



Explosive Ordnance Disposal Technicians with Explosive Ordnance Disposal Mobile Unit ELEVEN (EODMU-11) dispose of hazardous material during a chemical, biological, radiological, and nuclear (CBRN) drill on Naval Air Weapons Station China Lake, Dec. 18, 2025. EODMU-11, a subordinate command of Explosive Ordnance Disposal Group ONE (EODGRU-1), operates as part of the Navy Expeditionary Combat Force, providing skilled, capable, and deployable maritime EOD and Navy Diver forces around the globe to support a range of operations.
(U.S. Navy Photo by Mass Communication Specialist 2nd Class August Clawson)

Developing CBRN Situational Understanding for Decision Support

By Dr. Alan C. Samuels

Confronting an adversary able and willing to employ chemical or biological weapons requires due diligence and an integrated early warning system-of-systems approach. Emerging technologies play a key role in the development of early warning throughout the continuum of conflict, as seen in Figure 1. Understanding the capabilities and limitations of each contributing source of data is crucial to the chemical, biological, radiological, and nuclear (CBRN) subject matter expert so that they can adequately inform commanders and their staffs of contamination risks when possible.

The most effective application of advanced integrated early warning systems can be achieved with a deliberate understanding of their employment and analytical outcomes. At the heart of any integrated early warning system is the data management and integration environment, which consumes information from a given situation and processes the data to reliably develop a concise and cogent understanding of the operational environment.

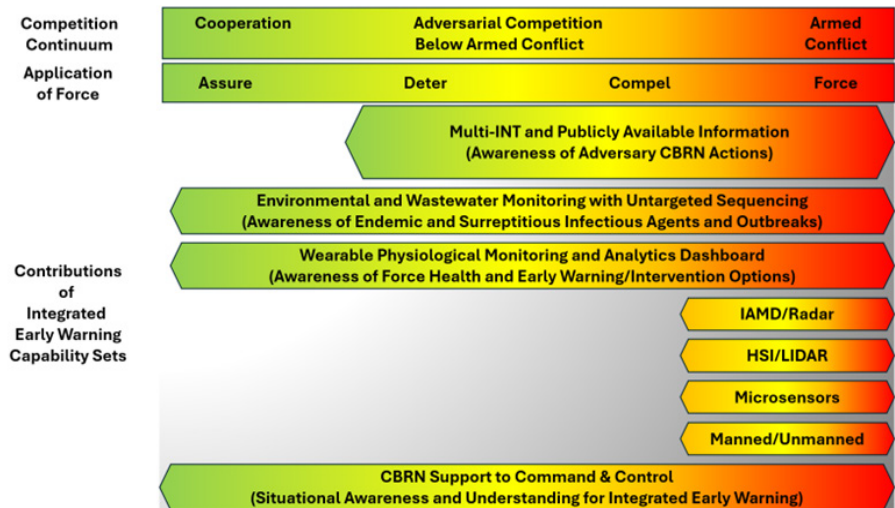


Figure 1. Application and benefits accrued by a system-of-systems approach to achieve integrated early warning across the continuum of conflict. The appropriate technology shifts in utility from a deter function in competition to a defend function in conflict, preserving combat power. Multi-INT=multiple intelligence sources of data, IAMD=Integrated Air and Missile Defense, HSI=hyperspectral imaging, and LIDAR=light detection and ranging.

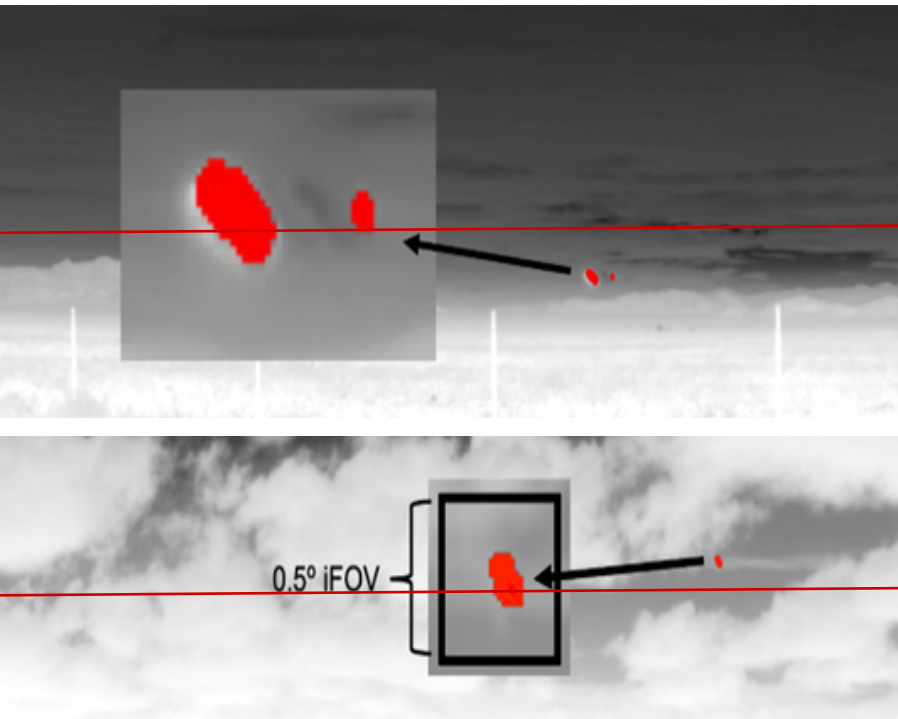


Figure 2. Hyperspectral images with false color (red) pixel demarcation indicating the presence of a chemical simulant's signature in the image as discerned by the sensor and its library spectrum of the chemical. Top: polyethylene glycol (PEG) detected after a 64-meter-high airburst at 2.5 km. Bottom: PEG detected after a 499-meter-high airburst at 5.1 km. (Imagery courtesy Spectrum Photonics, Inc.)(iFOV: instantaneous field of view)

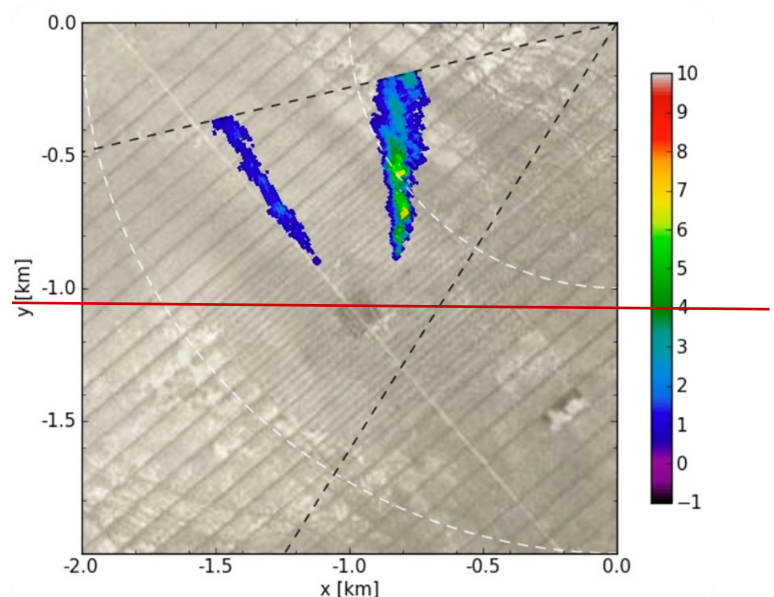
An adversary may employ chemical or biological threat agents to achieve their perceived advantage at early stages in the transition to conflict. The agents may be surreptitiously deployed under plausible deniability circumstances by special operations or even by a proxy, such as sympathetic actors. A covert attack aimed at contaminating air, food, or water sources supporting a concentration of troops may be attempted to disrupt and degrade the force before open hostilities begin. Emerging technologies that continuously monitor the environment and population can provide a deterrent effect while also enabling earlier responses that mitigate the adverse outcomes of such operations. Untargeted sequencing of complex samples, including air and wastewater, can reveal the causative pathogen much earlier in the evolution of an outbreak than would normally be realized through regular clinical presentation. In addition, systematic physiological monitoring can reveal indications of the potential onset of illness or infection sooner in the onset of an outbreak, affording opportunities for early treatment and prophylaxis options.

Once the situation escalates into open conflict, emerging intelligence, surveillance, and reconnaissance tools can provide awareness and understanding of an adversary's decision to employ chemical or biological agents well before an attack is carried out (as shown by Multi-INT and Publicly Available

Information in Figure 1). The deployment chain necessary to support a successful CBRN attack presents opportunities for observing the handling, transport, and preattack positioning of such agents. This is due to the perpetrator's need for protective equipment and specialized facilities and resources to handle and store the agents. Properly applied, these chemical and biological observables can be identified before an adversary executes a planned offensive action, creating opportunities for interdiction and potentially deterring further hostile decisions.

Attacks involving chemical or biological weapons during open conflict do not require waiting for weapon effects or detection by specialized systems, as their delivery typically relies on overt means such as artillery, mortars, rockets, missiles, or drone-based dissemination. Radar and integrated air and missile defense systems provide awareness of incoming threats and enable remote-sensing systems, including hyperspectral imaging (HSI) and backscatter light detection and ranging (LIDAR). Properly cued, these systems can quickly assess and track the plumes that result from a chemical or biological attack. In the case of hyperspectral sensing, gas-phase threat agents can be detected and identified almost instantaneously, provided the system observes the initial release. A 2018 test at Dugway Proving Ground involving an airburst release of a chemical simulant demonstrated the effectiveness of an HSI system in detecting and identifying chemical agents, as shown in Figure 2. To ensure that the initial release was observed, the HSI system was cued by radar to the point of arrival of the incoming artillery shells.

Figure 3. Backscatter LIDAR scan overlaid on aerial imagery, with the LIDAR positioned at the upper-right corner (0,0). The color scale represents the logarithmic change in signal relative to ambient background aerosol levels. (Imagery courtesy of Spectral Sensor Solutions, LLC.)



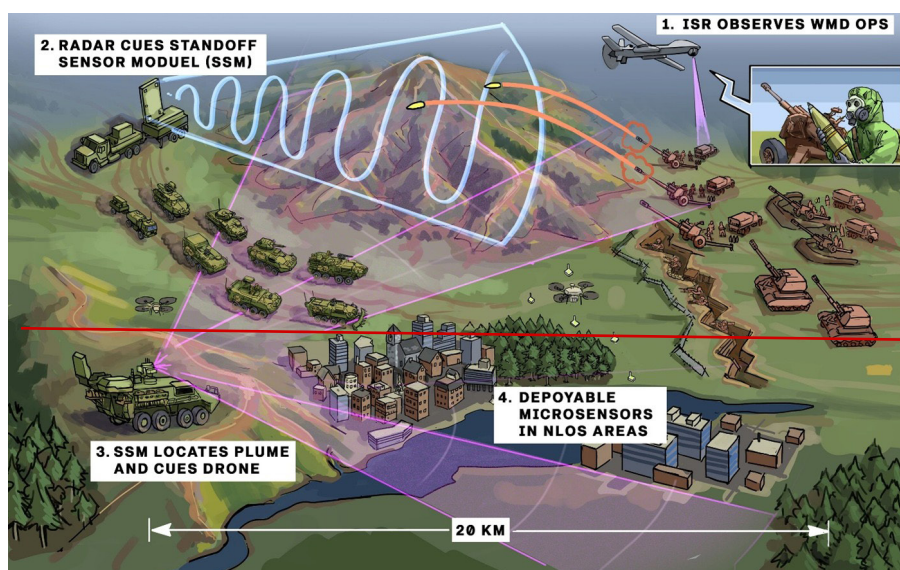
Not all threat agents present in the gas phase. Some are intentionally deployed as low volatility hazards that disperse to yield a persistent area effect on equipment or to deny access to affected terrain. A properly cued backscatter LIDAR system fills the awareness gap caused by the lack of a gas phase signature that can be observed by an HSI system. The LIDAR affords an understanding of the plume location and dispersion pattern being disseminated and/or the deposition of persistent hazards onto terrain, enabling the further investigation of the effects of such an attack by properly equipped CBRN response elements. Figure 3 shows a sample backscatter LIDAR scan that has developed a geospatial plume dispersion and dispersion pattern. Two aerosol plumes are detected: a narrow, low-density plume from a stationary burning tire to the left and a broader, more intense plume created by a mobile release of a biothreat aerosol simulant from a vehicle-mounted disseminator to the right. This aerosol threat simulant plume is at a 45-degree angle to the wind due to the disseminator vehicle moving perpendicular to the wind. The color scale indicates relative backscattered intensity, with higher values corresponding to denser aerosol concentrations. This scan provides real-time situational awareness by showing the location, shape, and intensity of airborne hazards. This information can be used to cue sensors mounted on uncrewed aerial systems (UAS) into specific locations within airborne plumes for further interrogation or sample collection. This expansive real estate coverage afforded by the LIDAR, with short mission life but precise sortie management of the UAS, accentuates the advantage of integrating the wide area.

The advent of low-cost autonomous systems has enabled the execution of a sampling mission cued by the LIDAR so that the area impacted by the plume, or even the plume itself, can be intercepted and either identified by an onboard sensor or have the sample brought back for analysis by trained CBRN operators equipped with far-forward analytic sensors and instruments.

Another emerging technology and chemical defense capability that enhances situational understanding in the integrated early warning system-of-systems is the CBRN microsensor (C-MS). These low-cost deployable arrays of microelectronic devices can be deposited along routes, zones, and areas that are beyond the line of sight of an optical sensor such as the hyperspectral or LIDAR sensors, affording an early

warning and cross-cueing capability even when the optical systems are unable to continuously observe or track the event. The sequence of events contributing to integrated early warning as described are depicted in Figure 4.

Figure 4. Conceptual rendition of integrated early warning. CBRN Microsensors are depicted as red/yellow circles. Optical system fields of view (FOV) are depicted as blue fans. [ISR: Intelligence, Surveillance, and Reconnaissance. WMD: Weapons of Mass Destruction. NLOS: Non-Line-Of-Sight]



The CBRN Support to Command and Control (CSC2) program is delivering a modernized CBRN data management computational environment that consumes the disparate data from both CBRN and non-CBRN data sources. It then fuses and analyzes the data and projects the likely source terms and downwind hazards to provide immediate decision support benefit. The program is continuously updating the deployed computational systems, analytic algorithms, and command and control interfaces to effectively deliver CBRN threat awareness and understanding to operational commanders and staffs at the tactical edge. CBRN professionals are responsible for the effective application of the full complement of situational awareness and understanding systems and analytic tools at their disposal to continuously inform the Observe-Orient-Decide-Act (OODA) cycle so that commanders preserve freedom of maneuver and decision space inside the adversary's OODA loop.

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