Asan Report

Science and Technology to Prevent and Respond to CBRN Disasters: ROK and US Perspectives

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The Asan Institute for Policy Studies

About

The Asan Institute for Policy Studies is an independent, non-partisan think tank that undertakes policy-relevant research to foster domestic, regional, and international environments that promote peace and prosperity on the Korean Peninsula, East Asia, and the world-at-large.

The Science & Technology Policy Program aims to provide a comprehensive public understanding of science, technology, and innovation, while assisting organizations and governments in science and technology (S&T) policy decision-making. The Program provides policy recommendations and alternatives through independent and interdisciplinary assessments of socio-economic contributions of science and technology programs to the nation.

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Surnames are written first for the people from Asia.

Contents

Executive Summary

The advancement of science and technology brings us prosperous futures and gives comfort to our lives. The tools and knowledge generated by science and technology have transformed the way we approach health, agriculture, energy, development, communications, education, social interactions, and security. Many of these advances and uses offer great benefit to modern society, but some have increased risks to health, security, and sovereignty. Sometimes it brings adverse effects on human life with respect to security on account of being misused accidently or intentionally. The major areas of concern regarding adverse effects are chemical, biological, radiological, and nuclear (CBRN) because they may induce mass casualties and have the potential for damaging long-term effects. The science and technology community should therefore make every effort to contribute to the prevention of CBRN types of disasters.

The scientific community is an important partner in preventing and responding to, as well as remediating disasters involving these agents. Science can create research environments that minimize misuse and negligence. It can also provide information about given situations that help policymakers, which is a very important interface between the science community and the policymaking community to make informed or policy-relevant decisions that are based on the appropriate and most relevant information.

The United States national security community is unique in its interactions with its science and technology community. The US government has established several programs during the past two decades to reach out to scientists to access expertise, raise awareness of security risks associated with emerging technologies and research or diagnostic facilities, and build trust and partnership with key federal agencies. Examples of these efforts include the National Science Advisory Board for Biosecurity and the outreach activities of the Weapons of Mass Destruction Directorate (WMDD) of the Federal Bureau of Investigation (FBI). Both of these efforts have sought to engage the scientific community in preventing potential national security risks from within their scientific environments.

The Korean government provides 81 types of safety information and 14 agencies at different levels are operating 26 websites. To promote science and technology regarding disaster and safety management, the Minister of Security and Public Administration must put together the disaster and safety management technology development plans of related central administrative agencies every 5 years, have them reviewed by the coordinating committee and the national science and technology council, establish comprehensive disaster and safety management technology development plans, and prepare and enforce policies for promoting science and technology in disaster and safety management. Korea is ranked No. 7 in the world in terms of R&D investments, but the disaster and safety sector accounts for only 1.26 percent of the government's R&D budget. As disasters do not occur continuously or regularly, and happen randomly at any time in various sizes and shapes, it is impossible to accurately predict the effects of investments in their prevention or responses thereto, but the effects of safety inspection technologies, fine detection technologies, and technologies for recovering from polluted soil, air, and water cannot be anticipated without related technologies and R&D. Science, technology, and R&D are playing a pivotal role in maintaining the sound development of Korea, which transformed itself from an agricultural country into an industrial country in half a century.

The case of the Fukushima disaster is introduced as an example of an S&T role in responding to CBRN accidents. The S&T community can support the community by providing its expertise towards the overall response to a wide-area incident. The supporting actions start with customer identification and their needs, development of target products, and delivery of the developed products to the customers. The S&T community needs to develop strong lines of communication within the S&T community itself regarding effective customer support and outreach activities. In addition, the S&T community should continue to promote its scientific integrity for individual scientists and engineers. This integrity promotion effort will ensure the transparent support to customers with the highest quality scientific and ethical standards.

This report is the outcome of the workshop held by the Asan Institute for Policy Studies of the Republic of Korea and the American Association for the Advancement of Science Center for Science, Technology, and Security Policy on *Science and Technology to Prevent and Respond to CBRN Disasters: US and South Korean Perspectives*. Through this report, the diverse roles and solutions that science and technology can provide to prevent and mitigate disasters involving chemical, biological, radiological, and nuclear materials is introduced. The outcome of this work will be increased awareness of the integral role that the science and technology community plays in addressing local, national, and transnational CBRN incidents; the importance of building on the multi-disciplinary expertise of the scientific community; and the strength of integrating the social and natural sciences together to enhance efforts and policy discussions related to prevention and response to natural or man-made disasters involving CBRN materials.

Chapter 1. Science and Technology Solutions to Preventing and Responding to CBRN Disasters

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Science and technology (S&T) have permeated every aspect of 21st century society. The tools and knowledge generated by science and technology have transformed the way we approach health, agriculture, energy, development, communications, education, social interactions, and security. Many of these advances and uses offer great benefit to modern society, but some have increased risks to health, security, and sovereignty. Simultaneously, global, national, and international security concerns have expanded significantly, from nuclear, chemical, and biological weapons to naturally occurring infectious diseases and the underlying causes of terrorism and national instability. New advances in neuroscience, additive manufacturing (i.e., 3D printing), crowdsourcing, Big Data, and many other fields have transformed the way information is learned, shared, and used. The S&T community is a critical stakeholder in addressing national security problems in this era where the sciences are converging, new applications are being discovered and developed, increasing amounts of information are publically available and generated, amateur scientists have greater access to analytic and experimental tools, global entrepreneurship and innovation are increasingly supported, and national and international security threats are expanding significantly from state-sponsored weapons programs to terrorism.

In this paper, we explore the role that science and technology play in contributing to, preventing, and mitigating disasters involving chemical, biological, radiological, and nuclear materials. The concepts introduced in this paper provides the foundation for a workshop jointly held by the Asan Institute for Policy Studies of the Republic of Korea and the American Association for the Advancement of Science Center for Science, Technology, and Security Policy on *Science and Technology to Prevent and Respond to CBRN Disasters: US and South Korean Perspectives*. It is in this context in which this paper should be read.[1]

Historically, science and technology were limited to a few select scientists in a small number of countries. S&T advancements in the early 20th century were mainly concentrated in North America, Europe, and parts of Asia and occurred in the military and civilian sectors. Advances in fundamental science—in physics, chemistry, biology, and mathematics—formed the basis for significant technology advancement in health, agriculture, industry, and military weapons. Some basic research was conducted in classified environments leading to fundamental scientific advances and technologies that both aided national security interests and increased international security threats. The best example of this is nuclear physics and nuclear weapons. Simultaneously, significant scientific and technological advances were increasing in unclassified environments, including academia, private industry, and other research institutions. These advances created a dichotomy of applications—those applications that provide societal benefit and those that increased harm to individuals, groups, or nations. This dichotomy has continued to emerge throughout the past 60 years as new technologies were

1. Science and Technology to Prevent and Respond to CBRN Disasters, accessed May 11, 2014, http://www.aaas.org/page/cstsp_event_asan.

developed and new uses of scientific knowledge were identified.

Today, science and technology is truly a global and distributed enterprise. Many countries have established strong S&T educational, research, and industrial sectors and several others have developed (and are continuing to develop) a "knowledge-based economy." (Knowledge-based economies are based on developing strong educational systems that teach citizens about science, technology, engineering, and math from an early age. The idea is that underdeveloped countries can improve their socio-economic situation if their citizens are well-educated and possess critical skills for addressing social problems, including health, agriculture, and clean water.) Many companies have expanded their global reach, establishing facilities throughout the world, granting product licenses to foreign companies, and supporting scientists and engineers from several countries to conduct research, develop and test products, and manufacture products. Technology parks have been established in many countries to provide a centralized location for supporting industry, entrepreneurship, and innovation. Several academic organizations have established joint educational programs with universities from one or more countries; some of these programs are degree-granting and allow students to receive degrees from the affiliated universities. Non-governmental organizations have established international competitions, supported research and education, and used scientific tools to address social problems. Finally, a growing number of amateur scientists from several countries are conducting experiments in their homes, making science more accessible to the populous, and establishing community labs to facilitate research in the do-it-yourself community.

This increased globalization and access to science and technology has expanded the number of individuals involved in gathering, sharing, and using data to address specific problems. Examples include the personal genome projects in which members of the public voluntarily provide samples to be sequenced and included in the project database; environmental sampling in which amateur and professional scientists identify organisms in the environment; and open-source software development. These examples illustrate the transformation underway in the sciences from a few researchers having access to data and tools to data and technology that is available for a wide range of individuals. In this new environment of open science, open data, and open technology, the potential for society to reap the benefits of science and technology advancement is high. However, the potential for these advancements to harm society might also exist.

As S&T becomes increasingly more inclusive and open, so too has the threat space for national and international security. Not more than 20 years ago, the primary threats facing nations were other nations. Militaries developed offensive capabilities using conventional and sometimes unconventional weapons, including chemical, biological and nuclear weapons. To prevent destabilizing arms races, countries signed and ratified the international arms control and nonproliferation treaties limiting proliferation of nuclear weapons and banning biological and chemical weapons altogether. In addition, many countries were engaged in negotiations to ban development, possession, and use of chemical weapons. Today, nations face a number of threats that range from nation-state to accidental release of chemical, biological, radiological, or nuclear materials (CBRN). In general, the threats include nation-states; terrorist organizations; non-state political groups; individuals; accidental releases from nuclear facilities, biological research or diagnostic laboratories, or chemical industry facilities; and natural exposure to biological agents. The complexity of these threats is high with transnational threats from actors and CBRN materials, extreme weather causing CBRN incidents, and human error.

Preventing and responding to today's heterogeneous threats requires creative solutions which science and technology can offer. These solutions can come in the form of tools, such as biometric sensors for permitting access to restricted areas; knowledge, such as information learned by new neuroscience research to better understand deterrence or information about newly emerging pathogens that have the potential to cause international epidemics; know-how, such as the expertise needed to engineer "kill switches" into synthetically created life forms or to evaluate links between individuals with malicious intent through network analysis; and education and training, such as training to work safely and securely with select chemicals, biological agents, and radioisotopes. In addition to these easier-to-articulate solutions, the science and technology community are instrumental in preventing, detecting, and mitigating risks in their research, diagnostic, and/or industrial environments. Through heightened awareness of the security issues most relevant to their environments, scientists and engineers can minimize potential risks associated with their research (e.g., harmful use of materials and information from legitimate, peaceful research) and address concerning behaviors (e.g., negligence and not following laboratory and/or institutional policies). The breadth of science that enables or informs these solutions includes the natural, social, engineering, computer, and mathematical sciences. The S&T community is equally as diverse including both junior and senior professional scientists and engineers, amateur scientists, and technologists.

The US Perspective

The United States national security community is unique in its interactions with its science and technology community. The US government has established several programs during the past two decades to reach out to scientists to access expertise, raise awareness of security risks associated with emerging technologies and research or diagnostic facilities, and build trust and partnership with key federal agencies. Examples of these efforts include the National Science Advisory Board for Biosecurity—an expert advisory group to provide policy recommendations for "dual use life sciences research of concern"—and the outreach activities of the Weapons of Mass Destruction Directorate (WMDD) of the Federal Bureau of Investigation (FBI). Both of these efforts have sought to engage the scientific community in preventing potential national security risks from within their scientific environments.

"Dual Use Life Sciences Research"

In 1999, concerns arose about the risk that legitimate, openly published biological sciences data could be used to harm individuals. These concerns prompted the US National Research Council to establish an expert committee consisting of leading scientists, clinicians, and security experts to evaluate the potential for malicious individuals to use biotechnology and biological sciences research to harm the United States, its citizens, or its allies.[2] The committee identified seven experiments which they said could be used to develop biological weapons. It also recommended that the US government establish an external advisory body, which they called the National Science Advisory Board for Biodefense, to provide recommendations about what constitutes "dual use life sciences research" and how to minimize potential risks associate with this type of research. The US government responded by establishing the external advisory group—National Science Advisory Board

2. National Research Council, *Biotechnology Research in an Age of Terrorism* (Washington, DC: National Academy Press 2004).

for Biosecurity (NSABB)—under the auspices of the National Institutes of Health.[3] Since its creation in 2004, the NSABB has issued recommendations on the criteria for what constitutes "dual use research of concern" (i.e., legitimate life science research that could be directly misapplied to cause harm to people, animals, the environment, material, and plants), communication strategies, review and oversight approaches, and education. In addition, the NSABB issues reports for using synthetic biology to create Biological Select Agents and Toxins and personnel reliability, which is the vetting of personnel who have or are seeking access to CBRN. (Synthetic biology is defined as the use of synthetically-derived genetic elements to create organisms or types of organisms that are not found in nature).

On rare occasions, the NSABB has been requested to review pre-published scientific papers. Most recently, the editors of *Science* and *Nature* alerted the NSABB of two papers describing mutations in the H5 hemagglutinin gene that could make the H5N1 influenza virus transmit between mammals, which natural forms of the virus do not do.[4] To those who raised concerns, the mutations might offer a blueprint to malicious individuals who might want to use the modified influenza virus to cause harm. The science, medicine, and security experts on the NSABB agreed that the paper submitted to *Science* raised security concerns and should be considered "dual use research of concern" whereas the NSABB members were divided in its assessment of whether the paper submitted to *Nature* raised security concerns and should be considered "dual use research of concern." The NSABB recommended that

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3. National Science Advisory Board for Biosecurity, accessed May 11, 2014, http://osp.od.nih.gov/office-biotechnology-activities/biosecurity/nsabb.
4. PS Keim, "The NSABB Recommendations: Rationale, Impact, and Implications," *mBIO* 3, no. 1 (2012); A Casadevall and T Shenk, "The H5N1 Manuscript Redaction Controversy," *mBIO* 3, no. 1 (2012).

parts of the papers be redacted before publication. This recommendation caused significant dialogue in the scientific community, including among editors of scientific journals. This raised important questions about the consequences of redacting information from the articles. These questions were: with whom and how could it be shared, especially if the information was valuable to better understand H5N1 clinically and to enhance detection and surveillance of naturally circulating strains of H5N1 influenza viruses. Royal Society in the United Kingdom[5] and the World Health Organization[6] held a few international meetings in which the lead researchers on the papers and experts from the science, health, and security communities discussed the research, purpose, risk mitigation strategies taken prior to initiating the projects, and the project results. The conclusion of the WHO meetings was that the research had significant public health value by providing the exact mutations for which human and animal health officials should look. In this context, scientists who conducted similar research with avian influenza viruses imposed a voluntary 60-day moratorium until an acceptable path forward could be identified;[7] eventually, the moratorium was lifted but only after a prolonged time period and after significant dialogue.[8] Throughout this process leading scientists involved in the WHO discussions, including

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5. Martin Enserink, "Free to Speak, Kawaoka Reveals Flu Details while Fouchier Stays Mum" *Science*, April 3, 2012, accessed May 11, 2014, http://news.sciencemag.org/2012/04/free-speak-kawaoka-reveals-flu-details-while-fouchier-stays-mum.
6. Robert Roos, "Fouchier study reveals changes enabling airborne spread of H5N1," CIDRAP, June 21, 2012, accessed May 11, 2014, http://www.cidrap.umn.edu/news-perspective/2012/06/fouchier-study-reveals-changes-enabling-airborne-spread-h5n1.
7. David Malakoff et al., (2012) "In Dramatic Move, Flu Researchers Announce Moratorium on Some H5N1 Flu Research, Call for Global Summit," *Science*, January 20, 2012, accessed May 11, 2014, http://news.sciencemag.org/2012/01/dramatic-move-flu-researchers-announce-moratorium-some-h5n1-flu-research-call-global-summit.

high-level science policy-makers, the lead researchers, and officials associated with the scientific journals were required to get export control licenses to discuss the research and results in the international setting or publish in the scientific journals.[9] (The authors were not from the same countries where the journals are published).

Scientists played several crucial roles in setting the foundation for the US government policy on "dual use research of concern," reviewing the H5N1 papers, and identifying solutions to mitigate security risks during research and communication of research results. Scientists and institutional administrators, many of whom are scientists themselves, have also played a significant role in the issue of "dual use life sciences research." After the NSABB issued recommendations and before the controversy and debate over the two H5N1 influenza papers, scientists and administrators at several research institutions developed measures to review, oversee, and educate scientists about use of legitimate research to cause harm.[10] Education programs were developed based on NSABB recommendations but designed and carried out by scientists and educators. In 2008, the American Association for the Advancement of Science Center for Science, Technology, and Security Policy (AAAS/CSTSP) and the Program on Scientific Freedom, Responsibility and

8. David Malakoff, "H5N1 Researchers Announce End of Research Moratorium," Science, January 23, 2013, accessed May 11, 2014, http://news.sciencemag.org/people-events/2013/01/h5n1-researchers-announce-end-research-moratorium.
9. Martin Enserink, "Fight Over Dutch H5N1 Paper Enters Endgame," Science, April 24, 2012, accessed May 11, 2014, http://news.sciencemag.org/2012/04/fight-over-dutch-h5n1-paper-enters-endgame.
10. AAAS, AAU, APLU, FBI, "Bridging Science and Security for Biological Research: A Discussion about Dual Use Review and Oversight at Research Institutions," September 2012, accessed May 11, 2014, http://www.aaas.org/report/discussion-about-dual-use-review-and-oversight-research-institutions.

Law surveyed US universities for existing dual use education programs; some of these programs exist today.[11] More recently, the AAAS/CSTSP discussed with and drew policy suggestions from scientists and high-level administrators for major US research institutions on existing review and oversight of "dual use life sciences research."[12] Other scientific organizations have been as engaged, including the US National Academy of Sciences and the Inter Academy Panel. In addition, several universities throughout the world have begun developing education and review programs on "dual use life sciences research."

Federal Bureau of Investigation

In another example, the Biological Countermeasures Unit of the Federal Bureau of Investigation Weapons of Mass Destruction Directorate has established a strong, flourishing outreach program with the US scientific community.[13] The WMDD, the preventative arm of the FBI, and its scientific outreach pro-

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11. AAAS, "Professional and Graduate-level Programs on Research and Biosecurity for Scientists Working in the Biological Sciences," November 21, 2008, accessed May 11, 2014, http://www.aaas.org/report/professional-and-graduate-level-programs-dual-use-research-and-biosecurity-scientists-working.
12. AAAS, AAU, APLU, FBI, "Bridging Science and Security for Biological Research: A Discussion about Dual Use Review and Oversight at Research Institutions," September 2012, accessed May 11, 2014, http://www.aaas.org/report/discussion-about-dual-use-review-and-oversight-research-institutions.
13. Vahid Majidi, "Ten Years After 9/11 and the Anthrax Attacks: Protecting Against Biological Threats," Statement before the Senate Committee on Homeland Security and Governmental Affairs, October 18, 2011, accessed May 11, 2014, http://www.fbi.gov/news/testimony/ten-years-after-9-11-and-the-anthrax-attacks-protecting-against-biological-threats.

gram was designed to prevent further acts of terrorism and/or disasters involving CBRN materials. The Biological Countermeasures Unit has been on the leading edge of engagement with the US, and now international, scientific community. In 2009 when synthetic biology was an emerging area of research, the FBI in collaboration with the US Department of State and Department of Health and Human Services and AAAS/CSTSP held its first annual conference on synthetic biology (described as organisms created in a laboratory using synthetically-derived genetic material). Synthetic biologists (in this case professional scientists) and representatives from major gene synthesis companies attended the conference. This first conference focused heavily on understanding perspectives and practices of the different sectors (research, industry, security, and law enforcement) and the processes and practices in place to minimize potential security risks associated with synthetic genomics and biology. Leading up to this conference, scientists and security experts alike raised concerns about a paper describing the chemical synthesis of polio virus. Although the laboratory made polio virus was not as robust as natural forms and the techniques used were not new, members of the scientific and security communities still viewed this publication as a blueprint for malicious individuals to make pathogens from scratch (i.e., without any source materials).

Building off of this initial success, the FBI has continued engaging professional and amateur scientists and maintained a strong partnership with AAAS/CSTSP.[14] Working together, the FBI and AAAS/CSTSP held a total of three annual conferences on synthetic biology, each time involving more amateur scientists; discussed critical issues at the intersection between scien-

14. AAAS Bridging Science and Security for Biology Program, accessed May 11, 2014, http://www.aaas.org//cstsp/programs/bridging-science.

tific research and security with institutional administrators and researchers, particularly those associated with Institutional Biosafety Committees, Institutional Animal Care and Use Committees, and Institutional Review Boards; engaged the amateur science community; and held five policy-relevant meetings which resulted in increased sharing on best practices, challenges faced in effective implementation of security requirements while carrying out its mission activities (i.e., education and research), and suggestions for addressing the challenges. This year, the FBI and AAAS/CSTSP are engaged in a new project on big data, life sciences, and national security, which will evaluate the implications of big data on national and international biological security (including both applications to address national security problems and risks associated with the technologies and uses).

The FBI has also become a strong proponent of balancing security with scientific progress. For several years, it has sponsored an international competition—the international Genetically Engineered Machine competition (iGEM) —which is a science competition in synthetic biology.[15] This competition reaches would-be scientists in high school and undergraduate students from the US and several countries around the world. The young scientists in this competition are required to evaluate the "human practices" associated with their science project. These "human practices" include safety, ethics, and security considerations. This year, the competition is beginning a new policy category of the competition. Competitors and their mentors are encouraged to consider and address potential security risks associated with scientific experiments.

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15. International Genetic Machine Competition, accessed May 11, 2014, http://igem.org/Main_Page.

US Government Policy and Programs

Under President Bush and through the transition to President Obama, high-level policy was developed to both harness the benefits offered by science and technology, and minimize risks associated with that same technology. President Bush issued a number of Executive Orders, Presidential-level national security directives, and Homeland Security Decision Directives laying out the CBRN threat space and needed capabilities to prevent and respond to CBRN disasters. The high-level policy documents included diverse topics incident management, biodefense, and medical preparedness for any CBRN incident. During the Bush Administration, Congress passed several bills strengthening security of Biological Select Agents and Toxins, establishing terrorism risk assessments, promoting the use of new technologies to detect radiological and nuclear materials in containers, and creating a systematic pipeline for characterization of pathogens, development of medicines to protect citizens from infection with priority threat agents, process for approving these medicines, and stockpiling of the medicines. In addition, the US government established a network of laboratories to detect human diseases, animal and zoonotic (diseases infecting both human and animals) diseases, food-borne disease, and crop diseases. New systems for collecting and testing samples from the environment were created to identify potential biological agents in the soil or air.

Nearly all US government agencies developed in-house capacity to conduct scientific, engineering, and mathematically based studies and several agencies supported research and development to draw on the rich scientific expertise in US universities, public health laboratories, and private industry. The National Institute for Allergy and Infectious Diseases created eleven university-based consortiums for biodefense and emerging infectious diseases,[16] nearly all of which were associated with regional or national bio-containment laboratories.[17] The researchers in these consortiums characterized newly emerging or high-priority threat pathogens, and/or developed new vaccines, drugs, and diagnostic tools to prevent, detect, and/or treat infections. In addition, the Department of Homeland Security (DHS) established university-based consortiums (referred to as "Centers of Excellence") to expand its scientific base for addressing its most critical homeland security problems.[18] For example, the University of Minnesota hosts the National Center for Food Protection and Defense, which focuses on security problems that could occur throughout the entire food processing, packaging, and distribution system. The National Consortium for the Study of Terrorism and Response to Terrorism (START), an original DHS Center of Excellence at the University of Maryland, carries out social science projects to learn more about the terrorist threat, including non-state actor interests and motivations for using CBRN as unconventional weapons. A final example is the Foreign Animal and Zoonotic Disease Center (now called, the Institute for Infectious Animal Diseases) at Texas A&M University. This program focused its research activities on infectious diseases that infect animals only or animals and humans (zoonotic diseases).

In parallel, US scientists from the chemical and biological sciences disciplines

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16. National Institute of Allergy and Infectious Diseases, Regional Centers of Excellence for Biodefense and Emerging Infectious Diseases, accessed May 11, 2014, http://www.niaid.nih.gov/labsandresources/resources/rce/Pages/default.aspx.
17. National Institute of Allergy and Infectious Diseases, Current National Biocontainment Laboratories (NBL) and Regional Biocontainment laboratories (RBL), accessed May 11, 2014, http://www.niaid.nih.gov/labsandresources/resources/dmid/nbl_rbl/Pages/site.aspx.
18. Department of Homeland Security, Science & Technology Directorate Centers of Excellence, accessed May 11, 2014, http://www.dhs.gov/st-centers-excellence.

began interacting with their counterparts in the Middle East, Africa, and Southeast Asia in addition to Central Asia and Russia. These cooperative engagement activities focused on building scientific partnerships to develop or enhance capacity and capability in research, public health, and animal health to rapidly identify, characterize, and communicate pathogen outbreaks of international concern; strengthen safety and security in chemical and biological laboratories through physical upgrades and scientist training; and educate scientists about responsible science. Scientists and engineers contributed their expertise to carry out these activities.

Many of these activities were reinforced at the end of the Bush Administration and beginning of the Obama Administration through issuance of high-level policies, such as the National Strategy for Countering Biological Threats.[19] The Obama Administration has continued to involve the scientists and engineers to enhance the security of harmful chemical, biological, radiological, and nuclear security and develop new tools to address significant national security concerns, including those dealing with prevention and response to CBRN disasters. For example, the Departments of Defense and Health and Human Services, among others, have begun efforts to better understand personnel surety using knowledge gained through recent advances in neuroscience and the US Brain Initiative. (Personnel surety refers to vetting personnel with access to CBRN for their competency, reliability, and trustworthiness). These studies attempt to correlate changes or differences in neurotransmitter levels and synaptic transmission with the likelihood that an individual will harm another individual or group.

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19. National Security Council, National Strategy for Countering Biological Threats, accessed May 11, 2014, http://www.whitehouse.gov/sites/default/files/National_Strategy_for_Countering_BioThreats.pdf.

Neuroscience is also being used by scientists in international security policy organizations to better understand deterrence theory.[20] Specifically, these scientists are trying to build on years of neuroscience-based human behavior studies to learn how countries, groups, and key officials make decisions. These studies suggest that certain decision-making behaviors have or elicit specific neurological patterns and that these patterns can enhance approaches used national security officials to deter the development and use of nuclear weapons.

The Obama administration has invested in several other technologies and public-private partnerships to address critical national security issues. The US government has established programs to develop and use additive manufacturing (i.e., 3D printing) capability to address US national interests; used and engaged in policy discussions about big data; and created public-private partnerships with universities and private industry to facilitate medical countermeasure (i.e., vaccine and drug) development.

Additive manufacturing

Advances in 3D printing not only provides innovative manufacturing opportunities in the US, it also offers new opportunities to recover from wounds and disease. Recent research in 3D bioprinting—making of organs and tailored, synthetic body parts using 3D printing technology—provides unique opportunities for members of the armed forces (and other affected individuals) to replace organs, limbs, or other body part at the site of an incident.

20. Wright N.D., "The biology of cooperative decision-making: neurobiology to international relations," in Handbook of international negotiation: Interpersonal, intercultural and diplomatic perspectives, ed. Galluccio M, Springer (forthcoming, 2014).

As 3D and 4D printing improve, so will the prospect of forward deploying the technology to locations of greatest risk of experiencing CBRN disasters. Four dimensional (4D) printing creates products that can respond to stimuli, which is critical for developing functional organs. Despite its significant benefits, additive manufacturing of living organs might enable the creation of functional CBRN materials. Measures to ensure that advancement of this technology is maximized while any associated risks are minimized will be critically important for harnessing the potential for additive manufacturing to address health consequences of disasters involving CBRN.

Big data

The US government has invested in big data technologies to address national problems or inform policy in a number of areas, including education, health, and law enforcement. Big data is defined large amounts of continuously changing data from multiple sources that are too complex to analyze using standard statistical and computer science methods. Big data technologies, which include data collection and analysis, have been used in several national security applications, including intelligence gathering and infectious disease surveillance. The rapidly advancing and dynamic technologies are driving the use of big data to provide advanced warning of potential CBRN incidents. Within the context of biosurveillance, nongovernmental organizations, private companies, the US government, and the World Health Organization have developed automated tools to identify potential unusual infections or diseases from the unofficial sources such as the internet, pharmaceutical sales, public health and clinical reports, and other information. The US Intelligence Advanced Research Projects Activity (IARPA) has had a program on rapid infectious disease surveillance in which performers have developed automated system for collecting huge amounts of data from a number of health and non-health related sources and analyzing the varied and continuously changing data to identify potential outbreaks.[21] For example, one team of performers, Harvard University and Boston Children's Hospital, has developed a semi-automated tool—HealthMap—that includes canceled restaurant reservations as an indicator of potential illness.[22] The overall IAPRA program on infectious disease surveillance, including HealthMap, can identify potential outbreaks of influenza earlier than Google Flu Trends, another automated system for tracking and predicting trends in influenza infection, and laboratory-confirmed infections. A different private company has combined big data analytics with crowdsourcing to evaluate the validity of collected data. As technologies for big data collection, sharing, and analysis; crowdsourcing; and artificial intelligence (e.g., IBM Watson) continue to advance and as these technologies continue to become more accessible to the broader community of interested individuals, new capabilities for early detection of potential CBRN disasters could be added.

Medical countermeasures

Since the mid-2000s, the US government has invested billions of dollars in research and development of new and/or more effective vaccines and drugs for prevention and treatment of CBRN infections.[23] An elaborate pipeline for vaccine and drug development was established. This pipeline included the National Institute of Allergy and Infectious Diseases university consortiums

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21. IARPA Open Source Indicators, accessed May 11, 2014, http://www.iarpa.gov/index.php/research-programs/osi.
22. HealthMap, accessed May 11, 2014, http://healthmap.org/en/.
23. Public Health Emergency Medical Countermeasures Enterprise, accessed May 11, 2014, http://www.phe.gov/preparedness/mcm/phemce/Pages/default.aspx.

on emerging infections and biodefense to characterize priority chemical, biological, and radiological threat agents and conduct basic and pre-clinical research and development of new vaccines and drugs; private companies to carry out Phases I–III safety and efficacy trials in humans or surrogate animals; Food and Drug Administration (FDA) to evaluate the safety and efficacy data; and the Centers for Disease Control and Prevention to house the FDA-approved (or nearly FDA-approved) vaccine or drug in the Strategic National Stockpile. The Department of Homeland Security and the Office of the Assistant Secretary for Preparedness and Response (ASPR) of the Department of Health and Human Services were major drivers of the research, development, and acquisition efforts. One significant challenge this Public Health Emergency Medical Countermeasure Enterprise (PHEMCE) was that the major pharmaceutical and biotechnology companies—i.e., those companies with significant knowhow for pharmaceutical manufacturing, marketing, and postmarket testing—were not interested in developing vaccines and drugs to prevent or treat disease caused by CBRN agents. One solution to address this problem was the development of a public-private partnership between government, university, and major pharmaceutical firms to help transition new vaccines and drugs from pre-clinical to advanced development and manufacturing of projects. Three of these consortiums have been developed thus far with major universities and large pharmaceutical companies.

In addition to supporting science and technology innovation, some of which supports CBRN prevention and response efforts, the Obama administration has issued several high-level policies that involve specific expertise of the science and technology communities. Since 2001, the US government has issued strategies, passed laws, and developed and continuously updated programs to monitor infections of biological agents, identify the presence of high-priority biological threat agents in the air, and integrate different disease surveillance networks. The US Department of Homeland Security was given responsibility for monitoring airborne release of high-priority threat agents through the BioWatch Program.[24] It also attempted to integrate current infectious disease surveillance networks to enhance the United States' ability to identify unusual incidents within its borders; this effort is carried out by the National Biosurveillance Integration Center and intended to identify rare, but potentially devastating disease in the US. The US Department of Defense has supported several efforts on biosurveillance, including the research conducted at the Navy Medical Research Units[25] and other efforts to integrate global infectious disease surveillance networks. The US Agency for International Development (USAID) has developed the Predict program in which scientists and veterinarians detect and discover infectious diseases that infect wild animals and humans.[26] The US Centers for Disease Control and Prevention has established a number of infectious disease surveillance programs and have been integrated with state and local public health departments through its Laboratory Response Network.[27] This Network speaks to other infectious disease networks supported by nine US government agencies through the Integrated Consortium of Laboratory Networks.[28] All of these efforts, as well as other not mentioned in this paper, were initiated or existed

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24. Department of Homeland Security. Health Threats Resilience Division, accessed on May 11, 2014, https://www.dhs.gov/health-threats-resilience-division.
25. Naval Medical Research Center, accessed on May 11, 2014, http://www.med.navy.mil/sites/nmrc/Pages/index.htm.
26. USAID Predict Program, accessed on May 11, 2014, http://www.vetmed.ucdavis.edu/ohi/predict/Index.cfm.
27. Centers for Disease Control and Prevention, Laboratory Response Network Partners in Preparedness, accessed on May 11, 2014 http://www.bt.cdc.gov/lrn/.
28. Integrated Consortium of Laboratory Networks, accessed on May 11, 2014https://www.icln.org/.

prior to the issuance of the US National Strategy for Biosurveillance in 2012. The following year, the White House released its National Biosurveillance Science and Technology Roadmap to identify and prioritize the research and development needs for early and rapid detection of biological events that threatens the health of the US population.[29]

Global Efforts Supported by the US government

Most recently, the White House released its Global Health Security Agenda (GHSA), which prioritizes nine specific objectives within three goals—prevent, detect, and respond.[30] This agenda, which was released in February 2014 to approximately thirty countries in coordination with the World Health Organization, integrates a number of US national strategies on or related to global health security and interests to the International Health Regulations into a single initiative. The International Health Regulations is an international agreement through the World Health Assembly that provides a framework for strengthening national health systems and reporting processes to detect and report public health emergencies of international concern.[31] The US government has initiated efforts to engage other countries in implementing the core competencies of the International Health Regulations and the objectives of the Global Health Security Agenda. With encouragement from the US

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29. National Science and Technology Council, Executive Office of the President, "National Biosurveillance Science and Technology Roadmap," June 2013, accessed on May 11, 2014, http://www.whitehouse.gov/sites/default/files/microsites/ostp/biosurveillance_roadmap_2013.pdf.
30. The Global Health Security Agenda, accessed on May 11, 2014, http://www.globalhealth.gov/global-health-topics/global-health-security/ghsagenda.html.
31. International Health Regulations, accessed on May 11, 2014, http://www.who.int/topics/international_health_regulations/en/.

Department of State, US nongovernmental organizations (NGO) that directly and/or indirectly support the nine objectives of the GHSA are beginning to establish an NGO network that would parallel the governmental efforts. This NGO network would include health, security, scientific, and clinical (both human and veterinary) organizations that support the GHSA objectives. The science and technology communities are critical to successful implementation of the GHSA objectives. Examples of what the S&T communities can offer the global health security community include: characterization of pathogens; development of new diagnostic and surveillance tools; and greater understanding of personnel reliability using social, behavioral, and neurosciences. The fate of these efforts is not yet known, but they hold significant promise for integrating science and technology into the fabric of global health security efforts.

In addition to this and its several other multilateral efforts to address CBRN threats, the US government engages in bilateral activities with its allies around the world to facilitate prevention and response to CBRN disasters. During the past several years, the United States has engaged the Republic of Korea (ROK) on nuclear security and bioterrorism exercises. The threat of nuclear and biological threats emanating from North Korea has raised significant security concerns within the ROK. Among its other activities to assist the ROK in handling North Korea's threatening actions, the United States has held exercises with ROK defense officials to help them prepare for and respond to intentional biological incidents. This exercise, called Able Response, also intended to identify shared strategies for emergency response to intentional and natural biological incidents.[32]

32. "South Korea Announces Biodefense Exercise," Global Security Newswire, May 11, 2012, accessed on May 11, 2014, http://www.nti.org/gsn/article/south-korea-announces-biodefense-exercise-us/.

In addition, the 2011 Fukushima disaster has raised significant concerns about radioisotope contamination of the ocean, fresh water, and marine-life in and near the ROK. In the aftermath of this disaster, environmental and marine scientists examined the degree to which radioisotopes from the power plant spilled into the ocean. Scientists have developed models for radiological contamination of ocean water and marine life. However, little, if any, of this information has reached scientists, policymakers, and the general public in the Republic of Korea. Some Korean scientists are exploring ways in which they can access and communicate scientific information to policymakers and the public on the contamination situation and water and food security. This is an area in which cooperation between the US and ROK could help respond to and remediate any contamination of radioactive materials reaching ROK.

In addition to its bilateral and multilateral efforts, the US government engages in international dialogues through several international forums, such as the United Nations Security Council, the Biological and Toxins Weapons Convention, Nuclear Security Summit, and the World Health Organization. The Intersessional Meetings of the Biological and Toxins Weapons Convention (BWC) illustrate how the United States has shared information about its science and technology capacity in preventing and detecting deliberate and natural biological threats. In these meetings, US scientists—along with scientists from other States Parties—share information about science and technology activities that address different issues that support the goals of the BWC.[33] Past meetings focused on preventing misuse of scientific knowledge, tools, and expertise; accidental exposure (biosafety) and intentional release (laboratory

33. Biological Weapons and Toxins Convention, accessed on May 11, 2014, http://www.unog.ch/80256EE600585943/(httpPages)/04FBBDD6315AC720C1257180004B1B2F?OpenDocument.

biosecurity, including theft); and pathogen detection and surveillance. These meetings have not only enhanced sharing of information about national-level capabilities, but also have promoted sharing of scientific tools and programs to address the issues of interest.

Conclusions

This paper does not provide an exhaustive description of US efforts to develop, improve, and use science and technology to prevent and respond to CBRN disasters. Many of the tools presented in this paper are from the natural or engineering sciences and focused on addressing the biological security threats and risks. But, a broad array of scientific disciplines contributes to different aspects of hard and soft prevention and response activities.

- The social and behavioral sciences offer many more insights about effective approaches for implementing successful and sustainable programs, including the design of education and training programs, design of effective science engagement programs, development of effective and lasting laboratory safety and security procedures, development of program evaluation, and deterrence from development and/or use of CBRN weapons.

- The physics, chemistry, and engineering sciences provide significant perspective on preventing nuclear and chemical disasters caused by natural hazards (e.g., earthquakes, tsunamis, hurricanes, and flooding) and deliberate means (e.g., dirty bombs, release of nerve agents, release of harmful industrial-grade chemicals such as chlorine).

- The computer sciences are extremely critical in developing information technology, network technology, artificial intelligence, analytic tools, software that addresses critical security and privacy concerns, and other solutions to assist a number of efforts in preventing and responding to CBRN disasters. The cyber infrastructure affects all aspects of preventing accidental and deliberate release of CBRN materials, detecting and report of potential release of materials, and facilitating response efforts to mitigate and remediate CBRN disasters. This coupled with today's dependence on information technologies to communicate, access and analyze information, ensure consistent facility security and safety measures, and link individuals together have elevated the importance of computer scientists, cybersecurity experts, and data security experts in efforts to prevent and respond to CBRN disasters.

- Scientists, health practitioners, and computer scientists have begun discussing how to prevent accidental release or theft of CBRN materials from secured facilities during disruptions in critical infrastructure, such as the electrical grid (i.e., in blackout situations). Many of these facilities have backup power supplies but concerns have persisted and engineering and policy solutions have been explored.

The diverse roles and solutions that the science and technology communities can provide to governments, intergovernmental organizations, and implementing organizations to enhance efforts to prevent, detect, and respond to chemical, biological, radiological, and nuclear disasters were the foundation upon which the Asan Institute for Policy Studies (Asan Institute) from the Republic of Korea and the American Association for the Advancement of

Science (AAAS) Center for Science, Technology, and Security Policy held the January 22-23, 2014, workshop on *Science and Technology to Prevent and Respond to CBRN Disasters: US and South Korean Perspective*s. This event explored ways in which the science and technology communities can assist in preventing and remediating or responding to CBRN disasters. Speakers from the United States and Republic of Korea discussed a wide range of contributions from the health, behavioral, marine, and environmental sciences to prevention and response capabilities. The workshop ended with a special session on the Fukushima disaster from 2011. During this session, speakers discuss the scientific information needed to understand the extent of the environmental contamination from the Fukushima disaster and how this information influenced public opinion and policy decisions.

The outcome of this workshop will hopefully be increased awareness of the integral role of the science and technology community plays in addressing local, national, and transnational CBRN incidents; the importance of building on the multi-disciplinary expertise of the scientific community; and the strength of integrating the social and natural sciences together to enhance efforts and policy discussions related to prevention and response to natural or man-made disasters involving CBRN materials.

Chapter 2.
Approach to Chemical Biological Radiological and Nuclear Disasters: Role of Science and Technology in Korea

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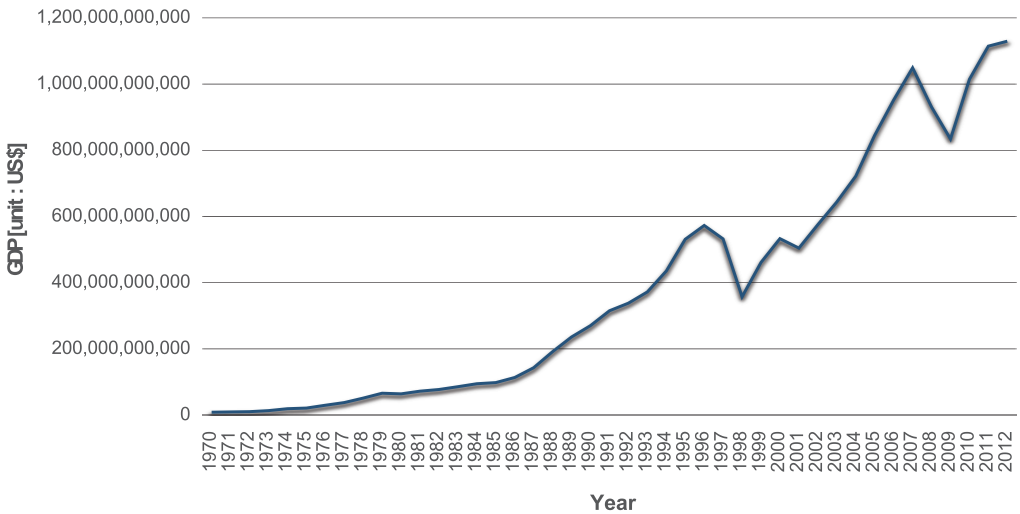
Rapid Industrialization and CBRN Disasters in Korea

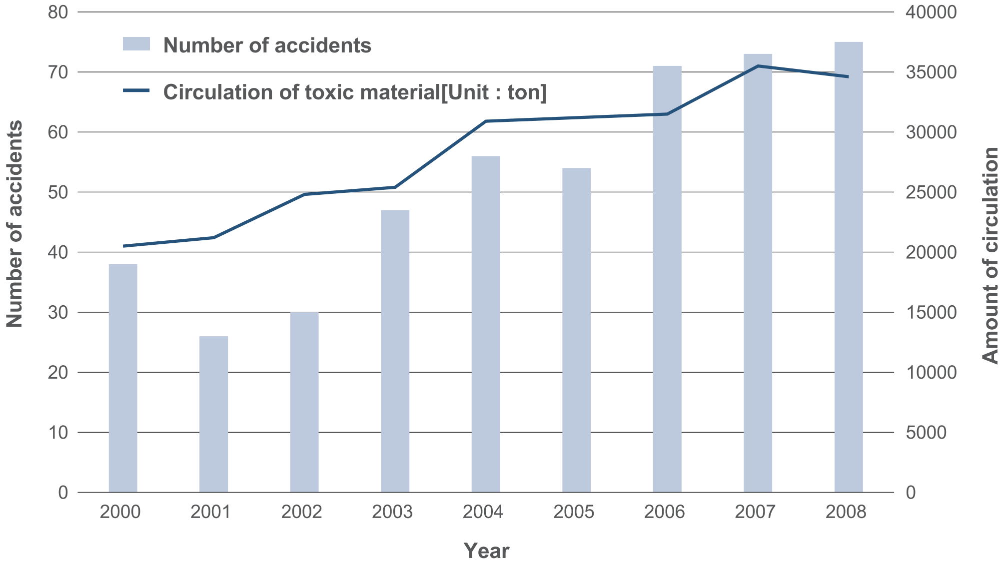
The GDP per capita of Korea increased from about USD 2 in 1948 when the Korean Government was established to USD 23,679 (Source: IMF as of 2012) in 2013.

Figure 1. Gross Domestic Product (GDP) per capita of the Republic of Korea[1]



The transformation from a traditional agricultural country into an industrial country began in the 1960s, and the introduction of the heavy chemical industry fueled the development of Korea. Carbon monoxide poisoning due to the use of anthracite at houses for heating was a major chemical accident. As the economy grew in the 1980s, the size of the heavy chemical industry grew as well. As a result, the size of chemical accidents, such as the pollution of the river by phenol leakage, hydrofluoric acid leakage and explosion of toxic materials began to grow gradually.

Figure 2. Number of accidents and amount of toxic material circulation in Korea[2]



1. UN National Accounts Main Aggregates Database (2014), http://unstats.un.org/unsd/snaama/dnllist.asp.
2. Jeonggyu Park, Yangwon Seo, "Study on the improvement of the chemical accident response system", Korea Environment Institute (2013), http://dlps.nanet.go.kr/SearchDetailView.do?cn=MONO1201327330.

With the liberalization of overseas travel, the frequency and size of communicable disease between men and beasts (zoonosis) and communicable diseases between people, such as influenza, avian influenza and SARS, grew as well. Animal epidemics like the foot and mouth disease are serious enough to strike at the foundation of the livestock industry, and zoonosis like BSE (bovine spongiform encephalopathy) caused not only public anxiety, but also political disturbances.

Radioactive isotopes and radiation generators, which were used in industries and medical service in small scales, have now developed into a high-value-added industry, and 6,094 organizations are now using them. Industrially used radiation inspection devices are lost sometimes, or pollution accidents occur in the process of separating radioactive isotopes. Korea imports scrap metals worth about USD 350,000 a month on average. The radioactive isotopes, which may be mixed in the scrap metals, may be spread indiscriminately. Recently a local government removed all asphalt pavement contaminated by radioactivity and is troubled by what it had to do to handle the contaminated asphalt.

Table 1. Status of radioisotope and radiation gauges in Korea[3]

Type of Institution	RI	RG	RI/RG	Total
Educational	172	232	109	295
Military	14	58	5	67
Medical	201	94	89	206
Industry	1,371	3,583	355	4,599
Research	194	157	69	282
Public	381	334	70	645
Total	**2,333**	**4,458**	**697**	**6,094**

Table 2. Recent scrap iron import in Korea[4]

Period	Imported price [$/ton]	Imports [ton]	Total [$]
2013.01	434	666	289,044
2013.02	434	811	351,974
2013.03	404	843	340,572
2013.04	424	981	415,944
2013.05	451	799	360,349
2013.06	436	706	307,816
2013.07	380	723	274,740
2013.08	401	651	261,051
2013.09	370	741	274,170
2013.10	380	714	271,320
2013.11	386	764	294,904
Total Average			**345,574**

The first nuclear power plant (NPP) began operation in 1978, and currently 23 NPPs are in operation, and more NPPs will be continuously constructed, and about 40 NPPs in total will be operating in the 2030s. The nuclear power generation industry of Korea has grown so much that we can export it while boasting of its high utilization rate and safety. There have been some unexpected reactor trips in some NPPs, but they attracted local attention only. However, as an increasing number of people are aware that nuclear power plant accidents can spread on a large scale after experiencing the Fukushima nuclear power plant accident in Japan, the government and nuclear operators are taking effective follow-up measures. The news about radioactive

3. Korea Institute of Nuclear Safety, Radiation Safety Information System, licensing statistical information, September 1, 2014 standards, http://rasis.kins.re.kr/rasis/index.jsp.
4. Korean Statistical Information Service, November 2013 standards.

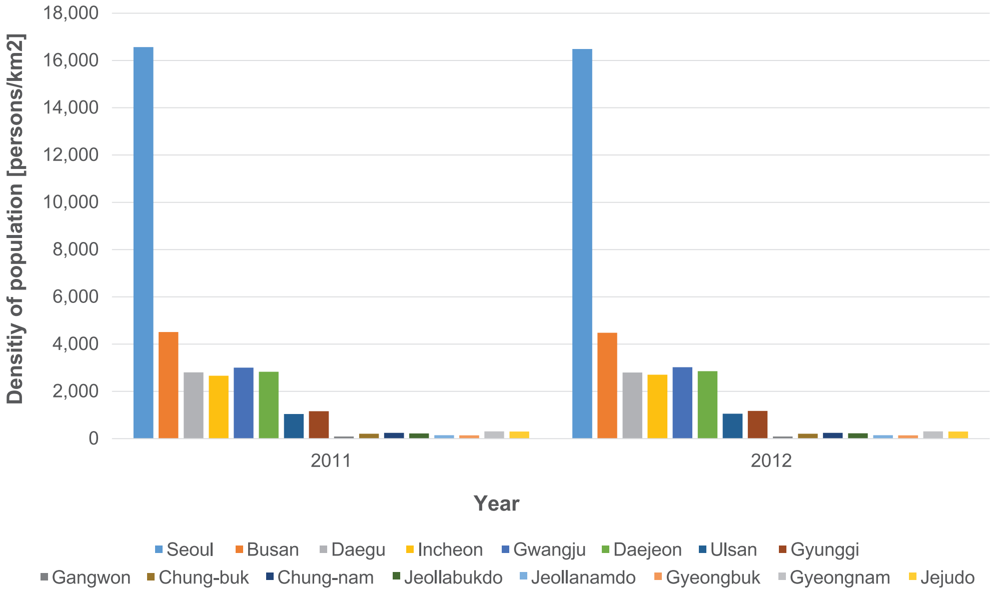
contaminated water being dumped into the sea in the Fukushima nuclear power plant is creating a concern about contaminated marine products, and the domestic consumption of marine products sharply declined as a result, giving a serious blow to fisheries.

Institutional and Organizational Efforts to Protect Dense Population from CBRN Disasters

Korea is ranked 23rd in the world in terms of population density. The population density of cities is also very high due to economic growth and urbanization. 43 percent of the entire population lives in big cities, and 48 percent of the entire population is concentrated in the metropolitan area, which accounts for 11.8 percent of the national land. In the factories, located in cities and suburbs, people are conducting work with a high level of chemical and biological and radiological hazard. In the sites for Korean NPPs chosen in consideration of the small land and environmental conditions, several nuclear power plants are concentrated in one location. If a chemical, biological, radiological or nuclear accident takes place in a country with a high population density, the impact will be very large as compared to the size of the accident, and not only the hazard to the health of residents, but also the psychological effects and subsequent influence may be uncontrollable. Accordingly, various safety inspection agencies will prevent such accidents from escalating into large disasters.

To protect the environment, workers and residents, Korea develops various safety technologies, and installs and operates safety inspection agencies. The primary duties of these agencies are to secure safety and prevent accidents. For the sake of industrial and chemical safety, Korea has 88 agencies under

Figure 3. Density of local population[5]



government ministries, such as the Ministry of Trade, Industry and Energy has 41 agencies, the Ministry of Science, ICT & Future Planning has 10, the Ministry of Environment has 18, the Ministry of Security and Public Administration has 11, and the Ministry of Land, Infrastructure and Transport has 8. For the sake of medical and biological safety, Korea has 48 agencies of which the Ministry of Health and Welfare has 29, the Ministry of Agriculture, Food and Rural Affairs has 5, and the Ministry of Oceans and Fisheries has 14. For the sake of radiological and nuclear safety, Korea has the Nuclear Safety and Security Commission and two related agencies under its auspices. The technologies they develop and the safety inspections they conduct are all based on basic sciences, such as chemistry, physics, and mathematics, as

5. Statistics Korea, *Future population projection, cities and provinces chapter: 2010-2040*, Ministry of Land, Transport and Maritime Affairs *Cadastre of land statistics.*

well as engineering technologies, such as machinery, materials, chemical engineering, and nuclear engineering.

R&D for Protection from CBRN Disasters

According to the "Framework Act on the Management of Disasters and Safety" enacted in 2004, a "disaster" causes or is likely to cause damage to the life, body, and property of citizens and the country. It is divided into a natural disaster and a social disaster. A social disaster includes a chemical, biological, and radiological disaster, and damages caused by infectious diseases in humans and in domestic animals. This Act has been revised so that the scope of disaster safety management in the national disaster safety management focused on measures against natural disasters is expanded, and the foundation of a comprehensive national disaster management system can be laid down. The new government is trying to further reinforce and systematize it, and regards technology development as one of the most important items, and it is estimated that the government needs to invest KRW 2.15 trillion in the 2013-2017 period.

Korea is ranked No. 7 in the world in terms of R&D investments, and No. 2 in terms of proportion of GDP after Israel, but the disaster and safety sector accounts for only 1.26 percent (KRW 213.1 billion as of 2013) of the government's R&D budget. The government provides 81 types of safety information. 14 agencies at different levels are operating 26 web sites. To promote science and technology regarding disaster and safety management, the Minister of Security and Public Administration must put together the disaster and safety management technology development plans of related central administrative agencies every five years, have them reviewed by the coordinating committee and the national science and technology council, establish comprehensive disaster and safety management technology development plans, and prepare and enforce policies for promoting science and technology in disaster and safety management. Accordingly, the Korean Government organized a consultative group of disaster and safety research institutions and conducts multi-agency joint research projects so that disaster and safety statistics and knowledge can be shared and synergies can be created in R&D with the Ministry of Security and Public Administration playing the central role, and to promote academics and industries related to disaster and safety, the government is trying to add the disaster and safety category to the national science and technology standard classification system.

In 2013, the disaster and safety technology development action plan consists of five strategies and 15 key projects, and the budget increased by about 20 percent over 2012, more than the increase rate of the national R&D budget, but as the basic investment amount is small, the effects of the increased budget is still measly. The five technology development strategies are comprised of customized, proactive and community-based technology development, infrastructure building and application of outcomes to the field. Among different types of disasters, 37.5 percent of the budget will go to natural disaster R&D, whereas 53.8 percent will go to human and social disaster R&D. In particular, investments in technologies responding to human and social disasters went up 32 percent over the previous year. Among the action plans, what attracts our attention as technology development topics related to this paper are "development of technologies for early discovery and detection of environmental hazards and bio-chemical terrorism substances," "development of the chemical, biological and radiological exercise simulator," "development of technology for responding to new and variant zoonosis," and "development of nuclear safety regulation technology."

Table 3. Disaster safety technology development action plan in 2013

Strategic Areas (Hundred million Won)	Key projection	Budget (Hundred million Won)
1. Damage reduction with 『Customized technology development』 **Total: 9,193**	① Risk analysis and forecasting major disasters	1,266
	② Repetitive disaster reduction technology	3,116
	③ Local information-based disaster management system	4,811
2. New disaster preparedness with 『Preemptive technology development』 **Total: 10,534**	④ Future disaster prediction and reaction technology	5,935
	⑤ Combined disaster prediction and reaction technology	4,059
	⑥ Interdisciplinary technology	540
3. Ensure public safety with 『life-close technology』 **Total: 621**	⑦ Disaster accident response ability improvement	324
	⑧ Life-close safety management	254
	⑨ Safety management technology for disabled or old people	43
4. Efficiency with 『Strengthening technology development ability』 **Total: 838**	⑩ Safety infrastructure construction	683
	⑪ Strengthening related human resources	94
	⑫ International cooperation	61
5. 『Application platform construction』 **Total: 340**	⑬ Knowledge database(DB) construction	52
	⑭ In-situ application	193
	⑮ Safety related industry development	95
Total		**21,526**

Further Remarks

Modern disasters, such as the Fukushima Nuclear Accident, avian influenza, the inflow of heavy metals due to particulate matters and Asian dust, are affecting other countries across borders. Korea, China, and Japan must urgently cooperate with one another to share information on the safety of nuclear power generation, and international joint research needs to be developed with regard to blocking the migration and diffusion of avian influenza and technological approaches for preventing the desertification of China's interior.

As disasters do not occur continuously or regularly, and happen randomly at any time in various sizes and shapes, it is impossible to accurately predict the effects of investments in their prevention or responses thereto, but the effects of safety inspection technologies, fine detection technologies, and technologies for recovering from polluted soil, air, and water cannot be anticipated without related technologies and R&D. Science, technology and R&D are playing a pivotal role in maintaining the sound development of Korea, which transformed itself from an agricultural country into an industrial country in half a century.

Chapter 3. Science and Technology as a Solution to CBRN Disasters

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Martin, Blanck & Associates

Introduction

The title of this paper may be viewed as an assertion, but I believe that it really poses a question and asks whether or not science and technology are the solution to Chemical, Biological, Radiation, or Nuclear (CBRN) disasters. I believe that the answer to the question is a qualified yes; that these solutions exist. At the very least, it calls for a description of how science and technology may provide solutions, if they exist. But it should be clear from this paper that the pursuit of science and technology alone is not sufficient. The knowledge and tools developed must be communicated effectively to those not in the scientific community who are critical to establishing policy priorities and strategic goals for use of the knowledge and tools. I will also describe how the use of science and technology, and, the education of policymakers have driven significant United States government (USG) activity over the last few decades, but with a real increase in emphasis since 2001.

My focus will be on the public health and medical sector since many uses of science and technology in solving the problems associated with CBRN events can be well demonstrated in these areas. The uses of science and technology in understanding biological systems (and the effects of radiation and chemical exposures on these systems) as we move through the 21st Century are likely to increase and inform the human systems for prevention, preparedness, and response and additional knowledge about the threats and potential responses emerge through scientific analysis.

Science and Technology as Tools

The first step in answering the question of whether science and technology are solutions to the CBRN issues is to clarify what one means by the use of the words, science, and technology, which are really quite broad concepts. If one reviews the definitions of science and technology, it is clear that they are both methodologic constructs that guide human actions to understand the workings of the natural world. Merriam Webster states that the English word science derives from a Latin word, *scientia*, which means knowledge. It goes on to state that science is "a way of pursuing knowledge to explain nature and how things occur." It is the study of nature based on facts learned through observation and experiments testing the ideas generated from observation to establish the facts and their importance. Its purpose is to generate reproducible evidence that articulates the functioning of natural systems and the causal relationships underlying those functions. It is in the end, a process for providing knowledge.

Technology is closely related, but more functional in its outcomes. It translates the understandings derived from science into tools that extend our ability to effect the natural world. Again, Merriam Webster defines technology as "the practical application of science knowledge to accomplish tasks using processes and methods derived from science." Technology allows for "the making, modification, and usage of tools, machines, techniques, and methods of organization to solve a problem or achieve goals."

In essence, science informs us about how things work and the technology allows us to use that information in practical problem solving. Discovery science exposes the insight or idea and technology translates that into practical products for our use. The two must be employed in concert if the knowledge will have real world meaning and not just remain an abstract notion. This synergy and linkage of the two has been a hallmark of many improvements in the ability to address a variety of health matters, but in particular our understanding of CBRN threats and the means to address them. Science and Technology have been very effective tools for providing greater security. But they must be understood in the context of an overall enterprise approach to CBRN matters.

The balance of this discussion will briefly describe the prevention, preparedness, and response enterprise across all sectors and then examine more closely the applications of science and technology in developing solutions for the public health and medical sector in preparing for and responding to CBRN events.

Enterprise Understanding to Achieve Success

The notion of labeling the process as "an enterprise" has been utilized with success by the US government. What does an enterprise approach mean? Why is it important? What may be learned from utilizing such an approach? Let us start by defining enterprise and its general application.

If one reviews the definition of enterprise, one discovers that it is defined as "a project or undertaking involving many different people and is risky or difficult to accomplish." The effort to exploit science and technology to address the issues at hand involves many different people across many different areas of activity. It involves the research scientist who is dedicated to the discovery of new insights and knowledge. It involves specialists in technology transfer who can take the findings of discovery science and convert these insights into useful tools. It involves policymakers who define priorities and strategies for government activity. It involves end users in a variety of disciplines who are confronted with unique problems or specific tasks in addressing the threats and their impacts. The successful outcome of all these efforts requires coherent and collaborative effort focused on a defined set of expectations and goals.

The definition goes on to clarify that "initiative and a readiness to engage in some daring or difficult action" is required. The CBRN preparedness and response arena is a risky environment since many of the ideas generated by discovery science are very difficult to translate into mature technologic tools. The experience within the human biologic sciences is instructive. The ability to convert laboratory research findings into useful pharmaceuticals for example has been somewhat dismal. The history of efforts funded by NIH and its pharmaceutical partners reveals that for every thousand or so discoveries of potentially useful compounds in treating or preventing disease, fewer than a handful ever reach the point of clinical use on a regular basis. The barriers are significant: therapeutic benefits may, upon further evaluation, be less than promised; side effects may outweigh therapeutic benefits; economical production in large quantities may be unachievable; etc. More broadly, the theoretical uses initially demonstrated may not meet clinical effectiveness and safety expectations.

As an example, the current available technologies for assessing total body radiation exposure, an important requirement for effective treatment, are predicated on useful science insights and indeed do provide useful measurements. But the size and cost of the technology is prohibitive of use with the exception of a few major research facilities. A radiation event may not occur in proximity to these tools and more mobile capabilities are needed. In this case, a different approach to technology, based on the known science is being explored. A collaboration between discovery scientists and technology innovators is central to this effort to make point of care diagnosis widely available for those who must care for affected individuals.

The riskiness of the environment is a special challenge for policymakers. Many of the potential CBRN events are low probability and very high impact. The presence of ambiguity in the process of conversion of discovery ideas into technologic tools and opportunities for intervention freights the decision making with potential policy and political pitfalls. Policymakers are frequently quite risk averse in the face of this lack of certainty. Therefore they are unwilling to make the investments needed to successfully develop the needed tools. The challenge of translating the scientific and technologic knowledge in a manner that provides as much clarity as possible can be daunting in convincing legislators or government executives to make the policy decisions and investments necessary to provide the maximum security. Effective communication skills, based on sound science, can ease the deliberations and decisions for those with policy authority. This places special burdens on the science and technology community who must provide this communication.

Lastly the definition notes that there is a requirement for systematic effort to achieve the desired outcomes. The difficulty of achieving the desired outcomes has not dissuaded the desire and willingness of the US government to invest in these efforts. Studies conducted by the University of Pittsburgh Medical Center's Center for Health Security have described USG expenditures on Biosecurity security as high as USD 60 billion in aggregate since 2001. This includes a wide range of multi-purpose costs that are only tangential to Biosecurity directed costs. But the US Department of Health and Human Services has invested in excess of USD 11 billion in the last decade in on activities clearly directly associated with mitigation of biosecurity threats. The investment in the private commercial sector is enormous as well. The difficulty of the task has been accepted and efforts supported, notwithstanding the levels of difficulty and the challenges of prioritizing government spending. Certainly there are strategic approaches to reduce the difficulty and increase the possibilities of success that employ very systematic approaches to the issues. More will be said about that in some of the specific examples which follow.

In the 20th Century such undertakings involving many different people and disciplines had many applications in science and government policy when applied to the understanding and uses of atomic energy and tools. The Apollo Project to place a man on the moon was a classic example of an enterprise approach to solving a challenging desire to apply science insights from theoretical physics and engineering technologies to real world issues. In less than a decade, the goal was achieved because of the focused effort of many people and interests to solve the problems and mitigate the risks that were barriers to completion of the stated goal.

The history of the Bell Laboratories offers other examples and is most interesting. The history is replete with examples of how discovery science could be converted into practical everyday use when bench and theoretical scientists, technology engineering innovators, business executives, and end users teamed up to achieve desired goals. The enterprise approach utilized in that setting, including the development of the uses of transistors and ultimately, their applications in computing allowed the information revolution to proceed at a very rapid pace. The nature of societal interactions has been irrevocably changed by the enterprise.

These examples are indicative of how an enterprise approach involving a wide range of people indeed demonstrates how the effort to exploit science and technologic knowledge to understand and solve the problems associated with the threats may be applied in the CBRN environment.

In summary, despite the difficulty of the tasks and the range of involved entities and individuals, the US government has embraced the notion that an enterprise approach is needed to utilize the science and technology to the best advantage. The enterprise must have clear goals and metrics to measure progress. It must include the relevant disciplines. Roles and responsibilities must be clearly defined and accountable. Success relies on constant and effective communication between and among the parties involved. Inherent to the success of the enterprise is the recognition that this is a human endeavor first and foremost. Without a systematic effort to identify and engage all of those who have a stake in the effort, and means to elicit their involvement, perspective and commitment, effective use of the tools of science and technology would not be possible no matter the strength of discovery science and the adeptness of the technologic community. It is focus on a common mission that has led to the successes (and useful failures) in the US efforts to understand and counter the threats that exist from CBRN risks.

The Public Health Emergency Countermeasure Enterprise (PHEMCE) as a Representative Approach

The overall enterprise for addressing the CBRN threats to US security involves a wide range of questions that must be answered, responsibilities to discharge, and therefore a wide range of engaged parties. It involves a sequence of activities and interventions requiring the skills and expertise of these parties. The enterprise utilizes a series of analyses and algorithms to assure the desired outcome. Public health and medical science have a critical role to play.

The determination of which CBRN potential threats constitute real threats to health and social functioning must be answered in order to target prevention, preparedness, and response efforts. Once those threats are identified, further intelligence about who has the capability to develop and use the threat instrument must be answered. The activities of those with the capability and intent must be monitored to determine the imminence. Preventing the use of the threat through interdiction efforts is the first line of defense. If interdiction fails, early and precise detection of the threat in the domestic environment is required. Public health does contribute to interdiction in that some biologic threats are preventable through vaccine use. However, in the case of manmade threats, interdiction predominately involves law enforcement and security means. Following detection, the mounting of an effective response and recovery effort must be implemented to assure that there is continuity of the social order and the wellbeing of the population. Public health and medical science and technology play critical roles in this stepwise approach to achieve those ends.

In the United States the primary responsibility for threat identification and prevention efforts resides with the intelligence, security, and law enforcement communities and the national defense team. They have the leadership for assessing the threat and the capability and willingness of hostile parties to employ the threat. Predicated on this analysis policy makers are provided an assessment of the threat and the options available for prevention or interdiction of the use of that threat. The intelligence and security officials are however informed by important work conducted by the public health and medical community.

A significant component of understanding the threat potential includes an analysis of the unique characteristics of the threat and the impact of that threat on the health and wellbeing of the population. Medical science has a role in defining the known characteristics of the agents involved. For example, basic research about the life cycle of various micro-organisms, their impact on human physiology, and the lethality of these organisms become critical considerations in evaluating biological threats. This knowledge can then be exploited in public health modeling of how that threat will affect social functioning and productivity in the society. Epidemiologic science about transmissibility and social science tools for analyzing human movement which will affect the spread of biological agents are critical to the reliability and validity of public health modeling. The PHEMCE plays a critical, but supportive role to the responsible intelligence and security elements in this portion of the overall enterprise.

The rapid expansion of science and technology tools developed in the last half of the 20th century and the early years of the 21st have significantly improved the analysis and modeling. For example, the rapid progression of genomics and the technologic ability to perform complete genetic mapping have contributed in this area significantly. The routine use of these science and technology tools in identifying emerging or modified biologic agents allows for earlier identification of sources and forensic information that facilitate the security and intelligence community efforts to interdict the use of agents. The identification of unique anthrax variants was critical to tracking the source of the anthrax used in the 2001 anthrax mailings and deaths.

Based upon this multi-entity effort, the USG has identified 15 specific threats, 13 of which are CBRN. The majority are infectious disease related, but the list includes chemical agents (nerve agents predominately), radiation detonation devices (i.e., bombs that have emitting radiation sources impregnated in the device), and improvised nuclear devices. The bio agents are numerous because their production and delivery are relatively easy to accomplish and the health and other societal effects very significant. This list provides the focus for the efforts of the public health and medical communities, and the PHEMCE.

The lead role for the public health and medical community is to prepare for the event should prevention or interdiction fail. It is the public health role to provide early identification of the threat in the domestic environment. It is the public health and medical responsibility to conduct the component of the response needed to save lives and reduce the burden of illness. Public health professionals must act to speed the recovery of the health and medical system and the wellbeing of the society's members to assure functioning in the new conditions following the event.

This is a large and significant responsibility involving elements of both the US public and private sector (e.g., more than 90 percent of medical facilities in the US are privately owned). It crosses sector boundaries in that the health and medical response is quite dependent upon many other sectors (e.g., transportation, energy, etc.) to fulfil its mission. It crosses jurisdictions in that its activities must be coordinated at the local, tribal, state, and federal level to be effective. In addition it must assure the availability of the proper tools to address the particular threat. So, although the public health and medical activities are subordinate to other elements in the threat determination and prevention phase, during an event it has a very critical and central role in assuring the continuity of societal functioning.

In executing these responsibilities, a Public Health Emergency Countermeasures Enterprise has been formed.

Elements of the PHEMCE

As noted above, the first element of the PHEMCE of importance is the ability to identify the presence of the threat. This involves disease surveillance technologies and analytic science. The current structure of US disease surveillance extends well beyond the domestic geographic boundaries. Both the US military and civilian (CDC) public health programs conduct international disease surveillance. In general these activities are designed to provide information about emerging disease patterns and trends that may be used to inform and assist health officials globally in preventing epidemic or pandemic disease spread. But they also are used for US purposes in protecting its military and civilian populations who may be in the affected areas. The information is also useful in identifying anomalous disease appearance that may suggest a manmade threat.

The surveillance is based upon the appearance of clinical disease in hospitals or clinics that provide reporting through their national public health entities. Through agreements with various national governments, these disease patterns are shared with US public health elements who analyze the information and share their interpretations of this information with agreed parties. Much of this is conducted routinely through the World Health Organization or other multilateral agreements, and also on the basis of bilateral agreements between the US and the affected countries. The rapid development of computer technologies and communication tools has significantly enhanced these efforts and facilitated analysis and communication of results.

This surveillance also includes laboratory assessment of the agents involved. As noted above, the ability to share organisms and conduct rapid genetic sequencing has facilitated understanding of the character of the threat. The sequencing of an organism also allows comparison with other organisms that may be related to assess potential mutations of closely related organisms that may be natural or manmade. The identification of specific alleles known to contribute to lethality also allow for an analysis of potential severity. The analysis may also reveal changes in certain alleles that may control responsiveness of an organism to the usual treatment such as antivirals, or antibiotics. These insights become important in planning for the impact of the agent and response planning and use of critical assets.

Identification outside the domestic borders may not be possible. Therefore the domestic surveillance capabilities must be robust, as comprehensive as possible, and tightly linked to assure timely communication and valid analysis. Thus the PHEMCE has made investments to assure that these criteria are met.

To be robust the science and technology utilized must be widely available and as reliable, specific, and sensitive as possible. Traditional surveillance has (and is) routinely based on reporting of clinical diagnoses from hospitals and clinics. But the specificity of these diagnoses is often in question and case definitions may vary significantly early in the course of a community disease outbreak. Therefore development and adaptation of science knowledge and technologic tools from the laboratory into the community must be aggressively pursued to provide more specificity and sensitivity.

So for example, the use of PCR technologies which were limited to research facilities in the recent past must be pursued to create "point of care" tools that will provide sound scientific identification and understanding of the unique agent involved in a more disseminated, and therefore more timely, manner. This has been accomplished for various agents but continues to expand. The first information that H1N1 had appeared in the US in 2009 was provided by health clinics employing a newer point of care assessment tool that was in developmental beta testing at the time. This tool designed for local use to distinguish various types of influenza quickly gave rapid evidence of a new organism that may have posed a significant epidemic threat demonstrating the usefulness of extending these tools.

To be comprehensive, the surveillance system must be as widely used as possible and employ all the tools available. So, while dissemination of certain technological tools should assure that as many communities as possible have access directly to the robust tools, some analysis still does not lend itself to wide dissemination, but they must be available to complete the analysis of the threat in detail sufficient to facilitate appropriate response. More sophisticated laboratory tools and techniques must be functional and timely. In the US this is stratified through development of advanced laboratory capabilities in a variety of geographic locations, but coordinated by a lead national laboratory. For biologic agents this leadership is provided by the CDC and its containment facilities labs that can conduct the most advanced study of agents. The FDA and the USDA provide advanced laboratory capabilities in analyzing food for threat agents and the identification of those agents. But there has been significant development of a variety of other labs both in the public health and academic domain to conduct early identification and advanced studies to understand threats. The existence of these labs provides a most comprehensive ability to understand and respond to threats.

Lastly, all of these capabilities must be linked in a timely, consistent, and reliable manner. The clinical diagnosis monitoring systems and laboratory analytics are linked through the PHEMCE. The CDC coordinates the acquisition and analysis of the clinical impressions and diagnoses reporting relying on state and local public health departments and clinicians. This is a very robust and comprehensive system that is funded through state and local sources and federal funding support. The CDC also coordinates the Laboratory Reference Network which links laboratories with a variety of capabilities and locations to assure rapid analysis and communication of results.

But it is not sufficient to assume that these scientific and technical entities are the only important partners in the PHEMCE. It requires continued education of the public and the health community to be effective. Without the commitment and participation of these components the information would not be acquired and acted upon. It also requires education of policy makers to assure its sustainment and operational strength. This part of the PHEMCE has continually displayed its utilities, but currently is in threat of decline as policymakers at all levels of government have made budgetary decisions focused on spending reductions (the US has lost over 40,000 public health workers over the last decade as federal, state, and local governments have reduced spending in this area) reinforcing the importance of policymakers in the enterprise viability.

Another pillar of PHEMCE is assuring that the nation is prepared to address the threats if they are identified in the domestic environment. Preparedness has many dimensions but begins with understanding the threats involved as a society and committing the needed time, effort, and resources to the effort. Science and technology will be central to these activities. To the degree that the threats can be described and understood with reliability and precision, the society will support an effort to address them. Science and technology allow for this reliability and precision and allow the threat discussion to be rationally based rather than on the basis of fear and anxiety. The PHEMCE has embraced the use of science knowledge and technological tools as the core of its approach to engaging the public, its own parties, and policymakers.

As suggested above, utilizing science to understand and describe the threats and their potential impact on the health and well-being of the society informs the PHEMCE understanding of what can be done to address the threat. This knowledge has been exploited very effectively through the PHEMCE in developing new and previously unavailable capabilities in diagnostics, preventive agents, and treatment compounds and devices. The vehicle for these advances has been the provision of authorities and funding to support a formal enterprise process involving both government and private sector partners, first through Project Bioshield, and then through the Pandemic and All Hazards Preparedness Act (PAHPA). This major movement forward came about through the impact of events in 2001 and educational efforts by the science and technology community.

Bioshield, PAHPA, and BARDA

In 2001, the US experienced significant events creating disasters involving manmade threat delivery. The destruction of the World Trade Center and damage to the Pentagon put the nation on alert that terrorist destruction could be delivered to the domestic environment. This was followed quickly by the delivery of anthrax spores to a variety of locations causing a number of deaths. The impact was to create a desire in policymakers to act in a way that would provide more effective protections to the population and the society. This presented an opportunity for the science and technology community to educate and inform on the nature of the threats and needed support for both expanded scientific knowledge and technological development of appropriate response capabilities.

A significant challenge was to articulate the difficulties in transitioning discovery or bench science into real products with useful applications in clinical and other settings. This was especially difficult for products that would have a limited market and use in emergency situations. Because the threats of highest interest at that moment were infectious diseases, the focus was on vaccine development and production and the limited market which inhibited very costly and risky private advanced development research investments.

Traditionally, private firms would invest in advanced development and research where there was a significant likelihood of a profitable market for the drug in question. The business model was focused on "blockbuster" products that would have a large target population, daily use, and a lengthy period of use (often decades) requirement. However, vaccines as a preventive measure historically have a limited clinical market (usually limited to pediatric populations), limited frequency of use (not required on a daily basis like chronic disease medications), and little or no repeat business (administered in a short series and no further). The investment in high cost and risky advanced vaccine development provided significant disincentives to further basic or advanced development research.

The solution arrived at by policymakers in 2004 was to provide legislation for Project Bioshield, a focused authority and multi-year funding stream to "guarantee" a meaningful public buyer for products that might not otherwise be available. The belief was that by declaring that the USG was willing to buy products to address specific infectious diseases and other CBRN threats, established drug manufacturers and emerging biotech firms would engage in the necessary research and development to bring these products to a safe and effective level for use. This was a major step forward in setting a national policy of focused effort to "push" the development of specific new science knowledge and technologic innovation as a compliment to the more traditional investigator driven approach to research funding. It established the principle that there was a national focused mission to protect the health and well-being of the society with specific outcome expectations for collective effort to achieve these difficult goals in an inherently risky environment using the science and technology capabilities of a wide variety of entities. It established the enterprise.

Almost immediately, contracts were awarded to the newer biotech firms who realized an opportunity to translate their young science into a more effective means of delivering needed products. An early investment was for a large contract awarded to guarantee purchase of a new re-combinent vaccine for anthrax. This technology was extremely immature, but like many new technologies based on genomics held great promise. It was believed that it might lead to a vaccine production process with less cumbersome and slow production requirements than traditional egg based vaccines. It also had the potential to reduce side effects associated with some traditional vaccines. It was also believed that the re-combinent protein would elicit a more predictable and significant immune response in the host upon administration. This last feature it was hoped would also reduce the number of doses required to elicit appropriate protection since the anthrax vaccine then in existence required multiple rounds of administration.

Eventually this contract was cancelled as lessons were learned about the difficulties in translating the underlying science knowledge about genomics and proteomics into technologic innovation and production. Laboratory techniques used to create research quantities were difficult to transition to production scale needed to produce millions of copies. It demonstrated the riskiness of the enterprise, but also provided meaningful understanding about the process that led to new policy developments that more effectively supported the enterprise.

Subsequently, legislative policymakers, working with the science and technology communities in the Executive branch and in the private sector, developed corrective authorities to allow for the management of risk in the development process. This was codified in the PAHPA in late 2006. This Act defined a coherent process for addressing federal goals and responsibilities in addressing CBRN threats and their effect on the public's health.

Federal public health and medical preparedness and response as a responsibility was formalized through the establishment of the Assistant Secretary for Preparedness and Response (ASPR) at the Department of Health and Human Services (DHHS) as the lead federal official for those activities. PAHPA also established the formal link between the preparedness funding for development of public health capabilities (such as the Laboratory Reference Network and Community Public Health Emergency Preparedness Program) and the medical preparedness activities at the state and local level (the Hospital Preparedness Program to expand surge capabilities in disaster events). The Biodefense Acquisition, Research and Development Authority (BARDA) was specifically authorized to conduct the advanced development efforts needed to assure progress in bringing new products or countermeasures to completion.

The challenge of bringing to coherency all the federal elements with a role in preparedness and response was significant. Within DHHS the responsibility for basic health research resides at the National Institutes of Health (NIH). Public health efforts in surveillance and disease prevention reside with the Centers for Disease Control (CDC). The responsibility for evaluation of new drugs and food safety (for non-meat products) resides with the Food and Drug Administration (FDA). These elements all have a role in the sequence of evaluating the need for new products, the science available for development and evaluation of new products, and the oversight and approval of these new drugs for specific use in humans. Aligning all these DHHS stakeholders to focus on which new potential products to support, how they can best be developed, and approving them for use in humans requires very clear understanding of the science involved and the technologies with promise. Some of the science is still immature and therefore the universally held knowledge is not fully established making for variable willingness to make decisions about approval of specific plans and investments.

Other federal partners have a role as well. The Department of Defense has actively supported basic and advanced development for decades in addressing CBRN threats. The end uses of these products are somewhat different in detail from the uses projected for the broad civilian population, but their experience and successes are of importance in acting in a coherent way to achieve the solutions desired and codified in PAHPA. In addition, there are specific authorities for very high risk research that they can employ to inform the enterprise efforts.

Private partners have a significant role and stake in this process. This includes the pharmaceutical firms, biotech businesses, engineering and device developers and manufacturers, investment firms, and business more widely (who have concerns about continuity of business in the face of CBRN threats). This is also reflected in the interests and concerns of local public officials who have a focus on sustainment of local economies in addition to their responsibilities for local health and well-being. Their engagement and support for the authorities and appropriations needed to assure that the needed tools can be supported through the whole process is crucial.

Therefore ASPR and BARDA must employ the best science and technology to assess its investments and educate and engage the stakeholders and effectively lead the enterprise. The science and technologic progress has been significant and widely communicated. Different elements of this enterprise in countermeasure development have been able to exploit and push forward various science insights and technologic improvements and even potential breakthrough approaches.

The DOD contributions are many. To highlight just a few is illustrative. In the area of early technologic development, vaccine production utilizing plant based technologies has been very effectively demonstrated. In 2012, one biotech firm employing DOD funding demonstrated the ability to produce 10 million units in 30 days of a vaccine with the safety of and immunogenicity approaching existing vaccines with a plant based method. This has promise in addressing the ability to produce large volumes of effective vaccine that because of its low cast and relatively simple technology may have special utilities for developing nations and their ability to meet their own vaccine needs. Another approach to changing the platform technologies in vaccine development is found in DOD supported studies examining the use of messenger RNA encoated in nanoparticles to stimulate endogenous antigen formation and subsequent immune response in mice. This vaccine has comparable immunogenicity to live attenuated vaccines and approaches 100 percent immunogenicity. This platform can also produce large quantities of vaccine in relatively short periods of time thus shortening the ability to respond found in the more traditional vaccine production methods.

BARDA and DOD have jointly funded products for use in Acute Radiation Sickness. At least one product has led to new insights into the role of Toll Like Receptors (TLR-5 specifically) in mediating the effects of ionizing radiation. In studies in non-human primates this product has reduced lethality of a dose of 6.9 Gys from 80 percent to 30 percent if administered within 48 hours of exposure. It is thought that a small molecule protein (salmonella flagella derived) used in this product binds to TLR-5 on cell membranes reverses cell apoptosis and also mediates certain cytokine actions to effect this improvement in outcome. Further studies are needed to demonstrate safety and elucidation of exact mechanism of action, but much has already been learned.

BARDA has funded significant product development and has 150 new products across the CBRN spectrum in its pipeline in various stages of development. It is a risky business since many products do not reach final approval through the FDA process. Indeed, the FDA process of review and approval itself is in a development science phase. Since the majority of these products cannot ethically be tested in humans to establish efficacy, the FDA is attempting to develop more science around the appropriateness and applicability of various animal models to understand if animal efficacy is correlative of human efficacy. Thus a new category of science exploration has developed around studying and cataloging animal models that most closely correlate to human efficacy. Given these limitations BARDA has been able to deliver 12 new products for acquisition and storage in the Strategic National Stockpile, but believes based on the scientific progress demonstrated in the development process that this will rise to 25 in the next few years. Included in the new products delivered to date are a newer, safer smallpox vaccine, a smallpox antiviral, botulinum antitoxin, anthrax anti-toxin, and H7N9 and H5N1 vaccines.

Even new devices have showed real progress. The need for large scale ventilator support is a clear need in certain Bio threat scenarios. BARDA sought a new design that was very low cost, low maintenance, and very easy to operate without requiring highly specialized support. Industry provided such a device within two years and these ventilators are now included in the stockpile. As noted above, the need for a tool for to provide point of care ability to assess total body irradiation quantitatively has led to significant progress in miniaturizing "gold standard" technologies in this area. A final product is not yet available, but development is proceeding. This tool would assure more precise triage for treatment to any populations with potential radiation exposure and efficient use of precious resources in this arena.

The PHEMCE has not been challenged in a direct CBRN disaster. But the scientific and technologic progress in developing new and targeted CBRN solutions has been very significant. A wide enterprise effort has made this progress possible. Of major importance was the active engagement of policy makers in the overall enterprise in ways that have facilitated science and technology progress in solving the issues around CBRN events.

The fact that policymakers recognized the need for a focused and mission specific effort across the spectrum of stakeholders in this difficult area and have provided the needed support has led to a true enterprise with demonstrable success. The policymakers, as part of the enterprise, have also demonstrated the ability to learn from the education provided by the science community through adjusting the authorities when failures offered lessons for improvement. The scientific method utilized to examine the enterprise activity has been critical to measuring success and failure and developing more appropriate solutions. This quantitative information has assured continued policymaker support for the effort. So, not only does the science and technology offer CBRN solutions through the application of their knowledge and methods to specific products, but it has also improved the enterprise response to the basic challenge confronted in leading and managing such efforts.

Science and Technology do Offer Solutions

At the beginning of this paper, the question was posed as to whether or not science and technology can solve the CBRN issues. The answer provided was a conditional yes. The conditioning variables are: national purpose; a clear description of agreed upon goals; a collaborative planning and implementation process; and full policy support. Without these enterprise features, the solutions will only occur in a rather random and fragmented manner. With the embrace of an enterprise approach that is willing to accept the risks and difficulties on the way to achieving common and defined purposes and fully exploit science and technology tools and insights, real and coherent progress can be made. The lessons learned from the USG experience in constructing and implementing the Public Health Emergency Countermeasures Enterprise are instructive. By identifying 15 targeted threats, and establishing authorities and funding to focused activity to address these threats, over 150 new tools are in active development or currently available to address these threats to national health security and social stability. The early detection of threats has been enhanced. Most importantly, the ability to plan more effective response, should the threats become events has been improved and tested.

Achieving these outcomes has required wide involvement of the security and law enforcement community, public health and medical assets, research scientists, technologic innovators, public policy leadership, and corporate commitment. But at the core, the practitioners of science and technology must think and act outside their usual community. They must educate and inform. The science and technology community must increase its skills in communication and understanding of the forces that act upon the other members of the enterprise. It must embrace the enterprise approach to have real impact. Only then will science and technology create the solutions for CBRN threats and events.

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Chapter 4.
Science, Technology and the Prevention of CBRN disasters: Mitigating Intention to do Harm

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Abstract

The dual use dilemma in the sciences is by no means a new construct or concern. As long as beneficial components of the natural world have been shaped into weapons of any kind, their dual use nature has been recognized. However, the historical context of the maturation of various natural sciences is an important consideration, when examining effective governmental approaches to mitigate the dangers of dual use; a discussion of both nuclear and biological frameworks provides a constructive comparative platform for risk mitigation analyses. When dual use issues first came to the fore of discussion within the life sciences academic community, there was, initially, a quick and ready disclaimer that many aspects of the life sciences community were not comparable to the security frameworks required by nuclear laboratories. Certainly, issues of "proliferation" for example, are not readily applied to a field of scientific endeavor in which biological organisms, by nature, multiply. Some interesting convergences of academic and scientific cultures, as well as personnel reliability challenges, are apparent as life sciences continue to mature, and we approach an age of biological manufacturing. Dual use challenges in CBRN categories are not as disparate as once

thought, and may benefit one another from shared experience. Moreover, advances in the social, behavioral, and neurosciences may offer an added layer of resource tools in assisting these challenges.

Background

Nuclear physics became an acknowledged research field at the turn of the 19th century, and continued to mature in the first half of the 19th century in a collegially competitive and mostly collaborative international environment. As early as 1924, Winston Churchill penned an article that speculated about the consequences of military applications of atomic weapons,[1] and by 1939, physicists on both sides of the World War II conflict recognized the clear dangers. Many of these researchers were actively recruited to world powers' efforts, the most recognized of which was known as the "Manhattan Project." The US government, specifically the Executive Office of the President, in deliberative policy, created classified research sites "X" and "Y," devoted to uranium and plutonium isolation. After the war, between 1950 and 1970, nuclear research revolved around the creation of nuclear weaponry, bombs, and the workings of nuclear submarines, establishing the United States as a global nuclear power, challenged primarily only by the Soviet Union. A paradigm shift towards civilian use of nuclear power had its beginnings around 1945, when harnessing energy for naval propulsion presented the opportunity to use atomic energy for making electricity. This opportunity wasn't fully realized however, until 1973, at the onset of the "Energy Crisis," when Arab nations proclaimed an oil embargo. President Nixon established an En-

1. Graham Farmelo, *Churchill's Bomb: A Hidden History of Science, War and Politics* (London: Faber & Faber, 2013).

ergy Policy Office,[2] responsible for formulating and coordinating energy policies at the presidential level, and eventually becoming what is now known as the US Department of Energy. Secret sites X and Y are now Oakridge and Los Alamos National labs. Thus, nuclear physics, from its earliest establishment as an experimental research field, was pursued for weaponry and national defense. Decades later, today's Department of Energy S&T mission is devoted to the discovery of clean energy, science, and engineering to promote US economic prosperity, and the enhancement of nuclear safety and security (which still includes defense and nonproliferation).

The life sciences have a different history in terms of governmental development of its infrastructure and resources, being primarily focused on benefits for human health. In 1798, the Marine Hospital Service (MHS) was originally established to provide for the health and medical care of merchant marines. The MHS was then charged by Congress with examining passengers on arriving ships for clinical signs of infectious diseases, especially for cholera and yellow fever, to prevent epidemics—perhaps one of the earliest efforts in National health security. A one-room research laboratory was established in Staten Island—as people immigrated to the United States—and was relocated to Washington, DC in 1904. This lab eventually became the National Institutes of Health. In 1925, only two decades after Rutherford's discovery of the nucleus, and at the close of WWI, the Geneva Protocol was created to prohibit the use of chemical or biological weapons internationally.[3] For decades afterwards, despite controversial use of "riot-control" gases during conflicts, many countries determined that chemical or biological weapons were abominations to mankind and should not be pursued. Later, the Bacte-

2. Energy Policy and Conservation Act of 1975, United States.

3. http://www.un.org/disarmament/WMD/Bio/pdf/Status_Protocol.pdf.

riological Weapons and Toxins Convention imposed further prohibitions to include the possession of such weapons, while simultaneously, the US was engaged in the Cold War, busily building nuclear weapons stockpiles, and the "triad" approach. Both the US and Russia had developed biological weapons programs, which were eventually terminated by President Nixon, who used his Office of Science and Technology to convene a panel of scientific experts[4] to prepare a separate report on chemical and biological weapons to educate his decision. Today, although the life science S&T landscape contains fully recognized dual use research risks that have been heavily debated, the use of such S&T for nefarious means is anathema to the life sciences community.

So how is this history lesson useful to the CBRN dual use landscape faced today? It creates a clearer understanding of the issues that shaped nuclear S&T in the past: first, national security and weapons development have always been a reality for that scientific community, with the S&T hand in hand. The life sciences evolved from a very different cultural construct. Second, the global Cold War struggle for nuclear superiority heavily shaped the security approach at US national laboratories—thus, ideas like a two-person rule and counting resources for nonproliferation purposes really make little sense to today's life sciences approaches. However, that history being noted, this chapter identifies some common threads such as drastic changes in the global threat environment, and rapid maturation and innovation in the biological sciences, which bring nuclear and life sciences risk scenarios into a more common viewpoint. It could be proposed that, as the threat environment evolves, and is more focused on behavioral and personnel challenges,

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4. Ivan Bennett, dean of the New York University School of Medicine, chaired the panel, which included Harvard molecular biologist Matthew Meselson, Harvard chemistry professor Paul Doty, IBM physicist Richard Garwin, and others.

some common risk mitigation strategies for dual use across all CBRN laboratories may be possible.

Consideration for Dual Use: Safety and Security

Safety and security are two obvious key areas being pursued in S&T laboratories to prevent or mitigate disasters involving CBRN. Throughout the CBRN communities of research, safety has long been well addressed. In this category, *the primary risk is accidents*. Laboratory best practices are informed by documents such as the NIH Guidelines for Recombinant DNA, Biosafety in Microbiological and Biomedical Laboratories (BMBL),[5] and similar standards which exist for nuclear and atomic energy facilities. Attentive laboratory practice has been high level in the US and accidents, for the most part, have been minimal. That doesn't mean there isn't room for improvement in this arena; in fact, the increasing incidence of large-scale natural disasters means S&T labs need to develop more robust and standardized preparedness plans around this issue. The Biological Select Agents and Toxins program already provides a handbook for select agent labs that highlights preparedness steps required in the event of an earthquake, for example, or other catastrophic event.[6] Similarly, the National Labs have R&D efforts devoted to emergency response on a national scale. Whether individual labs have preparedness plans varies among institutions and risks associated with their locale (i.e. hurricane zone, near a fault line). Katrina and Sandy were both disastrous hurricanes in which research labs were heavily damaged or in some cases completely obliterated. Institutions could mitigate damage,

5. http://www.cdc.gov/biosafety/publications/bmbl5/BMBL.pdf.

6. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5119a1.htm

prevent CBRN exposures, and provide assistance to response and recovery if they plan ahead.[7] Fukushima clearly demonstrated the perils of natural disasters which affect nuclear reactor sites—continued lessons learned will educate preparedness planning for CBRN safety.[8,9]

In terms of security, the primary risk is intentional misuse—and the key component of that risk consideration, regardless of the dual use nature of the agent of harm, is the intention of the *individual or groups to do harm*. Understanding and mitigating this risk is a two-fold endeavor. First, the nature of the threat must be understood, and second, this understanding creates a basis from which to creating successful means of countering it. The nature of the threat itself has changed dramatically since the Cold War. Today's threat is highly asymmetric, fluid, complex, rapidly changing, and uncertain, and is hallmarked by a fragile global economy, stressed ecosystems, and ever increasing global sharing of information through cybertechnology. The threat may be in the form of emerging nuclear powers, failing states, virtual and non-state actors, as well as individual "lone wolf" type actors, which may represent the bulk of the high risk for dual use scientific research labs.

By its nature this risk is incredibly difficult to mitigate; individual threats can come from outside S&T organizations, or from within—the so called "insider threat." National labs and other S&T entities focused on nuclear R&D were built to maintain a high level of physical security in response to

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7. http://healthland.time.com/2013/02/14/three-months-after-sandy-inside-the-rebuilding-of-new-york-universitys-research-labs/.
8. Revankar ST (2012) Post-Fukushima Nuclear Power Plant Safety-A Review. J Nucl Ene Sci Power Generat Technol 1:1. doi:10.4172/2325-9809.1000101.
9. http://www.aps.org/units/fps/newsletters/201301/devolpi.cfm.

outsider threats, and have long recognized the insider threat. Nuclear labs focused on insider threats from several perspectives; first, they focused on the real threat of espionage during the Cold War, and second (and continuing to date), they hope to mitigate the threat of economic or industrial espionage, or theft of US intellectual property. Life sciences labs, however, which have traditionally been completely open, had neither high levels of physical security, nor was there comprehensive consideration of the insider threat. Life sciences labs have more recently, within the past decade, considered how to manage insider and outsider threats in a real fashion, and even then, many biosecurity professionals at life sciences laboratories will frequently pose the question to their government sponsors, "What exactly are the risks we are attempting to protect against?" In many cases, this has not been spelled out in detail to life sciences academics, which are compelled to be compliant, but in an environment of growing fiscal constraints, have trouble swallowing the administrative and financial burden for a threat they don't truly understand or believe might materialize. In recent years, the FBI has made great progress on outreach programs to provide this kind of education.[10]

Another dynamic factor is that the life sciences are advancing at a rapid pace. The convergence of genome discovery with data capability has created the growing field of synthetic biology, and along with it, an advancing era of biological manufacturing, frequently now referred to as the "bioeconomy."[11] According to the USDA Economic Research Service, the US agricultural sector added USD 331 billion to the economy in 2009; this impressive figure is likely to be surpassed by genetically modified products. In 2010, US revenues

10. Bridging Science and Security for Biological Research: A Discussion about Dual Use Review and Oversight at Research Institutions. AAAS publication, Sept 2012.
11. http://www.whitehouse.gov/blog/2012/04/26/national-bioeconomy-blueprint-released.

from genetically modified products were greater than USD 300 billion, or the equivalent of more than 2 percent of GDP.[12] These can range to be anything from alternative fuels and energy sources, genetically altered food sources, "biobricks," biological climate detectors, bio-based clean chemical manufacturing, cell based combinatorial chemistry, living self-repairing materials, molecular medical devices, disease fighting cells/materials, implantable living batteries…the list continues to expand as the technology advances.[13] This means that the biological sciences are rife for the same kinds of industrial espionage or economic sabotage regarding technological innovation or discovery that nuclear labs continue to face in terms of national security.

Thus, an interesting kind of convergence has occurred, given that the threat environment for dual use risks has changed for both nuclear and biological laboratories, such that the challenges faced are more common than originally supposed. Whereas life sciences groups felt distinctly separate from all that Cold War security platforms implied, those distinctions are already being cast aside to mitigate extemporaneous threats that present risks across all S&T dual use laboratories.

A timely opportunity exists within dual use science and technology research to fully engage with the international community to address these risks and their potential mitigation jointly—so that global standards will benefit all in the scientific R&D community. Several forums for this engagement have happened over the last several years. Several years after the anthrax mailings, HHS convened the Federal Experts Security Advisory Panel (FESAP) in

12. http://www.synthesis.cc/library/Building_a_21st_Century_Bioeconomy.pdf.

13. Biology is Technology: The Promise, Peril, and New Business of Engineering Life, published in 2010 by Harvard University Press.

response to a presidential Executive Order, "Strengthening Laboratory Biosecurity in the United States."[14] A goal of FESAP was to recommend tools to assist in behavioral as well as other security methods for biosurety. This included things like physical security for high containment labs, and recommendations on ensuring personnel reliability.[15] *Personnel reliability, in fact, is a single common area of risk mitigation to all CBRN fields of dual use research.* The second global forum for discussion occurred in response to published gain-of-function experiments on highly pathogenic avian influenza. Over a two year period, countries participated in many international engagements, hosted by the World Health Organization and the Global Health Security Initiative, for example, so that international standards for treatment of dual use research could be discussed and created. Most recently, this culminated in the development of the dual use institutional policy, the final version of which will shortly be released by the USG.

As noted above, the common risk associated with all CBRN research is willful misuse, and personnel reliability programs were conceived to mitigate this risk. But the goals are broader than just screening out individuals—the goals could be described as:

1) How to more reliably identify those individuals that may be likely to perpetrate harm,
2) deter them from doing harm, and
3) to influence and promote an ethical culture of responsibility and

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14. Executive Order (EO) 13486 entitled "Strengthening Laboratory Biosecurity in the United States." http://georgewbush-whitehouse.archives.gov/news/releases/2009/01/20090109-6.html.
15. http://www.phe.gov/Preparedness/legal/boards/fesap/Documents/fesap-recommendations-101102.pdf.

awareness as the norm across all personnel.

In general, the social and behavioral sciences have had much to offer in terms understanding behavioral phenotypes. But to date, there have been few concrete tools or innovative ways to not only deter individuals, but to also influence individuals in appropriate behaviors. Advances in understanding the neural mechanisms underlying social cognitive processes such as social perception, attitude formation, emotion recognition, and decision making, have provided a novel layer to understanding the psychosocial milieu of violent behavior, radicalism, and conflict. This research convergence is also moving forward to encompass the influence of the environmental and social backdrop upon which it occurs, which many refer to as "neuroecology."[16]

"Neuroecology" is a term that refers to the combination of cognition, emotion, and behavior that influence's a person's decisions and actions. People are not simply brains; people live in and are influenced by their environment. Assessment of individuals for suitability and trustworthy behavior in CBRN research laboratories should be revitalized to encompass new tools and insights coming from these neuroecological constructs.

The need to identify individuals who may have intent to do harm is a challenge going far beyond the dual use arena. Widespread incidences of violent shootings, acts of terror, blue on green violence, and even domestic and workplace violence could potentially be mitigated or prevented by knowledge of when individuals are poised for such violent actions. A few concrete tools exist that have been discussed in other arenas. A good example construct is provided by the Defense Personnel Security Research Center

16. Sherry DF. Neuroecology. Annu Rev Psychol. 2006;57:167-97.

(PERSEREC),[17] which was initially examined by FESAP. PERSEREC is a Department of Defense entity dedicated to improving the effectiveness, efficiency, and fairness of DoD personnel suitability, security and reliability systems. Shortly after the anthrax mailings, the US Department of Defense engaged PERSEREC to provide an extensive review of personnel reliability practices with the intent to overhaul and improve them. PERSEREC to date has created a number of reports and field recommendations in that regard.[18]

One personnel screening process researched and recommended by PERSEREC includes an initial vetting process, followed by focused interviews designed to raise red flags on potentially high risk individuals. This is predicated on a presumed understanding (through an evidence base of direct observation or other data gathered in the field) of what behaviors are most concerning or have been associated with those who commit violence. PERSEREC did a study of the behaviors that security managers are most concerned about in their personnel. They then aligned those behaviors to the DSM-IV; they most closely aligned to narcissism, personality disorders, and psychopathy. Based on that, they created a set of questions specific to these 'risky diagnoses', pulled from a series of different personality batteries. These were entered into a software coding program to rate the relative "risk" of these behaviors in individuals who are interviewed. *It is important to underscore the fact that there is an extensive scientific literature confirming that those who commit violent acts are NOT psychologically dissimilar to those who do not.* This tool simply allows the user the ability to connect particular concerning behaviors with risk—it is not "personality testing" per se. Important questions for security managers of CBRN programs are what kinds of behaviors are most

17. http://www.dhra.mil/perserec/index.html.

18. http://www.dhra.mil/perserec/reports.html.

concerning? And what kinds of behavioral screens could be best utilized to minimize the risk?

Programs such as these may prove to be useful additions to the knowledge base for guiding selection of the lowest risk personnel for working with, or having access to, CBRN materials that could be misused. A combination of focused interviews, along with keen observations of behavior could perhaps help weed out the "high risk" personalities. Given the lack of specificity in screening measures, at present most operational psychologists perform detailed personnel assessments and base their recommendations on these. This is not a trivial issue and is directly relevant to other modes of assessment (physiological and neurobiological) in that *the way a person views themselves and others and their world drives the alterations in behavior, physiology and hormones*. Another major reason for why personality based screening tests have not been very useful at identifying threats is due to the ongoing and changing context of the test taker's life. All these factors could vary with a person's individual life experiences throughout the time they may be working in CBRN environments.

Outside of these tools, there are other documented capabilities to identify and validate indicators of suspicious behaviors used by the military and law enforcement in a given environment. Put simply, identification of "*what just doesn't look right*," or sometimes described as "Street Sense." These capabilities, learned from experience, inform training related to "street" level interdiction by law enforcement, and USG training related to defense, border crossings and transportation security. Many in law enforcement have come to recognize the value of those security professionals who possess law enforcement knowledge gained from the constant interaction with individuals who attempt to deceive, defraud, intimidate, coerce, and conceal for nefarious purposes. These individuals, over time, build an expertise in discerning what is "hidden in plain sight" to the untrained eye. They witness the changing adaptation cycle of criminals. Discerning "*what just doesn't look right*," is considered an essential survival skill among law enforcement professionals. Learning from this kind of experience could augment the curriculum being taught to security professionals in the CBRN arena.

The next tier for mitigating risks involves influencing or encouraging responsible and ethical behavior, while deterring individuals from doing harm with dual use materials. The interactive characteristics of deterrence and influence have long been assessed by students of political science, criminal justice, social and behavioral science, marketing and psychology. Their findings have not necessarily been hypotheses-driven, but rather shaped by the nature of the political challenges to be deterred or influenced. While this rich body of literature provides insight and distinct anecdotal experiences, tools outside of the classical deterrence theories have not been forthcoming. Moreover, the challenges have altered drastically in the last two decades, demanding novel approaches to meet a rapidly evolving threat environment as described above. There are many new observations within neuroscience and technology that might provide novel tools or resources. For example, punishment and reward strategies have been standard approaches to deterrence; neuroscience may substantiate prior social studies suggesting that reward may function less effectively as a behavior-changing strategy, but may function more effectively as a behavior-sustaining strategy.[19] This suggests it is important to foster rewards for "doing the right thing"—how could this be integrated into fostering cultures of ethical responsibility?

19. Pizzagalli, D. A., Sherwood, R., Henriques, J. B., and Davidson, R. J., "Frontal brain asymmetry and reward responsiveness: A source localization study" *Psychological Science* 16 (2005): 805-813.

Another important area for follow up could involve the neurobiology of narratives. Brains receive information through distinct mechanisms. Two of these can be described as story mode and analytic mode. When the brain functions in story mode, which might prove to be its "default" setting, a person may be more likely to accept new ideas. This receptive state is ideal for "narrative transportation." Evidence suggests that brains are actually altered in functioning for days after reading a novel.[20] For example, if a reader is reading about running, the areas of the brain that are activated if the reader were actually running are activated while reading about running; readers' brains can thus be readily transported into that of the protagonist. These findings suggest that narratives are powerful tools in terms of influencing actors, both from the viewpoint of encouraging bad actors or deterring bad actors. As this field of study matures, tools could emerge that improve our ability to forecast which narratives (and which parts of narratives) are more likely to influence individuals toward desired actions, versus those that would be effective in deterring individuals from undesired actions.

Final Thoughts

A few important themes emerge from examining the dual use dilemma from current perspectives. A rapidly evolving threat environment, with a primary risk factor being personnel reliability, along with a maturation of the life sciences toward synthetic biology, have combined to create more common risk mitigation needs across all CBRN fields than perhaps originally thought after the fateful anthrax mailings over a decade ago. Laboratory safety and

20. BernsGregory S., BlaineKristina, PrietulaMichael J., and PyeBrandon E., Brain Connectivity, 2013, 3(6): 590-600. doi:10.1089/brain.2013.0166.

security professionals can and should enhance already strong laboratory safety measures; they should continue to create a heightened awareness of security risks and responsibilities, and utilize existing well-proven infrastructure to mitigate the most obvious threats. Those threats which are less obvious, including the 'insider threats" and navigating the risk profiles of dual use experiments, is territory which requires continued public and thoughtful dialogue so that laboratories can become more familiar risks, as well as mitigating them. Lessons learned from National Labs may benefit life sciences labs more than previously thought, particularly in regards to individual malicious intent or insider threats, and what types of behavioral testing and screening paradigms are most successful. Tied to this, advances in neuroscience that are providing novel insights into understanding human behavior could be utilized to improve and validate personnel reliability programs. Neuroscience is providing a novel layer to understanding the psychosocial milieu of violent behavior and conflict, and as the body of research matures in this field, so may then emerge a set of revised influence and deterrence tools and approaches that are applicable to the 21st century security environment. The challenge will be to translate these kinds of approaches to the implementation of policy and program management at CBRN laboratories, or any settings in which dual use risks are present. Bringing together policy experts, security officials, influence and deterrence experts, along with those in fields of neuroscience and behavior will be an important next step.

Chapter 5.
Wide Area Radiological Incident Response Improvement through the Science and Technology Community

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Introduction

The 2011 Fukushima Daiichi nuclear power plant (NPP) accident in Japan resulted in widespread release of radioactive materials. This type of incident can affect nearby communities in various ways resulting in health, economic, and social issues. Considerable time and money are required to resolve these issues. The recovery from this accident is a great challenge to the entire community. The science and technology (S&T) community can help the response community reduce the overall time and cost to recover from a wide-area incident by providing advanced technologies for remediation and unbiased information to the response community and the public. The S&T community can play a critical role by providing tools to characterize the contaminated areas, developing decontamination and waste management technologies, and generating useful information for the affected communities. The resolution of technical issues can help alleviate other social issues. Effective communication between the science community and the response community is essential to ensure that real solutions are brought forward. Effective communication with the public is also critical to improve their confidence in the messages provided and the response/remediation actions taken. Customer-oriented support from the S&T community will help communities effectively and efficiently recover from such a wide-area radioactive disaster.

Fukushima Nuclear Power Plant Incident

The Fukushima Daiichi NPP accident in Japan was triggered by the 2011 earthquake and tsunami. This accident is categorized as a Level 7 (major accident) according to the International Nuclear Radiological Event scale, which is the same level as the Chernobyl accident in 1986. The major contaminants are ^{137}Cs, ^{134}Cs and ^{131}I, and the estimated atmospheric release amounts are approximately 1.5×10^{17} Bq and 1.3×10^{16} Bq for ^{131}I and ^{137}Cs, respectively.[1,2] The Fukushima NPP accident resulted in a large area contaminated with these radionuclides. The size of the restricted area is approximately 1,100 km^2 near the NPP site, and nearly 100,000 residents are still displaced from their homes.[3,4,5] The approximate size of the area considered contaminated is 13,000 km^2, similar to the size of the state of Connecticut in the United

1. Peter C. Burns, Rodney C. Ewing, and Alexandra Navrotsky, "Nuclear Fuel in a Reactor Accident," *Science 335*, no. 6073 (2012): 1184-1187.
2. Masamichi Chino et al., "Preliminary Estimation of Release Amounts of ^{131}I and ^{137}Cs Accidentally Discharged from the Fukushima Daiichi Nuclear Power Plant into the Atmosphere," *Journal of Nuclear Science and Technology* 48, no. 7 (2011):1129-1134.
3. Naohiro Yoshida and Jota Kanda, "Tracking the Fukushima Radionuclides," *Science* 336, no. 6085 (2012): 1115-1116.
4. Yasutaka Tetsuo et al. "A GIS-based Evaluation of the Effect of Decontamination on Effective Doses due to Long-term External Exposures in Fukushima Chemosphere," (2013): 1222-9, http://dx.doi.org/10.1016/j.chemosphere.2013.06.083.
5. Naohiro Yoshida and Yoshio Takahashi, "Land-surface Contamination by Radionuclides from the Fukushima Daiichi Nuclear Power Plant Accident," *Elements* 8, no. 3 (2012): 201-206.

States and the size of Gyeongsangnam-do in Korea.[6] These contaminated areas are being remediated by the local communities and the central government of Japan to reduce the radiation exposure of the residents. These types of major radioactive accidents result in an impacted area of extensive size and a lengthy recovery time. The offsite (outside the NPP) contamination impacts the community directly in their everyday lives via evacuation and remediation activities. This paper addresses how the S&T community can help in the response and recovery from wide-area radiological incidents.

Remediation of the Contaminated Area

As observed in the Fukushima accident, the contaminated area includes every type of natural and anthropogenic region such as urban, rural, farmlands, forests, inland water, ocean, etc. The communities have been impacted in numerous ways resulting in potential health, economic, political and social issues.[7,8,9] Prompt and proper remediation is a must to lessen the impact from the accident and to help rebuild the communities.

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6. World Nuclear Association, Fukushima Accident, updated January 13, 2014, accessed on February 18, 2014, http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Fukushima-Accident/.
7. Wouter Poortinga, Midori Aoyagi, and Nick F. Pidgeon, "Public Perceptions of Climate Change and Energy Futures Before and After the Fukuhsima Accident: a Comparison between Britain and Japan," *Energy Policy* 62 (2013): 1204-1211.
8. Fumihiro Yamane et al., "Study Plans Concerning Monetary Evaluation of Mitigation Measures for the Fukushima Daiichi Accident," *Energy Procedia* 34 (2013): 937-944.
9. Najih Imtihani and Yanai Mariko, "Media Coverage of Fukuhsima Nuclear Power Station Accident 2011 (A Case Study of NHK and BBC WORLD TV Stations)," *Procedia Environmental Sciences* 17 (2013): 938-946.

From the observations in Fukushima, the impacted areas can be separated into three different zones depending on the urgency of the response. These areas are onsite, offsite for immediate remediation, and offsite for long-term remediation. The onsite area is the NPP accident site itself that caused the wide-area contamination. The main objective of onsite response is to stop any further release of contamination to the environment. The facility will ultimately be decommissioned.

The second area is offsite where the public is at risk of continuous radiation exposure. The contamination level of this area is between the cleanup level and the evacuation level. For the Fukushima incident, the targeted cleanup level is 1 mSv/year for additional exposure dose measured at the height of 1 m above ground, and the evacuation level is 20 mSv/year.[10]

Remediation of this area needs to be implemented immediately to reduce the radiation dose of the residents and to recover the community from the incident promptly. The residents are expected to occupy this area while remediation is in progress. Due to the extensive area requiring remediation in Japan, generation of large volumes of radioactive waste are expected. Systematic evaluation is, therefore, necessary before conducting remediation in the contaminated area. Continuous monitoring is also necessary to provide better guidance to the public during remediation and to observe the effectiveness of the ongoing remediation.

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10. "Ministry of the Environment, Decontamination Guidelines 2nd Edition" (tentative translation), 2013, accessed February 18 2014, http://josen.env.go.jp/en/framework/pdf/decontamination_guidelines_2nd.pdf.

The third area is offsite that does not sustain constant public activity. For the Fukushima incident, this area is defined as having 20 mSv/year additional dose and required evacuation of citizens. This area may be highly contaminated but poses no direct public exposure risk. These offsite areas include, but are not limited to, the evacuated area, forest, river, ocean, etc. However, because these areas exist near the site for immediate remediation, contaminants may be transported to the decontaminated or uncontaminated areas. This re-entrainment of radioactive materials can happen via natural processes such as rain runoff and re-suspension. These offsite areas need to be controlled to prevent the contaminants from spreading. In addition, monitoring of these areas is essential to understand the behavior of the contaminants and to assess the potential risk to the public.

The above-mentioned three areas require different remediation strategies depending on their characteristics such as the surface type, weather, and human activities. Individual remediation strategies can be implemented effectively when the site characteristics are well assessed and the appropriate technical resources (e.g., methods, technologies, and information) are available.

Role of Science and Technology Community in Remediation

The S&T community has provided various methods and technologies useful for remediation (characterization, decontamination, and waste management). These technologies have been improved through their use in numerous radioactive incident responses, exercises, and research activities. The S&T community has also played a major role in generating relevant scientific information on the fate of the radioactive contaminants in the environment.

Each incident may result in different contamination type, level, and size of the affected areas. These differences are due to various causes of the incidents and meteorological conditions during the incident process. The variation of these incidents may result in different chemical and physical properties of contaminants and potentially varying risks to human health and the environment. Appropriate tools and information for the specific contamination areas are required for efficient and effective remediation. Selection of remediation technologies and necessary information depends on the pre- and post-accidental conditions of the contaminated areas. The S&T community can provide its support to improve and develop necessary procedures and methods for remediation. Each technology can be evaluated and recorded for better implementation by providing technical specifications such as application procedure, efficiency, environmental impact, cost, etc. This information will improve the quality of remediation for a widely contaminated area. As an example, the Japanese government has evaluated traditional and new technologies to assess their decontamination effectiveness before full scale application.[11] This process has helped estimate the waste volume, develop standard operating methods, and select the best performing technologies for the radioactively contaminated surfaces. In addition, the S&T community maintains a knowledge base of decontamination experience from Fukushima so that the most effective technologies for any given situation can be quickly identified. If a future incident occurs, the responders should have ready access to the knowledge and lessons learned from the Fukushima incident.

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11. Japan Atomic Energy Agency, "Overview of the Results of the Decontamination Model Projects, Role and Overview of the Model Projects," 2012, accessed February 18, 2014, http://fukushima.jaea.go.jp/english/decontamination/pdf/1%20Overview.pdf.

In addition to technology development and assessment, the S&T community can contribute to a wide-area radiological incident response by estimating the behavior of contaminants in the environment. Following the initial deposition, the radioactive contaminants are redistributed continuously throughout the environment via natural processes (e.g., precipitation, wind, uptake by animals, plants, etc.) and human activities (e.g., remediation, farming, construction, etc.). This prediction capability will help identify movement of contaminants and accumulation in the environment to answer questions such as whether the cleaned area will become re-contaminated, where to set up a monitor, which decontamination technology will be effective, how long the areas need to be monitored, etc. This scientific information will help the response community make scientifically supported decisions with regards to developing evacuation, remediation, and monitoring strategies.

Wide-area remediation demands simultaneous operation of multiple processes such as monitoring, decontamination, waste staging, transportation, etc. Optimization of this process can help reduce the cost and time for remediation. The S&T community can conduct a systematic analysis of the existing remediation process to identify any factors or practices that can be improved.

The S&T community also provides scientific and technical expertise to the government officials, public and stakeholder groups. Scientists and engineers can serve as subject matter experts from various fields. Areas of expertise include but are not limited to: technical assessment, data analysis, inputs for regulatory requirements, cost analyses, and risk analyses.

The S&T community does not have first response roles during a wide area radiological incident. However, the S&T community can help reduce the overall time and cost to recover from a wide area incident by providing advanced technologies for remediation and unbiased information to the response community and to the public, where applicable.

Customer Engagement Strategy

Following the Fukushima incident, the S&T community has generated some relevant tools and information. However, it is uncertain whether these scientific resources have met the needs of the response community. The affected public wants to know whether they are safe or not. The response community and the affected public are the customers of the S&T community. The S&T community should identify its customers, assess its customers' needs, develop scientific products that are targeted to their needs, and develop methods to deliver the necessary scientific resources effectively.

Identifying customers and assessing their needs

A wide-area NPP incident, like the incident in Japan, affects many different groups of people. Each impacted group needs to make decisions in response to the incident. The decisions include whether the public needs to be evacuated, how clean is safe for the public, whether food and water are safe, which areas need to be remediated first, etc.

For the Fukushima incident, three different customer groups can be identified as a function of their needs. The first customer group is the general public that is not living in the radioactively contaminated areas. However, this group might be at risk via ingestion of contaminated food or water, inhalation of radioactive materials transported from the contaminated areas, travel within the contaminated areas, etc. The major concern of this group is whether they are safe from these potential exposures.

The second group is the people who are directly impacted by the incident. The people in this group include residents, workers, farmers, fishermen, students within the contaminated areas, etc. Some may have to live away from their home due to evacuation, and others may live in the contaminated area where remediation is in progress. Due to the significant impact on their everyday lives, this grou p has the most urgent needs among the three customer groups. Their primary need is returning to their normal lives. They need to know many different things such as the exposure risk living for in the area, how soon they can go back to their home, how effective the remediation will be, how they will be compensated for their losses, etc.

The third group is the response community that is tasked with remediating contaminated areas and helping the community to recover from the accident. Their primary mission is to protect the health and welfare of the residents and environment of the impacted areas from the accident. Responding to a wide-area NPP incident, the response community needs various tools, information, and methods to remediate the area efficiently. Tools should be well-characterized before implementation to know the application costs, operational difficulties, efficacy, environmental impact, etc. In addition, knowledge of the fate of contaminants in the environment will help in the planning of the optimal remediation and monitoring strategies by providing scientific insights on contaminant behavior.

Each customer group may have specific questions related to the situation. For example, regarding the radionuclide release into the Pacific Ocean, the general public may be interested in the safety of the seafood. Their main question will be "Is the seafood safe to eat?" One stakeholder group is the fishermen in the impacted offshore areas. Their interests might include the following questions: Where and when can I fish? Is it safe to fish in the ocean? Which fish or seafood can I catch and sell? Will I be compensated for the impact on my business? The response community may ask the following questions: What areas need to be monitored? Which marine items need to be regulated? What radiation level needs to be regulated for seafood? Is it necessary to prepare for evacuation? What kind of communication does the government require with the public and the stakeholders? Customers may have different concerns and questions depending on their own circumstances and may need to deal with numerous issues simultaneously.

Developing targeted products

In addition to the customers' interests, the type and depth of information should be identified, which requires determining what matters to the customers. Although scientific resources for responding to a wide-area NPP incident are available, individual customers may not be able to recognize what they need. The customers may have difficulty evaluating their observations and the extent of their own knowledge. The S&T community can provide unbiased and scientifically sound evaluation of the observed information. The products developed by the S&T community can be designed to meet with the customers' needs so that the customers can deal with their practical issues. Specifically, the S&T community should aim to develop useful products for their customers. These products can be used during the customer's decision-making process.

Delivery of S&T products

The resources should be accessible to customers, and the format should be easy to use or understand. The translation of the scientific resources should be designed in partnership with the customers. Depending on the financial and structural status, resources can be provided to customers in various ways: in person (e.g., meetings, briefings, or phone contacts) and remotely (e.g., journal publications, fact sheets, newsletters, websites, repositories, press and media, social media).

Throughout the partner engagement process, the S&T community should clarify its willingness and openness to help the customers. Scientists may have little chance to get to know the response community and the public prior to responding to a wide-area incident. The customers may also not have the opportunity to gain incident-related knowledge prior to it occurring. Successful communication will help build long-lasting trusting relationships between the S&T community and its customers. The increased credibility will result in effective and efficient ways to support the customers during the response to a wide area incident.

Summary

The S&T community can support the community by providing its expertise towards the overall response to a wide-area incident. The supporting actions start with customer identification and their needs, development of target products, and delivery of the developed products to the customers. The S&T community needs to develop strong lines of communication within the S&T community itself regarding effective customer support and outreach activities. In addition, the S&T community should continue to promote its scientific integrity for individual scientists and engineers. This integrity promotion effort will ensure the transparent support to customers with the highest quality scientific and ethical standards. Following successful engagement with the customers during the response to a wide-area incident, the S&T community will be rewarded by the community with an elevated reputation. The customers will consider the funds into the S&T community as a successful return on their investment. The customers will provide full support to the S&T community. Numerous scientific fields are expected to be recognized for significance and response to the customers' interests. In summary, the S&T community will be regarded as a main pillar to build a sustainable and resilient community during and after a wide-area radioactive incident.

Chapter 6.
Understanding the Environmental Effects of the Fukushima Disaster through Science and Technology

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Introduction

At the outset, the attempt to characterize the Fukushima disaster with respect to the radiological consequences is made and the response to the Fukushima disaster by the Korean government and the understanding of Fukushima disaster by Korean public will follow.

After the 2011 Fukushima disaster, the general public of the Republic of Korea, as the closest neighbor to Japan, has been deeply concerned with possible radiological risks due to the radioactive material released into the environment over an extended period during the initial stage of the disaster. The Korean public's interest in radiation risk has been significantly heightened. After the disaster, the public began to purchase their own radiation survey meters as a daily life necessity, started to measure radiation levels, and tried to detect any abnormal increase in radiation in their everyday lives.

As a result of this change, around the end of the year 2011, they finally began to discover several cases of radioactive contamination by artificial radionuclides such as ^{137}Cs, ^{60}Co and ^{131}I in some samples such as public roads in Seoul and a kitchen utensil being sold at a supermarket. These cases could not have been discovered and become a social issue that received heavy coverage in the media if they were not detected and reported by the general public.

The second largest political party openly declared that the energy policy of their party is no more new nuclear power plant construction and a phase-out of existing nuclear power plants. New anti-nuclear activist groups were organized among so-called "community leading intellectuals" such as lawyers, university professors, and medical doctors and their involvement in policymaking and implementation of a national radiation safety program has become more active and more influential.

In the wake of the series of incidents involving the leakage of contaminated water from the tanks and the contaminated underground water release into the marine environment at the Fukushima Daiichi Nuclear Power Station site since the end of July 2013, Korean public interest and anxiety over radiological risk has been once again enkindled and turned into a social phenomenon—the so-called "radioactive marine product ghost story."

Based on these changes of circumstances in radiological risk and its perception by the general public, the radiation protection issues in Korea during the past a few years in the aspects of both practices and principles are lastly highlighted.

Characterization of Fukushima Disaster

About three years ago, as we all know very well, an unfortunate nuclear accident occurred at the Fukushima Daiichi Nuclear Power Station. Units one and three of the reactor buildings experienced a hydrogen explosion and core meltdown. As a result, a large amount of radioactive material was released into the atmosphere and into the sea.

One of the eminent international organizations in the area of radiation protection, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), has initiated a program to evaluate information from 2011 and 2012 on the levels of radiation exposure due to this disaster. More than 80 experts from 27 member states have participated in this exercise and the publication of the report is slightly delayed but is about to be finished, hopefully within the first quarter of 2014. This part of the paper is largely based on this report.[1]

Radioactive material was released into the environment over an extended period during the initial stage of the disaster. However, the pattern of release was complex, both temporally and spatially. Releases began on March 12, 2011, and the rate of release varied considerably in magnitude over the following week, with marked increases associated with particular events at each unit.

The Japanese authorities decided on a number of measures to protect the public, including immediate evacuation within 20 kilometers of the station and late, so-called “deliberate” evacuation of Litate village, where the cumulative effective dose was expected to exceed 20 mSv within a year, and sheltering in homes, restricting distribution and consumption of contaminated food and water, and instructions to take stable iodine.

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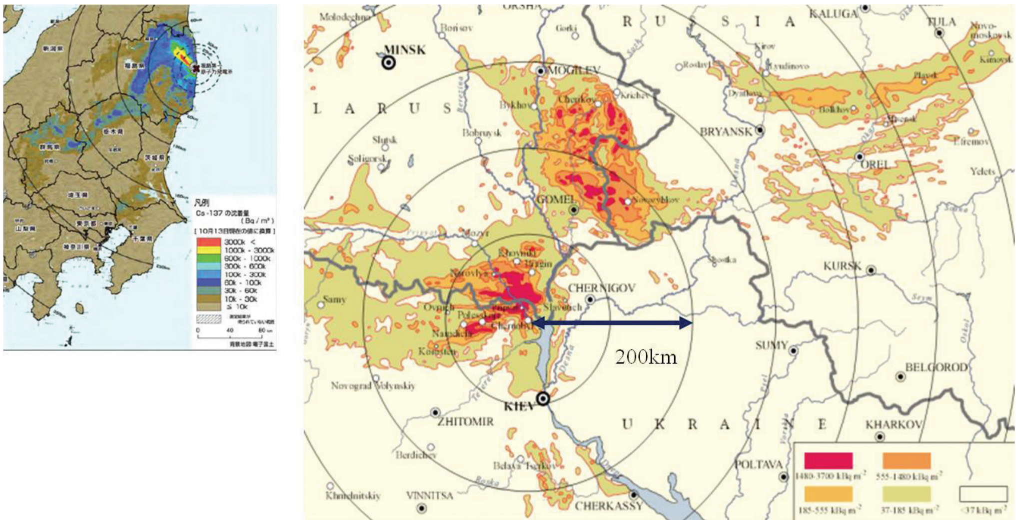
1. UNSCEAR 2014 Report, Annex A Levels and effects of radiation exposure due to the Fukushima nuclear accident.

The estimates of the release of I-131 fall within the range of about 100 to 500 PBq and those of Cs-137 within the range of about 6 to 40 PBq. Compared to the Chernobyl accident in 1986, the estimated releases from the Fukushima Daiichi are lower than those estimated for the Chernobyl accident, by factors of about 10 and 5 for I-131 and Cs-137, respectively.

Figure 1. Cs-137 deposition density at Fukushima and Chernobyl, Courtesy of Mr. Toshimitsu Homma, ICRP C4

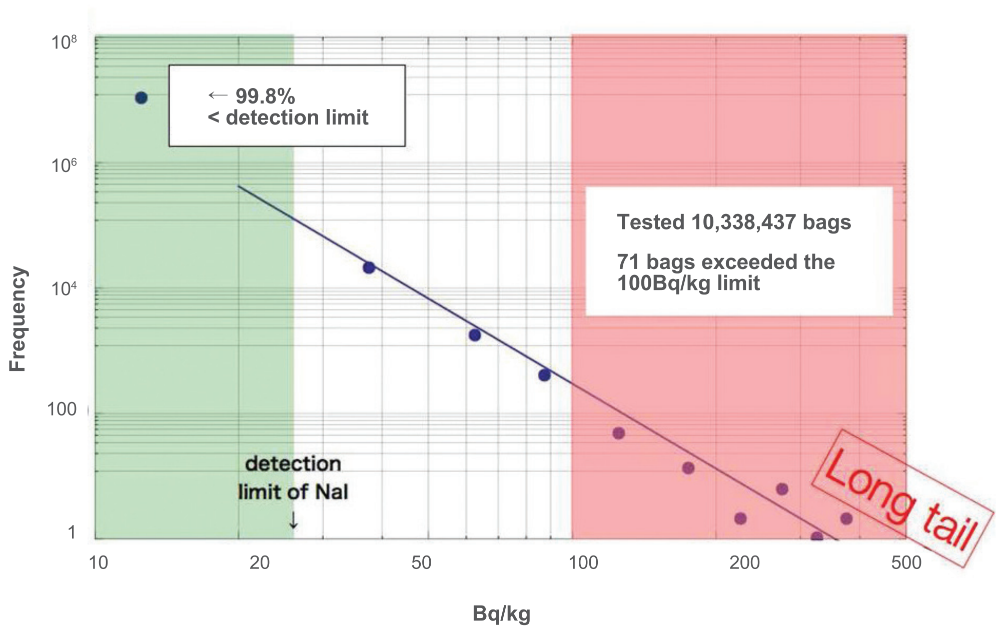


Note: Same Scale

Figure 1 includes the two maps drawn in the same scale, which show the difference of the magnitude of the affected areas in land mass. One of the reasons that make this difference is the meteorological conditions pertaining at the time of release. For a significant fraction of the period when the releases were largest, that is from March 12 until the beginning of April, the wind was blowing out to sea. It was estimated that about 40 percent and 30 percent, respectively, of the total releases of I-131 and Cs-137 were dispersed wholly over the ocean.

Measurement of radiocesium was done for more than 10 million bags of brown-rice harvested in the Fukushima prefecture during the year of 2012. Figure 2 shows the result and is given in log-log plot. More than 99 percent were found to be less than the detection limit, which was about 25 Bq/kg and only 71 bags out of 10 million bags exceeded the 100 Bq/kg limit. More importantly, it should also be noted that there was a very long tail of the distribution. However, it can be easily expected that the length of this long tail will be shortened soon as time goes on.

Figure 2. Data of the measurement for radiocesium for the bags (30kg each) of brown-rice harvested in Fukushima in 2012, Courtesy of Mr. Ryugo Hayano, ICRP2013



Note: Same date in log-log plot

Statistics on the amount of radioactive material released into the ocean showed that the deposition on ocean surface from the atmosphere were estimated to be 5–7.6 PBq and 57–99 PBq for Cs-137 and I-131, respectively, and the direct release into the ocean were estimated to be 3.6–27 PBq and 11 PBq for Cs-137 and I-131, respectively. And it should be mentioned that many people around the world, including the Korean public, have been anxious about the possible radiological hazards from contaminated marine products, such as fish.

The result of the simulations of Cs-137 dispersion across the Pacific Ocean over the next 30 years has indicated that radionuclides released would reach the US Californian coast four-to-five years after the accident, but this timescale is likely to be a little bit overestimated. However, simulated concentrations were found to be of the same order of magnitude as the average Cs-137 concentration in the Pacific Ocean that existed before the accident, which is about 3 mBq/liter. The model indicates that Cs-137 released from the Fukushima Daiichi will have been distributed throughout the North Pacific within ten years of the accident at concentrations below 1 mBq/liter.

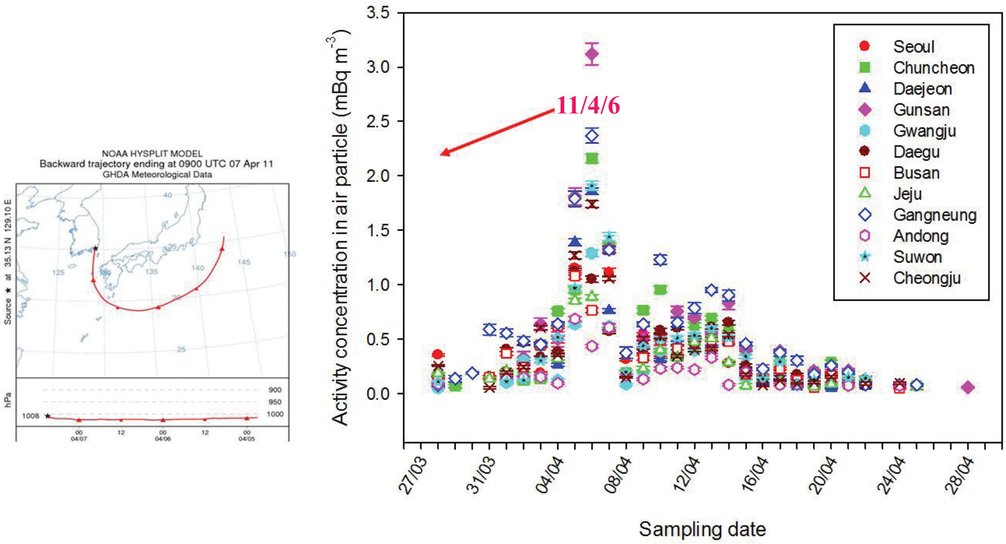
One of the remaining challenges is the long-term rehabilitation of living conditions in the areas affected by the accident. In this regard, the International Commission on Radiological Protection (ICRP) initiated a dialogue in fall 2011 to find ways to respond to this challenge. Over the last seven rounds of dialogues, progress in understanding the situation on the rehabilitation of living conditions in the affected areas was made and complex problems such as the contaminated foodstuffs, the education of children at school, the delicate issue of “returning or not, staying or not” in the affected areas, and the current specific problems and challenges being faced by the people of Iitate and Iwaki villages were discussed.

Response to the Fukushima Disaster by the Korean Government

About one hour after the major tsunami attacked the Fukushima Daiichi Station, the Korea Institute of Nuclear Safety (KINS), which is the Korean nuclear safety regulatory expert organization, made its first report about the situation in Japan to the relevant Korean government ministry, activated the emergency response team, and strengthened the environmental radiation monitoring program.

On March 23, radioactive xenon was first detected in air samples and on March 26, a radioactivity monitoring plan for seawater and marine products was initiated. On March 28, the sampling period of various environmental samples was further reduced and on March 29, radioactive iodine was first

Figure 3. Data of the measurement for I-131 after the Fukushima disaster



Note: Temporal variation of ^{131}I activities in airborne dust samples at 12 regional monitoring stations At April 6, the maximum ^{131}I was detected.

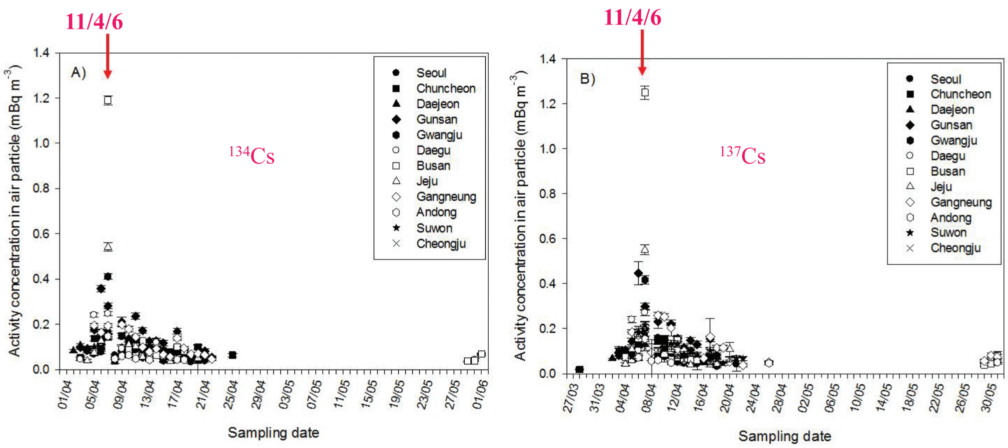
detected in air samples.

Figure 3 shows the temporal variation of I-131 in airborne dust samples and the peak of the distribution can be seen on April 6, when it rained. Figure 4 also shows the temporal variation of Cs-134 and Cs-137 in the same airborne dust samples and again the maximum value can be seen on April 6. However, the concentrations were found to be quite low and be in the order of few mBq per cubic meters. If we convert this concentration into radiation dose with some very conservative assumptions, it was found to be the level of about 1 percent and/or far below the public dose limit, which is 1 mSv per year.

KINS also measured radioactivity such as Cs-134 and Cs-137 in seawater around the Korean peninsula at 27 sampling locations and, so far, all of the results show no notable change at all between, before, and after the Fukushima accident. The average concentration of Cs-137 in seawater was measured to be ND (Non-detectable)-2.75 mBq/kg for the years from 2011 to 2013, while those for the years from 2006 to 2010 were ND-4.04 mBq/kg. For Cs-134, all measurement results were found to be ND.

That is the same for the radioactivity in fish. The average concentration of Cs-137 in fish at 29 sampling locations was measured to be ND-0.174 Bq/kg for the year 2013, while those for the years from 2006 to 2010 were ND-0.184 Bq/kg. For better understanding of the levels of background radioactivity, it should be noted that the radioactive concentration of K-40, which is one of the typical natural radionuclides, in fish was found to be 18–118 Bq/kg for the year of 2013.

Figure 4. Data of the measurement for Cs-134 and Cs-137 after the Fukushima disaster



Note: Temporal variation of ^{134}Cs and ^{137}Cs activities in airborne samples at 12 regional monitoring stations

At April 6, the maximum ^{134}Cs and ^{137}Cs were detected.

Korean Public Understanding of the Fukushima Disaster

For the Korean public, it is all about the radiation and the possible radiological hazards to their family members, especially to babies and young school children. People's anxiety and fear over radiation risk was first provoked by the mistake in the Korean government response. A few government officers came on TV news and said that radioactive material released from Fukushima will never come to the Korean Peninsula, since the wind always blows from the west to the east. However, the wind that came to the Korean Peninsula on April 6 originated from the Fukushima region and brought rain together with radioactive material, though the concentration was extremely low. This evoked people's anxiety over radiation risk and provided a reason for the distrust toward the government announcement on Fukushima disaster.

Since March 11, the interest of the Korean public in radiation risk has been significantly heightened and people began to purchase their own portable radiation survey meters on account of strong interest in and fear of radiation risk. They measured radiation levels in their nearby living environments, such as schools, supermarkets, playgrounds, etc., and several new anti-nuclear web communities, such as ChildSave and KnowLive.Net, were formed, especially among young housewives who have school children, and became very active in leading public opinion on radiation risk perceptions via already well-developed Internet infrastructure and social network services (SNS).

During the years of 2011 and 2012, the most significant change in Korean society with respect to anti-nuclear activities was intellectuals such as university professors, medical doctors, lawyers and even members of the national assembly forming anti-nuclear NGO's such as the Post-nuclear Professors Association, Anti-nuclear MD Association, No-nuclear Lawyers Association, and the Members of Parliament Study Group for No-nuclear Energy. They publically raised their voices and began to be influential across the whole of Korean society.

In summary, with regard to the Korean people's perception on radiation risk at low doses after March 11, 2011, there is still certainly a high level of anxiety and concern over radiation risk among the population, which is a little bit over-amplified. There existed a few so-called "non-expertise experts" who tried to enlarge the health concern and anti-nuclear NGOs strengthened their activities with some political intentions. So-called "ghost stories" were quickly and widely spread through SNS. Here "ghost story" means "a false rumor, without any basis." Korea radiation protection experts tried to mitigate the over-exaggerated health concern by informing the public of scientific knowledge on risk, but failed to find ways to discuss the tolerability of radiation risk and risk in comparison to other hazards. As a result, the deep distrust in government reactions to the Fukushima disaster prevails and the loss of credibility in remarks by government-based experts is unavoidable.

Radiation Protection Issues in Korea regarding Practices

Around the end of 2011 and the beginning of 2012, a series of radioactive contamination cases were identified and all of these cases were discovered by members of the general public, including the following four examples.

First, a public road in a residential area in Seoul was founded to be contaminated with Cs-137. After thorough investigation by KINS, it was concluded that the contamination was due to the mixing of asphalt with the ash from a steel mill, which was tainted by melted radiocesium orphan sources. This case received extensive coverage by mass media.

Second, a housewife detected a relatively high level of radiation in one of the rooms of her house. As the case turned out, the wallpaper of the room for her child was specially manufactured with a high content of monazite, which also has a high content of natural radionuclides, such as thorium-232 and uranium-238. The wallpaper producer advertised that their paper is good for health because of the negative ions generated by the wallpaper.

Third, a plate rack for standing washed dishes to dry, which was arranged on a display stand for sale in one of Seoul's major supermarkets, was found to emit a high level of radiation. In this case, it was confirmed that the raw material of a steel pipe used for the fabrication of the plate rack was contaminated with Co-60 in its manufacturing process and was imported from a neighboring country.

Fourth, in the middle of January 2012, a report was sent to KINS through the local police station that a high level of radiation was detected in a certain area of Seoul. It was found that this case happened because of a thyroid cancer patient who had just been administered I-131 and stopped by a restaurant in front of the hospital while returning to her home.

After this series of cases through to the beginning of 2012, it seemed that public anxiety and interest in radiation in the aftermath of the Fukushima disaster had cooled for a while. However, since the end of July 2013, at the Fukushima Daiichi Nuclear Power Station site there were a series of incidents involving the leakage of contaminated water from the tanks and the continuous release of contaminated underground water into the marine environment. This once again raised Korean public interest and anxiety over radiological risk and turned into a social phenomenon—the so-called "radioactivity marine product ghost story." Because of this ungrounded rumor on the high level of contamination of seawater and fish by radioactive material and the issue of the ban on imports of fish from Japan, the sale of marine products in the market sharply decreased through to the end of 2013.

Further releases of radioactive water to the marine environment are still ongoing at the end of 2013 and we know that these continuing release rates are at a level much lower than the major releases that occurred in the immediate aftermath of the accident, and measures are being taken to attempt to control these sources. Though the current liquid discharge is considered unlikely to significantly affect the marine environment, continued monitoring and assessment of their implications are warranted to better estimate the effects on people and non-human biota.

Radiation Protection Issues in Korea regarding Safety Level

The issue can be summarized as one question, "What is a safe level?" Since July 2013, Korean mass media such as TV and newspapers again extensively covered the issue of radioactive contamination of fish and resultant possible harmful health effects such as cancer incidences. Two different views on the health risk of low-level radiation exposure were expressed by different experts.

The public dose limit is set within margins below the level that can be regarded as "dangerous." However, there are a few medical doctors in Korea who have different views and they have raised and/or argued the following:

- It is safe if it's under the limit.
- Though under the limit, it does not mean "safe" medically.
- The dose limit is not a value with a medical background.
- Unless the dose becomes zero, nobody can say that it is safe.
- There is no safe radiation dose, since research results and text-books in medical school state that as exposure increases, cancer incidence also increases.
- No matter how small the dose is, no one can guarantee that there is no health effect from the dose.
- The Cs-137 limit for fish in Korea is crazily high. One hundredth of 370 Bq/kg would be appropriate. International Physicians for the Prevention of Nuclear War (IPPNW), a Nobel Prize laureate, suggests that 8 Bq/kg for adults and 4 Bq/kg for children as the limits. Germany already accepted this limit. Compared with the Korean limit, these values are extremely low.

ICRP stated in its 2007 recommendations that there are uncertainties regarding doses of about 100 mSv or less.[2] UNSCEAR stated that it is only doses above about 100 mGy where a significant increase in cancer risk is detectable and for doses below 100 mGy, it is prudent to adopt the linear non-threshold (LNT) hypothesis for protection purposes.[3] A BEIR VII report suggested that approximately one instance of cancer per 100 people could result from a single exposure to 100 mSv of low-LET radiation background.

When ICRP established the basic principles of its radiological protection system, they relied not only on a scientific basis such as the results of epidemiological and radiobiological studies, but also on the value judgments because of the uncertainties at the level of below 100 mSv and the adoption of the LNT hypothesis. ICRP also used the risk model of tolerability and set the dose limit at the borderline between unacceptable risk and tolerable risk and recommended, in the region of below the dose limit, that the dose should be reduced further as low as reasonably achievable by using the dose constraints for the purpose of optimization.

However, it can be noted that all the currently ongoing confusion over radiation risk perception in Korean society comes from this difference. Namely, the scientific understanding is that 100 mSv is the borderline between safe and unsafe, while the public and political understanding is that any level is on the borderline between safe and unsafe.

This kind of confusion and misperception regarding radiation risk, which resulted in excessive concern over the risk of low radiation doses by the pub-

2. ICRP 2007 Radiological Protection Recommendation, ICRP 103, para. 62

3. UNSCEAR 2000 Report, Sources and Effects of Ionizing Radiation.

lic, was caused by a few so-called "non-expertise experts." This is due to the lack of both sufficient and reasonable discussion and debate, and the shortage of radiation protection experts. Therefore, there is a strong and urgent need to disseminate the correct information about the possible harms of the ionizing radiation exposure and knowledge of the health effects of low-level radiation exposure, including the LNT hypothesis.

Conclusion

Currently, Korea is experiencing failure in communication with the public about the magnitude of radiation risk and its tolerability and the loss of trust in government and its experts. There is a very weak base of radiation protection specialists and a tendency among government officers to not normally think highly of the opinion of technical experts in their decision-making processes.

Based on these observations, the following includes some suggestions regarding these issues for the future of Korea:

- There is a need to further strengthen the national human and material infrastructure for radioactivity analysis. This would contribute to the improvement of the reliability of radioactivity measurement and analysis and the assurance of radioactivity analysis capability for a possible similar scale NPP accident in a neighboring country.

- There is need for the recognition of the big gap between the true and perceived levels of radiation risk, and its resolution. For this, the openness of all radiation safety related information to the public in more active ways and means, including via SNS and the development of measures for clearer and easier communication on radiation risk, as well as strong governmental support for all radiation risk communication efforts by experts are desirable.

- There is need for the establishment and strengthening of a firm and solid governmental control tower for the management of radiation safety. For this, the establishment of an integrated system for rapid and coordinated government response and continuous strengthening of the current role and function of the Nuclear Safety and Security Commission as a governmental control tower for radiation safety are worthy of pursuit.

In conclusion, the regaining and securing of mutual trust in Korean society through effective risk communication is the key to the solution of the existing problems in radiation risk perception. There is certainly a big challenge ahead in transforming a society of distrust into a society of trust.

ASAN
REPORT

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