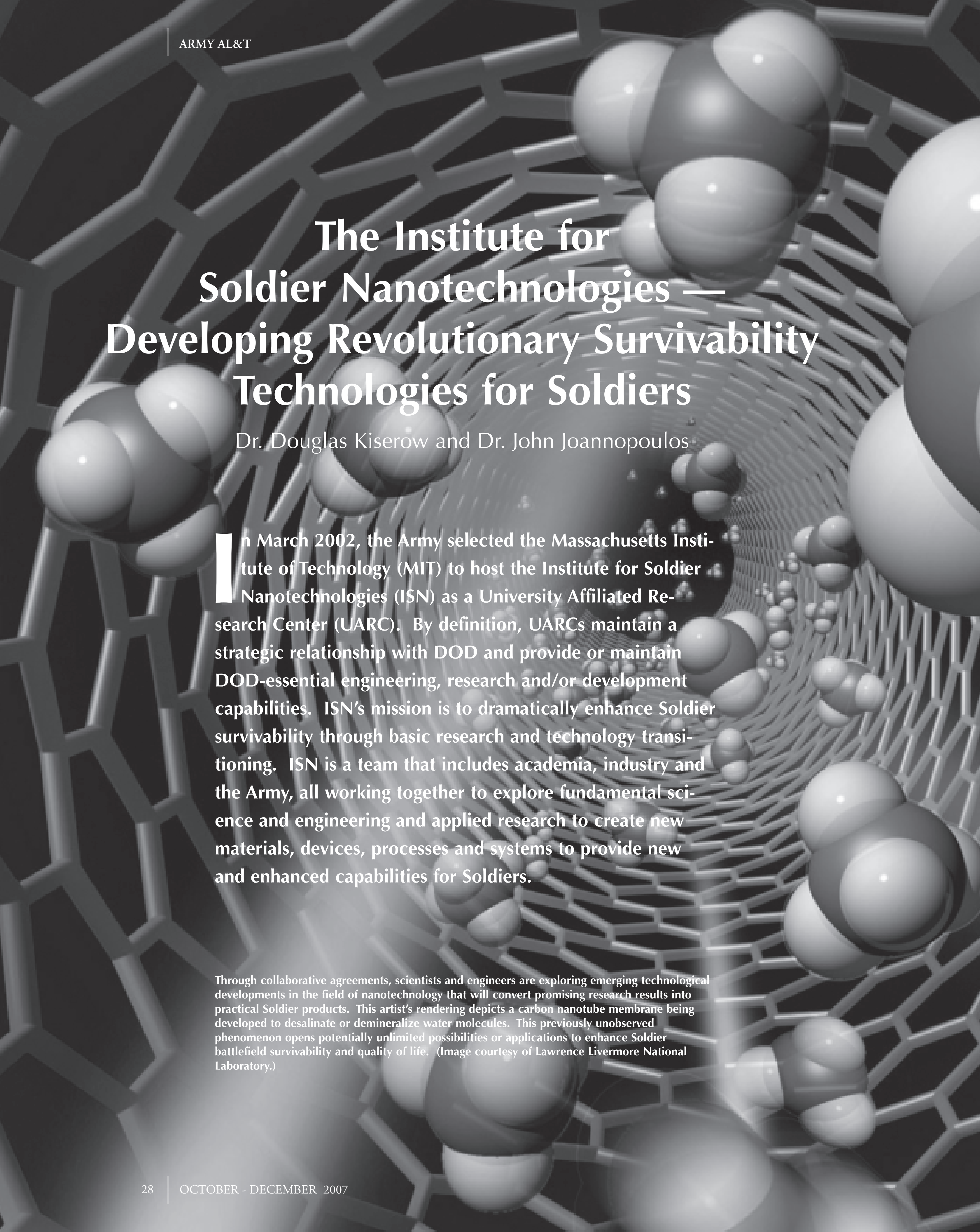

The Institute for Soldier Nanotechnologies — Developing Revolutionary Survivability Technologies for Soldiers

Dr. Douglas Kiserow and Dr. John Joannopoulos

In March 2002, the Army selected the Massachusetts Institute of Technology (MIT) to host the Institute for Soldier Nanotechnologies (ISN) as a University Affiliated Research Center (UARC). By definition, UARCs maintain a strategic relationship with DOD and provide or maintain DOD-essential engineering, research and/or development capabilities. ISN's mission is to dramatically enhance Soldier survivability through basic research and technology transitioning. ISN is a team that includes academia, industry and the Army, all working together to explore fundamental science and engineering and applied research to create new materials, devices, processes and systems to provide new and enhanced capabilities for Soldiers.

Through collaborative agreements, scientists and engineers are exploring emerging technological developments in the field of nanotechnology that will convert promising research results into practical Soldier products. This artist's rendering depicts a carbon nanotube membrane being developed to desalinate or demineralize water molecules. This previously unobserved phenomenon opens potentially unlimited possibilities or applications to enhance Soldier battlefield survivability and quality of life. (Image courtesy of Lawrence Livermore National Laboratory.)

The Army plays a critical role by providing guidance on Soldier survivability needs and the relevancy of new ISN research concepts. In addition, Army and industry personnel provide valuable expertise on how to convert promising results into practical products that work in harmony with other Soldier technologies. ISN innovations are beneficial for Soldiers, but also have broad applicability for DOD and the private sector, including first responders, law enforcement officers and U.S. Customs officials. As a UARC, the ISN provides the Army with a large, multidisciplinary academic and industrial team that can meet diverse scientific and engineering challenges in developing revolutionary survivability technologies for Soldiers.

The Challenge

Today's Soldier may carry more than 140 pounds of clothing and related equipment while facing a broad array of lethal threats, including ballistic, blast waves and shrapnel from improvised explosive devices (IEDs); lasers, chemical and biological weapons; and other hazardous materials. Moreover, Soldiers are expected to function effectively in climates, terrain and environments that can present significant risk of injury and medical problems. The ISN's challenge is to discover and transition technologies that can provide new and enhanced protective capabilities integrated into durable, comfortable, lightweight uniforms and equipment as depicted in the figure at right. By grounding its research portfolio in nanotechnology, the ISN is harnessing innovative science and engineering that is well-matched to Soldier requirements' challenges.

Nanotechnology research is focused on understanding and harnessing the size-dependence of the properties of matter at "tiny" length scales to generate fundamentally different and useful physical, chemical and biological properties. These tiny length scales range from less than 1,000 nanometers (nm) down to just a few nm. These sizes are truly minute — the diameter of a single human hair is roughly 80,000 nm. This size-dependent behavior opens up potentially paradigm-shifting opportunities to create materials and devices with unique electrical, optical, magnetic, thermal and chemical properties that may be exploited for Soldier survivability. Nanoscale materials and devices, either directly or as components of larger systems, have the potential to bring multiple capabilities in the form of tiny, lightweight building blocks. Building on its nanotechnology foundations, ISN research also addresses larger dimension materials and systems that are essential to developing new Soldier safety and protection capabilities.

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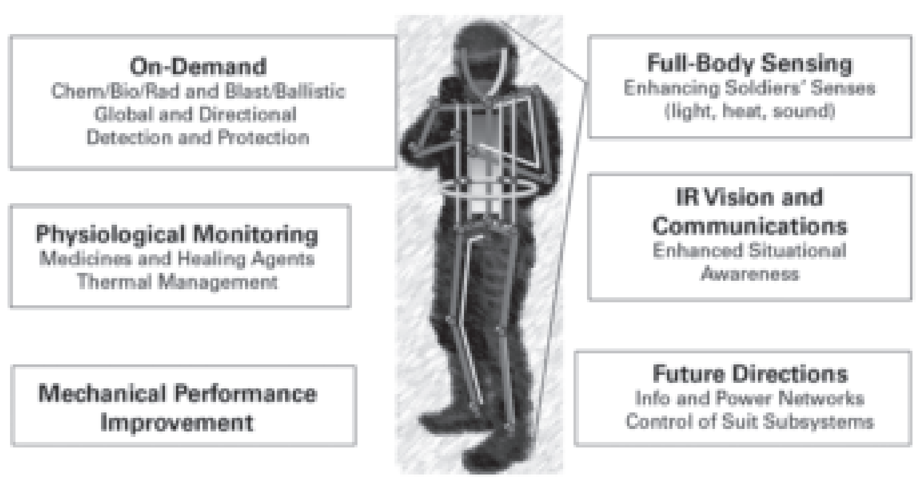
Strategic Research Areas (SRAs)

The ISN basic research program has five SRAs focused on Soldier survivability as follows:

- *SRA-1, Lightweight, Multifunctional Nanostructured Fibers and Materials:* focuses on creating and enhancing survivability capabilities, e.g., sensing, imaging, decontamination and communications, using fibers, fabrics, particles, coatings, membranes and other "building block" materials. A key focus area is creating nanoparticle materials known as quantum dots (QD) for enhanced infrared (IR) vision/communications. Engineering the size of QDs allows for tailored emission or detection of IR light. Research on QDs is being carried out to develop low-cost, uncooled night vision goggles by an ISN-Raytheon-Army team that includes the Army Research Laboratory Sensors and Electron Devices Directorate (ARL-SEDD) and Communications-Electronics Command Research, Development and Engineering Center (RDEC) Night Vision Electronic Sensors Directorate.
- *SRA-2, Battle Suit Medicine:* is exploring autonomous medical diagnosis and intervention through materials and devices for physiological monitoring and controlled delivery of medicines. Research includes



Areas of Soldier protection and capabilities the ISN is exploring.

NSRDEC and ISN successfully demonstrated the IR laser-to-helmet combat identification and communications capabilities for the ICOM-H prototype. Nanoenabled materials and devices and optoelectronic fibers are enhancing potential Soldier battlefield survivability and communication capabilities. (U.S. Army photo by SSG Michael J. Carden.)

exploring tiny devices for autonomous medical care, e.g., to automatically monitor a Soldier's medical condition and, when needed, administer care, which could include arresting bleeding and preventing the onset of hemorrhagic shock.

- *SRA-3, Blast and Ballistic Protection:* focuses on understanding how blast waves and ballistic threats interact with and damage human tissues; and on creating a new generation of lighter weight yet stronger polymeric, metallic, ceramic and hybrid materials to protect the Soldier. One area of interest is creating nano- and micro-scale architectures, analogous to truss structures used for buildings, bridges and towers, to provide high strength-to-weight capability. Picatinny Arsenal, NJ, is collaborating with the ISN to investigate the use of ceramic composite structures to further strengthen these materials.
- *SRA-4, Chemical and Biological Materials Science:* is developing a new foundational understanding to enable sensing and identification of harmful substances in the Soldier's environment, as well as materials and coatings to protect Soldiers from a range of toxic materials. A particularly promising technology being explored is "gentle" chemical vapor deposition, which is effective for coating individual fibers in materials, such as cloth and fabrics, and for coating other surfaces, such as vehicles. This technique generates ultra-thin polymeric coatings that provide multiple protective capabilities without damaging the material being coated. Potential Soldier applications include lightweight, conducting polymer coatings to protect fabrics from hazardous substances, while also detecting and decontaminating toxic materials. In addition, ISN researchers are collaborating with ARL-SEDD to improve the performance of field effect transistors and with the Natick Soldier RDEC (NSRDEC) to facilitate biorecognition using nanofiber structures.
- *SRA-5, Nanosystems Integration Research:* is creating and bringing together nanoscale and nanoenabled materials and devices to provide new and enhanced systems for communications and other applications. A most promising technology being explored and developed is optoelectronic fibers that can be engineered to detect light or heat at any point along the fiber. In collaboration with NSRDEC, IR laser-to-helmet combat identification and communications capabilities were successfully demonstrated using the Identification and Communication-Helmet (ICOM-H) prototype by U.S. Army Special Operations Command (USASOC) Soldiers at Fort Devens, MA. This collaboration is ongoing and is refining and extending the communications and situational awareness capabilities of these devices. Potential Soldier applications include full-body sensing of light, heat, sound and non-radio frequency (RF) local area networking.

Technology Transitions

The most significant technology transition to date has put a new, highly accurate and sensitive explosives detector in the hands of Soldiers on the battlefield. ISN basic research exploring amplifying fluorescent polymer sensors, with roots in the Defense Advanced Research Projects Agency (DARPA) "Dog's Nose Program," has been transitioned by ISN industrial partner ICX/Nomadics into the Fido XT explosives detector, which won 2005 and 2006 Army's Greatest Invention Awards (See related articles in the August 2007 edition of *Army AL&T Online Monthly*) and is in use by Soldiers and Marines in Iraq and Afghanistan, USASOC and by U.S. Customs officials at U.S. ports of entry.

The use of these sensors is being explored for other applications, including an applied research project at NSRDEC on detecting food-borne pathogens. In another critical area, fabric modeling codes — based upon ISN research accomplishments in analytical modeling and numerical simulation of blast and ballistic impacts on structures and humans — have been transitioned to ParaSym Inc., which won an Armament Research, Development and Engineering Center Phase II Small Business Innovation Research (SBIR) award. The benefit to the Soldier is a tool that can more reliably analyze and predict the behavior of blast protective gear and to guide the design of stronger, yet lighter materials for blast and ballistic protection.

Basic research on antimicrobial coatings is being transitioned to industry via SBIR. Recently, small-business qualifier ICEO Inc. began transitioning and commercializing ISN basic research. They have licensed five ISN technology patents from MIT and are developing a microfluidic mixer that has no moving parts for biological sampling and portable medical diagnostics. The list of businesses licensing and transitioning ISN research include

DuPont®, Dow Corning, Raytheon, Triton®, ICx™/Nomadics, Parasym, GVD Corp., MicroCHIPS™ and QD Vision. Research areas include sensors for explosives, blast mitigation, medical treatment, displays and conformal electronics.

Established in 2003, the Soldier Design Competition (SDC) provides MIT students and U.S. Military Academy cadets with opportunities to perform research in the design and prototyping of technology solutions for real-world challenges faced by Soldiers. Teams compete for $20,000 in prize money donated by industrial sponsors that include Boeing, Foster-Miller, L3 Communications and Lockheed Martin. Winning prototypes are selected by a panel of experts from the Army, U.S. Marine Corps, industry and MIT. This highly successful initiative has engaged more than 125 students from the two campuses and spawned 11 startup companies. Transitions from the SDC include a battery scavenger technology and a "gesture engineering" system now funded in the Army Phase II SBIR program.

Looking to the Future

In the near term (2-5 years), ISN will continue creating and transitioning novel materials, devices and systems to provide Soldiers with new survivability capabilities. Examples include, but are not limited to:

- "Designer" polymer molecules that can detect trace quantities of a variety of explosives and toxic chemicals.
- Multifunctional optoelectronic fiber devices that sense heat, light and sound along the entire fiber length.
- Devices that monitor the Soldier's surroundings and provide non-RF bandwidth for communications.
- Ultra-thin coatings to impart diverse threat detection and protective capabilities.
- Wireless transmission of electricity over room-size distances.
- Potential Soldier applications include powering electronics within vehicles while reducing clutter and eliminating the weight of wires and cables, automatic recharging of Soldier electronic devices and supplying power to robots.

Additional academic expertise will strengthen the ISN in 2008 under a new program to engage faculty and students from Historically Black Colleges and Universities and Minority Institutions (HBCU-MIs) in ISN research. This effort will seek to develop research collaborations between the ISN and HBCU-MIs to enhance ongoing ISN programs and provide a wealth of previously untapped scientists and engineers.

DARPA's "Dog's Nose Program" has been transitioned by ISN industrial partner ICx/Nomadics into the Fido XT explosives detector (see inset photo). DARPA is also working with small business qualifier Boston Dynamics Inc. The company is building a dog-like robot that could eventually accompany Soldiers in the field as a load-carrier across nearly any terrain. The prototype pictured here is dubbed BigDog and measures 40" long, 28" tall and weighs 165 pounds. Once perfected, other sensors such as the Fido XT explosives detector could be programmed into the robot. (Photo courtesy of *Defense Industry Daily*.)

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