Perspective

Broader Impact through the National Academies

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Introduction

"What is the broader impact of the proposed activity?". Anyone who has applied for an NSF grant in the last 10 years will recognize that question. Answering it requires quickly refocusing eyes and perspective from the details of a nanoscale structure, or an amino acid sequence to the eventual impact the work might have in helping to cure disease, create a new material, improve our standards of living, or contribute to the general health and well-being of our nation and the world.

Swirling just beyond the realm of discoveries and patents is a realm that might be less familiar to some scientists—that of public policy. It is a realm where leaders face tough decisions related to some of society's most pressing issues. Top priorities in recent years include national security in the face of worldwide terrorism, recovery from devastating natural disasters, climate change, and environmental health, to name a few. Addressing these issues requires considering the needs of the several "publics" that hold various values, ideas and often competing interests. Science plays an informing role; it represents the best mechanism we have to provide objective information about risks, costs, and benefits of policy decisions.

Members of the engineering community have expertise and experience to help answer specific questions related to these issues, but they are not always aware of the problems federal and state officials are grappling with. The engineering and government communities can come together through the work of the National Academies—the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine, and their advisory arm, the National Research Council.

This article illustrates the advisory work of the National Academies through selected examples of recent reports issued by the National Research Council, and suggests ways in which chemical engineers can participate in this important endeavor.

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What are the National Academies?

The National Academies are nonprofit organizations that work outside the realm of government and special interest groups. When requested by a federal agency or Congress to provide scientific and engineering advice and guidance on a topic, the National Academies identify and convene committees of experts drawn from the appropriate disciplines and from across sectors (industry, academia). The selection of study committee members is done without interference by the federal sponsors; members are screened for conflict of interest and serve without compensation. The report resulting from the committee's deliberations is subjected to a peer review process, and only when the National Academies deem that the review comments have been adequately addressed is a report released to the federal sponsor and to the public.

Because of the independence of its study process and the strict quality-control measures in place for the final report, National Academies studies are generally considered the ultimate in expert opinion. Many garner extensive media coverage. These studies often provide decision makers with the information they need to move to enact legislation, to establish new government programs or research initiatives, or take other action.

Chemical engineers, working with colleagues in other disciplines through National Academies study committees, have recently addressed a number of issues for federal decision-makers. Committee members extend knowledge from existing research and their own general expertise and experiences to a new question posed by the federal or state agencies.

Solutions for National Security

The Department of Defense's Defense Threat Reduction Agency (DTRA) is responsible for assuring that technology deployed in the battlefield meets warfighters' needs. In 2002 DTRA came to the National Academies for assistance in assuring that its testing and evaluation protocol for standoff chemical detection systems was adequate to provide a reliable measure of system confidence that could be used by commanders to make battlefield decisions about troop protection.

Standoff chemical detection refers to the capacity to detect and identify a chemical warfare agent release at some distance, in this case several kilometers. Standoff detection capability is desired to give commanders advance information on chemical threats, enabling real-time decision making on the necessity of donning chemical protective gear or other protective measures.

The challenge in evaluating the performance of standoff chemical detection systems lies in the fact that international treaty, as well as human health and environmental concerns make challenging these detection systems with real chemical warfare agents under realistic field conditions difficult, time-consuming and expensive, if possible at all. Another means for reliably assessing the performance of these systems is required.

An interdisciplinary study committee with expertise in laser imaging detection and ranging (LIDAR); infrared, vibrational and Raman spectroscopy; sensing; atmospheric chemistry; aerosols; and risk assessment considered various possibilities for testing in the field and in chambers; for testing with chemical warfare agent and with stimulant chemicals; and for testing system components versus whole-system testing. One particularly challenging aspect of the problem was accounting for the large number of interfering chemical species expected to be found in actual battlefield experience—smoke, diesel fumes and exhaust, and concomitants. The committee recommended test and evaluation regimes for both passive and active detection systems. In each case, a complex protocol involving obtaining and archiving large numbers of background spectra from battlefield conditions; verifying algorithms for extrapolating data obtained with simulants to expected response with chemical warfare agent; and understanding the relationship between component performance and whole-system performance, was outlined (National Research Council, 2003a).

The study recommendations, although complex, were fully embraced by the Department of Defense (DOD). Subsequently, a second study was requested to examine testing and evaluation methodology of biological point detection systems (point detection refers to detection at the warfighter's location, rather than at a distance). Again, a complex but robust methodology involving a combination of chamber and field testing; testing with stimulant organisms, and with both killed and live biological agents; and component vs. whole-system testing was developed by the study committee (National Research Council, 2005). An on-going study will now extend those results to biological standoff detection.

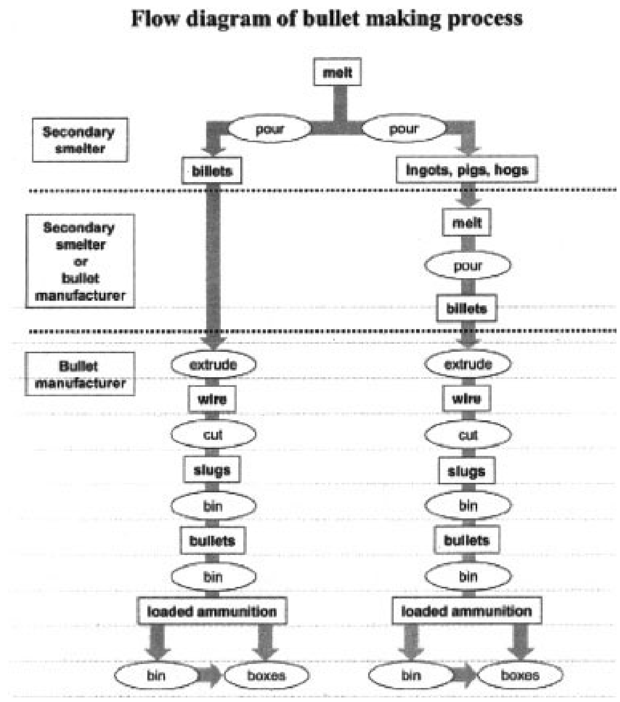

Figure 1. Conclusions of a study on forensic analysis of bullet lead composition hinged on an understanding of the bullet manufacturing process, depicted here, and its variability.

Like most National Academies studies, this analysis was highly interdisciplinary, involving experts in analytic techniques, quality control, statistics, and relevant case law. Reprinted with permission from *Forensic Analysis: Weighing Bullet Lead Evidence*, copyright 2004 by The National Academy of Sciences, courtesy of The National Academies Press, Washington, DC.

Criminal Justice in the Balance

Since at least the time of the Kennedy assassination, the FBI has examined the elemental composition of the alloy in bullet lead as one possible piece of forensic evidence to tie a suspect to a crime scene. Where a bullet found at a crime scene is too mangled or otherwise unsuitable to test for gun markings, analytical techniques can be used to measure the percentage of trace elements in the alloy. This elemental composition has been compared to that of bullets in the possession of a suspect in order to make statements about the likelihood that the suspect was the source of the crime scene bullet. Although used infrequently compared to other forensic techniques, compositional analysis of bullet lead (CABL) has played an important role in some convictions, including some death penalty cases.

The appropriateness of CABL, however, was under question, most notably by a former FBI examiner (Randich et al., 2002). The FBI Laboratory approached the National Academies to provide a definitive examination of this technique, and its appropriate use in criminal cases.

A committee of analytical experts, quality assurance/quality control blackbelts, forensic examiners, statisticians, and criminal lawyers examined the analytical and statistical protocols used by the FBI in conducting CABL; explored the process of bullet lead manufacturing in the United States, and its variability from batch to batch, and from manufacturer to manufacturer; and considered actual FBI courtroom testimony on CABL results to reach its conclusions. The committee concluded that although the analytical technology used in CABL was sound, statistical protocol did not adequately account for the variability in the bullet manufacturing process, and CABL could not be used to tie a suspect to the crime scene in a quantitative or probabilistic way (Figure 1) (National Research Council, 2004a). Subsequent to release of these conclusions, the FBI announced that it would no longer use CABL as a criminal forensic tool (Lichtblau, 2005). At least one conviction was overturned in an appeal that used the conclusions of this report to argue against evidence (Washington Post, 2005).

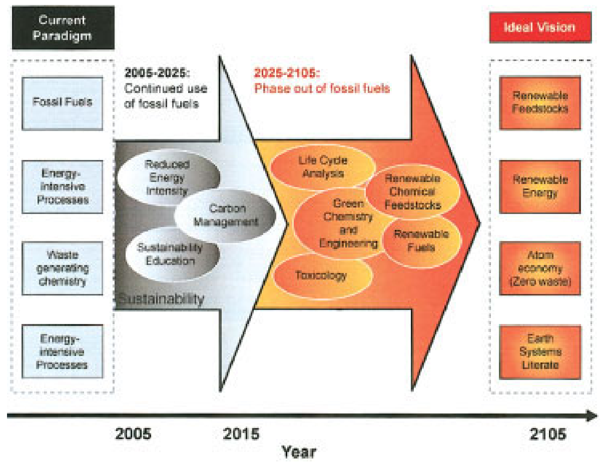

Figure 2. The report "Sustainability in the Chemical Industry: Grand Challenges and Research Needs" addresses how to transition from current practices to an ideal vision of the chemical industry in 100 years.
Reprinted with permission from *Sustainability in the Chemical Industry: Grand Challenges and Research Needs*, copyright 2006 by The National Academy of Sciences, courtesy of The National Academies Press, Washington, DC.

Securing our Chemical Infrastructure

The risks posed to our population by the nation's chemical infrastructure have been a focus of particular concern since the terrorist attacks of 2001. In Washington and in some states, legislators debate whether new regulations on security of chemical plants are needed, and what form they should take. At the request of the Department of Homeland Security, the National Academies considered the nation's chemical supply chain, examining it for potential disruptions of catastrophic physical or economic consequence. The objective was to make recommendations for research and technology investments that could help prevent an attack or mitigate its consequences.

Process engineers and safety specialists joined forces with industry analysts, economists, transportation engineers and emergency response experts to conduct this analysis. The expert committee created a high-level model of the chemical supply chain, and examined the characteristics of that model to determine points of vulnerability sufficient to cause catastrophic consequences. In keeping with guidance from the Department of Homeland Security, "catastrophic consequences" were taken to be casualties in the thousands to tens of thousands or economic consequences of tens to hundreds of billions of dollars.

Various estimates have been made of possible casualty levels resulting from chemical attack, and these estimates have been controversial since they generally differ from one another by orders of magnitude. Instead of these numerical estimates, the committee utilized the existing worldwide accident record for the chemical industry as its means of determining the possible consequences of various event scenarios. It concluded that while catastrophic levels of casualties could result from a single chemical attack if (and only if) the right congruence of circumstances was obtained, catastrophic economic consequences would require a series of successful attacks on carefully chosen targets.

The report noted that the success of an attack was in every case dependent on factors outside the control of terrorists, including the reaction of local emergency responders and the populace. Absent any specific threat, it recommended investments in measures that were protective against all chemical hazards and all modes of disruption—namely, investments to improve emergency planning, response, and recovery, and research to improve the cost-effectiveness and utilization of inherently safer technologies (National Research Council, 2006a).

Working Toward a Sustainable Chemical Industry

Chemical producers have been challenged by the rising cost of energy and feedstocks for their processes. In addition, public interest groups continue to pressure industry to reduce even further its environmental, health, and safety impacts. Major firms are turning toward renewable feedstocks, biotechnology, and "green" processes for business, environmental, and public relations purposes. As concerns about global climate change increase and the world continues to move up the supply/demand curve for petroleum and natural gas, the chemical industry must find ways to make its business environmentally and economically sustainable. A coalition of federal agencies asked the National Academies to outline the major research challenges that, if met, could substantially move the chemical industry toward that goal of sustainability.

A steering committee with chemical engineers and chemists from both the academic and industrial sectors organized a broad-based workshop to examine the major challenges facing the industry, and to point to Grand Research Challenges that research funders should support. That process of convening the community around this issue lead to recommendations for increased research in green chemistry and engineering; life cycle analysis; toxicology; renewable chemical feedstocks and fuels; energy efficiency; and managing of the carbon dioxide cycle. In addition, participants noted the need for education at every level to develop the science literacy needed to address sustainability issues (National Research Council, 2006b). Figure 2 depicts the resultant view of transition to sustainability, and the grand challenges that must be met to achieve that vision.

Seeing the Way to New Research Opportunities

Imaging techniques have been key to breakthroughs occurring in recent decades in areas such as materials development, understanding of biological processes, development and understanding of electronic devices, and novel medical diagnostics and treatments. Researchers from across a spectrum of disciplines continue to push the edge of our imaging capabilities further and further. To facilitate and encourage improvements in the imaging of molecular scale processes, the National Academies was asked to review the current state of

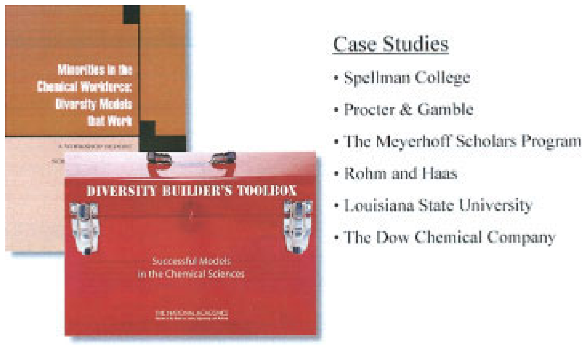

Figure 3. A 2003 report and subsequent "Diversity Toolbox" provides educators, administrators, and managers solid examples of how institutions have successfully recruited and retained minority candidates to their programs.
Reprinted with permission from *Sustainability in the Chemical Industry: Grand Challenges and Research Needs*, copyright 2003 and *Diversity Builders' Toolbox* by The National Academy of Sciences, courtesy of The National Academies Press, Washington, DC.

chemical imaging, identify gaps in our knowledge and capabilities, recommend research to enable advances in these capabilities and discuss the opportunities that would open up if such capabilities existed (National Research Council, 2006c).

This committee, composed of chemists, biochemists, physicists and engineers working in varied applications areas consulted with other top researchers to outline the current state-of-the-art and to make recommendations for future advances. The report identified a two-fold goal of such advances: (1) to gain a fundamental understanding of complex chemical structures and processes, and (2) to use that knowledge to control processes and create structures on demand. Research was identified to help achieve those goals. Development of better light sources, improved detectors, new chemical probes and markers, further miniaturization of instrumentation, higher-data acquisition speeds, and better data storage and management were all identified as hurdles to be met along that path. These needs cross virtually all types of existing imaging techniques and their applications areas.

Ensuring the Future Workforce

Workshops held at the National Academies and featuring participation by both chemists and chemical engineers have resulted in reports highlighting best practices in recruitment and retention of women and minorities to the study of and employment in chemistry and chemical engineering fields. These materials point to the importance of such factors as committed leadership, role models, and mentoring in the successful recruitment and retention of minorities and women in the technical workforce. Case studies were utilized to show how these techniques can be used in practice to build a successful diversity program. These reports and short summary brochures derived from them have been widely disseminated not only to chemistry and chemical engineering departments but have also been sought by leaders in other disciplines as they work to ensure that the nation has the technical workforce it needs to meet the challenges of the future (Figure 3) (National Research Council 2000, 2003b, 2004b).

How Can Chemical Engineers Participate in the Work of the Academies?

The work of the National Academies is enabled through the service of members of the technical community. Community awareness and support of the National Academies work and capabilities, and willingness to participate in the work of the National Academies when asked, both can help further this effort.

National Academies studies relating to chemistry and chemical engineering are coordinated by its Board on Chemical Science and Technology (BCST) (http://dels.nas.edu/dels/bcst.shtml). This group of advisors from academe and industry works with the National Academies professional staff to assure the quality and appropriateness of all studies undertaken in this area. The BCST website contains information about all ongoing studies and links to recent reports and other materials. Through the BCST website, you can request email updates on activities relevant to chemical engineering. A quarterly email newsletter is also available.

If approached by the National Academies to assist with a study, give your time in service if at all possible. The time commitment made by committee members is compensated for by the knowledge gained from interactions with top scientists and engineers from across the nation on complex, interdisciplinary topics. Most committee participants are also satisfied that they have given service to our nation, as well as the science and engineering community. Service as a report reviewer helps assure that the final results of studies remain as technically excellent and objective as possible, and assure federal decision-makers of the quality of the advice that the community provides.

Here are some comments from chemical engineers who have served on committees:

It's an excellent way to learn more about the administrative and policy aspects of the chemical sciences, including the goals and direction of funding agencies;

It bring chemical engineers together with other scientific disciplines in a common enterprise;

It's an excellent way to influence the direction of the field by clearly articulating, within the committee setting, what you think is important;

Because of the rigor of the National Academies' review process, the reports are authoritative and therefore very influential.

Even if not serving directly, engineers can review the research needs identified in National Academies reports and consider whether their own work can contribute in any way. We can all help disseminate the results of National Academies studies by drawing them to the attention of colleagues, program managers, and sometimes even our legislators who would find them relevant.

You can also help the next generation of engineers learn about the broader impact of their work by directing interested students toward internships available at the National Academies (http://www7.nationalacademies.org/policyfellows/). These 10 week experiences designed for current graduate students or recent recipients of graduate degrees give young people an expanded perspective on how engineering and technology interacts with social and political factors to shape our society.

Engineering is all about broader impact. The National Academies provides one unique venue through which the chemical engineering community can strive to achieve its broadest impact. The cooperation and participation of chemical engineers in the work of the National Academies produces a win-win situation, in which the nation's need for advice is met and the importance of engineering to the common good is demonstrated.

Acknowledgements

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Literature Cited

Lichtblau, E., "FBI Abandons Disputed Test for Bullets from Crime Scenes,", *New York Times,* A12 (2005).

National Research Council. *Women in the Chemical Workforce*: *A Workshop Report*, The National Academies Press, Washington, DC (2000).

National Research Council. *Testing and Evaluation of Standoff Chemical Agent Detectors*, The National Academies Press, Washington, DC (2003a).

National Research Council. *Minorities in the Chemical Workforce: Diversity Models that Work*, The National Academies Press, Washington, DC (2003b).

National Research Council. *Forensic Analysis: Weighing Bullet Lead Evidence*, The National Academies Press, Washington, DC (2004a).

National Research Council. *Diversity Builder's Toolbox: Successful Models in the Chemical Sciences*, The National Academies Press, Washington, DC (2004b).

National Research Council. *Review of Testing and Evaluation Methodology for Biological Point Detectors*,The National Academies Press, Washington, DC (2005).

National Research Council. *Terrorism and the Chemical Infrastructure: Protecting People and Reducing Vulnerabilities*, The National Academies Press, Washington, DC (2006a).

National Research Council. *Sustainability in the Chemical Industry*, The National Academies Press, Washington, DC (2006b).

National Research Council. *Visualizing Chemistry: The Progress and Promise of Advanced Chemical Imaging*, The National Academies Press, Washington, DC (2006c).

Randich, E., Duerfeldt, W., McLendon, W., and Tobin, W, *Foren. Sci. Int.* 127,174–191 (2002).

Washington Post. "N.J. Murder Case Reversed Over FBI Bullet Tests," *Washington Post,* A08 (2005).