes are used to track the position and orientation of the user's head and the wand. The wand consists of an off-the-shelf wireless presenter, an infrared LED, and a wireless gyroscope. Inside the virtual reality environment, the user can manipulate the CAD models and the buttons using a virtual laser pointer, which is controlled by the wireless wand. A wireless gyroscope and another infrared LED are mounted on the HMD. The cameras track the two LEDs to determine position. Trainees interact with a component of the VTS called Virtual Workspace. The goal of this component of the VTS is to provide the basic infrastructure for multimodal training. Virtual Workspace offers three primary modes of training: (1) 3D Animation Mode which allows users to view the entire assembly via animations, (2) Interactive Simulation Mode, which is a fully user driven mode that allows users to manually perform the assembly tasks, and (3) Video Mode, which allows users to view the entire assembly via video clips.

The Virtual Mentor module simulates the classical master-apprentice training model by monitoring the actions of the user in the Virtual Workspace and assisting the user at appropriate times to enhance the trainee's understanding of the assembly/disassembly process. The Virtual Author enables the instructor to quickly create multi-media training instructions for use in the Virtual Workspace without writing any code.

Performance

System performance was assessed using thirty subjects and two tutorials. The first study involved a rocket motor and 94 percent steps were performed correctly by the users during the physical demonstration after completing the training. In the second study, using a model airplane engine, 97 percent steps were performed correctly.

Shock Wave and Detonics Research

Dr. Jerry Forbes

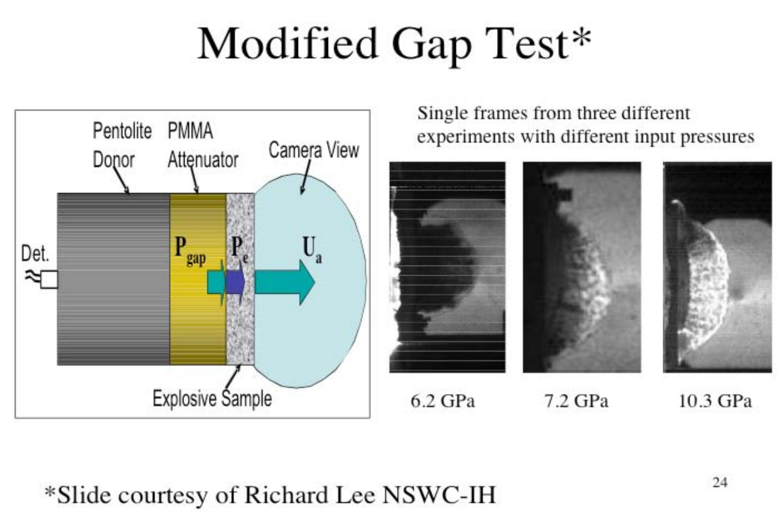
This is a multi-task program in support of research activities in energetics at NSWCIH. The main research focus is to explore with NSWCIH scientists how electromagnetic fields can change sensitivity and performance of explosives.

The modified gap shock sensitivity test is being used to see if electric fields change the sensitivity of HMX compositions with concentrations by mass 92% and 88%. This task is in collaboration with Dr. Richard Lee at NSWCIH. One composition was cast cured and the other pressed. The surface velocities of shocked explosive samples (see figure) were measured with and without electric fields, using a high-speed digital-camera.

Velocity versus input pressure plots give shock sensitivity thresholds for first reaction, deflagration, and detonation. The data showed higher levels of reaction when a modest field was applied for the cast cured explosive. The data for the pressed explosive displayed too much variance with and without fields applied to determine any effect.

A number of specialized education/training exercises in shock wave and detonation physics were conducted. These were:

- A series of lectures on shock wave and detonation physics was provided for summer interns and Post-docs at NSWCIH. A 6-week course on shock wave thermodynamics of condensed matter was also provided to NSWCIH research staff.
- A three-day workshop was given at ARL on shockwave and detonation physics. The workshop was recognized by ARL via a letter of commendation for its technical breadth and depth.
- Two lectures were given on "Detonation Physics Grand Challenges" at the Research and Engineering Education Facility (REEF) campus of University of Florida. This campus supports Eglin Air Force Base in energetics research activities.



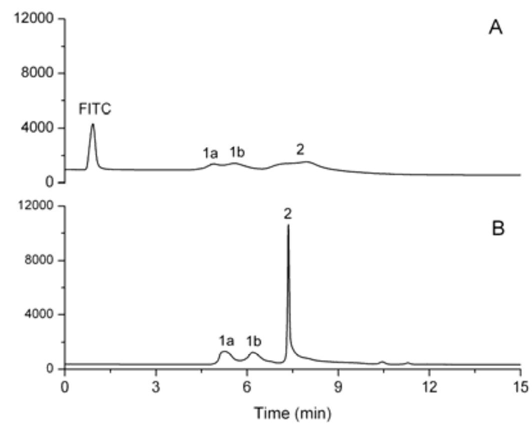
Laser Desorption/Ionization Mass Spectrometry for Trace Explosives Detection

Professor Don DeVoe

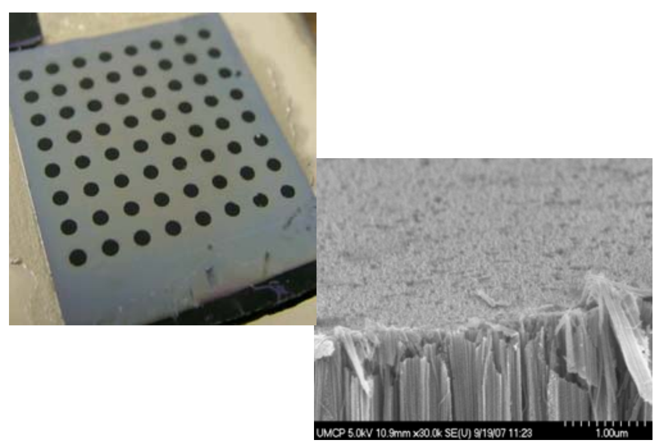
A novel matrix-free laser desorption/ionization mass spectrometry (LDI-MS) platform has been developed based on nanofilament silicon (nSi) substrates. The technology overcomes key limitations of existing LDI-MS systems for trace explosives detection by enabling increased surface/analyte binding, improved contaminant removal, enhanced ionization at low laser powers for higher sensitivity detection, and on-target sample concentration. While optimization of the technology is ongoing, proof-of-concept has been demonstrated with detection of nitroaromatic and nitramine-based energetic materials well below the current limit of other emerging platforms such as desorption/ionization (DESI).

While our initial efforts have primarily been focused on demonstrating the nanofilament silicon fabrication process and leveraging a proprietary electrowetting methodology to achieve efficient adsorption of purified sample on the nSi surfaces, commercial application of the technology will require compatibility with "dirty" samples acquired from a variety of sources. Preparing the sample for nSi-MS demands the removal of particulates and fractionation to isolate the target molecules to the greatest degree possible without sacrificing detection sensitivity. To this end, we are developing a disposable microfluidic sample collection cartridge, combining multi-stage filtration of particulate matter, solid-phase extraction of low molecular weight species on the basis of both differential hydrophobicity and ion exchange properties, buffer exchange to bring the sample to the optimal pH for nSi-MS sensitivity optimization, and final deposition onto an integrated nSi chip within the microfluidic system. The cartridge will only require a user to add a sample volume in dry or solvated form to a loading reservoir, followed by manual pressure actuation of on-chip buffers and solvents to drive the sample preparation and deposition process. The result will be a sample loaded onto the nSi substrate ready for

LDI-MS analysis. The combination of the nanofilament silicon and microfluidic sample preparation is expected to position the resulting technology at the forefront of presently-available commercial trace explosives detection platforms.



Demonstration of sample cleanup and concentration using on-chip monolithic solid phase extraction column



Nanofilament silicon array chip (left) and electron micrograph of the nanofilament surface (right)

Mild Traumatic Brain Injury

Professor Bala Balachandran, Professor Davinder K. Anand, Professor James Short, Professor William Fourney, Professor Gary Fiskum, Professor Rao Gullapalli, Dr. Thomas McGrath, Mr. Kenneth Kiddy

The Mild Traumatic Brain Injury (*MTBI*) Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitation Medicine has defined *MTBI* as traumatically induced physiological disruption of brain function manifested by at least one of the following: i) any period of loss of consciousness; ii) any loss of memory for events immediately before or after the accident; and iii) any alteration in mental state at the time of the accident.

We have formed a group consisting of CECD and ETC engineers with medical scientists from the University of Maryland School of Medicine to model situations where explosives are thought to cause MTBI and understand the medical consequences. For modeling and simulation purposes, we plan to use the DYSMAS code (DYnamic System Mechanics Advanced Simulation), a finite element structural code coupled to Eulerian and Lagrangian hydrodynamic algorithms, to simulate the events. The goal is to use the numerical simulations to design protective equipment to prevent or delay onset of MTBI.

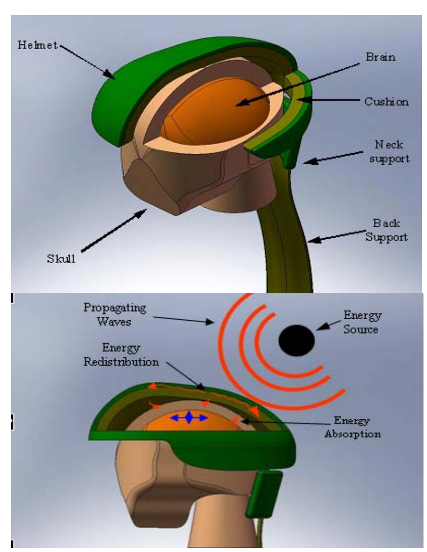
State of the Art

Pellman *et al*. (2006) have investigated the performance of National Football League helmets under impact. It was shown that a new design improved the absorption of impact energy during conditions typical of impacts during a football game. Accelerometers are now being used to measure real time impacts during college football games. The sensor data may help understand when concussions occur.

Ongoing Studies

Our group is using a systems approach involving medical scientists and engineers to study an array of explosively induced causes of MTBI. Issues, which we are considering, include the following:

- Standard criteria used for establishing injury criteria consider only the motion of the center of mass of the head. Injury criteria are formulated as empirical relationships that depend on the acceleration of the head. The empirical approaches suffer from the shortcoming that the relative motion of the brain relative to the skull is not explicitly taken into account. Furthermore, despite the brain being a highly deformable entity, brain deformations are not taken into account in the models.
- While finite element models point to pressure and shear strain as failure criteria and also show that the use of helmets reduces the pressure and shear stress on the skull elements, they offer little insight into the actual mechanism of energy transfer to the brain as a result of impacts on the skull.
- Recent experimental work at Washington University in St Louis based on MRI methods has provided in vivo strain measurements on the brain. These results point to the importance of developing injury criteria that are based on brain deformation. Helmets could be designed as energy absorbing and redistributing mechanisms in the energy path to the brain (see figure).
- Perhaps a redesign of the cushion padding inside a military helmet can enhance blast protection and reduce the translational acceleration levels experienced by the brain (see figure).



PRESENTERS OF RESEARCH PROJECTS AND THEIR SHORT BIOS

Don L. DeVoe
Professor, Department of Mechanical Engineering
University of Maryland, College Park

Don L. DeVoe is a Professor of Mechanical Engineering at the University of Maryland, College Park, with affiliate appointments in the Department of Bioengineering and Department of Chemical and Biomolecular Engineering. He received his B.S. and M.S. degrees in Mechanical Engineering from the University of Maryland, College Park, and his Ph.D. degree from the University of California, Berkeley in 1997. His research interests are focused on piezoelectric microsystems and microfluidic technologies for biomolecular analysis, with an emphasis on analytical techniques for high-throughput biosensing from highly limited specimens. Dr. DeVoe serves as a Subject Editor for the *Journal of Microelectromechanical Systems*, and is a founding Director of the Center for Micro Engineering at the University of Maryland. He is a recipient of the Presidential Early Career Award for Scientists and Engineers from the National Science Foundation for advances in microsystems technology, and has authored over sixty journal articles, five book chapters, and six U.S. patents in this area.

Satyandra K. Gupta
Professor, Department of Mechanical Engineering
University of Maryland, College Park

Satyandra K. Gupta is Professor of Mechanical Engineering and Systems Research at the University of Maryland. He received a Bachelor of Engineering (B.E.) degree in Mechanical Engineering from the University of Roorkee (presently known as the Indian Institute of Technology, Roorkee) in 1988. He received a Master of Technology (M. Tech.) in Production Engineering from the Indian Institute of Technology, Delhi in 1989. He received a Ph.D. in Mechanical Engineering from the University of Maryland at College Park in 1994. He has authored or co-authored more than one hundred and ninety articles in journals, conference proceedings, and book chapters. Dr. Gupta is a fellow of the American Society of Mechanical Engineers (ASME) and a senior member of the Society of Manufacturing Engineers (SME). Dr. Gupta has won many honors and awards for his research contributions to computer-aided design, manufacturing automation, and robotics areas. He received three Best Paper Awards from ASME. He received the Young Investigator Award from the Office of Naval Research in 2000, the Robert W. Galvin Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers in 2001, a CAREER Award from the National Science Foundation in 2001, and the Presidential Early Career Award for Scientists and Engineers (PECASE) in 2001.

Darrin Z. Krivitsky
Head, Applied Technology Directorate
Indian Head Division, Naval Surface Warfare Center

Darrin Z. Krivitsky is the Head of Applied Technology Directorate, Indian Head Division Naval Surface Warfare Center. Mr. Krivitsky provides technical and safety leadership and oversight for the Applied Technology Directorate, which includes development, scale-up, full scale demonstration, destructive and non-destructive testing of energetic formulations for chemicals, munitions, explosives, propellants, pyrotechnics and energetic ingredients. Mr. Krivitsky directs a workforce of over 400 employees at the Indian Head main site and at the Indian Head Division Detachment in Yorktown, Virginia. Mr. Krivitsky obtained his Bachelor of Science degree in Mechanical Engineering from the University of Maryland, College Park in 1990 through a Cooperative Education (COOP) program with the Naval Ordnance Station. Prior to his current position, Mr. Krivitsky held various management positions in the Applied Technology Directorate, including Director of the CAD/PAD Manufacturing Division, Director of the Cast Products Technology Division, and Head of the Ordnance Department.

James Short
Visiting Professor and CECD Deputy Director
Center for Energetic Concepts Development
University of Maryland, College Park

James Short has been the Deputy Director of the Center for Energetic Concepts Development since its inception in 1998. He joined the University of Maryland as the full time Deputy in September 2007. His was an unpaid position while employed by the Department of Defense. In January 2009, he was selected by Taylor & Francis Journals to be Executive Editor of the *Journal of Energetic Materials*. For three years he was the Director of Defense Laboratory Programs in the Office of the Secretary of Defense. The previous 27 years he was employed by the Naval Surface Warfare Center, first the Dahlgren Division; later the Indian Head Division. For 20 of those years he was the Chairman of the International Detonation Symposium, the primary forum for discussion of solid and liquid energetic materials research. He has a PhD in mechanical engineering from the University of California at Berkeley. His research was in combustion and detonation physics. His undergraduate degrees are from Syracuse University--an AB in mathematics and a BS in aerospace engineering.