Institute for Soldier Nanotechnologies

Founded in 2002, the Institute for Soldier Nanotechnologies (ISN) is a three-member team designed to leverage the unique capabilities of the US Army, industry, and MIT. The ISN mission is to dramatically improve the survivability of the soldier by working at and extending the frontiers of nanotechnology through fundamental research and transitioning with our Army and industry partners. This mission includes not only decreasing the weight that soldiers carry but also improving blast and ballistic protection, creating new methods of detecting and detoxifying chemical and biological threats, and providing physiological monitoring and automated medical intervention. The ultimate goal is to help the Army create a sleek 21st-century battlesuit that combines high-tech protection and survivability capabilities with light weight and increased comfort.

Army funding for ISN stands at approximately a $75 million ceiling over five years, with substantial co-investment by industry partners and MIT. Each year approximately 50 faculty members from 10 MIT academic departments, 80 graduate students, and 30 postdoctoral associates participate in ISN research. During the past year, ISN research has resulted in over 175 refereed publications in journals such as *Nature*, *Nature Materials*, *Nature Nanotechnology*, and *Advanced Materials*. Additionally, approximately 400 people have visited ISN during this period.

Research

ISN's signature interdisciplinary research agenda evolved over the course its first five years into a more focused program, reflecting the areas where ISN leadership and the Army see the potential for especially strong soldier impacts emerging. The renewed contract, enacted in 2007, supports a substantially streamlined research structure. Still, team-based innovation continues to be a hallmark of ISN's intellectual course, as new ideas and collaborations emerge. Areas of research interest are divided into five distinct Strategic Research Areas (SRAs) that are, in turn, split into themes and specific projects.

Strategic Research Area 1: Lightweight, Multifunctional Nanostructured Materials

ISN's exploration into the development of multifunctional fibers and constructs takes many forms, encompassing a total of six themes and seven projects concerned with research to impart diverse, nano-enabled functionalities to materials that can serve as building blocks for clothing and other gear to provide soldier protection and survivability. Of particular interest are nanoscale coatings, core-shell and rod-rod nanostructures, carbon nanotubes, fibers, fabrics, and layered and membrane structures. In this SRA, specific themes are as follows:

- Theme 1.1: Surface Active Multifunctional Fibers and Fabrics
- Theme 1.2: Smart Quantum Dots: Microfluidic Fabrication, Detection, and Sensing
- Theme 1.3: Imaging and Sensing with Carbon-Nanotube Devices
- Theme 1.4: Multimaterial Multifunctional Fibers

- Theme 1.5: Functional and Responsive Elastomers
- Theme 1.6: Nanostructured Materials for Simultaneous Control of Light and Sound

Strategic Research Area 2: Battle Suit Medicine

This SRA is concerned with research that can lead to improved medical and combat casualty care for the soldier. Of particular interest are nano-enabled materials and devices applicable to far-forward medical treatment. In the nearer term, these would find application in field hospitals and via battlefield medics. In the longer term, monitoring, diagnostic, and treatment technologies derived from the basic research of SRA-2 would be incorporated in the multicapability battlesuit. Ultimately, qualified medical personnel and soldiers in the field could activate these technologies. Autonomous activation would also be possible, with appropriate safeguards including soldier and medic override capabilities. Examples of SRA-2 research include polymer actuators for imparting rigidity-on-demand (e.g., for splinting wounds or preventing adverse movements after head or neck injury), materials and devices to enable controlled release of medications, methods for accelerated diagnostics of adverse medical conditions, and a microelectromechanical systems–based device to prevent hemorrhagic shock. In this SRA, there are a total of seven projects across the following three themes:

- Theme 2.1: Nanostructured Actuators: First Principles Prediction to Fabrication
- Theme 2.2: Nanostructured Films and Functional Surfaces for Battlefield Medicine
- Theme 2.3: Noninvasive Medical Monitoring and Drug Delivery

Strategic Research Area 3: Blast and Ballistic Protection

SRA-3 concentrates its research on blast and ballistic protection. Recognizing the importance of blast-related soldier injuries in current operations, ISN has increased its efforts in blast protection. This complements and indeed enriches our ballistic protection research. In particular, SRA-3 directs considerable assets toward understanding blast interactions with materials including human (brain) tissue as well as various anthropogenic energy absorbing materials, including microframe structures that contain nanotrusses. In this SRA, there are a total of nine projects allocated among the following three themes:

- Theme 3.1: Lightweight Nano-architectures for Ultra-strong and Energy Absorbing Materials
- Theme 3.2: Materials and Structures for Blast Protection and Injury Mitigation
- Theme 3.3: Lightweight Nanocrystalline Alloy Fibers for Blast Protection

Strategic Research Area 4: Chem/Bio Detection and Protection

This SRA is concerned with research to provide new scientific and engineering understanding to enable the detection of hazardous substances in the environment as well as a means to protect the soldier from those substances. The research will provide foundational information for transitioning of promising outcomes by the Army and industry partners. One activity focuses on different means to obtain nanoscale polymeric coatings that provide specific protective functionalities. Another thrust concentrates on different approaches to the sensing and characterization of various materials, including toxic substances. A third activity seeks to develop the understanding needed to manufacture multilayered 3D nanostructures from foldable 2D nanopatterned surfaces. Potential applications include the ability to scaffold and integrate multiple threat detection capabilities in lightweight and low-energy consumption platforms. In this SRA, there are a total of six projects across the following three themes:

- Theme 4.1: Functional, Switchable, and Microbicidal Nanocoatings
- Theme 4.2: Ultrasensitive Nanoengineered Chemical Sensing
- Theme 4.3: Nanostructured Origami

Strategic Research Area 5: Nanosystems Integration

Systems of components that contain nanoscale materials and devices can enable powerful protection and survivability capabilities for the soldier. This SRA is concerned with research to create or exploit such nanoscale materials and devices and to understand their behavior within capability-enabling systems. Of particular interest are nanoelectromechanical devices, integrated systems-level performance from unique ISN metal-insulator-semiconductor fibers, non–radio frequency (RF) fabric-enabled communications, and nanostructured materials for observable optical nonlinear responses at very low power levels. The research in SRA-5 is divided among four themes each involving one research project:

- Theme 5.1: Nanoelectronics
- Theme 5.2: Integrated Fiber and Fabric Systems
- Theme 5.3: Non-RF Fabric-enabled Communications
- Theme 5.4: Enabling Optical Nonlinear Capabilities for the Soldier

Army Collaboration

Army partners are vital to the ISN mission They collaborate on basic and applied research, provide guidance on the soldier relevancy of ISN projects, and participate in transitioning (i.e., technological maturation and scale-up of the outcomes of ISN basic research). At present, ISN has active research collaborations with the following Army science and technology laboratories:

- Army Research Laboratory
- Aviation and Missile Research, Development, and Engineering Center
- Edgewood Chemical/Biological Center
- Natick Soldier Research, Development, and Engineering Center
- Night Vision and Electronic Sensors Directorate

- Picatinny Armament Research, Development, and Engineering Center
- US Army Corps of Engineers
- Walter Reed Army Institute of Research
- Walter Reed Army Medical Center

Industrial Collaboration

Industry partners are critical to the ISN mission, helping to turn laboratory innovations into real products and scale them up for affordable manufacture in quantity. ISN currently has 14 industry partners:

- Battelle
- CIMIT (Center for the Integration of Medicine and Innovative Technology)
- Dow Corning
- DuPont
- Foster-Miller
- Honeywell
- ICx-Nomadics
- JEOL USA
- Mine Safety Appliances
- Nano-C
- Northrop Grumman
- Raytheon
- Triton Systems
- W.L. Gore and Associates

Soldier Design Competition

The MIT Soldier Design Competition continued into its sixth year. The objective of the competition is to provide an engineering design and prototype building experience for undergraduates that will address real technology problems faced by modern soldiers and first responders. United States Military Academy cadets joined the competition in its second year, several participating as part of their capstone engineering design, and they have continued with great success in the subsequent iterations of the competition.

Sixth-year challenges included an autonomous robot design for the deployment of sensing systems, a soldier portable navigation device for GPS-constrained environments, and a pest-repellent soldier uniform, among others. Participants could also propose their own challenge and responding invention in an open design category.

Teams compete for prize money provided by industry sponsors in a final judging by senior personnel from industry, the Army, and academia. In the finals of the 6th Soldier Design Competition, held April 16, 2009, prize-winning inventions included an inflatable parabolic dish to enable field concentration of solar energy for electric power generation, a device for the rapid neutralization of chemical and biological agents associated with improvised explosive devices, and a signal analysis system to enhance situational awareness in GPS-denied environments.

Competition participants own the intellectual property rights to their inventions and are encouraged to pursue patents and commercialization. To that end, several Soldier Design Competition alumni have founded companies and transitioned technology for practical applications.

ISN continues the Soldier Design Competition on an annual basis, with the 2009–2010 competition finals scheduled for April 15, 2010.

Summer Internship Program

Coordinated by professor Christine Ortiz, the ISN has begun a new Summer Internship Program to provide MIT students with opportunities to perform research at Army laboratories under the guidance of Army scientists.

Historically Black Colleges and Universities and Minority Institutions Program

With professor Paula Hammond as program director, ISN has recently begun a new program to engage faculty and students from historically black colleges and universities and minority institutions (HBCU-MIs) in the ISN mission. This program funds basic research projects at HBCU-MIs and facilitates collaborations between HBCU-MI and ISN scientists.

Future Plans

ISN's mission remains extremely relevant to current national priorities and to the future needs of soldiers. It is expected that key research directions will continue and new research themes will be added in response to emerging challenges in soldier protection and survivability.

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More information about the Institute for Soldier Nanotechnologies can be found at http://web.mit.edu/isn/.