JSTO in the News

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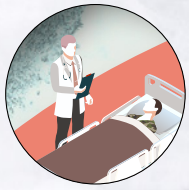
Finding Data in the Drift



Breathing Room

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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.

DEFENSE THREAT REDUCTION AGENCY

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Chemical and Biological Technologies Department
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Front cover: Airmen assigned to the 673d Civil Engineer Squadron, Explosives Ordinance Disposal (EOD) Flight, prepare C-4 for a live-fire demolitions exercise in Mission Oriented Protective Posture 4 on Joint Base Elmendorf-Richardson, Alaska. The airmen were conducting EOD training in a simulated chemical weapons contaminated environment. (U.S. Air Force photo by Justin Connaher)

Inside cover: A ventilator sits at the foot of a simulated U.S. Marine casualty during a mass casualty drill aboard an amphibious assault ship. (U.S. Marine Corps photo by Cpl. Brandon Salas)

Back cover: A respiratory therapist changes ventilator settings during a simulation for the initial Critical Care Air Transport Team (CCATT) course at Wright-Patterson Air Force Base, Ohio. CCATTs are medical teams that turn aircraft into flying intensive care units by boarding injured service members and providing in-flight care. (U.S. Air Force photo by Richard Eldridge)

FINDING DATA IN THE DRIFT

MACHINE LEARNING IS CUTTING THROUGH THE FOG IN AERIAL DISPERSION OF CHEMICAL THREATS.

Understanding and predicting the dispersion and concentration of chemical warfare agents is a central factor in protecting the Joint Force. Currently, military commanders and staff plan large-scale combat operations using a best-guess method of where the enemy would place their chemical weapons on the battlefield. Reconnaissance teams in protective gear would confirm these estimates.

To improve the odds of locating chemical weapons, 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 scientists at the Pacific Northwest National Laboratory (PNNL) to uncover the capabilities of deep learning, a subset of machine learning, in the domain of hazardous material quantification using 2D images, such as photographs, of chemical plumes.

Although not always, deep learning is often formed through the implementation of a neural network, which is a system of mathematical layers that identify and extract important features from nearly any kind of data, such as numerical, categorical, image, audio, and video. A Convolutional Neural Network (CNN) interprets individual pixels from images and assigns weights to specific features or groups of pixels in each image to assist in classifying the entire image. The CNN model is first trained on a set of labeled images. This means that the model is provided with the correct category for each of the initial images. Once the model is sufficiently trained, it can identify similarities and key features in the dataset and can then calculate the probability that the image belongs to any number of existing categories. The category with the highest resulting probability is the one assigned to the image.

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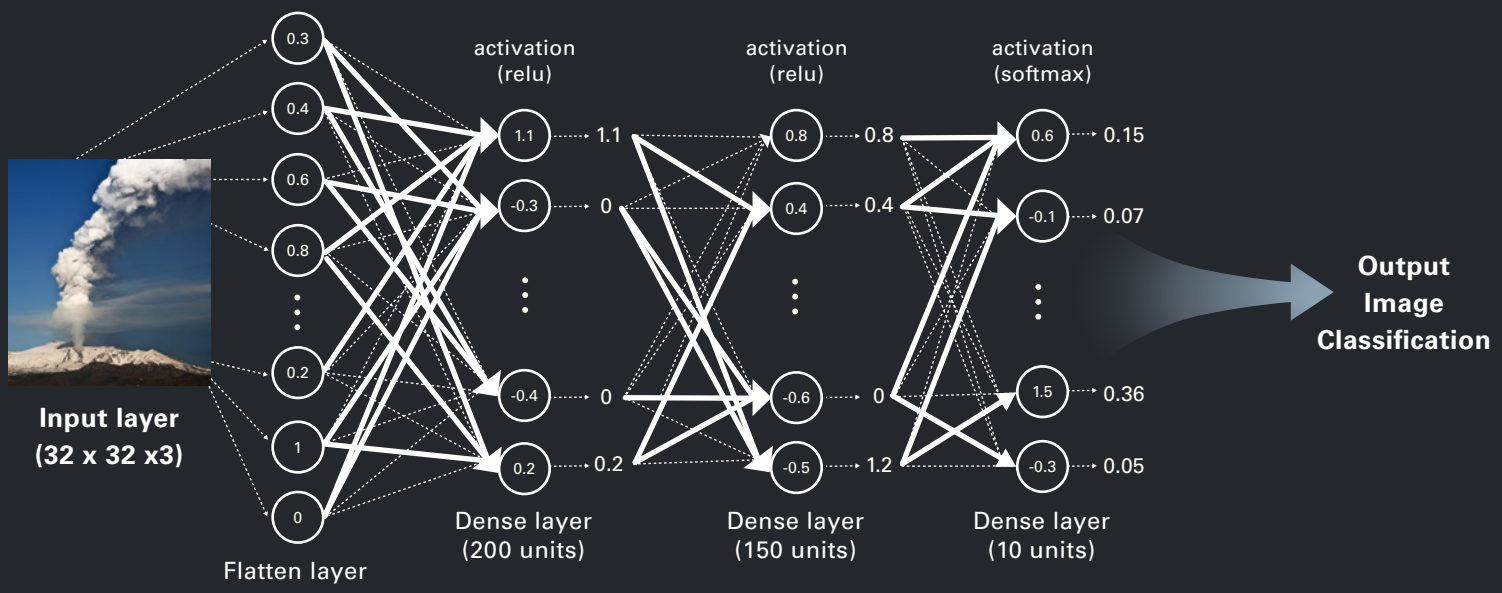

Deep learning model approach. Image of volcanic plume is fed to the machine learning algorithm, which predicts a classification for the release plume. (PNNL image)

In collaboration with JSTO, PNNL researchers created a CNN model designed to classify plumes so it could characterize chemical plumes. They used images pulled from publicly available sources that simulated the plumes exhibited by many chemical warfare agents. The collected photos are a combination of ground, aerial, and satellite imagery of multiple volcanic plume events. The results of this research preliminarily demonstrated a high efficacy of deep-learning models in classifying volcanic plume data, which can reduce human biases and errors.

The results from this study could lead to further integration of deep learning into military decision-making processes and create the opportunity for Joint Force leaders to plan military operations with more accurate chemical threat predictions.

JSTO plans to apply the final CNN model to the problem of quantifying hazardous materials on the battlefield from two-dimensional images. This ability will enable commanders in a post-engagement environment to better assess follow-on maneuvers to counter the adversary's use of chemical area-denial systems in persistent (long lasting) or nonpersistent (short-term) forms. Through this technique, commanders can preserve combat power and maximize capabilities against continued use of chemical weapons against the U.S. Joint Force and allied forces. The results from this study could lead to further integration of deep learning into military decision-making processes and create the opportunity for Joint Force leaders to plan military operations with more accurate chemical threat predictions.

Machine learning is an emerging discipline that ensures more efficient and more accurate analyses of complex topics. JSTO's exploration of machine learning capabilities in countering chemical weapons can enable more reliable modeling and forecasting of threats to warfighters on the battlefield and better-informed decisions for Joint Force commanders. ●

A CNN model used images pulled from publicly available sources of ground, aerial, and satellite imagery of volcanic plume events that simulated the plumes exhibited by many chemical warfare agents. (Public images)

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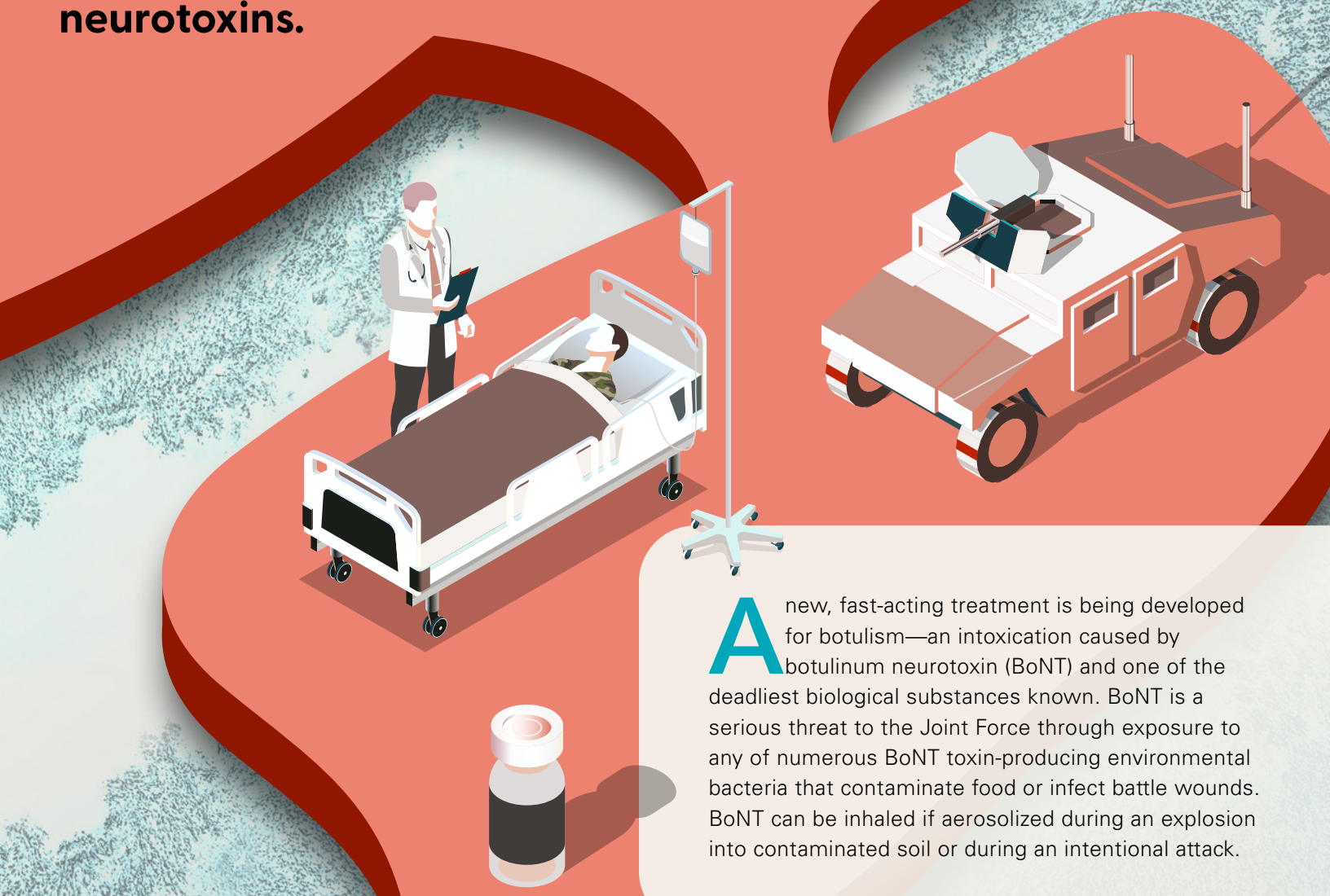
Breathing Room

A fast-acting, broad-spectrum therapeutic can treat the Joint Force after exposure to one of the most dangerous neurotoxins.



A new, fast-acting treatment is being developed for botulism—an intoxication caused by botulinum neurotoxin (BoNT) and one of the deadliest biological substances known. BoNT is a serious threat to the Joint Force through exposure to any of numerous BoNT toxin-producing environmental bacteria that contaminate food or infect battle wounds. BoNT can be inhaled if aerosolized during an explosion into contaminated soil or during an intentional attack.

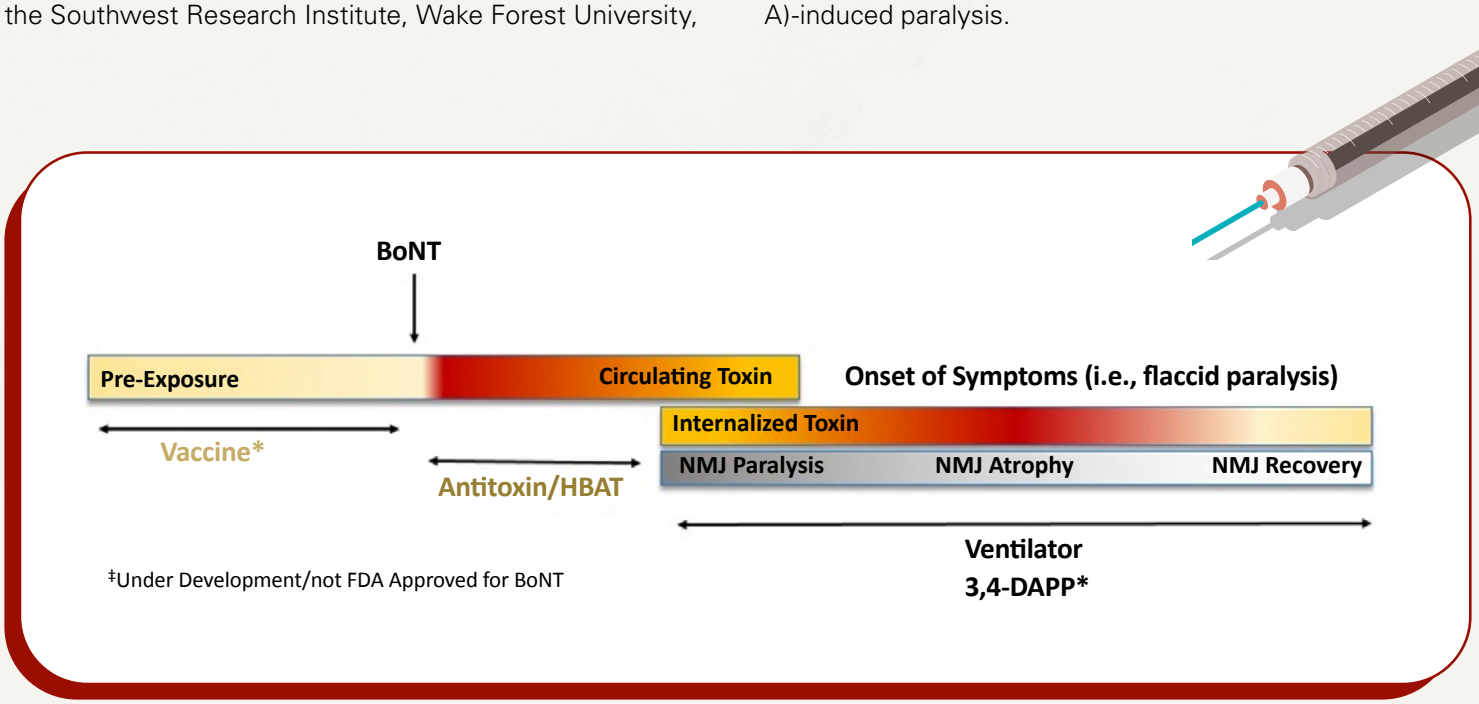
BoNTs act by blocking the release of acetylcholine, the principal neurotransmitter at the neuromuscular junction (NMJ), resulting in muscle weakness that rapidly progresses to paralysis. Within 12 to 72 hours after exposure, BoNT causes symptoms such as blurred vision, drooping eyelids, difficulty in swallowing, talking, or breathing, and muscle weakness. Weakened or paralyzed muscles involved in breathing, primarily the diaphragm, can cause respiratory distress and death. Depending on the BoNT dose, muscle paralysis can last from weeks to months until BoNT is degraded or excreted, and nerve damage heals in the paralyzed muscles.

In the United States, botulism patients experiencing difficulty in breathing or respiratory distress are treated promptly using a forced oxygen mask or assisted mechanical ventilation with intravenous nutritional supplements, as needed, for long periods.

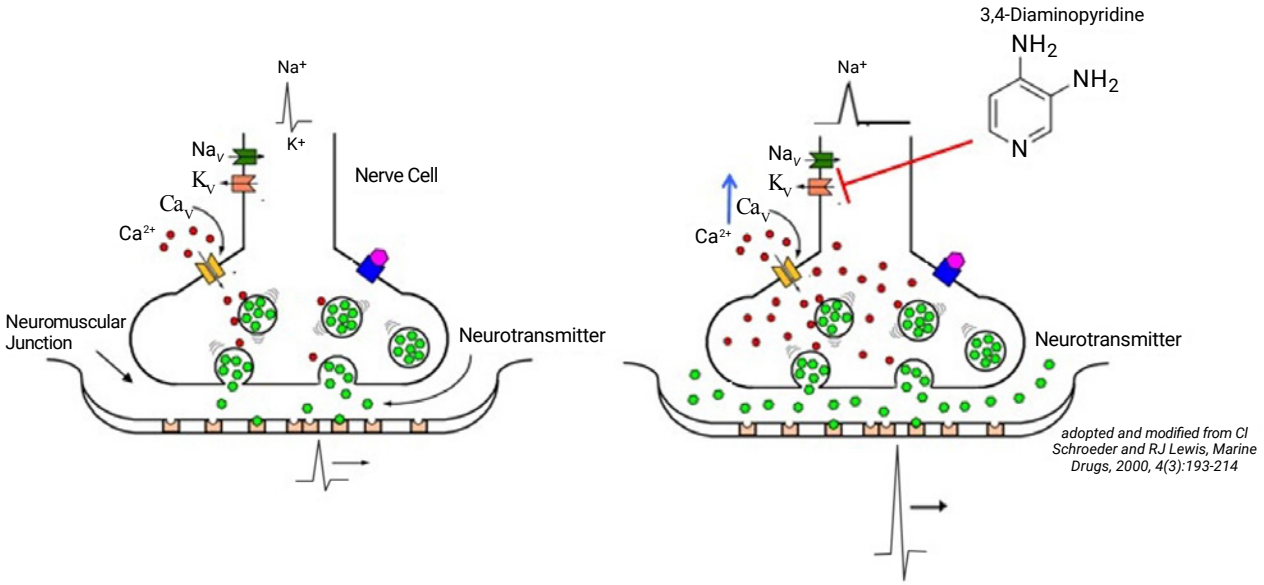
The Defense Threat Reduction Agency's (DTRA) Chemical and Biological Technologies Department in its role as the Joint Science and Technology Office (JSTO) for Chemical and Biological Defense, an integral component of the Chemical and Biological Defense Program, collaborated with researchers at the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD), Battelle Memorial Institute, the Southwest Research Institute, Wake Forest University, MRI Global, Aclairo Pharmaceutical Development Group, Inc., and manufacturer Catalyst Pharmaceuticals to develop an FDA-approved, small-molecule therapeutic called 3,4-Diaminopyridine Phosphate (3,4 DAPP) that can be administered to patients for a quick recovery from BoNT-induced paralysis at the NMJ.

Presently, the only FDA-approved treatment for adult botulism is a horse polyclonal hyperimmune serum named Botulism Antitoxin Heptavalent (HBAT). HBAT binds circulating BoNT like a sponge preventing it from getting into organ cells, where HBAT does not penetrate. This limits the window after exposure when HBAT can be effective since it is unable to act on BoNT that entered neurons, where the toxin acts. A neuron-penetrating therapy is needed to delay or mitigate the harm caused by BoNT.

Studies at USAMRICD screened current FDA-approved, small-molecule inhibitors that could potentially reverse BoNT-induced paralysis and focused on 3,4-DAPP based on its mechanism of action. To regulate the opening and closing of calcium channels, 3,4-DAPP blocks potassium channels on the nerve cell, prolonging the time that calcium channels remain open, which allows for an influx calcium into the nerve cell that reverses BoNT A serotype (BoTN/A)-induced paralysis.



Botulism Neurotoxin Intoxication and Current Medical Countermeasure Development: If a mass casualty event occurs, the immediate effects of 3,4-DAPP could save lives by mitigating BoNT-induced flaccid paralysis. (DTRA JSTO image)



(Left) Nerve cell and the Neuromuscular Junction (NMJ) where the neurotransmitter acetylcholine triggers a muscle contraction through the exchange of sodium (Na) and potassium (K) across muscle fibers. Voltage-gated potassium and calcium channels on the nerve cell regulate the amount of acetylcholine in the NMJ. The greater the calcium influx into the nerve cell, the more acetylcholine is available at the NMJ for muscle contraction. Exposure to botulism neurotoxins causes paralysis by blocking the release of acetylcholine from the nerve terminal. (Right) 3,4-DAPP blocks voltage-gated potassium channels, allowing calcium channels to remain open for a longer period and increasing the probability of releasing more acetylcholine. (DTRA JSTO image)

As 3,4-DAPP is broad spectrum in nature, it represents a potential therapeutic for many chemical or biological threats to the Joint Force that reduces respiratory drive...

The collaborative research group endeavors to generate sufficient safety, toxicity, and BoNT/A efficacy data to file an Investigational New Drug application with the FDA and conduct Phase I clinical safety trials. With the success of the studies invested in by DTRA JSTO, the Joint Program Executive Office for Chemical and Biological Defense will support the continued development of 3,4-DAPP for BoNT/A, including seeking new drug approval with the FDA for treating botulism.

It could be that 3,4-DAPP will be the first FDA-approved, fast-acting, small-molecule drug for the treatment of botulism. As 3,4-DAPP is broad spectrum in nature, it represents a potential therapeutic for many chemical or biological threats to the Joint Force that reduces respiratory drive, such as the synthetic opioids fentanyl and carfentanil, and biological toxins that reduce neuromuscular transmission. Continued studies with 3,4-DAPP against these agents will help researchers to understand the full broad-spectrum potential of this repurposed drug to treat chemical and biological threats and protect our warfighters, nation, and allies. ●

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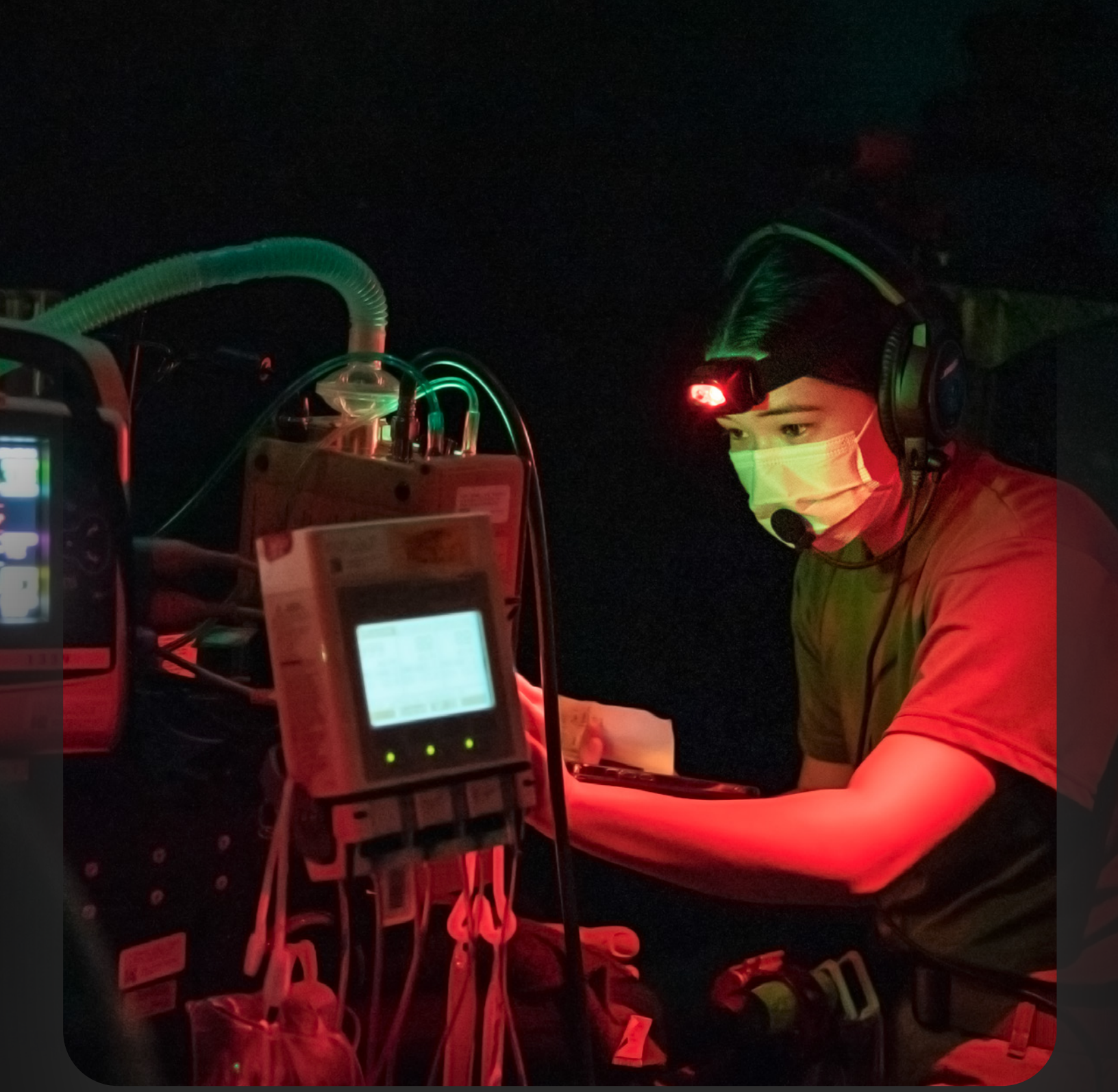

Within the Defense Threat Reduction Agency's Research and Development Directorate resides the Chemical and Biological Technologies Department performing the role of Joint Science and Technology Office for Chemical and Biological Defense, an integral component of the Chemical and Biological Defense Program. 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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