JSTO in the News

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Throw to Know

Detoxification by the Yard

DTRA MISSION

DTRA provides cross-cutting solutions to enable the Department of Defense, the United States Government, and international partners to Deter strategic attack against the United States and its allies; Prevent, reduce, and counter Weapons of Mass Destruction (WMD) and emerging threats; and Prevail against WMD-armed adversaries in crisis and conflict.

CHEMICAL AND BIOLOGICAL TECHNOLOGIES DEPARTMENT MISSION

Lead DoD science and technology to enable the Joint Force, nation, and our allies to anticipate, safeguard, and defend against chemical and biological threats.

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Research and Development Directorate
Chemical and Biological Technologies Department
Joint Science and Technology Office
for Chemical and Biological Defense

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Front cover: U.S. Marines with Headquarters Company, Chemical Biological Incident Response Force (CBIRF), conduct practical application drills using the AN/PDR-77 Radiac Set during exercise Arctic Edge 2023 (AE23). CBIRF Marines familiarized themselves with equipment used for detecting and measuring various forms of radiation and hazardous chemical vapors. AE23 is a U.S. Northern Command-led exercise demonstrating the U.S. military's capabilities in extreme cold weather, Joint Force readiness, and U.S. military and local homeland defense commitment to mutual strategic security interests in the Arctic region. (U.S. Marine Corps photo by Staff Sgt. Jacqueline A. Clifford)

Inside cover: A grader points at M8 paper during chemical, biological, radiological, and nuclear training conducted with Army Civilians from the Maneuver Support Center of Excellence. M8 paper is used to test liquid substances for the presence of nerve and blister agents. It is similar to the litmus (pH) paper found in most laboratories that changes color when detecting chemical agents. (U.S. Army photo by Pfc. Joshua Zayas)

Back cover: A Chemical, Biological, Radiological, and Nuclear specialist assigned to the U.S. Army 15th Civil Support Team, Vermont Army National Guard, disassembles an M249 Squad Automatic Weapon. Soldiers had to disassemble and reassemble the weapon while wearing chemical and biological agent protective clothing, known as mission oriented protective posture or MOPP. (U.S. Army photo by Sgt. Matthew Lucibello)

Throw to Know

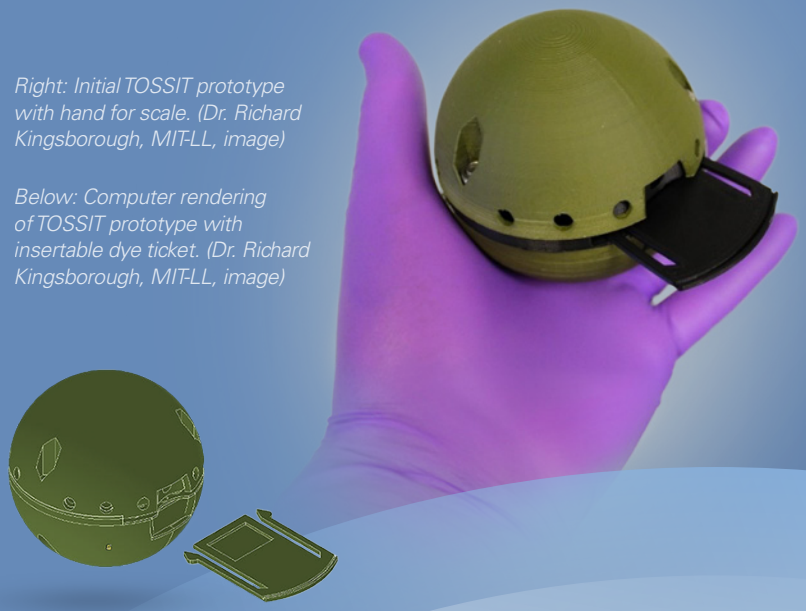
Compact, throwable sensors allow the Joint Force to remotely identify chemical threats in the air.

Advancements in small, chip-based optical readout packages, coupled with low-power electronics and wireless communications modules, have led to developing a hands-free colorimetry-based chemical sensor that effectively acts as self-reading M8 Chemical Detection Paper used to detect the presence of nerve and blister chemical agents as vapor-phase chemical threats.

Colorimetric chemical sensors are some of the simplest and lowest-cost sensors available to the Joint Force today yet are not fully utilized due to ambiguities in visually detecting a color change in the sensing element. Colorimetric papers work well for liquids; the challenge is getting them to work quickly for vapors. Coupling the colorimetric sensing element with an electronic readout results in a much more reliable detection mechanism.

Right: Initial TOSSIT prototype with hand for scale. (Dr. Richard Kingsborough, MIT-LL, image)

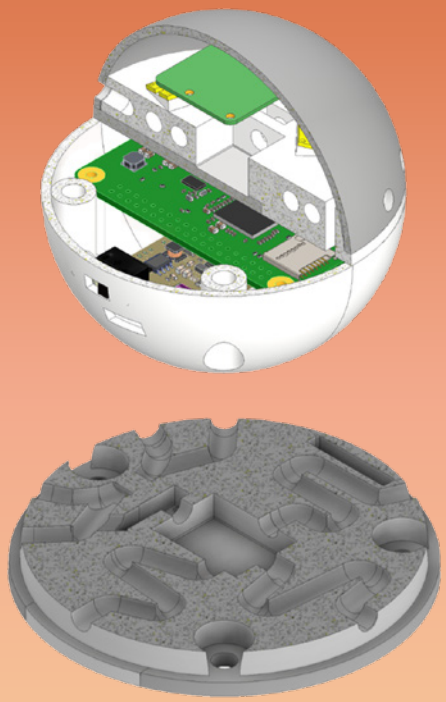
Below: Computer rendering of TOSSIT prototype with insertable dye ticket. (Dr. Richard Kingsborough, MIT-LL, image)



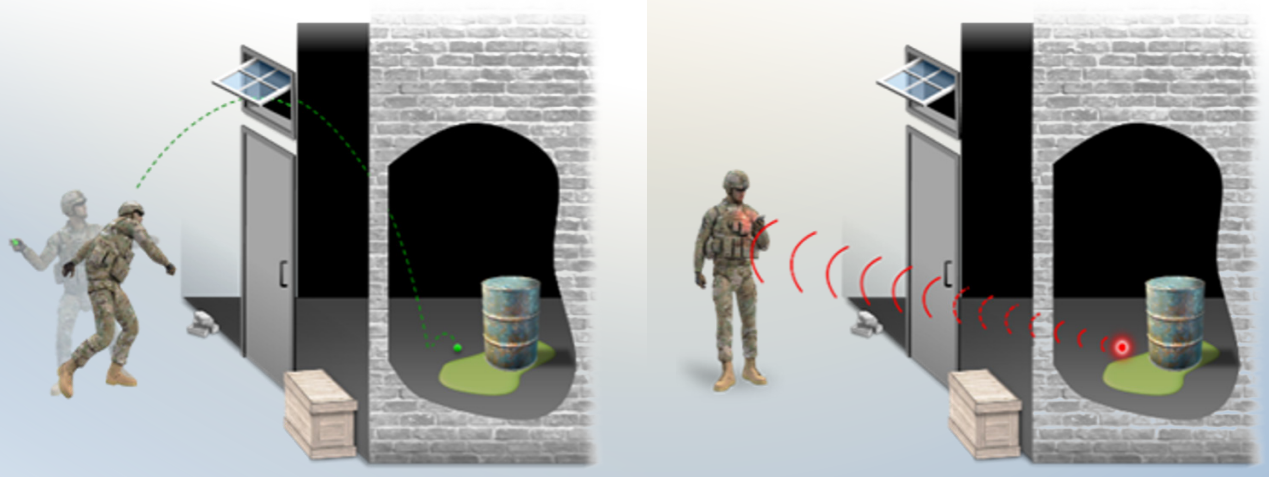
The TOSSIT sensor features a removable and disposable card containing an array of multiple colorimetric dyes, each specific to a different chemical threat or class of threats.

The Defense Threat Reduction Agency's (DTRA) Chemical and Biological Technologies Department in its role as the Joint Science and Technology Office (JSTO) for Chemical and Biological Defense, an integral component of the Chemical and Biological Defense Program, invested with researchers at the Massachusetts Institute of Technology Lincoln Laboratory (MIT-LL) and the U.S. Army Combat Capabilities Development Command–Chemical Biological Center (DEVCOM CBC) to develop a self-contained, throwable, and possibly reusable prototype called TOSSIT—the Tactical Optical Spherical Sensor for Interrogating Threats. TOSSIT can be used by the Joint Force as a remote point vapor sensor to provide early warning of a chemical threat.

To use the TOSSIT, warfighters simply power up the device and the sensor automatically connects to a handheld readout device (currently a smartphone application) using a secure wireless connection. The application lets the end user see the alarm state of the device at any time. In a typical site-assessment mission, the user rolls or tosses the device into a room, and TOSSIT quickly lets the user know if there were chemical threats present by giving out a warning. In addition to chemical threats, the developers have a function that alerts the user to the oxygen level of the enclosed space, as well as the presence of explosive fuel vapors that would make it unsafe to fire a weapon.



Top: 3D rendering showing internal design of the TOSSIT sensor. Bottom: Design of passive air sampling for vapor threats. (Dr. Richard Kingsborough, MIT-LL, image)



A visual concept of TOSSIT's use providing situational awareness to warfighters about potential chemical hazards. (Dr. Richard Kingsborough, MIT-LL, image)

The TOSSIT sensor features a removable and disposable card containing an array of multiple colorimetric dyes, each specific to a different chemical threat or class of threats, and a camera readout to quantify the color change, with shielding from varying ambient lighting conditions. In practice, multiple dyes target the same threat to confirm detection and minimize the chance of false alarms. The dye indicators used to detect the threats come from a menu of traditional indicator dyes, custom-designed and synthesized dyes, and the Self-Indicating Colorimetric inorganic materials pioneered by researchers at DEVCOM CBC.

These data help researchers test the performance of the system as well as set realistic alarm levels to help minimize potential false alarms in the field.

An onboard blower pulls ambient air into the system that moves toward a sampling chamber where it interacts with the colorimetric dyes. An internal imaging device observes the dye card illuminated by multiple white light or ultraviolet light emitting diodes acting as a camera flash. The onboard electronics determine the color of each spot in the dye array and compare it to a baseline value. Color changes outside a prescribed window for each dye trigger an alarm. Which dye displays a color change upon exposure to the ambient sample determines the identity of the chemical being detected.

Prior iterations of sensor and colorimetric indicators have been tested against toxic industrial chemical vapors in the lab and have undergone surety testing against select chemical agent threats. These data help researchers test the performance of the system as well as set realistic alarm levels to help minimize potential false alarms in the field.

The further development of low-size, -weight, -power, and -cost sensors that provide an early warning to chemical threats is an important mission area for DTRA JSTO to reduce the CB risks to the Joint Force in the field. Success in developing TOSSIT may open its use in other mission areas such as perimeter defense using the sensor in unobtrusive packaging as well as wide-area deployment by aerial assets. ●

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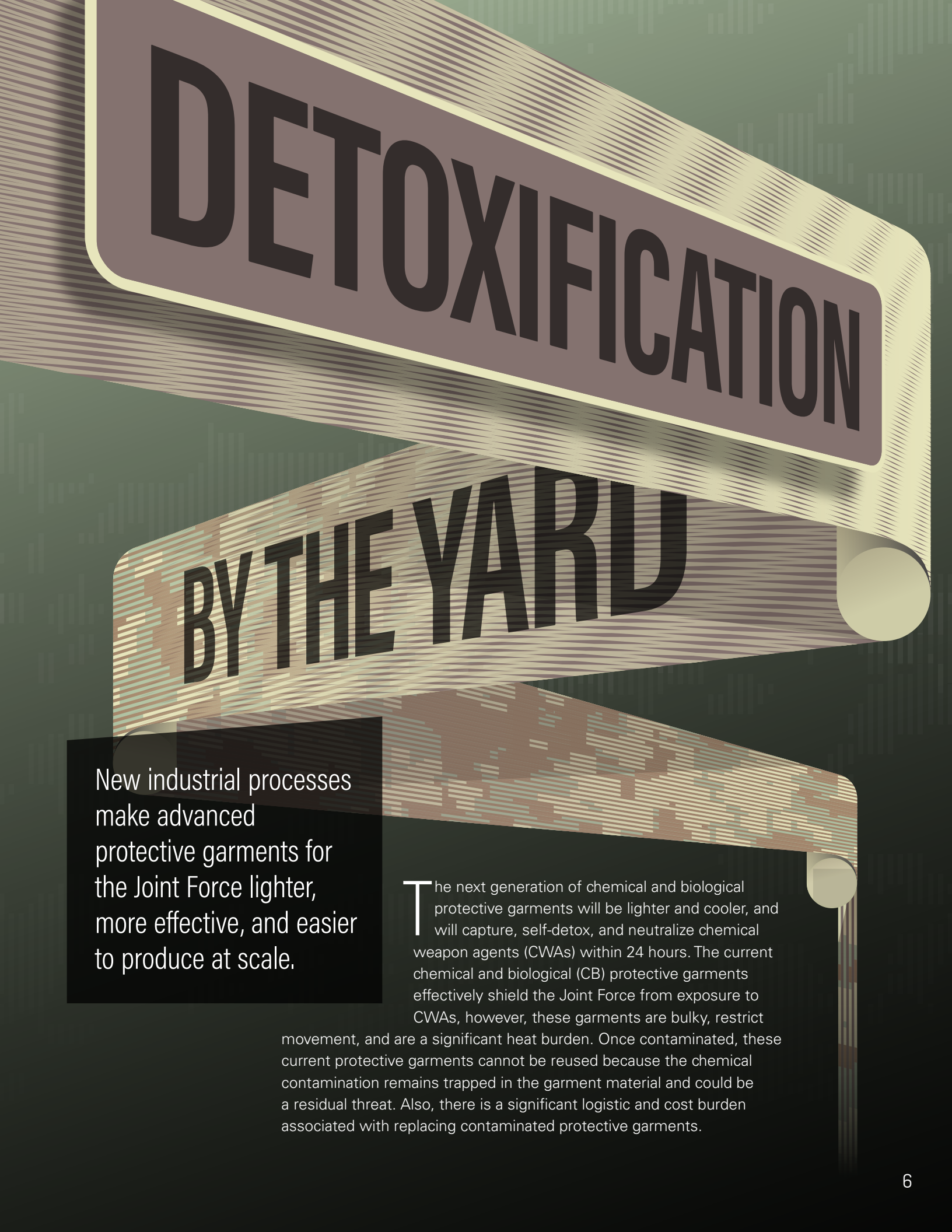


New industrial processes make advanced protective garments for the Joint Force lighter, more effective, and easier to produce at scale.

The next generation of chemical and biological protective garments will be lighter and cooler, and will capture, self-detox, and neutralize chemical weapon agents (CWAs) within 24 hours. The current chemical and biological (CB) protective garments effectively shield the Joint Force from exposure to CWAs, however, these garments are bulky, restrict movement, and are a significant heat burden. Once contaminated, these current protective garments cannot be reused because the chemical contamination remains trapped in the garment material and could be a residual threat. Also, there is a significant logistic and cost burden associated with replacing contaminated protective garments.

NuMat Technologies MOF-based commercial solution. (NuMat Technologies photo)

The Defense Threat Reduction Agency's (DTRA) Chemical and Biological Technologies Department in its role as the Joint Science and Technology Office (JSTO) for Chemical and Biological Defense, an integral component of the Chemical and Biological Defense Program, partnered with industry performer NuMat Technologies to create protective garments that are regenerating, self-detoxifying, and reusable, while also improving their thermal burden, fit, flexibility, weight, and service life.

New fabric and state-of-the-art fabrication and lamination techniques compose garments that are lighter, fit better, and improve moisture vapor transfer.

The researchers' strategy uses two simultaneous materials systems to create next-generation protective garments. The first uses new fabric and state-of-the-art fabrication and lamination techniques to create garments that are lighter, fit better, and improve moisture vapor transfer. The second system incorporates new, specialized adsorbent materials that capture and retain chemicals. NuMat developed adsorbents that capture and reactively destroy CWAs, which would enhance or even replace current adsorbent technologies.

NuMat developed a prototype self-detoxifying garment with zirconium-based metal organic frameworks (MOFs) as new adsorbents embedded into the garment fabric. MOFs absorb CWAs and chemically react to detoxify the threat over time, while enhancing capture capacity and decontamination capabilities. MOFs offer ultra-high porosity and vast surface area and are capable of effectively removing contaminants, but traditionally they have been tedious and expensive to manufacture. NuMat recently developed processes to manufacture MOFs on an industrial scale and have successfully integrated them into protective garment fabrics.

Industrial-scale MOF manufacturing is the result of decades of DTRA JSTO investments in basic and applied research. Practical applications of MOFs include chemical sensing, water purification, hydrogen gas storage, and breakdown of toxic chemicals. Scientists recognized the potential application of MOFs for breaking down toxic chemicals, and DTRA JSTO began a long-term commitment to fund academic researchers to develop and characterize highly reactive and adsorbent MOFs for efficient toxic chemical destruction. These efforts helped develop the fundamental principles of MOF synthesis at the University of California, Berkeley, and other academic institutions.

Simultaneously, DTRA JSTO funded U.S. Department of Defense (DoD) and industry laboratories to apply the results of fundamental research toward improving MOF synthesis, scaling, and integration into textile fabrics. At first, the synthesis process was slow, expensive, and generated only micrograms of functional MOFs. As JSTO fundamental research investments continued and techniques advanced, costs decreased, and yields improved. Similarly, researchers

developed techniques to stabilize MOF crystals on fabric fibers and engineer them into yards of garment material.

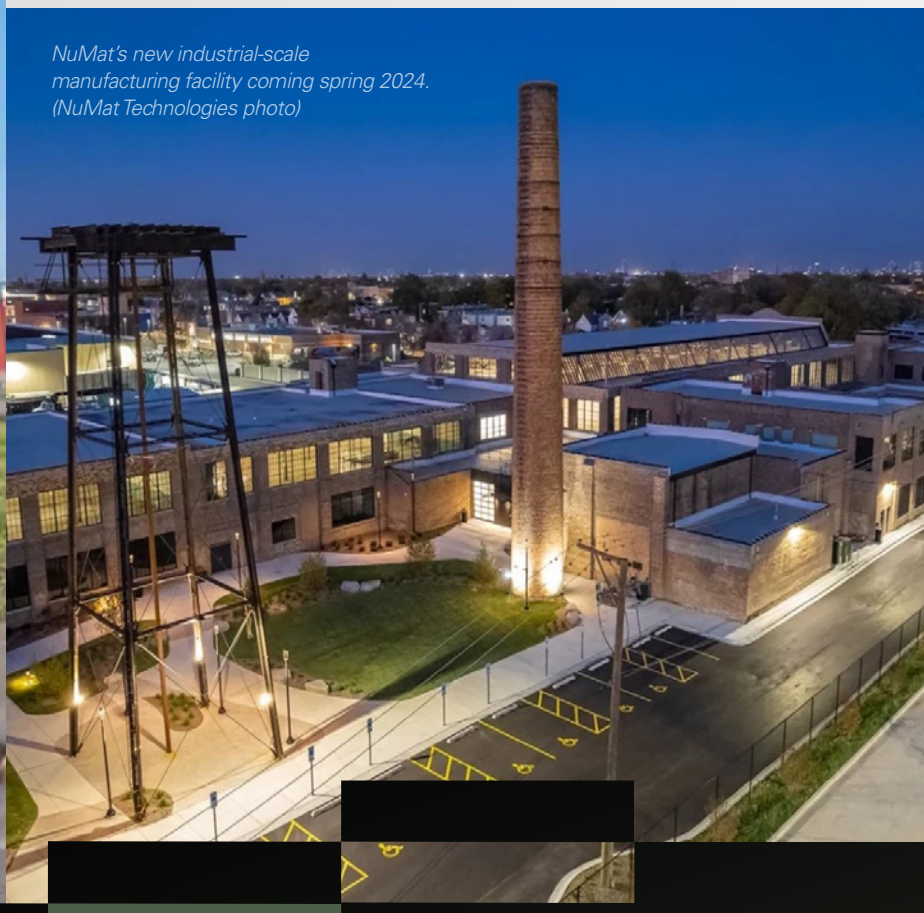
Recently, NuMat announced construction of the world's first industrial-scale MOF manufacturing campus in Chicago, Illinois. This site will use digital technologies to accelerate the development of MOF-based solutions and allow for high-volume manufacturing, such as for self-detoxifying garments. NuMat is collaborating with the U.S. Combat Capability Development Command Soldier Center (DEVCOM SC) to test protective garment prototypes.

They will use standardized whole-system test methods to evaluate CWA absorbance and detoxification, followed by moisture vapor transfer, air permeability, durability, and laundering. When prototypes are available, DEVCOM SC and their collaborators will use live CWAs and perform whole system testing to compare prototype garment performance using operationally relevant test methods.

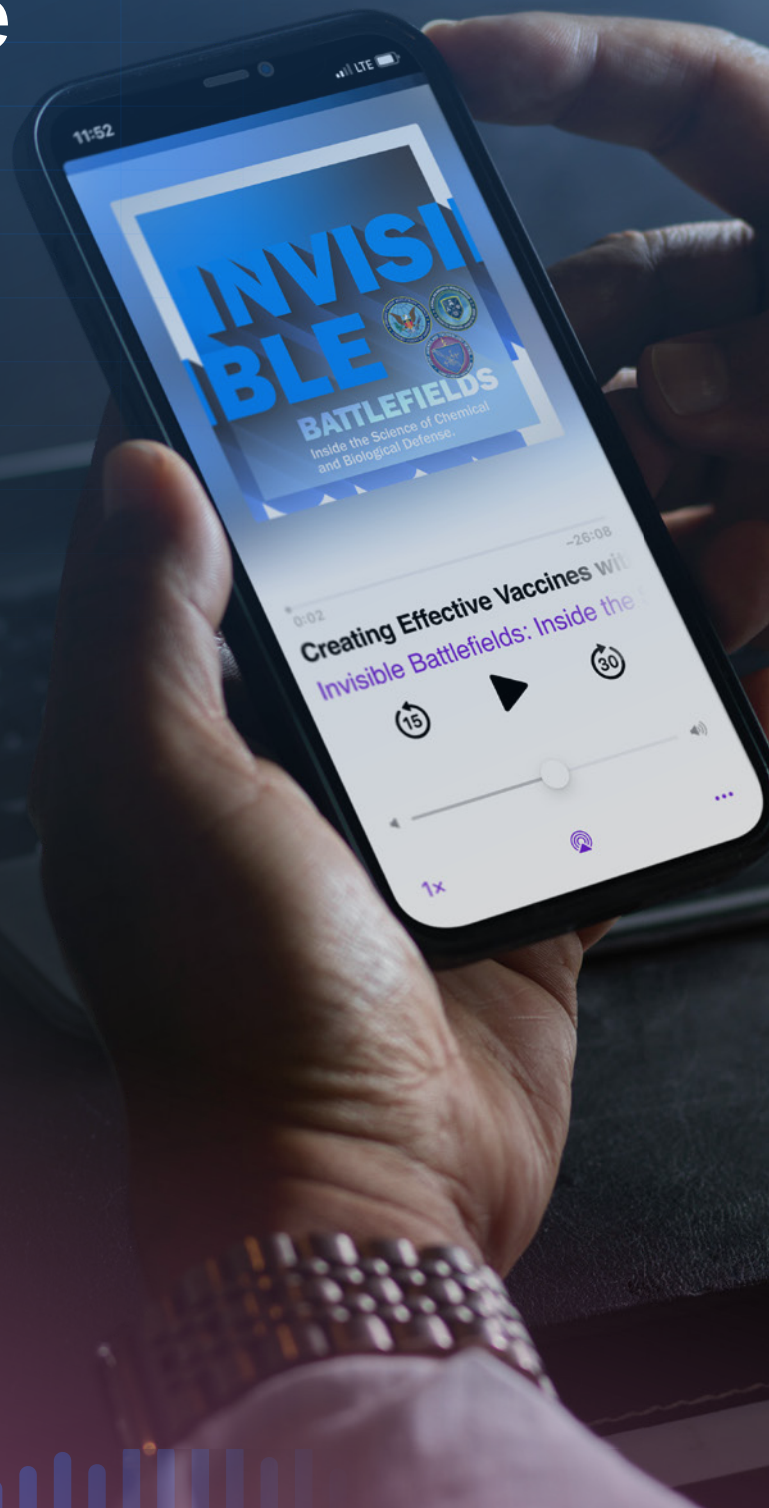
This ongoing collaboration of industry and DoD laboratories will develop self-detoxifying, protective garments that will absorb and destroy contamination within 24 hours instead of just absorbing it like the activated carbon currently used. This greatly reduces the risk of contact exposure for warfighters and ensures that garments can be reused, which will increase service life and reduce garment costs, while meeting or exceeding CWA protection, reducing thermal burden, and providing better fit and mobility. ●

Self-detoxifying MOF-based garment during live demo at CBOA 23 for Chemical/Biological Operational Analysis at Camp Dawson, WV. (DTRA JSTO photo)

NuMat's new industrial-scale manufacturing facility coming spring 2024. (NuMat Technologies photo)



Invisible Battlefields: Inside the Science of Chemical and Biological Defense



Within DTRA JSTO is a program for Rapid Assessment of Platform Technologies Expediting Research. Scientists working on the RAPTER program are developing plug-and-play vaccine technology to create effective vaccines more quickly and efficiently. Join us in this episode of *Invisible Battlefields* as Traci Pals, Ph.D., a DTRA JSTO scientist working on RAPTER, gives us an inside look into how RAPTER creates disruptive innovation in chemical and biological defense.

AVAILABLE NOW

EPISODE 02

Traci Pals, Ph.D., offers an insider's perspective on RAPTER's revolutionary impact on chemical and biological defense.

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Important Dates

March 19, 2024
Call for papers opens

May 3, 2024
Abstract submission deadline

May 10, 2024
Extended abstract submission deadline

June 17, 2024
Registration opens

June 17, 2024
Exhibitor registration opens

September 17, 2024
Full conference agenda posted on website

October 4, 2024
Exhibitor registration deadline

November 8, 2024
Registration deadline

December 2-5, 2024
2024 Chemical and Biological Defense Science & Technology (CBD S&T) Conference

Within the Defense Threat Reduction Agency's Research and Development Directorate resides the Chemical and Biological Technologies Department performing the role of Joint Science and Technology Office for Chemical and Biological Defense, an integral component of the Chemical and Biological Defense Program. This publication highlights the department's advancements in protecting the Joint Force, our nation, and allies from chemical and biological threats through the innovative application of science and technology.

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