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Science and Technology Challenges for Homeland Security

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Preventing and protecting against catastrophic terrorism is a complex and dynamic challenge. Small groups or individuals can use advanced technology to cause massive destruction, and the rapid pace of technology and ease of information dissemination continually gives terrorists new tools. A 100% defense is not possible. It's a numbers problem—there are simply too many possible targets to protect and too many potential attack scenarios and adversaries to defend against.

However, science and technology (S&T) is a powerful force multiplier for defense. We must use S&T to get ahead of the game by making terrorist attacks more difficult to execute, more likely to be interdicted, and less devastating in terms of casualties, economic damage, or lasting disruption. Several S&T areas have potential to significantly enhance homeland security efforts with regard to detecting radiation, pathogens, explosives, and chemical signatures of weapons activities. All of these areas require interdisciplinary research and development (R&D), and many critically depend on advances in materials science.

For example, the science of nuclear signatures lies at the core of efforts to develop enhanced radiation detection and nuclear attribution capabilities. Current radiation detectors require cryogenic cooling and are too bulky and expensive. Novel signatures of nuclear decay, new detector materials that provide high resolution at ambient temperatures, and new imaging detectors are needed. Such technologies will improve our ability to detect and locate small, distant, or moving sources and to discriminate threat materials from legitimate sources. A more complete understanding of isotopic ratios via secondary ion mass spectrometry (SIMS), NanoSIMS, or yet-to-be-developed technologies is required to elucidate critical characteristics of nuclear materials (e.g., isotopics, age, reprocessing) in order to identify their source and route history.

S&T challenges abound in the biodefense arena as well. Improved biodetectors are needed—autonomous instruments that continuously monitor the environment for threat pathogens, promptly alert authorities in the event of a positive detection, and have an extremely low false alarm rate. Because many threat pathogens are endemic to various regions of the world, the natural microbial environment must be characterized so that background detections can be distinguished from a deliberate release. In addition, most current detection approaches require an *a priori* knowledge of the pathogens of concern and thus won't work in the face of a new, naturally occurring disease, such as a mutated avian influenza that effects humans, or a deliberately manipulated organism. Thus, we must move from species-specific detection to function-based detection based on a fundamental understanding of the mechanisms and genetic markers of infectivity, pathogenicity, antibiotic resistance, and other traits that distinguish a harmful organism from an innocuous one. Last but not least, new vaccines and treatments are needed, which in turn require in-depth understanding of cellular surfaces, protein folding, and myriad nano-bio aspects of host-pathogen interactions.

Much attention is being devoted to countering weapons-of-mass-destruction terrorism, since Al-Qaeda and other terrorist groups have repeatedly stated their intention to acquire and use nuclear, chemical, or biological weapons. However, terrorists in Iraq and elsewhere continue to wreak havoc using improvised explosive devices. Thus, there is a pressing security need for better methods for detecting explosive materials and devices. Transformational S&T such as pulsed fast-neutron analysis or terahertz spectroscopy for material- and element-specific imaging offer the promise of greatly improved explosive detection. For bioscience-based approaches, the development of highly multiplexed transducer arrays and molecular recognition methods that mimic biological systems would similarly provide the foundation for vastly improved capabilities.

Likewise, new materials and technologies are needed for the detection of chemical signatures of weapons activities. One grand challenge is the detection and characterization of chemical effluents indicative of weapons production, either biological, chemical, or nuclear. Ideally, one would like to be able to detect such chemical signatures remotely, via satellite or other high-altitude platform. To do so, one must know what chemicals, singly or in combination, would be produced in various production processes, how they would behave in the environment, and how those chemicals, their precursors, and degradation products could be sampled. Then, one must devise an appropriate detection technology, together with the necessary pointing and tracking, data analysis, and communications systems. All of this must be sized to fit on an airborne platform or satellite and able to function reliably in a hostile high-altitude environment.

Clearly, these are no small feats of science or engineering. Multidisciplinary collaborations among the national labs, universities, and industry will be needed to tap the full range of innovation embodied by the broad science and engineering community. Effective partnerships with user communities, such as first responders and port and border security officials, are also essential. The products of R&D must not only meet user needs and be affordable, they must be compatible with a wide range of customer operating and training systems.

I am confident that homeland security S&T challenges can be met. The widespread deployment of new homeland security capabilities will not only protect against terrorist attack, it will bring great benefits to public health, environmental monitoring, and many other spinoff applications.

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