The US Army's Institute for Soldier Nanotechnologies at MIT
# Table of Contents

A Message from Our Director .............................................................................................................. 1

About the ISN ........................................................................................................................................ 2
- Mission
- History

Challenges .......................................................................................................................................... 3

Nanotechnology for the Soldier

Core Competencies ............................................................................................................................ 4-5
- Science and Technology
- Operating Model

People .................................................................................................................................................. 6
- ISN Headquarters Team
- Affiliated Faculty
- Visits
- Post-Doctoral Researchers and Students
- Army Visiting Scientists

Facilities .............................................................................................................................................. 7
- Industry
- Army
- Other DoD, Government, and Academia

Research ............................................................................................................................................. 8-9
- Strategic Research Area 1: Soldier Protection, Battlefield Care, and Sensing
- Strategic Research Area 2: Augmenting Situational Awareness
- Strategic Research Area 3: Transformational Nano-Optoelectronic Soldier Capabilities

Select Research Accomplishments .................................................................................................... 10
- Protecting 3D Materials from Corrosion
- Overcoming Drug Resistance with Engineered Viruses
- 3D Printing with Multimaterial "Ink"
- "Blackest" Material to Date Absorbs >99.99% of Incoming Light
- Non-Abelian Aharonov-Bohm Effect Observed
- Robots Designed to Thread Through the Brain
- Fast-Acting Cancer Drug Skin Patch
- NMR-Based Hydration Status Monitoring
- Ultrafast, Sub-Altojoule Matrix Multiplication
- Metasurface Lenses
- Electron Beam Atom Manipulation
- Training Hydrogels like Muscles
- Tuning Color and Thermal Properties Separately
- Using AI to Summarize Scientific Texts
- Structural Color in Drops of Water
- Improved 3D Patterning and Fabrication
- Cleaner Graphene
- Harvesting Electricity from WiFi Signals
- Implosion Fabrication
- Cataloging "Acromolecules"

Microfluidic Fibers............................................................................................................................... 15
- Mass-Produced, Cell-Sized Robots
- Understanding Microparticle Impact
- Quiet, Light Battlefield Power Sources

Nanostructured Metal Alloys for Lightweight Protection................................................................. 16
- Quantum Dot-Enabled Hyperspectral Imaging
- Optoelectronic Fiber Devices
- UV Visualization with IR Imagers

Nanostructured Shape Memory Alloys .............................................................................................. 17
- Tough, Strong Nanoscale Fibers
- CVD-Enabled Wires for Advanced Microchip Design
- Fluid-Like Electron Flow

A Colloidal Quantum Dot Spectrometer............................................................................................. 18
- New Test Array Reveals that PUU Polymer Strengthens on Impact
- Optical Neural Circuits
- Implantable Biosensor Allowing Real-Time Monitoring
- "Motors" Driven by Light .................................................................................................................. 19
- Janus Emulsions for Food Safety Testing
- A New Way to Generate X-Rays
- Understanding Impact-Bonding of Metals

Nano-Enabled Incandescent Lighting ............................................................................................... 20
- 3D-Printed "Tattoo" Made of Living Cells
- Understanding Electron Conductivity in Polymers
- The Experimental Observation of Weyl Points

Self-Curing Composite Materials...................................................................................................... 21
- Transparent Displays Using Nanoparticle Scattering
- Water-Based Electronic Barstages
- Angular Selectivity of Light Transmission

Significant Transitions ....................................................................................................................... 21-23

Outreach ............................................................................................................................................. 24
- SN/Lincoln Laboratory Soldier Design Competition
- Visits

For More Information .......................................................................................................................... Inside Back Cover

Sponsorship and Oversight .................................................................................................................. Back Cover
The mission of the ISN is to help the US Army and other US military services dramatically improve the survivability and effectiveness of the Soldier and other warfighters, their platforms, and their devices.

By working at and extending the frontiers of nanoscience through fundamental research, by collaborating with our Army and industry partners, by advancing the limits of nanotechnology through the transitioning the positive outcomes of our research, and by responding rapidly to emerging opportunities and challenges, the ISN endeavors to make Soldiers and warfighters not only safer but also more efficient, more productive, and more comfortable.

There is an extremely important aspect of working at the nanoscale that goes beyond just making things small: the intrinsic characteristics of matter - the dielectric, mechanical, and transport properties - become size dependent below a critical length-scale of a few hundred nanometers. This provides opportunities for the discovery of new materials and systems with attributes and phenomena that are otherwise unattainable in nature.

Transitioning these discoveries is vital, and MIT has a long history and accomplished culture of entrepreneurship. Members of the faculty, students, and research staff strive to reap the rewards of basic research and rapidly deploy them to the customer. In this regard, the focus of the ISN on Soldier and warfighter capability and welfare has many dual-use applications to first responders, law enforcement officers, firefighters, and the civilian community at large.

Prof. John D. Joannopoulos
Director, Institute for Soldier Nanotechnologies
Francis Wright Davis Professor of Physics
Elected Member, National Academy of Sciences
The ISN mission is to help the US Army and other US military services dramatically improve the protection, survivability and other capabilities of the Soldier, other US warfighters, and their platforms and systems, through basic research on nanotechnology and by transitioning promising outcomes of that research in partnership with the Army, other US military services, and industrial companies. This mission includes decreasing the weight that Soldiers carry, improving blast and ballistic protection, creating new methods of detecting and detoxifying chemical and biological analytes, providing physiological monitoring and automated medical intervention, and enhancing situational awareness.

To carry out this mission, the ISN has developed a diverse set of core S&T competencies strengthened by an operating model that emphasizes cutting edge research coupled with rapid transitioning through Army and industry partners, as well as startup companies fostered by MIT’s strong culture of entrepreneurship.

The ISN is an Army-supported University-Affiliated Research Center (UARC), and a product of the Army’s vision to explore the potential power of nanotechnology to enable unprecedented advances in Soldier protection and survivability. The ISN was designed to collaborate on basic and early applied research with Army and industry partners, and enable both to transition promising results. On March 12, 2002, the Army announced that it had selected MIT’s proposal from a host of submissions by some of the nation’s best colleges and universities, and the ISN was officially founded two days later on March 14, 2002. The official opening ceremony of the ISN dedicated facility was held on May 22, 2003.
Soldiers and other members of the US Armed Forces face many challenges in performing their diverse missions. Military threats include blast and ballistic impacts, chemical and biological weapons, radiological and other hazardous materials, directed energy weapons, nuclear devices, and electronic and cyber warfare. Beyond these threats, warfighters must function in varied climates and weather conditions, and in environments ranging from remote wilderness to densely populated cities. These conditions and venues present risks of personal injury and illness, significantly exacerbating already complex military challenges. Clothing, equipage, and platforms must provide high functionality while minimizing their size, weight, power demand, and cost (SWaP-C).

The breadth and depth of these challenges is documented in the following Army Modernization Priorities and the corresponding Cross-functional Teams that form the foundation of the US Army Futures Command:

- Long Range Precision Fires
- Next Generation Combat Vehicle
- Future Vertical Lift
- Network
- Assured Positioning, Navigation, and Timing (an Enabling Area)
- Air and Missile Defense
- Soldier Lethality
- Synthetic Training Environment (an Enabling Area)

Nanotechnology can enable cutting-edge technologies that provide potentially transformational capabilities by harnessing the size dependence of physical, optical, electrical, and chemical phenomena that occur at tiny length scales. The result can be new materials, processes, devices, and systems that provide unprecedented advances in technologies to provide protection and other capabilities to the warfighter and the warfighter’s platforms.

The nanoscale range is truly minute — the diameter of a single human hair is roughly 80,000 nm — and size-related behavior opens up potentially paradigm shifting opportunities. Nanoscale materials and devices, either directly or as components of larger products, allow for multiple capabilities in tiny, lightweight building blocks. Therefore, nanotechnology is ideally suited to enhance functionality at reduced weight, a key driver of the ISN Mission. ISN researchers have demonstrated that a wide variety of nanomaterials can be synthesized and integrated into prototype devices and fabrics.

Theoretical and computational efforts at the ISN complement experimental research programs in order to understand and optimize material properties. Moreover, nanotechnology is inherently interdisciplinary, bringing together areas of science that are historically very different, allowing innovators to capitalize on the unique features of each. For example, ISN scientists are combining the traditionally low cost and high production volumes of textiles manufacturing with the exquisitely customized electronic properties typically achieved via the expensive processing of semi-conductors. The potential impact is unique optoelectronic fibers for full-body coverage of the Soldier, buildings, and vehicles to detect heat, light and sound, made possible by the ability to produce these fibers at the speeds, costs, and quantities expected from mass production of textiles.
Core Competencies

Science and Technology

- **Advanced Structural Materials** for enhanced blast and ballistic protection of humans and platforms, damage detection and repair, lethality, weight reduction of manned and unmanned platforms, and vibration damping

- **Artificial Intelligence Through Neuromorphic Optical Computing Systems** enabled by ultra-fast, ultra-low power deep-learning optical computing architectures and physics-inspired algorithms

- **Groundbreaking Energy and Power Technologies** for compact, lightweight power generation, ultra-long lifetime “batteries,” and the wireless, non-radiative transmission of electric power

- **High-Fidelity 3D Dynamical Modeling** of the durability, fracture, and failure of materials, platforms, and structures owing to blast, ballistic, and other mechanical and thermal stresses

- **Hypersonic Flow Environments** for the better understanding of materials behavior and durability, the informed design of new materials and structures, and the investigation of shock-related phenomena in condensed phase materials

- **Innovative Manufacturing** of revolutionary alloys, fibers and fabrics, and multifunctional materials via liquid spray, fiber drawing, 3D printing, and other innovative fabrication methods

- **Multi-Material Fiber and Fabric Devices** supporting combat identification and communications, the detection and emission of heat, light, and sound, the generation and storage of energy, the synthesis of tiny particles, fiber-based computation, and real-time condition assessment

- **Nano-Plasmonic and Topological Phenomena** including electronic, photonic, and plasmonic processes for sensing, displays, obscurants, secure communications, and signal processing applications

- **Network and Information Science** facilitating network localization and navigation, network operation, interference exploitation, secret key generation, cognitive quantum entanglement distillation, multi-party quantum communication, and multi-target tracking

- **Next-generation “Electronics”** including optoelectronic and other unconventional information carriers, 2D photonic integrated circuits for compact LIDAR, and innovative displays

- **Novel EMR Sources** that are compact, portable, efficient, high intensity, near monochromatic, and widely tunable from THz to hard X-rays

- **Innovative Sensing Technologies for Full Spectrum Situational Awareness** including imaging, CBRNE sensing, and ranging of stationary and mobile targets in multi-band and hyperspectral regimes

- **Unmanned Land and Air Vehicle Technologies** including novel energy sources, lightweight structural and protective materials, real-time sensing technologies, AI applications, air defense measures, and tracking and defending against swarms of unmanned platforms

- **Advanced Warfighter Medicine** for far-forward and battlespace medical care, including disease and wound detection, prevention, and remediation, as well as sensing technologies for human physiological monitoring
Operating Model

- **Basic (6.1) Research** in the physical, biological, and information sciences, with engineering capabilities to enable novel technologies for US military and homeland security applications.

- **Applied (6.2 and 6.3) Research** performed on the MIT campus and with Army and industry partners to facilitate technology maturation.

- **Seed Funding** enabling fast-track exploration and early prototyping of promising new research ideas.

- **MIT R&D Infrastructure** to rapidly engage experts and facilities from across the MIT campus and MIT Lincoln Laboratory providing a critical mass of talent and R&D facilities to solve complex S&T problems.

- **Rapid Transitioning** to accelerate transfer of promising results of on-campus research by partnering with the Army, other US military services, MIT Lincoln Laboratory, industry, and the AFFOA Manufacturing Innovation Institute.

- **R&D Collaborations** formed through substantive, symbiotic partnering with the Army, other US Military Services, MIT Lincoln Laboratory, and industry to discover and advance transformative technology solutions for US defense and homeland security needs.

- **Building on the MIT Ethos of Innovation and Defense R&D** by participating in and leveraging MIT’s culture of entrepreneurship and Defense Research Ecosystem (i.e., academic departments, research labs and centers performing research in support of National defense and homeland security).

- **Performing Non-Classified Research Relevant to Sensitive R&D** with information firewalls at off-campus partners enabling the ISN to perform non-classified research on the MIT campus that supports classified work at extramural locations (e.g., Army, other US Military Services, MIT Lincoln Lab, industry).
People

Headquarters Team

Director
Prof. John D. Joannopoulos
Francis Wright Davis Professor of Physics

Associate Director
Prof. Raúl A. Radovitzky
Raymond L. Bisplinghoff Professor of Aeronautics and Astronautics

Executive Director
Dr. William A. Peters

Outreach and Communications Director
Franklin E.W. Hadley

Assistant Director of Administration and Finance
Josh Freedman

Principal Research Scientist
Dr. Ivan Celanovic

Principal Research Scientist
Dr. Steven Kooi

Laboratory and Facilities Manager
Amy Tatem-Bannister

Electron and Surface Microscopy Instrumentation Specialist
Nicole E. Bohn

Research Specialist/SDC Coordinator
Kurt Keville

Research Support Associate
Donna Johnson

Finance Assistant
Maureen Caulfield

Executive Administrative Assistant
Marlisha McDaniels

Affiliated Faculty
Each year, between 25 and 50 MIT faculty members participate in ISN research. These faculty members hail from 14 academic departments and centers, making the ISN one of the most scientifically diverse research organizations at MIT.

Post-Docs and Students
The ISN provides an intellectual home to some of the world’s most talented post-doctoral associates and graduate students. More than 100 post-docs and students participate actively on ISN projects. In total, nearly 500 MIT researchers have access to utilize the ISN’s extensive equipment inventory and laboratory space.

Army Visiting Scientists
While the majority of people working at the ISN are faculty, post doctoral associates, students, and staff of MIT, the ISN is also pleased to host a number of visiting scientists and researchers from the US Army science and technology communities. Current appointments at the ISN include:

Dr. Yassine Ait-El-Aoud, CCDC Soldier Center
Dr. Stephen Bartolucci, Jr., CCDC Armament Center
Mr. Ronald Davis, CCDC Army Research Laboratory
Dr. Christopher Doona, CCDC Soldier Center
Dr. Michael Ghebrebrhan, CCDC Soldier Center
Dr. Alex Hsieh, CCDC Army Research Lab
Dr. Robert Jensen, CCDC Army Research Lab
Dr. Joshua Maurer, CCDC Armament Center
Dr. Charlene Mello, CCDC Soldier Center
Dr. Richard Osgood III, CCDC Soldier Center
Dr. Eric Wetzel, CCDC Army Research Laboratory

Facilities

Headquarters
The ISN maintains more than 40,000 square feet of space in a dedicated facility located in Cambridge’s Technology Square. Approximately 500 registered users from across MIT have access to ISN facilities that include wet and dry labs, computer clusters, and mechanical testing and research instrumentation, including equipment for low- and high-rate mechanical characterization of the dynamic response of materials, electron microscopy, and femtosecond laser spectroscopy.
Collaborators

**Army**

Army research 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). The ISN has had substantial interactions with many Army science and technology laboratories and centers, most commonly with centers of the Combat Capabilities Developments Command (CCDC), including:

- CCDC Armaments Center
- CCDC Army Research Laboratory
- CCDC Aviation & Missile Center
- CCDC C5ISR Center
- CCDC Chemical Biological Center
- CCDC Ground Vehicle Systems Center
- CCDC Soldier Center

Other Army research collaborators include:

- US Army Corps of Engineers
- Program Executive Office - Soldier
- US Army Medical Research and Development Command
  - US Army Institute of Surgical Research
  - US Army Medical Research Institute of Infectious Diseases
  - US Army Research Institute of Environmental Medicine
  - Walter Reed Army Institute of Research

**Industry**

Industry partners are critical to the ISN Mission, helping turn innovative results of basic research into real products and scale them up for affordable manufacture in the quantities needed by end users. ISN industry partners have included:

- CIMIT
- Dow Corning
- DuPont
- FLIR Systems
- General Atomics
- W.L. Gore and Associates
- Honeywell
- JEOL USA
- Lockheed Martin
- Mine Safety Appliances
- Nano-C
- Nike
- Northrop Grumman
- QD Vision
- QinetiQ North America
- Raytheon
- Total American Services
- Triton Systems
- Veloxint
- VF Corporation
- Xtalic
- Zyvex

**Other DoD, Government, and Academia**

- Camp Roberts
- Deployed Warfighter Protection Program
- National Intrepid Center of Excellence
- Naval Postgraduate School
- Naval Sea Systems Command
- US Air Force
- US Special Operations Command
- Walter Reed National Military Medical Center
- US Department of Agriculture
- US Food and Drug Administration
- MIT Lincoln Laboratory
- Institute for Collaborative Biotechnologies
- Howard University
- City College of New York
ISN research is organized into three Strategic Research Areas (SRAs), representing the most fundamental subject areas for scientific inquiry at the ISN. SRAs are designed to address broad strategic challenges facing the Soldier, and are subdivided into specific Projects.

Strategic Research Area 1: Soldier Protection, Battlefield Care, and Sensing

SRA-1 focuses on studies to develop lighter weight, stronger materials to protect the Soldier and Soldier-augmenting platforms and systems from mechanical damage owing to blast waves, ballistic impacts, and mechanical vibrations, using various mechanisms of energy absorption including phase transitions and material deformation. Specific materials of interest include molecular composites, organic polymers, superelastic nanocrystalline metal alloys and ultra-high strength ceramic formulations. This SRA includes research to elucidate how materials fail under high rate mechanical loads. This work provides new understanding of how to design and make new types of lightweight, durable, high strength materials, on how to reliably test protective materials under simulated battlefield conditions and how to interpret the results of these tests to obtain further insights to improve protective materials. One project examines the use of packed granular particles of shape memory ceramic materials to dissipate energy through inter-particle friction and intra-particle martensitic phase transformations with interest in applications to vibrational damping. Another project features basic research on three different nanomaterials to arrest bleeding in battlefield wounds that cannot be treated by traditional methods of macro-compression, including use of injectable hemostats to counter the vexing problem of internal bleeding. Another project focuses on novel means to protect the Soldier against infections. The approach is to safely intervene in the human immune system through the design of novel lymphoid- and leukocyte-targeting nanomaterials that concentrate adjuvant compounds and immunomodulators in immune cell populations to respectively enhance prophylactic vaccines and anti-microbial therapies.

- Project 1.1: Advanced Multiscale Methods for Modeling of Fracture in Novel Nanomaterials
- Project 1.2: Shock Mitigating and Reinforcing Molecular Nanocomposites
- Project 1.3: Design & Testing of Polymers for Improved Soldier Protection
- Project 1.4: Superelastic Granular Materials for Impact Absorption
- Project 1.5: Rapid Hemostasis for the Treatment of Incompressible Wounds
- Project 1.6: Empowering Future Vaccines & Immunotherapies with Nanotechnology-Based Adjuvants
**Strategic Research Area 2: Augmenting Situational Awareness**

SRA-2 concentrates on providing the Soldier and Soldier platforms with the next level of capabilities for secure communications, multi-faceted situational cognition and visualization, and invulnerability to enemy detection and potentially for some cases, immunity to enemy EMP and spoofing technologies. The approach is an in depth examination of diverse segments of the EM spectrum currently under-exploited owing to inadequate scientific understanding of the basic physics of novel electronic, optical, and electromagnetic phenomena, or the unavailability of efficacious materials and devices to capitalize on recent progress in this understanding. For example, one project performs experimental and modeling studies to develop materials and devices that will bring hyperspectral resolution to thermal- and mid-IR imagers based on graphene and thereby produce a fully functional hyperspectral focal plane array. To tackle a longer wavelength domain a different project focuses on providing fundamental understanding of field-enhanced electroluminescence in quantum dots to enable up-conversion of LWIR and THz radiation to emissions in the visible. A third project features systematic studies of nanoplasmonic phenomena that enable non-intuitive shrinking of light waves with potential applications to compact radiation sources from THz to X-rays, secure communications, and more powerful obscurant particles. Another project seeks to synthesize novel mechano-optic, electro-optic and thermo-optic fibers that can be used to enable high bandwidth communications and reflectivity management of Soldier clothing and platforms. Finally, SRA-2 includes *in situ* studies of electrode-electrolyte interfaces of an operating solid-state lithium ion battery to gain new fundamental understanding of the battery chemistry to improve the power density and shelf life of these power sources used in diverse equipment for Soldier communications, ISR, etc.

- Project 2.1: Uncovering Chemical Stability & Charge Transfer Mechanisms at Electrode-Electrolyte Interfaces
- Project 2.2: Mid- & LW-Infrared Detector Arrays on Flexible Substrates
- Project 2.3: Room Temperature LWIR-THz Detection via E-Field Enhancement-Induced Quantum Dot Up-conversion
- Project 2.4: Particulate Fluid Fiber Processing for Fabric Communications
- Project 2.5: Nano-Plasmonics for Soldier Applications

**Strategic Research Area 3: Transformational Nano-Optoelectronic Soldier Capabilities**

SRA-3 primarily focuses on understanding fundamental optical, electronic and transport/reaction phenomena in nanostructured materials and learning how to apply these phenomena to enable major advances in portable power, communications, signal processing and detection. One project seeks to harness non-Planck thermal radiation spectra from photonic crystal surfaces and near-field surface emission phenomena to provide compact thermophotovoltaic (TPV) and TPV/thermoelectric solid state electric power generators in the 1-100 W range. Another project studies fundamental mechanisms of photon transport in 3D and 2D materials to enable 2D optical integrated circuits for LIDARs, displays, communications and ultra-fast architectures for neuromorphic, optical deep learning computing architectures. A third team capitalizes on unusual optical resonances in condensed matter arising from Weyl points, other exceptional points, and stable topological bound states within the continuum to advance the state-of-the-art in high power IR and THz lasers for applications to amplifiers, spatial modulators, optical sensing and optical image processing. Another project combines first principles and analytical studies with novel device design and materials synthesis to explore use of topological phenomena (both photonic and electronic) in novel communications, signal detection and signal processing. The fifth project works to establish the basic principles to eventuate multi-scale 3D printing of high functionality fiber devices through synergistic integration of thermal fiber device drawing with 3D printing of the material fed to the draw tower. Objectives of this project are to enable: (a) recursive-manufacturing processes able to introduce nanoscale features into macroscale products in a highly controlled manner; (b) by understanding fluid instability growth rate, new paradigms for creating solid state multimaterial “inks” for conversion into or functionalization of fibers; and (c) the capability to create non-equilibrium micro- and nanostructured multi-material solids of unusual shapes (e.g. Janus and beach ball-like spherical particles) within fibers through capillary breakup of multimaterial fiber cores.

- Project 3.1: Solid State Power Generation at Millimeter Scales
- Project 3.2: Photonic Integrated Circuits for LIDARs, Displays & Low-Power Computing
- Project 3.3: Nanophotonics Enhanced Systems for the Soldier
- Project 3.4: Applications of Novel Topological Phenomena
- Project 3.5: Novel Multimaterial Inks for Multiscale 3D Device Printing
Select Research Accomplishments

Protecting 2D Materials from Corrosion:
Two-dimensional materials such as graphene and hexagonal boron nitride show tremendous promise for novel electronic and optical applications, but their tendency to rapidly corrode in oxygen and water vapor has limited their usefulness. Existing protective coatings are toxic, expensive, and permanent. Now, an international team of researchers including Prof. Jing Kong has developed a coating technology that obviates each of these problems. This safe, inexpensive, removable surface treatment could extend the lifetimes of such 2D materials by a factor of 100.

Overcoming Drug Resistance with Engineered Viruses:
Professor Timothy Lu demonstrated the ability to program bacteriophages to seek out and kill various strains of E. coli. Because they work by different methods than antibiotics, they are less likely to promote drug resistance and have the potential to overcome some of the resistances that have already developed. Lu and members of his Synthetic Biology Group have been working to engineer viral “scaffolds” that can be rapidly edited to seek out different targets.

3D Printing with Multimaterial “Ink”:
A team led by ISN Director Prof. John Joannopoulos and MIT professor and Prof. Yoel Fink has succeeded in creating a multimaterial feedstock that can be used in a minimally modified 3D printer to generate objects that already have optoelectronic devices embedded within them. This new capability could eventually allow engineers to design objects and systems that have sensors and power systems incorporated directly into their structures.

“Blackest” Material to Date Absorbs >99.99% of Incoming Light:
Prof. Brian Wardle and his team have devised a material that absorbs no less than 99.995% of incoming light, more than ten times that of the next “blackest” material. The material, composed of vertically aligned carbon nanotubes, has been used in an artwork created in collaboration with MIT artist-in-residence Diemut Strebe in which the CNT material covers a polished and faceted yellow diamond, making it appear a flat, featureless void. The material could have other practical applications, in fields ranging from astronomy to military technology.
Non-Abelian Aharanov-Bohm Effect Observed:
A team led by ISN Director and Francis Wright Davis Professor of Physics John Joannopoulos and Prof. Marin Soljačić has successfully instigated and observed for the first time the Aharanov-Bohm Effect in a non-Abelian system. This research, detailed in an article in the journal Science, is at face value somewhat esoteric but could have ultimately have very practical applications in optoelectronics and has the potential to lead to fault-tolerant quantum computing systems.

Robots Designed to Thread Through the Brain:
Prof. Xuanhe Zhao and his team have devised a magnetically-guided robotic fiber that can slip through the tiny blood vessels of the brain and could eventually detect and treat abnormalities along the way, helping lessen the likelihood of potentially fatal events like strokes and aneurysms. These fibers, coated in a slick hydrogel to allow them to navigate fragile vasculature, could someday be functionalized with lasers or other devices in order to enhance their versatility.

Fast-Acting Cancer Drug Skin Patch:
A newly developed patch designed by Prof. Paula Hammond to administer medications for the treatment of the skin cancer melanoma shown promise both in mice and in human skin samples. The centimeter-scale microneedle patch, which can deliver a measured dose of medicine transdermally in just moments, has elicited a strong antibody response in testing. While the demonstration is an exciting and welcome sign of progress, the patch must still undergo testing on both murine and human melanoma samples.

NMR-Based Hydration Status Monitoring:
Led by Prof. Michael Cima, a team of researchers from MIT, Massachusetts General Hospital, and Harvard Medical School, has devised a novel means of assessing a person’s hydration status. Based on the same nuclear magnetic resonance (NMR) phenomena exploited in a magnetic resonance imager (MRI), this new technology returns results both more quickly and more economically than an MRI as there is no need to translate measurements into images. Furthermore, because the magnetic resonance signal in the body obtained in this technology comes exclusively from hydrogen atoms, and almost all hydrogen atoms in the body are from water, the measurements are vastly more accurate than traditional methods of assessing human hydration.
**Electron Beam Atom Manipulation:**
A team of scientists and engineers including Prof. Jing Kong has developed a means to reposition individual atoms, allowing for the control of both their location and their orientation. The technique uses a highly focused beam of electrons to move the atoms, and could be much faster than an existing technique whereby atoms are moved mechanically using the tip of an electron microscope, potentially leading to dramatic advances in materials construction from the atomic scale up.

**Ultrafast, Sub-Attojoule Matrix Multiplication:**
Professors Marin Soljačić and Dirk Englund with their team of students and other researchers have devised a new photonic accelerator chip that uses light rather than electrons to increase the speed and efficiency of the complex matrix multiplication functions necessary for the training of artificial intelligences based on deep neural networks. Fully realized, the system would be capable of achieving gigahertz speeds while consuming sub-attojoule energies per multiply and accumulate (MAC) function. Eventual applications of this technology could abound in areas where the fast, highly accurate and more energy efficient handling of large amounts of data is critical, including imaging, language processing, object identification, drug development, and the control and navigation tasks of driver-less vehicles.

**Metasurface Lenses:**
Metasurface lenses, ultrathin materials that precisely manipulate light by means of minuscule inscribed patterns on their surfaces, are of vital and increasing importance to a number of technical applications. A difficulty with metasurface lenses, conceptually similar to traditional Fresnel or lenticular lenses, is in devising the incredibly exact designs necessary to achieve a desired optical effect. Now, a team of MIT mathematicians led by Prof. Steven Johnson has constructed a new computational method for very quickly defining an optimized arrangement of surface features for increasingly complex functionalities. This technique could lead to advanced sensors as well as improved cellphone cameras.

**Training Hydrogels like Muscles:**
By repeatedly stretching hydrogel materials in water, Prof. Xuanhe Zhao and his team have succeeded in training them to mimic the properties of human skeletal muscle. The process aligns nanoscale fibers within the hydrogels, making them more resistant to fatigue, while retaining their preexisting strength, softness, and high water content. The new advancement could eventually lead to materials that are better suited to biomedical applications like implantable prosthetics, but could also be used for hydrogel-based robotics.
Tuning Color and Thermal Properties Separately:
Traditionally, color and temperature have been inextricably tied. A black car in the sun gets hot, while a white car stays comparatively cool. Now, MIT Research Scientist Svetlana Boriskina has developed a material for which color and heat properties can be tuned separately. Having the flexibility to disregard the thermal impacts of an objects would allow for dramatic changes to the way they are aesthetically designed, and the material could also eventually be used for more effective signature management of military vehicles and equipment.

Using AI to Summarize Scientific Texts:
Using a specially designed neural network, a team of scientists including Prof. Marin Soljačić has devised a way to effectively summarize complex scientific texts into plain English. The process uses a technology known as a “rotational unit of memory” (RUM), which enhances a neural network’s ability to perform certain tasks difficult tasks. Although it was not the team’s initial goal, these tasks bear a fundamental similarity to the way language is processed. The system could eventually impact a variety of fields by allowing for complicated data to be more readily communicated to end users.

Structural Color in Drops of Water:
A team that includes an ISN-affiliated MIT professor has discovered a phenomenon that causes droplets of water lit by white light to produce strongly colored iridescence. Rather than resulting from Mies scattering, which causes rainbows, this coloration is caused by total internal reflection of light inside the droplet. The team was able to model and predict the geometries necessary for specific colors, and was even able to trigger the same style of coloration in 3D printed transparent polymer domes and dots. The team thinks that it may be able to harness the technique to replace potentially harmful dyes, in makeup products, and even in novel color-changing applications.

Improved 2D Patterning and Fabrication:
While potential uses for circuitry enabled by 2D materials continue to increase, a roadblock to their widespread adoption has been the complexity of their manufacture. Now, a team including ISN-affiliated MIT professors has developed a new technique that greatly simplifies the process by depositing 2D materials directly onto patterned substrates, while also allowing the substrates to be reused rather than discarded. A field-effect transistor created using the new process has already demonstrated performance comparable with devices created using earlier methods. Research is planned to improve spatial resolution of the fabrication technique.
Cleaner Graphene:
Standard methods of transferring graphene from its growth substrate to its destination substrate involve coating it in a polymer that must then be removed once the graphene is settled. Unfortunately, this process regularly imparts flaws and wrinkles that degrade the graphene’s electrical performance. Now, a new process developed by Prof. Tomás Palacios that uses paraffin wax shows promise to dramatically reduce these imperfections. Replacing a coating of polymethyl methacrylate with one of wax has led to a simplified transfer and also to reduced wrinkling and minimized surface defects. Future plans include further reducing flaws and expanding the technique to other 2D materials.

Harvesting Electricity from WiFi Signals:
A team of MIT researchers including Prof. Tomás Palacios working with scientists from the CCDC Army Research Laboratory has invented the first fully flexible device to harvest the energy of WiFi signals and convert it to usable electricity. Devices for converting AC electromagnetic waves into DC electricity, known as “rectennas,” have existed for decades, but advances in their materials are making them much faster, allowing for the new devices to cover broader frequency ranges, including the range of WiFi. Full foldability could allow for their incorporation into a much greater variety of systems.

Implosion Fabrication:
By reversing the “expansion microscopy” technique that they conceived just a few years ago, a team led by ISN-affiliated MIT faculty has devised a groundbreaking “implosion fabrication” process. This new technology uses a hydrogel as a scaffold to which “anchors” have been connected through a two-photon microscopy process. A vast array of materials can be attached to the anchors. When acid is used to shrink the hydrogel scaffold, the anchored structure contracts with it, shrinking by as much as 90% in each dimension for a volume that is one thousandth that of the original. The research team foresees specialized lenses as an initial route of productization, potentially leading to improved cell phone cameras, but believes more complex systems could be made in the future as fabrication resolution improves.

Cataloguing “Antimolecules”
Tiny defects, or “holes,” that form in sheets of 2D material can change its electronic, magnetic, and mechanical properties. However, with some 400 billion possible arrangements resulting from the loss of just 30 atoms in a lattice, mapping them all out is unfeasible. Now a team led by an ISN-affiliated MIT professor has largely solved this issue by cataloguing and describing those holes, which the team calls “antimolecules,” that are most likely to appear under a given set of circumstances as opposed to the overwhelming set of theoretically possible configurations, most of which will never be found in experiments. Having a more realistic appraisal of antimolecule configurations could affect a variety of potential applications from barrier membranes to filtration systems to DNA sequencing.
Microfluidic Fibers:  
Microfluidics is vital to chemical and medical research, but traditional configurations are limited by the method of their fabrication. There are restrictions on device size, channel shape, and the ability to incorporate materials or sub-devices. By incorporating microfluidics into fiber devices, an ISN-affiliated MIT faculty member and his team have overcome these constraints. Systems resulting from the new technique can be hundreds of meters long with a variety of cross-sections and the ability to easily integrate internal devices and materials. Already, as a proof of concept, the team has fabricated a long fiber device capable of sorting live cells from dead, with more configurations planned.

Mass-produced, Cell-sized Robots:  
A key to the practical use of some types of robotics is the ability to produce them economically and at scale. A new process called “autoperforation,” developed by a team of ISN-affiliated researchers takes advantage of the natural brittleness of graphene and directs the material’s line of fracture along a desired path to create microscopic devices that the team has dubbed “syncells.” Multitudes of these devices, as small as human red blood cells, could be used to monitor conditions in environments as different as a human blood vessel and an oil pipeline.

Understanding Microparticle Impact:  
Understanding microparticle impact is crucial to a number of applications. Scenarios ranging from desert sandstorms to micrometeorite impact on satellites can weaken materials, while the accumulation of sprayed coatings is a common industrial technique used to strengthen materials. Despite a basic need, we lack a fundamental understanding of what happens when particles strike. Now, an ISN team featuring Profs. Keith Nelson and Chris Schuh, using a purpose-built ultra-high-speed camera, has created an experimental array that for the first time allows the imaging of microparticle impact as it happens, helping researchers better understand both ablation and accretion.

Quiet, Light Battlefield Power Sources:  
Recent developments in electronics have helped provide the Soldier with an unprecedented array of battlefield capabilities, but this has also increased the need for reliable, lightweight power sources. Batteries often add as much as 20 lbs. to a Soldier’s gear, but ISN Principal Research Scientist Ivan Celanovic and his team are developing an alternative: a portable thermophotovoltaic generator. Still in bench-level testing, the system already has a better power-to-weight ration than batteries, and could have an array of applications in both the military and consumer markets.
**Optoelectronic Fiber Devices:**
Despite changes to the Soldier’s uniform that increase comfort, enhance ergonomic functionality, and make camouflage more appropriate to an environment, adding capabilities has long required the addition of external devices. In a radical advance to fiber and fabric technology, ISN researchers have devised and manufactured a variety of multifunctional fibers that are comprised of the fundamental ingredients of optoelectronic devices that could one day be incorporated into garments and other fiber constructs. This ISN science was deemed so promising that it formed the basis for Advanced Functional Fabrics of America (AFFOA), a DoD Manufacturing Innovation Institute that is part of the Manufacturing USA network and counts frequent ISN partner Natick Soldier Systems Center as a founding member.

**Nanostructured Metal Alloys for Lightweight Protection:**
Thanks to ISN faculty and startup Veloxint, working with CCDC Army Research Laboratory and Armaments Center, advances in powder metallurgy have allowed for the creation of highly tailored nanocrystalline refractory metal alloys that combine unprecedented strength - in some cases several times that of traditional alloys - with easy, efficient processability and even 3D printability. Despite the daunting weight of some alloys, these advances have led to the potential for reduced weight protection due to the fact that less material can achieve the same standard of security.

**Quantum Dot-enabled Hyperspectral Imaging:**
Valuable information can be acquired by imaging outside the visible range of wavelengths. Hyperspectral imaging, the goal of which is to gather data from across the electromagnetic spectrum, has applications in fields including medicine, agriculture, astronomy, chemistry, and surveillance. Work by ISN faculty with colleagues at Raytheon and CCDC C5ISR’s Night Vision and Electronic Sensors Directorate has advanced the science and technology of hyperspectral imaging by replacing traditional optics - lenses and filters in complex configuration and precise alignment - with quantum dots capable of performing the same function at reduced size, weight, and expense.

**UV Visualization with IR Imagers:**
In recent decades, imaging outside the visible spectrum has become an increasingly important military capability. Infrared goggles have become a standard part of the Soldier’s toolkit, allowing enhanced visibility in darkness. Similarly, UV tagging is useful for covertly identifying objects, locations, and individuals. Now, advances by ISN faculty and colleagues at Raytheon and the CCDC Army Research Laboratory have the potential to combine these two capabilities in one device. Quantum dots have been developed that when applied to a focal plane array downshift from UV to IR, allowing a UV image to be viewed on an IR device. Additionally, the possibility of modulating the incoming UV signal is being explored, adding the ability to perform line-of-sight communications and information transmission in the ultraviolet regime.
**Fluid-like Electron Flow:**
An ISN-affiliated faculty member, in collaboration with investigators at the Weisman Institute of Science, has devised a way to demonstrate viscous behavior of electrons in sheets of graphene. Previously considered impossible, this fluid-like behavior of electrons leads to “eddies” and “whirlpools” of current, and could result in unforeseen possibilities in sensing technology.

**Nanostructured Shape Memory Alloys:**
Based on a bamboo-like oligocrystalline nanostructure pioneered by ISN researchers working with the CCDC Armaments Center, ISN-faculty startup Kinalco’s unique copper-based shape memory alloys (SMAs) boast extreme performance but come at a substantially reduced cost compared to the currently standard NiTi-based SMAs. They offer ultra-high dampening; excellent fatigue life, conductivity, and thermal actuation; they can be electrically actuated; and they can be soldered and welded. Kinalco’s SMAs are in development for a number of civilian and military applications, including cabling, orthopedics, electronic connectors, and even clothing.

**Tough, Strong Nanoscale Fibers:**
Working with CCDC Soldier Center scientists, ISN-affiliated MIT faculty have developed a new process to produce nano-diameter scale fibers that are remarkably strong and tough. The new process avoids many of the trade-offs of previous production methods, which would produce strength at the expense of ductility and vice versa. Inexpensive and easy to produce, these new fibers could lead to the development of improved body armors and composite materials.

**CVD-Enabled Wires for Advanced Microchip Design:**
Over the past several decades, increases to the speed and computational power of microchips have become expected. Recently, however, chip manufacturers have begun to approach fundamental limits to the size of essential connective wires. Now, a process developed by ISN faculty in collaboration with scientists at the University of Chicago and Argonne National Laboratory that combines standard photolithography with a new chemical vapor deposition-based technique not only allows for the fabrication of smaller, denser wires but also adds the potential for novel complex architectures and patterns.
Implantable Biosensor Allowing Real-time Monitoring:
While modern medicine offers a variety of treatment options for battling cancer, it lacks a way to monitor the effectiveness of those options in real-time. An ISN-affiliated MIT faculty member, working with USARIEM, has developed an implantable sensor that can continuously, wirelessly send data to clinicians, allowing them to adjust treatment in order to maximize efficiency while minimizing adverse side-effects.

A Colloidal Quantum Dot Spectrometer:
Optical spectrometers are fundamental tools for materials analysis across many scientific fields. Challenges exist, however, in making these devices small, simple, and inexpensive. ISN faculty have devised a possible solution to these challenges. By using a planar array of quantum dots, the device obviates the need for complex optics and multiple filters, allowing different spectra to be distinguished using a single filter and a single detector.

New Test Array Reveals that PUU Polymer Strengthens on Impact:
A collaborative team of ISN and CCDC Army Research Laboratory scientists, utilizing a unique experimental setup, discovered that high performance polymers made of poly(urethane urea) (PUU) display hyperelastic behavior when impacted by silica microparticles at extremely high speed. The hyperelastic response occurs when the material is significantly deformed in a very short amount of time, on the order of 1/100,000,000 of a second. The PUUs also show signs of rebounding from the deformation, unlike the response seen in other materials like cross-linked polydimethylsiloxane elastomers and polycarbonates. The researchers hope to use these discoveries to help design advanced composites for future Army combat helmets as well as face, body, and extremity protection, and even civilian gear such as athletic equipment.

Optical Neural Circuits:
ISN-affiliated MIT faculty members have created a programmable nanophotonic processor that may provide a dramatic advancement in so-called “deep learning” computer systems. By utilizing optical circuits rather than traditional electronics, researchers predict that “[this] chip, once you tune it, can carry out matrix multiplication with, in principle, zero energy, almost instantly.”

Implantable Biosensor Allowing Real-time Monitoring: While modern medicine offers a variety of treatment options for battling cancer, it lacks a way to monitor the effectiveness of those options in real-time. An ISN-affiliated MIT faculty member, working with USARIEM, has developed an implantable sensor that can continuously, wirelessly send data to clinicians, allowing them to adjust treatment in order to maximize efficiency while minimizing adverse side-effects.
A New Way to Generate X-Rays:
ISN researchers have led a team in predicting a new way to create x-rays by bombarding graphene with photons, creating plasmons (discrete oscillations in surface electron density). The plasmons, in turn, could be used to generate pulses of radiation ranging from infrared to x-ray wavelengths. These systems could be used to create chip-based UV light sources and high-powered, and extremely accurate, bench-top x-ray devices.

“Motors” Driven by Light:
A team led by an ISN-affiliated MIT faculty member has predicted through simulation a Janus particle that, unlike previously available Janus particles, can be manipulated with non-specialized light rather than heavily process laser light. The team has begun working to experimentally validate their theories. Ultimately, this work could have applications in a number of areas, including the medical field.

Janus Emulsions for Food Safety Testing:
By utilizing Janus emulsions - tiny droplets composed of two hemispheres of different materials - an ISN faculty member has developed a new sensing system for food-borne pathogens such as *E. coli*. The particular Janus droplets used have one half that binds to bacteria, creating a clear visual signal that can be detected by a cell phone, other imager, or the naked eye.

Understanding Impact-bonding of Metals:
ISN-affiliated MIT professors have collaborated on two different papers related to their work to better understand the mechanics of sprayed metal impacting a surface. The first paper details a revolutionary means of imaging the team’s experiments at high speed, while the second could affect future 3D printing and coating technologies.
3D-Printed “Tattoo” Made of Living Cells:
A team including ISN-affiliated faculty has devised a new 3D printing technique that uses an ink made of living cells. The tattoo has been designed so that it is responsive to certain chemicals. Future developments could include engineering the “tattoos” to produce medicines, and allowing them to be used in implantable and ingestible devices for the detection of toxins and the administration of medications.

Understanding Electron Conductivity in Polymers:
Conjugated polymers have long been considered promising materials for use in a variety of electronics applications, but a lack of fundamental understanding regarding how electrical conduction works in such materials, and an inability to predict their behavior, proved a stumbling-block to researchers. Work by ISN-affiliated MIT faculty and students, in collaboration with scientists at Brookhaven National Laboratory, has provided a new level of understanding of these areas, and could result in both more advanced research and new transparent, flexible, highly conductive polymeric materials.

Nano-Enabled Incandescent Lighting:
Long considered problematically inefficient, incandescent bulbs nonetheless were the standard for decades. More recently, however, more efficient alternatives such as LEDs and compact fluorescents have replaced incandescent bulbs. Now, a team led by ISN researchers has demonstrated an incandescent bulb that not only improves upon the efficiency of previous incandescents but also fluorescent and LED bulbs.

The Experimental Observation of Weyl Points:
Despite their prediction by noted physicist and mathematician Hermann Weyl in 1929, building on earlier work by English physicist Paul Dirac, “Weyl points” – massless subatomic particles - escaped observation for some 86 years. In early 2015, a team of scientists led by ISN faculty announced the detection of Weyl points through a process relying upon a gyroid photonic crystal designed to produce such particles. While the ramifications of the observation of Weyl points are not yet known, they could lead to improved high-power single frequency lasers and optical materials that provide angular selectivity for filtering light regardless of its 3D angle of incidence.
**Self-Curing Composite Materials:**
Composite materials made up of many layers of polymers are used in an array of applications, but a step in their manufacturing - baking them in giant ovens - makes the process far less efficient than it could be. Advances by ISN researchers led by MIT Prof. Brian Wardle allow for the heating process to be performed by a film containing carbon nanotubes, and that film can be included in the composite material itself. Not only could this process obviate the need for the industrial oven, it could decrease the energy needed to bake the material, as the heat is sent directly where it is needed.

**Transparent Displays Using Nanoparticle Scattering:**
With the ubiquity of electronic devices, the need for transparent display technologies will only continue to grow. Currently available transparent displays suffer from issues including limited angles of visibility, low transparency, and high cost. ISN researchers, working with scientists from Harvard University and the CCDC Chemical Biological Center, have pioneered a new technology that may alleviate many of these problems by embedding nanoparticles that only scatter light of a particular wavelength in a highly scalable polymer sheet, creating a low cost monochromatic display.

**Water-based Electronic Bandages:**
ISN researchers led by Prof. Xuanhe Zhao have developed a hydrogel material that could lead to future bandages that can be equipped with electronic devices, including sensors, lights, and drug-delivery tools. For more invasive treatments, these materials could also be implanted inside a patient’s body.

**Angular Selectivity of Light Transmission:**
In a breakthrough in the challenge to control the transmission of light through a medium based on the light’s incident angle rather than its frequency or polarization, a team lead by ISN and other MIT researchers working with CCDC Soldier Center have theoretically described and experimentally demonstrated a means to enable transparency at a specific angle and reflectivity at all other angles, potentially leading to advances in fields as varied as personal computing, smart optical devices, and astrophysics.
Efficient Wireless Non-Radiative Power Transfer over Distance:
Providing wireless power over distance at better than 90% efficiency, the WiTricity system utilizes magnetic resonance to safely transfer energy. WiTricity continues to develop this technology for use with vehicles, medical devices, and Soldier equipment and applications, as well as a host of other purposes.

Novel Nanostructured Lipid Shell Constructs for Drug Delivery:
Interbilayer-crosslinked multilamellar vesicles (ICMVs) are remarkable drug-delivery particles that help minimize the common problem of medications leaching out into the body before they can reach targeted locations in cells. Used to deliver a malaria vaccine developed with the Walter Reed Army Institute of Research, ICMVs resulted in an immune response that was 10 times that of other delivery methods but required only 1/100th the quantity of vaccine. Further developed by ISN-faculty startup Vedantra, ICMVs are being designed to contain medications for other illnesses.

Quantum Dot LEDs:
Producing narrow-bandwidth red, green, and blue light that generate very pure, saturated images, quantum dot (QD) LEDs developed by ISN-faculty startup QD Vision have been used in displays for entertainment and computing purposes by many of the most respected brands in the electronics industry, and the company was recently acquired by global electronics giant Samsung.

Powered Rope Ascension Technology:
Originally developed by a Soldier Design Competition team that subsequently incorporated as Atlas Devices, the Atlas Powered Ascender is a lightweight, battery-powered device that provides as much as 1400 feet of vertical lift up a fixed line and boasts a lifting capacity of as much as 600 lbs. Applications are varied in both the civilian and military communities.

Fracture Dynamics Code:
Enabling large-scale computer simulations of material fracture and structural failure in 3D, ISN-developed discontinuous Galerkin-based ΣMIT (“SUMMIT”) codes from faculty startup ParaSim are used at CCDC Army Research Laboratory, PEO-Soldier, CCDCC Soldier Center, and CCDC Ground Vehicle Systems Center for the analysis of protection systems and injury biomechanics.

Unique Nanoscale Kinematic Alloy Materials:
Based on a bamboo-like oligocrystalline nanostructure, ISN-faculty startup Kinalco’s unique shape memory alloys (SMAs) are made largely from copper, and their ultra-high performance comes at a substantially reduced price when compared to the currently standard NiTi-based SMAs. Kinalco’s SMAs are in development for a number of civilian and military applications, including cabling, device and industrial actuators, orthopedics, electronic connectors, and even clothing.

Hollow Fiber for Guiding CO₂ Laser Light Through Air:
Based on ISN-developed hollow cylindrical photonic crystals that can safely guide high-powered laser light through their cores, the OmniGuide high performance CO₂ laser fiber has been used in hundreds of thousands of procedures at more than 1,000 VA and civilian hospitals, and was supported and funded since its theoretical inception by the US Army.
Multimaterial Multifunctional Fiber Devices:
ISN-developed optoelectronic fiber devices became a foundational science for Advanced Functional Fabrics of America (AFFOA), the new, multimillion dollar DoD Manufacturing Innovation Institute and member of the Manufacturing USA network. AFFOA seeks to facilitate the transformation of fabrics and textiles into highly enabled, functional devices and platforms.

Thin Polymer Films for Drug Delivery:
Novel coatings that promote wound-healing developed by ISN-affiliated MIT researchers have been transitioned to startup LayerBio. Treated bandages can provide sequential release of medications including hemostatics, antibiotics, and analgesics directly to an injury through controlled degradation of polymer thin films. The films can also be applied subcutaneously for such purposes as tendon-repair.

Nanostructured Photonic Crystal LEDs:
Luminus Devices’ PhlatLight high performance LEDs, reliant upon intrinsic ISN-developed photonic crystals, are currently used in numerous products in general lighting, projection, transportation, entertainment, and other fields.

Advanced Optical Nanoparticle Materials:
ISN-developed nanoparticles that scatter light with an extremely wide cross-section have been transitioned to MIT startup company Lux Labs for implementation in transparent displays. Lux Labs’ ClearBright technology is a transparent film that boasts high contrast and high resolution in conjunction with high transparency and a 360° viewing angle. The film will work with most professional- or consumer-grade projectors and can be retrofit to any existing window.

Defended the ACH before Senate Arms Services Committee Senior Staff:
Cutting-edge biofidelic computational studies of blast impacts on a human head with and without the Advanced Combat Helmet (ACH) categorically refuted earlier National Laboratory studies indicating the potential for increased injury to Soldiers and warfighters wearing the ACH.

Thermodynamically Stable Nanocrystalline Alloys:
ISN-developed stable grain boundary-engineered metal alloys from Xtalic can provide dynamically tuned properties – like the strength of steel with the weight of aluminum, or dramatically improved corrosion and wear resistance – for use in a vast array of civilian and military equipment.

Spray Assisted Layer-by-Layer Thin-Film Deposition:
Svaya Nanotechnologies, responsible for the world’s first LbL-functionalized product to market at industrial volume, specialized in a molecular self-assembly process that produces highly uniform films on large-area substrates. Svaya has provided a free LbL coating unit to the CCDC Soldier Center for laser eye protection material development, and the LbL technology has been acquired by global science giant 3M.

Nanostructured Photonic Crystal LEDs:
Luminus Devices’ PhlatLight high performance LEDs, reliant upon intrinsic ISN-developed photonic crystals, are currently used in numerous products in general lighting, projection, transportation, entertainment, and other fields.

Spray Assisted Layer-by-Layer Thin-Film Deposition:
Svaya Nanotechnologies, responsible for the world’s first LbL-functionalized product to market at industrial volume, specialized in a molecular self-assembly process that produces highly uniform films on large-area substrates. Svaya has provided a free LbL coating unit to the CCDC Soldier Center for laser eye protection material development, and the LbL technology has been acquired by global science giant 3M.

Amplifying Fluorescent Polymers for Ultrasensitive Explosives Detection:
ISN-developed polymers have become the backbone of the FLIR Fido trace explosives detector, which has been deployed in Iraq and Afghanistan, as well as US airports.

Defended the ACH before Senate Arms Services Committee Senior Staff:
Cutting-edge biofidelic computational studies of blast impacts on a human head with and without the Advanced Combat Helmet (ACH) categorically refuted earlier National Laboratory studies indicating the potential for increased injury to Soldiers and warfighters wearing the ACH.

Advanced Optical Nanoparticle Materials:
ISN-developed nanoparticles that scatter light with an extremely wide cross-section have been transitioned to MIT startup company Lux Labs for implementation in transparent displays. Lux Labs’ ClearBright technology is a transparent film that boasts high contrast and high resolution in conjunction with high transparency and a 360° viewing angle. The film will work with most professional- or consumer-grade projectors and can be retrofit to any existing window.

Multimaterial Multifunctional Fiber Devices:
ISN-developed optoelectronic fiber devices became a foundational science for Advanced Functional Fabrics of America (AFFOA), the new, multimillion dollar DoD Manufacturing Innovation Institute and member of the Manufacturing USA network. AFFOA seeks to facilitate the transformation of fabrics and textiles into highly enabled, functional devices and platforms.

Direct Transition of ISN Research and Technology to Start-up Companies:
28 startups from ISN 6.1 projects, plus an additional 10 startups from the Soldier Design Competition.
ISN / Lincoln Laboratory Soldier Design Competition

The Soldier Design Competition (SDC) was established in 2003 to engage undergraduate students from the Massachusetts Institute of Technology in the activities of the Institute for Soldier Nanotechnologies, and in 2004 was expanded to include cadets from the United States Military Academy at West Point (USMA).

Drawing on the academic, Army, and industry communities that make up the ISN and, through a strategic partnership that began in 2018, with MIT Lincoln Laboratory, the SDC provides students with hands-on experience in the design and prototyping of technology solutions to real world problems in protection and survivability faced by Soldiers, other warfighters, and first responders.

Teams compete by addressing challenges provided by the Army and Marine Corps’ science and technology, acquisitions, and operations communities. A panel of leaders from the Army, industry, and MIT determines winning prototypes. To date, the SDC has engaged more than 400 MIT students and USMA cadets, who have founded more than a dozen startup companies.

The SDC provides a unique opportunity for students to apply their knowledge and creativity to make a difference for today’s Soldier. Teams develop perspective on how modern technology can help the US military, as well as fire fighters, law enforcement officers, and other emergency response personnel. Army mentors provide SDC team members with advice on the military relevancy and technical viability of proposed technology solutions. Finalists are judged according to the technical design practicality, innovativeness, likely military benefit, and logistical supportability of their prototype technology solutions.

SDC teams have wide latitude in choosing their project topics, which do not at all have to be nano-related. Projects on ISR, energy, communications and networking, unmanned vehicles, novel materials, medical monitoring, and many more subjects are all welcome. Topics can be designed to help maximize the creativity and innovativeness of the participating students, but are loosely tied to the Army Modernization Priorities defined in 2017 by GEN Mark Milley, then Army Chief of Staff, and Hon. Ryan McCarthy, then the Acting Secretary of the Army, that have since become the underpinnings for the cross-functional teams that help provide the research structure of the US Army Futures Command.

Visits

Each year the ISN hosts hundreds of visitors for research briefings and tours of ISN facilities. These visitors hail from a variety of sources, including the US Government, US and other military services, industry, and academic institutions across the world. Past visitors have included members of the US Senate and House of Representatives, the Secretary of the US Army, and the Chief of Staff of the US Army.
For More Information

Visit the ISN website at https://isn.mit.edu

If you wish to contact the ISN, please do so by emailing isn@mit.edu.

The mailing address of the ISN is:
Institute for Soldier Nanotechnologies
Massachusetts Institute of Technology
77 Massachusetts Avenue, NE47-4F
Cambridge, MA 02139

If you are a media representative looking for additional information about the ISN, or a representative of a company interested in becoming a member of the ISN Industry Program, please contact Franklin Hadley, ISN Director of Outreach and Communications, at fhadley@mit.edu.
The ISN is supported and administered for the US Army through the Army Research Office (ARO), a part of the Army Futures Command’s Combat Capabilities Development Command (CCDC) and its Army Research Laboratory. The ISN also receives guidance and oversight from the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)).

The ISN is a part of the Massachusetts Institute of Technology in Cambridge, Massachusetts, and is a reporting unit under the MIT Vice President for Research.