

# Pioneering Research for the Army at the Institute for Collaborative Biotechnologies (ICB)

Dr. Robert J. Kokoska and Dr. Daniel E. Morse

**T**he worlds of biology and biotechnology have found their way into the development of vital technologies that will have a positive impact on Soldier performance. This is being accomplished through the basic and applied research efforts of investigators within the Army's ICB.

Through the collaborative efforts of MIT and UCSB, the ICB is researching biologically based batteries and materials synthesis to develop semiconductive materials and alternate power sources to reduce Soldier operational loads. Here, SFC Robert Abram (left) radios in his position while PFC Matthew Murphy observes the progress of his fellow Soldiers from Alpha Battery, 2nd Battalion, 4th Stryker Brigade Combat Team, 2nd Infantry Division, during a cordon and search mission in Khan Bani Sa'ad, Iraq, on July 18, 2007. (U.S. Navy photo by MC2 Scott Taylor, Fleet Combat Camera-Pacific.)

# Report Documentation Page

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The ICB was established in 2003 and operated on behalf of the Army at the University of California at Santa Barbara (UCSB) in partnership with the Massachusetts Institute of Technology (MIT), the California Institute of Technology (Caltech) and partners in industry. The ICB is one of only a few Congressionally chartered University Affiliated Research Centers designed to facilitate and accelerate the transition from discovery to development and implementation. Through its own research and its strategic collaborations and alliances with Army laboratories; research, development and engineering centers (RDECs); and industrial partners, the ICB provides the Army with a single conduit for developing, assessing and adapting new products and biotechnologies in direct support of Army missions. The Army needs addressed by the ICB include research and development (R&D) improvements in the fields of advanced sensors, materials synthesis, power and

energy, information processing, network analysis and neuroscience.

Why has the field of biology been invoked to develop important engineering systems for the Army?

The answer lies in the observation that biological systems are essentially nature's own high-performance systems that display exquisitely high levels of control, function, structure and organization. This high performance is observed at a number of different levels: from the organization and control of biomolecular and genetic systems; to how the performance and function of individual cells and organs help to ensure the survival and health of an organism and

provide unique functions to different organisms; to how entire ecosystems are shaped, maintained and controlled.

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of modern biotechnology to discover the mechanisms responsible for the remarkably high performance of complex biological systems (such as sensors, the brain and energy-harvesting systems) and translate these into revolutionary advances in engineering for the support of Army operations," explains ICB Director Dr. Daniel E. Morse. The idea, then, behind ICB research is

to draw upon the basic principles underlying these finely tuned biological



ICB R&D in the fields of advanced sensors, power and energy, information processing and network analysis will, ultimately, improve Soldier operational capabilities, lethality and battlefield survivability. Here, a Soldier mans an M2 .50 caliber machine gun at an entry control point during Exercise Nimble Panther, on Sept. 12, 2007, Campo Pond, Hanau, Germany. (U.S. Army photo by Martin Greeson.)

systems to make us better engineers. The development of these technologies at the intersection of biology and engineering requires a multidisciplinary approach involving the talents and expertise of scientists in the fields of biology, chemistry, physics, mathematics, computer science and materials science, as well as engineers in the disciplines of mechanical, chemical and electrical engineering. More than 40 basic research projects are ongoing within the ICB. Highlighted here are some of these unique and creative ICB success stories that are making an impact on advancing Soldier capabilities within the Army.

### Advanced Biosensors for Force Protection

The development of detectors for lethal chemical and biological agents is a high

priority for protecting our Soldiers in the field. These detectors must have high sensitivity, reliability, ruggedness and compactness and are often based on biological systems. Nobel Laureate Dr. Alan Heeger and Dr. Kevin Plaxco of UCSB have developed a system in which specific DNA molecules bound to an electrical surface are used to sensitively detect DNA from biological pathogens. If a pathogen is recognized, an electrical signal is generated. Plaxco and Heeger have demonstrated that detection is effective even when the target DNA is contained within soil, blood serum or saliva.

This method has shown great potential for environmental sensing and for testing Soldiers for exposure. In addition, this system has been shown to be

operationally stable for weeks. This sensing system was developed in collaboration with the Army Research Laboratory, Sensors and Electron Devices Directorate (ARL-SEDD). Since its initial testing, the technology has further transitioned toward a hand-held device in collaboration with Nanex LLC under the ICB's 6.2 Applied Research program.

### Lightweight Power and Energy and New Methods for Materials Synthesis

Batteries are heavy and an important part of a Soldier's primary logistical load. To reduce this load, MIT MacArthur Scholar Dr. Angela Belcher is developing lightweight, flexible rechargeable batteries. Belcher has engineered nontoxic virus particles that bind metallic electrode materials in highly ordered structures that can self-assemble on flexible transparent films to produce high-performance battery materials. The half-cell specific capacity of this biologically based battery is over double the capacity of currently used lithium ion rechargeable batteries. Belcher is trying to integrate this battery material into textiles. Because the materials are synthesized in a liquid solution, it should also be possible to pour a battery into a mold of desired shape or to spray a battery electrode onto any suitable surface.

In the field of materials synthesis, UCSB's Dr. Daniel E. Morse has studied how marine sponges nanosynthesize silica. He is using his findings to develop a new low-temperature method to fabricate a host of conductive and semiconductive materials with superior structural characteristics. Morse's improvement in materials synthesis holds the promise for the development of more efficient lightweight 3-D batteries and solar cells and this method has been extended to other

metallic materials that may be useful in uncooled infrared (IR) detection. Morse has partnered with ARL's Infrared Materials & Devices Branch and the Aerospace Corp. to develop cheap uncooled IR sensors with low-power requirements for applications such as driver vision enhancement, rifle sights, physical security and target acquisition.

### **The Gecko — Nature's Reversible Adhesive**

The gecko's feet can reversibly adhere to and release from surfaces many times. This remarkably unique feature enables the gecko to climb walls and run across ceilings upside down. UCSB's Dr. Kim Turner has studied the mechanics that allow the gecko to perform these unusual feats and has developed metallic nanoscale structures that mimic the adhesion properties of the gecko's toe. When actuated by a magnetic field, these structures adhere to surfaces with a strength that is now beginning to approach the strength that the gecko uses for attachment. An ongoing collaboration with ARL-SEDD is focused on improvements in the adhesion of this system and the application of this technology for micro-autonomous robotic systems. This bio-inspired adhesive will greatly enhance the capabilities of walking robots to move over all-terrain horizontal and vertical surfaces and to support their own weight.

### **Translating Biological Networks to Effective Communications Networks**

The development of Future Combat Systems will require components that are smaller, lighter and safer, yet more lethal than current systems. These new systems will rely more on speed, agility and situational awareness than on heavy armor, and will require coordination of a multitude of networked sensors. To meet this challenge, ICB

has created a program in Bio-Inspired Network Science. Led by UCSB's Drs. Frank Doyle and Joao Hespanha, and Dr. Richard Murray of Caltech, this group investigates the basic principles and mechanisms of biological networks and seeks to apply this knowledge to design high-performance, robust communications networks.

One basic research component is directed toward the mathematical modeling of a number of complex biological networks including the genetic networks responsible for determining sleep patterns and the signaling patterns that control the life cycles of aquatic corals (both as individuals and as a community). Also, theoretical studies seek a clearer understanding of the organizational principles that guide the operation and control of biological networks.

The models developed will be tested with a number of case studies, including a project in cognitive neuroscience led by UCSB's Dr. Michael Gazzaniga. In the neuroscience project, brain imaging data will be used to determine the neurological differences among individuals: how they are hard-wired to learn and perform certain tasks. Finally, the dynamics of large-scale networks such as swarms, flocking patterns and insect colony formation are studied to provide clearer guidelines to the design of complex, adaptable network structures.

### **The ICB — Sustaining the Army's Future**

The ICB's working mission is highly collaborative and focused on Army needs. The Institute reaches out beyond basic research to productive collaborations with Army laboratories and actively works toward effective transitioning to the Army. "We're collaborating with the ARL, the RDECs and more than 25 private companies [ranging

from major defense contractors to small, technology-based startups] to accelerate the transition from basic discoveries in the university laboratories to manufacturing and acquisition by the Army," Morse explained. Every year an ICB-Army-Industry Conference is held at UCSB. This conference brings together ICB investigators with Army scientists and current and future industrial partners to focus interactions and shape efforts toward effective technology transitioning. Plans are underway for the 2008 ICB Army-Industry Collaboration Conference to be held at the Corwin Pavilion, UCSB campus, Feb. 12-13, 2008. Dr. Thomas H. Killion, Deputy Assistant Secretary of the Army for Research and Technology and Army Chief Scientist, will deliver the keynote address. Through working R&D collaborations during the year, regular reviews and major conferences, the ICB is building and maintaining a vital strategic relationship with the Army.

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**DR. DANIEL E. MORSE** is the ICB Director, Professor of Biochemistry and Molecular Genetics, and founder and past Chair of the Interdisciplinary Program in Biomolecular Science and Engineering at UCSB. He received his B.A. in biochemistry from Harvard University and his Ph.D. in molecular biology from Albert Einstein College of Medicine. He conducted postdoctoral studies in molecular genetics at Stanford University, and was appointed the Silas Arnold Houghton Associate Professor of Microbiology and Molecular Genetics at Harvard Medical School before joining the UCSB faculty.