U.S. SPACE & MISSILE DEFENSE TECHNICAL CENTER
HUNTSVILLE, Alabama

Title: Nanowire Technology for Missile Defense
The University of Louisville (UofL) performs extensive research in the field of nanotechnology. Their particular strength is in the study of nanowires—materials on the order of 1 to 100 nanometers in diameter, and microns to millimeters in length. Nanowire technology offers a combination of length and narrowness that can enable the development of new devices and materials for solution to critical missile defense needs. Varying the diameter provides a way to tune in different material properties, while the length simplifies manipulation and attachment. Nanowires are excellent materials for directed self-assembly into heterojunctions and nanowire networks. Blending of nanowires with polymers can produce light weight, high strength composites with embedded smart functions. Nanomaterials, especially nanowires, offer the promise of new materials and devices that realize the lowest cost of assembly, the greatest packaging density, and the highest degree of integration and functionality. Our studies continue to demonstrate that we can (1) identify, model and design enhanced physical properties of these materials; (2) design growth processes for synthesizing selected materials in nanowire form; (3) synthesize nanowire materials in the laboratory; (4) measure the actual physical properties of individual nanowires; (5) design, assemble and test novel and improved electronic, optoelectronic and electromechanical devices that derive their unique properties from the incorporation of nanowires; (6) conduct system analyses and identification of missile defense applications. UofL have assembled a single, vertically-integrated research and development team that focuses on application-specific exploitation of fundamental discoveries in nanowires and the expedited transition of these discoveries into those missile defense systems and defense technologies of central importance to DoD.

Title: Active Hyper Spectral Sensor Research
The sensitivity and range of laser radar (lidar) systems can be significantly extended through implementation of the STIRAP (Stimulated Inverse Raman Process) multicolor excitation mechanism. While requiring higher probe laser power, spatial and temporal coherence, the use of STIRAP in lidar systems can dramatically reduce the "clutter" attributable to scattering by the non-resonant but vastly more concentrated non-target molecules, dust and aerosol particles while increasing the effectiveness of excitation of the target molecules to nearly 100%. The performance of systems based on this approach have been studied through detailed analytic and numerical estimates of the signal to noise ratio attainable using this technique for detection of iodine in the presence of the more abundant stable iodine isotopes, a particularly demanding problem given the overlapping spectral features of these isotopes. The special tunable, high peak power laser and optical systems needed to test the effectiveness of this technique under representative conditions in the laboratory and open atmosphere have also been developed.

Title: Bulk Titanium Micro Electro-Mechanical System
A wafer-scale Titanium (Ti) process has been developed including the development of a high-aspect-ratio, reactive ion etch process. In addition, development efforts involved lapping and polishing processes to make Ti wafers that look like standard Silicon wafers; thus the Ti wafers can be processed using standard silicon processing equipment. The Ti wafers or Ti Chips can be micro-machined and macro-machined using standard machine shop tools to form the final product. The Ti wafers have a fracture toughness of fifty (50) times that of silicon wafers. Thus, making 3D MEMS by stacking multiple level Ti wafers and structures is a high yield process. In addition, we developed a Ti wafer-scale packaging technology for packaging silicon chips and Ti MEMS devices. Additionally, development efforts involved a process to grow Nano-Structured Titanium Dioxide (NST) on the Ti MES devices. The NST process was required to fabricate the various Ti-MEMS devices.The new Ti MEMS technology was used to make a number of MEMS devices that validate the use of the new Ti wafers and the Ti fabrication processes and the new, Ti 'HERMETIC' packaging technology. The Ti-fabricated devices include microwave transmission lines and relays; a Ti micro-needle array for painless injection of medicine; and a micro-mirror array for optical fiber switching. Titanium is both a Harsh Environment material and a material used in many medical applications. Ti MEMS is a new micro/macro metal wafer technology that addresses new applications not available in the Silicon-wafer- based technology

Development of Novel Standoff Multicolor Laser Sensor
Recent theoretical predictions suggest that a multicolor laser excitation scheme may provide a level of species selectivity and detection sensitivity not routinely achievable using single-color based laser techniques. Therefore we propose a systematic research investigation to explore the potential of this novel spectroscopic technology to serve as a standoff laser based sensor method for the detection of threat agents. As part of the investigation, the science surrounding the proposed multicolor laser based technology will be thoroughly examined via two concurrent efforts. One of these efforts will involve a series of laboratory experiments to determine appropriate laser protocols to successfully propagate a multiphoton excitation beam through the atmosphere. The focus of the other effort will be providing the high resolution spectral signature information for the threat molecules of interest.

Thermal Acoustic Piezo Energy Conversion
A group at the University of Utah, in collaboration with the University of Mississippi and Washington State University has researched development of a new technology for converting heat to electricity which can be used for thermal management of radar systems and which can provide electric power for battlefield operation. The approach taken consists of converting heat to sound in an acoustic resonator where the sound is directly converted into electricity using a piezoelectric device. Advantages of this type of energy converter are: simplicity, essentially no moving parts, environmentally friendly, and high efficiency. They developed devices which operate in the audio frequency range, from 2kHz up to the ultrasonic range, at 23kHz. The size of the device scaled inversely with operating frequency. They developed different size devices, the smallest one, 3.5mm long, operated at 22kHz. In order to take advantage of the increased power density as the frequency is raised, they also developed and studied arrays of up to 5 devices. The units were synchronized for maximum power output. Efficiency of thermoacoustic devices was raised by using traveling sound waves in annular configuration achieving 60% efficiency of Carnot. The project demonstrated proof of concept, opening the field of high frequency acoustic energy conversion. Prototypes are currently being evaluated as a source of renewable energy for a variety of applications, in particular the conversion of waste heat to electricity.